

DIGESTIBILITY OF CARBOHYDRATES, LIPIDS, AND
PROTEINS IN CHANNEL CATFISH ICTALURUS PUNCTATUS (Rafinesque)

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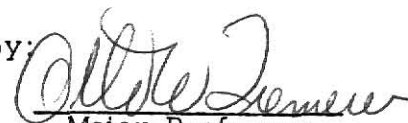
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INTRODUCTION

Channel catfish Ictalurus punctatus (Rafinesque) have become the mainstay of commercial fish producers throughout the southern and central states. It is well adapted to commercial production and takes artificial diets readily.

The purpose of this study was to search for solutions to reduce feed costs and reduce fish loss in the early spring in channel catfish production.

Loss of fish to parasites and disease is usually greatest in the early spring when fish have used up body reserves over the winter and are in their poorest condition. Outbreaks are fairly common at this time of the year and the organism most often blamed is Ichthyophthirius, commonly called Ich. Improving the condition of the fish at this time of year could reduce such outbreaks. If channel catfish would feed and utilize certain feed ingredients at cooler water temperatures; their condition would improve and thereby decrease their susceptibility to diseases and parasites in the spring.

Another problem in catfish production is the increasing cost of feed ingredients, particularly proteins. In order to decrease feed costs, cheaper yet digestible materials must replace more expensive ingredients. It has been thought for years that only animal protein could be used in fish diets. Recent research has shown that plant proteins can be substituted for more expensive animal proteins if the amino acid balance is maintained. Substituting carbohydrate and lipid feed ingredients for proteins might also reduce feed costs.

This study was designed to obtain answers to these problems. To accomplish this, digestibility of various carbohydrates, lipids, and proteins were determined and the effects of temperature on their digestibility. Digestion end-products in the blood were used as indicators of feed ingredient digestibility.

LITERATURE REVIEW

Carbohydrates

Normal variation of blood glucose levels have been reported for fish. Various freshwater fish in Japan, living in ponds and gentle streams, had blood sugar levels of 15 to 40 mg% while those in rapid streams had levels of 50 to 129 mg% (Fukuda, 1969). Variations in normal blood glucose values of toadfish can be accounted for on the basis of daily or seasonal effects and are, therefore, neither random nor uncontrolled (Nace et al., 1964). A mean level of 105 mg% with a range for 18 to 200 mg% in January to a mean of 30% and a range of 14 to 42 mg% in July was reported. Chavin and Young (1970) found no differences in serum glucose of fish weighing 1.5 to 7.1 g and that no difference occurred among well acclimated goldfish. Blood glucose levels in their study ranged from 12.9 to 91.4 mg% and averaged 28.5%. Fasting levels of blood glucose for channel catfish averaged 75 mg% while maintained at 24°C (Pappas, 1972). Lambert (1969) found channel catfish had a mean level of blood glucose for fed and nonfed fish of 74.84 mg% with a range of 20 to 230 mg%.

Temperature has been shown to affect blood sugar levels. Brook trout under starvation had no significant decrease in blood glucose for fish maintained at 47 and 52°F (Phillips, 1961). These fish when fed a meat meal diet while maintained at 52°F had higher blood glucose levels than fish maintained at 47°F and fed the same diet. In toadfish, increased temperature decreased blood sugar (Nace et al., 1961). Dean and Goodnight (1964) studied carbohydrate metabolism as affected by temperature and exercise. Black bullheads maintained at 5°C had higher blood glucose levels than fish maintained at 20°C, but the opposite was found in several Centrarchids. Channel catfish maintained at 26.6°C and 29.4°C were much more active

than fish maintained at lower temperatures (Shrable, 1968) and the rate of digestion was more rapid at higher temperatures.

Magnuson (1969) found blood glucose levels in tuna rose shortly after a meal and returned to prefeeding levels by the time the stomach was empty. Brook trout digested and absorbed carbohydrates over varying periods of time (Phillips et al., 1948). Blood glucose levels rose shortly after feeding and maintained increased levels for 15-24 hours. The rate at which carbohydrates were absorbed was dependent upon their molecular size, simpler ones being absorbed more readily. Order of utilization of ingredients fed from highest to lowest were glucose, sucrose, lactose, cooked corn starch, and raw corn starch. Cooked starch was utilized better than raw starch but neither were utilized well. Phillips and Brockway (1956) found that a more complex carbohydrate was easier to digest if cooked, because cooking disrupted the hard membranes surrounding the starch grains. Smith (1971) also found that complexity of carbohydrates has a direct influence on digestibility by rainbow trout. He found glucose and dextrin were digested about equally well and cooked starch was digested better than raw starch. Studies on channel catfish showed that blood sugar levels increased within four hours after feeding, followed by a sharp decrease during the next eight hours (Lambert, 1969). Pappas (1972) studied digestion of glucose, sucrose, dextrin, cellulose and a modified starch using blood glucose levels as indicators of digestibility and found blood glucose levels decreased as carbohydrate complexity increased.

A high protein, low carbohydrate diet fed to brook trout resulted in blood glucose lower than in a control (Phillips, 1961). Tiemeier et al., (1965) found carbohydrates had a sparing effect on protein in channel catfish. Using two 25% protein diets containing different energy levels due to added carbohydrates, they found significantly less protein was necessary to produce a given quantity of fish. Red seabream utilized carbohydrates

in their diets and produced good weight gains (Furiuchi and Yone, 1971). They found diets with glucose gave the best growth, feed, and protein efficiency ratios. Those using potato starch gave the poorest results.

Lipids

Studies on digestibility of various lipids by fishes are limited. Studies using digestion end-products as indicators of lipid digestibility have been made only with trout. McCartney (1965a) determined serum cholesterol levels in brown trout fed several diets and found higher serum cholesterol levels for fish maintained in warm water as opposed to levels for fish in cold water. He found serum cholesterol levels increased 49% over the control diet for fish fed a supplemental feeding oil.

McCartney (1965a) fed brown trout diets differing in fat content to fish maintained at 8.3° or 10.6°C. The diets were a control with no supplemental fat, a diet with 3% supplement A-D feeding oil, and a third diet with 3% supplemental cottonseed oil. His studies showed trout fed the A-D oil diet had higher serum cholesterol than those fed the other diets. Fish maintained at 8.3°C had higher serum cholesterol than fish maintained at 10.6°C. Fat did not supplement growth of fish at 8.3°C, but increased body fat, whereas, fish kept at 10.6°C had increased growth and body fat. Cottonseed oil showed an inhibitory effect on serum cholesterol levels.

Dietary fat is degraded to diglycerides and monoglycerides by a digestive lipase in cod (Brockhoff, 1966). Concentrations of blood cholesterol, phospholipids and total esterified fatty acids were highly correlated in Australian fresh and salt-water fishes (Morris, 1959), meaning changes in concentration of one might be indicative of change in another.

Studies on gastric evacuation of rainbow trout found lipid concentrations in excess of 15% in the diet inhibited or delayed gastric evacuation (Windell et. al., 1972). Feeding a high fat content diet to rainbow trout at 16°C

resulted in improved growth. More fat was absorbed at the higher temperatures which suggest fats replaced nitrogenous compounds as an energy source. In rainbow trout, fats replaced nitrogenous compounds as an energy source and particularly with increases in temperature (Atherton and Aitken, 1970). Trout maintained at 16°C excreted little ingested nitrogen when fed high levels of dietary fat, thus more nitrogen was available for growth.

Studies on channel catfish fed supplemental fat suggests more efficient digestion and absorption of corn oil than beef tallow (Dupree, 1969). However, McCartney (1965b) found brown trout were unable to utilize lard.

Proteins

Studies on amino acids in fish have centered on determining the amino acids essential for growth. Trout and catfish require the following amino acids: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine (Dupree, 1970; Shanks, 1962).

Little research has been done with amino acids in the blood of fish. This review will, therefore, report research on amino acids in the blood of more extensively studied animals, poultry in particular, as well as research done with fish. Poultry were used for comparison because both fish and poultry have a simple monogastric digestive system and require the same essential amino acids except for the requirement of glycine in poultry.

Serum levels of histidine in carp rose after consumption of feed containing 0.087 micromoles/gram of histidine, (Creach and Serfaty, 1964). Serum histidine levels ranged from 0.119 to 0.149 micromoles/ml 48 hours postfeeding and from 0.161 to 0.239 micromoles/ml 8 days postfeeding. Chance (1962) determined free amino acid levels in chinook salmon. A decrease in plasma amino acids was found with an increase in age and also after a 24-hour fasting period. Inspection of the plasma amino acid levels of spawning males showed

increases in arginine, lysine, methionine, and serine over fasting levels. Timoshina (1970) found free amino acid levels in plasma of rainbow trout increased during starvation. Eighteen free and 17 combined amino acids were detected in trout sera. As a result of starvation for one month in summer the combined amino acids showed no significant change but free amino acids sharply decreased then increased to reach a level near that of a control. Serum amino acids in channel catfish during pre-and postfeeding periods were determined by Lambert (1969). Values for urea, ammonia and 27 amino acids were obtained. Urea accounted for the major portion of amino nitrogen. Total free amino acid levels ranged from 1.979 micromoles/ml to 2.833 micromoles/ml. Total free amino acid levels were slightly higher during the postfeeding period and reached their highest levels 4 and 16 hours postfeeding.

Using inverted intestinal tracts of flounder fish, Rout et al., (1965) found L-tyrosine and D-tyrosine were transported from the mucosal side of the intestine to the serosal side against a concentration gradient. Among tryptophan compounds studied, L-tryptophan was actively transported while D-tryptophan and tryptamine were not. Mephram and Smith (1966) also used inverted intestinal tracts of goldfish to study absorption. The following amino acids were actively transported to the blood from the intestine: threonine, alanine, serine, histidine, valine, methionine, phenylalanine and leucine. L-aspartic acid transaminated prior to absorption to an unidentifiable amino acid. The intestinal transport of methionine and valine has been studied in vitro using goldfish acclimated to 8, 15, and 25°C by Kitchen and Morris (1971). The rate of uptake of valine increased at low acclimation temperatures but the rate of uptake of methionine decreased at low acclimation temperatures.

Munro (1970) reported that only 0.5% of the amino acids present in the rat body are as free amino acids. Alanine, glycine, glutamic acid and glutamine made up 80% of this total. The nonessential amino acids vary

less than do the essential amino acids and an increase in one is often offset by a decrease in another. Skeletal muscle has the largest amount of free amino acids in the rat body.

In a paper on avian nutrition, Featherston (1972) states that valuable information concerning amino acid nutrition and metabolism can be obtained by measuring free amino acids, particularly free amino acids in the tissue and blood. The increase in plasma amino acids is offset by their removal for tissue protein synthesis, degradation and metabolism for specialized purposes. The amino acid in shortest supply will, therefore, become the most limiting and will show the least increase after feeding a test diet in relation to the plasma level when a more adequate diet is fed. Plasma amino acid patterns are a reflection of changes occurring in the muscle and these patterns are useful in determining limiting amino acids resulting from dietary changes.

Chicks fed a lysine deficient diet showed decreased plasma lysine while threonine levels increased (Richardson et al., 1965). Leung (1968) fed diets devoid of threonine to rats and found levels fell below those of control rats. Pawlak and Pion (1968) increased intake of lysine from 30 to 200% which resulted in a 7-fold increase in plasma lysine.

Feeding chicks safflower meal resulted in markedly lower plasma amino acid levels than occurred by feeding soybean meal (Valadez et al., 1965). Plasma methionine was lower in chicks fed the soybean diet. When the soybean diet was supplemented with methionine, and safflower meal with lysine, plasma levels were similar. Smith and Scott (1965b) compared the plasma amino acid of chicks fed a diet in which sesame meal provided all of the protein to a reference diet of crystalline amino acids. Largest decreases in plasma amino acids of the chicks fed the sesame meal diet from largest to smallest were: lysine, methionine, threonine, and histidine. The high

content of arginine in sesame meal was shown by a large increase in the plasma amino acid level of arginine. By varying the dietary level of lysine, arginine or valine in diets of chicks which included suboptimal, and excessive amounts of the given amino acid needed for maximal growth, Zimmerman and Scott (1965) found dietary levels below optimum show a constant level of amino acid concentration until that needed to support maximum growth was reached. Dietary levels above this amount resulted in rapid accumulation of the amino acid in the plasma.

Anderson et al., (1969) observed a general increase in plasma amino acid levels of chicks at the onset of feeding a high protein diet. After adaptation to the diet, plasma amino acids except leucine, isoleucine and valine, decreased to normal levels. This decrease in concentration coincided with an increase in activity of liver serine dehydratase, an enzyme of amino acid degradation. The liver enzymes, following adaptation, are capable of regulating the systemic blood levels of most amino acids coming to the liver from the portal blood.

The total plasma amino acid levels of chicks were observed by Fonseca et al., (1970) to decrease linearly as dietary lysine and growth rate increased. This indicated increased utilization of body amino acids for protein synthesis. Similar results have been reported by other investigators (Askelson and Baloun, 1963). Hill and Olsen (1963) found plasma lysine increased linearly with increases in dietary lysine. Factors affecting this were type of diet, level of other dietary amino acids and length of time the experimental diet was fed.

Hill and Olsen (1967) studied time required for plasma amino acid levels of chicks to show response to removal of supplemental methionine from a diet of soybeans. A 70% decrease in plasma methionine 4 hours after feeding was noted. Four hours was the shortest interval measured.

Charkey et al., (1953) suggests that in poultry large amounts of amino acids are released into the blood during starvation due to protein catabolism.

Lysine and threonine accumulate as a result of their being resistant to deamination. Plasma amino acid levels compared between chicks during the starvation and when fed continuously a diet of 15% soybean protein or a nonprotein diet was studied by Hill and Olsen (1963). Lysine increased 5-fold higher in starved chicks than in those 24 hours after being fed. Threonine increased more slowly. Total plasma amino acid increased 50% during starvation but much was due to increased lysine and threonine levels.

Smith and Scott (1965a) observed that autoclaving fish meal for 2 hours at 121°C resulted in a great loss in lysine availability and all amino acids studied. Availability of methionine, histidine, and threonine was adversely affected but to a lesser degree. Autoclaving fish meal 12 hours at 121°C resulted in decreases of all plasma amino acids. Soybean meal autoclaved 1 hour showed a decline in plasma lysine of chicks and continued heating resulted in further losses. Smith and Scott (1965b) indicated decreased availability of amino acids of raw versus properly heated soybean meal. Overheating caused a decrease in plasma amino acids, lysine in particular, of chicks fed the overheated diet.

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Digestibility of carbohydrates, lipids and
proteins in channel catfish, Ictalurus punctatus (Rafinesque)¹

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ABSTRACT

This study determined digestibility of several carbohydrate, lipid, and protein feed ingredients in channel catfish, Ictalurus punctatus (Rafinesque) and effects of water temperature and time after feeding on digestion of ingredients. Digestion end-products in the sera were measured to indicate feed ingredient digestibility.

Channel catfish weighing 340 to 570 grams each were maintained at 13 or 24°C and sampled for blood at 0, 1, 2, 4, and 8 hours after force-feeding known quantities of ingredients. Levels of blood glucose were determined from sera of fish fed glucose, sucrose, raw and cooked starches (corn, wheat and potato), corn oil, lard, egg albumin, and soybean meal. Esterified fatty acids in the sera were determined for fish fed corn oil and lard. Sera amino acids were determined for fish fed egg albumin and soybean meal.

Results showed that: 1) sera glucose increased with decreases in complexity of the carbohydrate fed; 2) channel catfish digested carbohydrates at 13°C but at a slower rate than at 24°C; 3) cooking starches increased sera glucose more than raw starches; 4) corn oil and lard did not significantly effect sera esterified fatty acids or sera glucose, however, fish maintained at 24°C had higher sera glucose and esterified fatty acids than fish maintained at 13°C; 5) egg albumin and soybean meal had little effect on sera glucose; 6) generally, sera amino acids were greater for fish maintained at 24°C than 13°C; 7) methionine was the limiting amino acid when egg albumin and soybean meal were fed; 8) soybean meal resulted in as high or higher increases in sera amino acids than fish fed egg albumin, however, these higher increases are presumably due to decreased utilization of amino acids because of the low level of methionine in soybean meal.

INTRODUCTION

Rising feed ingredient prices in commercial production of channel catfish, Ictalurus punctatus (Rafinesque) prompted us to search for digestible, less expensive feed ingredients to reduce feed costs. Another economic problem is loss of fish to parasites in the early spring when fish are in poor condition. Information on digestibility of ingredients in cool water temperatures would show which ingredients fish can use at cooler temperatures, and aid in formulating early spring rations to improve the fish's condition and decrease losses to parasites and disease.

Research on digestibility of carbohydrates and lipids using digestion end-products in the blood have been limited primarily to trout. Limited studies on blood glucose levels after feeding certain carbohydrates to channel catfish have been made, but none have used digestion end-products in the blood to determine digestibility of various lipids and proteins. Because little information is available on digestion of feed ingredients by channel catfish, this study attempted to determine digestibility of various carbohydrate, lipid, and protein feed ingredients to determine how well ingredients are used at cool water temperatures and to compare digestibility of cooked and raw carbohydrate ingredients.

MATERIALS AND METHODS

Fish weighing 340 to 570 g were starved and acclimated to the desired water temperature, 48 to 60 hours, in 150 gallon aquaria before sampling. The aquaria were equipped with temperature controls and a continuous water flow. Fish were maintained at 13 and 24^o before and during the experimental period.

Glucose, sucrose, and raw and cooked corn starch were force-fed to fish maintained at 13 and 24^oC to determine their digestibility and the effect

of temperature on digestibility. Raw and cooked wheat and potato starch were fed to fish maintained at 13°C only to further determine how other starches were digested at cooler water temperatures. Ingredients chosen were of different structural complexity; glucose and sucrose being less complex than the starches. Starches were used in both the raw and cooked form. Starches were cooked by heating a 50:50 solution of starch and distilled water until gelatinization occurred. The starch was then dried and fine ground. Cooking disrupts the internal structure of starch granules making the starch more digestible.

Corn oil, lard, egg albumin, and soybean meal were force-fed to fish maintained at 13 and 24°C to determine their digestibility and the effect of temperature on digestibility. Lipid ingredients chosen differed in saturation, melting point and source. Corn oil, a plant lipid high in unsaturates, has a low melting point. Lard, an animal lipid low in unsaturates, has a higher melting point. Protein ingredients were of similar protein quality but from different sources. Also, egg albumin was higher in methionine and valine than was soybean meal.

Lipid and carbohydrate ingredients were prepared for force-feeding by dissolving or suspending 4.5 g of the ingredient into 10 ml of distilled water. Egg albumin was prepared by suspending 2.5 g albumin into 10 ml of distilled water but only 1.0 g soybean meal was used due to its hydroscopic properties.

Fish were force-fed through a plastic tube inserted into the stomach by expelling the ingredient from a 25 ml syringe. Blood samples were taken by removing a fish from the aquarium and placing it on its dorsal side in an apparatus designed to inhibit movement. A blood sample was taken with a disposable syringe, size 22 needle. The needle was inserted on the mid-ventral surface, slightly posterior to the cleithrum, into the sinus venosus

and a blood sample withdrawn. Sampling for blood did not kill the fish and the cardiac wound healed after several weeks.

Carbohydrate digestibility was determined using sera glucose as an indicator. A fish was removed from the aquarium, marked by fin clipping, sampled for blood (1 ml), force-fed, and returned to the aquarium for 1, 2, 4, or 8 hours. After a digestion period, the same fish was removed and a second 1 ml blood sample taken. Sera were collected from the pre-and post-feeding blood samples and analyzed for serum glucose in mg% (mg glucose/100 ml sera) using glucose oxidase and O-dianisidine (Keston, 1956). The change in serum glucose, attributable to digestion of the ingredient, was the postfeeding serum glucose level minus the prefeeding serum glucose level. Ten such determinations from ten fish were used to obtain a mean for each combination of feed ingredient, water temperature, and time after feeding.

Changes in sera glucose due to handling and sampling procedures were determined by a control. Control fish were sampled in the same manner except fish were not force-fed.

Sera esterified fatty acids and sera glucose were used to determine lipid digestibility. Fish were removed from the aquaria, force-fed, and returned to the aquaria for 1, 2, 4, or 8 hours. After a digestion period, a 1 ml blood sample was taken. Ten fish were used for each combination of feed ingredient, water temperature, and time after feeding and their blood samples pooled into two groups of five. Sera were obtained from the two samples of pooled blood and analyzed for glucose using glucose oxidase and O-dianisidine (Keston, 1956); for esterified fatty acid, using a modified hydroxamic method (Morgan and Kingsbury, 1959). Sera glucose and esterified fatty acids of the pooled samples of each group were then used to provide mean sera glucose and esterified fatty acids for each ingredient fed at each time interval and water temperature. Sera glucose and esterified fatty acids of blood

samples for control fish were determined in the same manner.

Protein digestibility was determined using sera glucose and free amino acids. Fish were removed from the aquaria, force-fed and returned to the aquaria for 1, 2, 4, or 8 hours. After a digestion period, a 2 ml blood sample was taken. Ten fish were used for each combination of feed ingredient, water temperature and time after feeding and their blood samples pooled into one. Sera were obtained from each pooled blood sample and a portion analyzed for sera glucose (Keston, 1956). A second portion of sera was prepared for amino acid analysis. A 4 ml aliquot of the pooled sera was deproteinated by adding 2 ml distilled water and 2 ml sulfosalicylic acid (Walters et al., 1966). The sample was then centrifuged at 4°C, 10,000 RPM, for 20 minutes. The supernatant was filtered and applied to a Beckman Amino Acid Analyzer 120C. Tryptophan, an essential amino acid, was not present in the standard calibration mixture and, therefore, was not included in the analysis. Levels of serum glucose and serum amino acids for nonfed fish were determined in the same manner. Amino acids of each ingredient fed were determined using a Beckman Analyzer 120C. Ingredients were prepared for the analyzer by acid hydrolysis.

RESULTS

Data on sera glucose (mg%) for control fish and fish force-fed glucose, sucrose, raw corn starch or cooked corn starch while maintained at 24°C appear in Figure 1; for fish maintained at 13°C, in Figure 2. Three-way analysis of variance of data from Figures 1 and 2 combined showed feed ingredient, water temperature, and time after feeding were significant ($P < 0.05$). All 2-way interactions except the feed ingredient-water temperature interaction were significant ($P < 0.05$). Three-way interaction was not significant ($P > 0.05$). The control was considered as a feed ingredient in the statistical analysis.

Data on sera glucose (mg%) for control fish and fish force-fed raw wheat starch, raw potato starch, cooked wheat starch, or cooked potato starch while maintained at 13°C are presented in Figure 3. A 2-way analysis of variance of data from Figures 2 and 3 combined showed feed ingredient, time after feeding and all 2-way interactions significant ($P < 0.05$). The control was considered as a feed ingredient in the statistical analysis.

Results of sera glucose of fish maintained at 24°C (Fig. 1) indicated simpler carbohydrates, glucose and sucrose, resulted in greater increases in sera glucose than did starches. Fish two hours postfeeding glucose showed the largest change in sera glucose, 159.90 mg%. Sera glucose of fish fed sucrose and cooked corn starch were similar. Raw corn starch showed the least increase in sera glucose above those of control fish. Sera glucose of fish fed glucose, sucrose and cooked corn starch were significantly higher than those of control fish except eight hours postfeeding cooked corn starch and sucrose.

Sera glucose of fish maintained at 13°C (Fig. 2) showed similar results. Fish fed glucose again showed the greatest increase in sera glucose two hours postfeeding. Sera glucose levels of fish fed sucrose and cooked corn starch were similar but raw corn starch showed the least increase in sera glucose. Sera glucose appear to increase slower, peak later, and taper off more gradually than sera glucose of fish maintained at 24°C (Figs. 1 and 2).

Fish maintained at 13°C (Fig. 3) show cooked ingredients generally resulted in higher serum glucose when compared to raw ingredients. Fish fed cooked wheat starch showed the greatest increase in serum glucose while fish fed raw potato starch showed the smallest increases.

Sera glucose of fish fed the simpler carbohydrates and cooked starches generally peaked two hour postfeeding whereas fish fed raw starches generally

peaked four hours postfeeding. Generally, sera glucose declined after four hours and approached levels observed in the control after eight hours.

Data on sera glucose (mg%) and esterified fatty acids of control fish and fish force-fed corn oil or lard while maintained at 13° or 24°C (Figs. 4 and 5, respectively), were analyzed by 2-way analysis of variance, and showed sera glucose and esterified fatty acids were significantly ($P < 0.05$) related to temperature. Sera glucose and esterified fatty acids of fish force-fed corn oil or lard did not differ significantly ($P > 0.05$) from those of control fish.

Fish force-fed corn oil or lard did not significantly increase sera glucose or esterified fatty acids above those of control fish (Figs. 4 and 5 respectively). Sera glucose and esterified fatty acids of fish maintained at 24°C were higher than those of fish maintained at 13°C.

Data on sera glucose of control fish and those force-fed egg albumin or soybean meal while maintained at 13 or 24°C appear in Table 1. Data on sera amino acids of control fish and those force-fed soybean meal while maintained at 13 and 24°C appear in Table 2; and for fish force-fed egg albumin in Table 3. Sera glucose and total essential sera amino acids were statistically analyzed using 2-way analysis of variance. Only one determination for each combination of feed ingredient, water temperature, and time after feeding was feasible. This resulted in not being able to determine the variance between fish and, therefore, the interaction and error variance estimate were inseparable. This made the error variance, which is the denominator of the F statistic, larger than its true value. It thus increased the possibility of not detecting a significant result when it may be present. Therefore, it should be noted that in interpreting the statistical analysis, a significant result was highly significant, however, nonsignificant effects could have also been significant. The statistical analysis showed sera glucose and sera amino acids were

significantly different ($P < 0.05$) with regard to temperature. Diet and time effects were nonsignificant ($P > 0.05$).

Sera glucose of fish force-fed soybean meal or egg albumin (Table 1) were similar to prefeeding levels. Sera glucose of fed and nonfed fish were higher for fish maintained at 24°C than those maintained at 13°C.

Postfeeding levels of arginine, isoleucine, leucine and valine (Table 2) showed substantial increases over prefeeding levels. Phenylalanine and threonine showed marked increases 1 and 2 hours postfeeding soybean meal to fish maintained at 13°C but then dropped near or below prefeeding levels. Levels then again increased 8 hours postfeeding. Fish fed soybean meal while maintained at 13 or 24°C showed decreases in methionine postfeeding as compared to prefeeding levels. Levels of methionine were the smallest observed of the amino acids and were lower at 24°C than at 13°C. Lysine levels were the highest of the amino acids observed. Generally, postfeeding levels of all amino acids of fish maintained at 24°C were greater and more constant than for fish maintained at 13°C. Prefeeding levels of fish maintained at 24°C were higher than those of fish maintained at 13°C except for arginine and methionine.

Total essential, nonessential, and total sera amino acids postfeeding soybean meal (Table 2) were generally higher than prefeeding levels. Total essential sera amino acids showed greater increases than total nonessential sera amino acid levels. Total essential, nonessential, and total sera amino acids of fish maintained at 13°C showed a drop in amino acid levels four hours postfeeding, whereas fish maintained at 24°C showed a more constant level during all postfeeding intervals. Total essential, nonessential, and total sera amino acids of fish maintained at 24°C were greater than levels of fish maintained at 13°C.

Sera levels of arginine, isoleucine, leucine, lysine, and phenylalanine postfeeding egg albumin to fish maintained at 13°C showed substantial increases over prefeeding levels (Table 3). Sera levels of arginine, methionine and phenylalanine postfeeding egg albumin to fish maintained at 24°C and postfeeding sera levels of threonine and valine of fish maintained at 13°C were higher than corresponding prefeeding levels and remained more constant during the postfeeding period. Postfeeding sera levels of histidine, isoleucine, leucine, lysine, threonine and valine of fish maintained at 24°C increased over prefeeding levels with the greater increases occurring one and two hours postfeeding and then decreased. Postfeeding sera levels of histidine of fish maintained at 13°C were generally lower than prefeeding levels. Postfeeding sera methionine levels of fish maintained at 13°C were the same as prefeeding levels 1 and 2 hours postfeeding. The methionine level increased slightly after 4 hours and then declined rapidly. Generally, all sera amino acids of fish maintained at 24°C were greater than those of fish maintained at 13°C. Lysine was present in the largest amount and methionine the smallest.

Total essential, and total sera amino acids postfeeding soybean meal to fish maintained at 13°C (Table 3) were greater than corresponding prefeeding levels. The lowest postfeeding level occurred after eight hours. Total essential, nonessential, and total sera amino acids of fish maintained at 24°C were greater than prefeeding levels except 8 hours postfeeding. Total essential nonessential, and total amino sera acids were higher for fish maintained at 24°C than those of fish maintained at 13°C.

DISCUSSION

My results indicated simpler carbohydrates caused a greater increase in sera glucose than more complex carbohydrates and support results reported (Phillips, et al., 1948; Phillips and Brockway, 1956; Smith, 1971; and Pappas,

1972. They indicated that as complexity of the carbohydrate molecule fed increased, sera glucose decreased. Cooked starches in my study resulted in greater increases in sera glucose than raw starches and also supported results obtained by Phillips (1961), Phillips and Brockway (1956), and Pappas (1972).

The effect of temperature on digestion of carbohydrates has been reported in other studies, (Phillips, 1961; Dean and Goodnight, 1964; Nace and Schuh, 1961; and Shrable, 1968). The effects of temperature varied between studies and species of fish. Shrable (1968) found digestion more rapid at warmer temperatures in channel catfish. Fasting fish showed higher sera glucose at cooler water temperatures, Nace and Schuh (1961) and Dean and Goodnight (1964). Asadi (1967) found digestive enzymes more active in channel catfish at higher water temperatures with reduced activity at cooler temperatures. Fish in this study showed higher sera glucose after being fed glucose while maintained at 24°C than for fish maintained at 13°C but sera glucose of fish fed the other ingredients were not significantly different at water temperatures of 13 and 24°C. Although sera glucose did not increase in our fish for all ingredients fed, it was noted that sera glucose levels of fish maintained at 13°C increased slower, peaked later and tapered off more gradually than for fish maintained at 24°C. These results correspond to the effect of temperature on digestive enzymes reported by Asadi (1967). It is important to note that carbohydrates were digested and absorbed by fish maintained at 13°C.

The increases in sera glucose 1, 2 and sometimes 4 hours postfeeding indicate digestion and absorption of glucose into the blood. The decline in sera glucose eight hours postfeeding was due to removal of glucose from the blood for energy and other metabolic uses. It was apparent that channel catfish were able to digest and absorb carbohydrates within four hours after

a meal and within eight hours sera glucose were near normal.

Any implications of results regarding the digestibility of corn oil and lard would assume that sera esterified fatty acids indicated lipid digestibility. Phillips (1969) reported that fat is degraded to fatty acids and glycerol before absorption, however, further research on fat digestion is necessary before conclusions on fat digestibility are drawn. Halver (1972) has pointed to the need for further research on mechanisms in lipid metabolism of fish. In this study corn oil and lard did not significantly affect sera glucose or esterified fatty acids. However, fish maintained at 24°C had higher levels of sera glucose and esterified fatty acids than fish maintained at 13°C.

Because few studies of dietary effects on sera amino acids have been made on fish, more comprehensive studies on poultry are used for comparison. Poultry were chosen for comparison because of the similarity of their simple monogastric digestive system and amino acid requirements to fish. Various factors, such as the amount of dietary amino acid fed and the effects of starvation on sera amino acids should be considered in examining the data.

As the level of an amino acid in the diet of chicks increased, a corresponding linear increase in the sera amino acid generally occurred (Hill and Olsen, 1963). The total sera amino acids of chicks observed by Fonseca et al., (1970) decreased linearly as dietary lysine and growth rate increased. While increasing dietary concentrations of amino acids often resulted in corresponding increases in serum amino acids, which could be attributed to an increased absorption and digestion; a decrease in the sera amino acids could be due to increased utilization for protein synthesis and other metabolic uses.

It has been shown by Timoshina (1970) with fish and Charkey (1953) with poultry that starvation increased sera amino acids due to catabolism of tissue proteins. Because the fish in this study were starved 48-60 hours

prior to experimentation, the prefeeding sera amino acids may be greater than under normal conditions. In spite of the fact that prefeeding levels may have increased due to starvation, it is apparent that postfeeding levels in general were higher than prefeeding levels. This was also evident in a study by Lambert (1969) on channel catfish.

Results showed sera amino acids in general, were greater in fish maintained at higher water temperatures. It is important to note, however, that an apparent digestion of protein and subsequent amino acid absorption of fish maintained at 13°C occurred. Comparison of studies on thermal effects on amino acids in poultry and fish are inappropriate due to their differences in thermal regulation.

The fact that the prefeeding level of methionine of fish fed either ingredient was the lowest observed and that postfeeding methionine levels showed the least increase of the essential amino acids; indicated that methionine was the limiting amino acid for fish fed soybean meal or egg albumin. Featherston (1970) in a paper on avian nutrition, stated that the amino acid in shortest supply will become the most limiting amino acid and will show the least increase after feeding a test diet in comparison to the plasma level when a more adequate diet was fed. Our results showed that methionine levels postfeeding were often below prefeeding levels. This same observation was made in a study on poultry by Hill and Olsen (1967). A 70% decrease in methionine was noted four hours postfeeding a diet low in methionine.

Albumin showed greater increases in sera methionine but data showed soybean meal caused as great or greater increases in total sera amino acids. Dean and Scott (1966) in a study on chickens found that when a test diet deficient in a single essential amino acid was fed, the levels of the other amino acids increased. This was presumably due to a decreased utilization

due to the limiting effect of the deficient amino acid in the diet. These observations indicated in our study that because soybean meal was lower in methionine, the total amino acid levels increased due to the limiting effect of methionine in the diet. Egg albumin, however, showed smaller increases in total amino acids than did fish fed soybean meal. This is presumably due to the fact that the higher level of methionine in egg albumin was not as limiting and, therefore, utilization of the amino acids was greater in fish fed egg albumin.

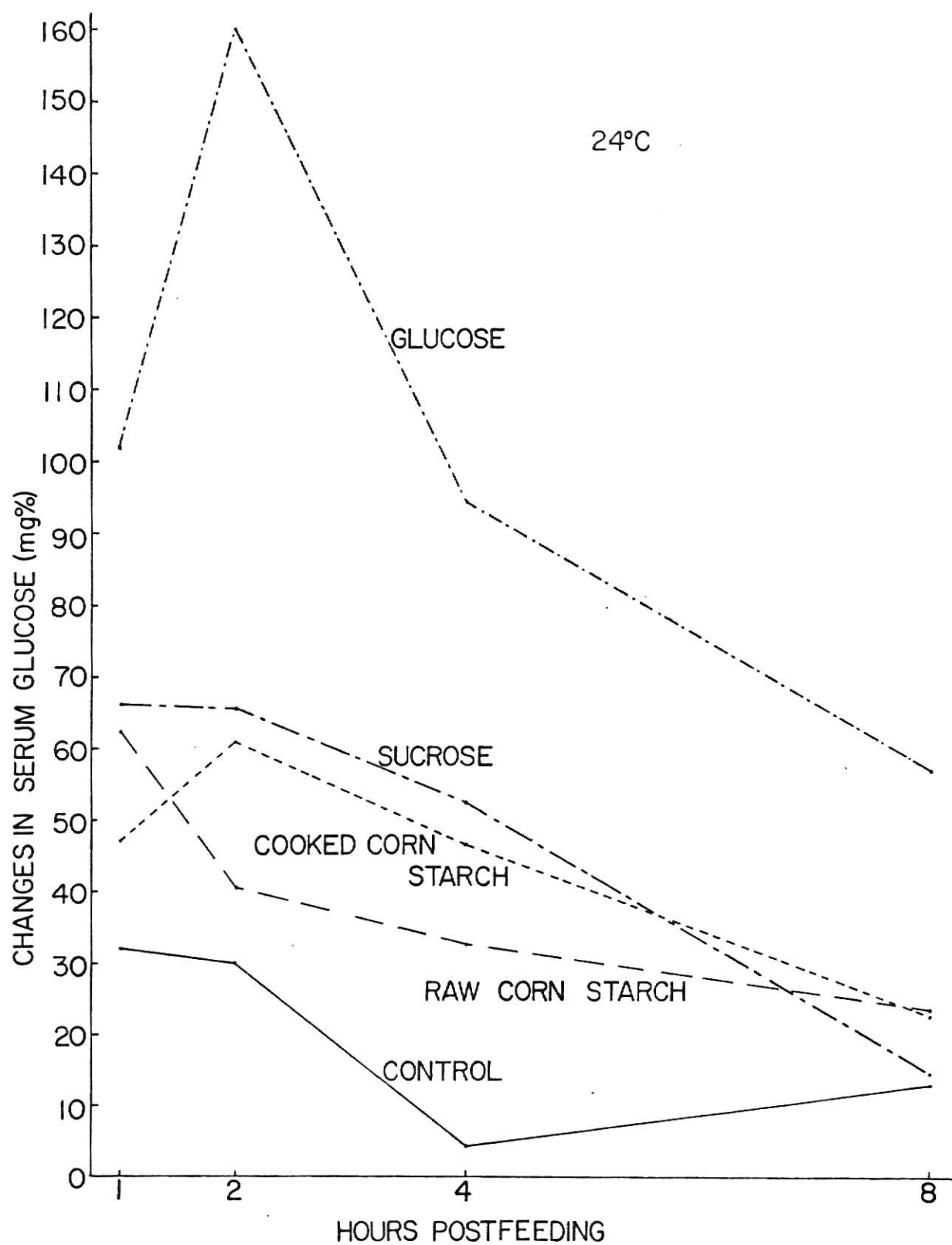


Figure 1. Changes in serum glucose (means of 10 fish each) of control fish and fish force-fed indicated carbohydrates while maintained in water at 24°C.

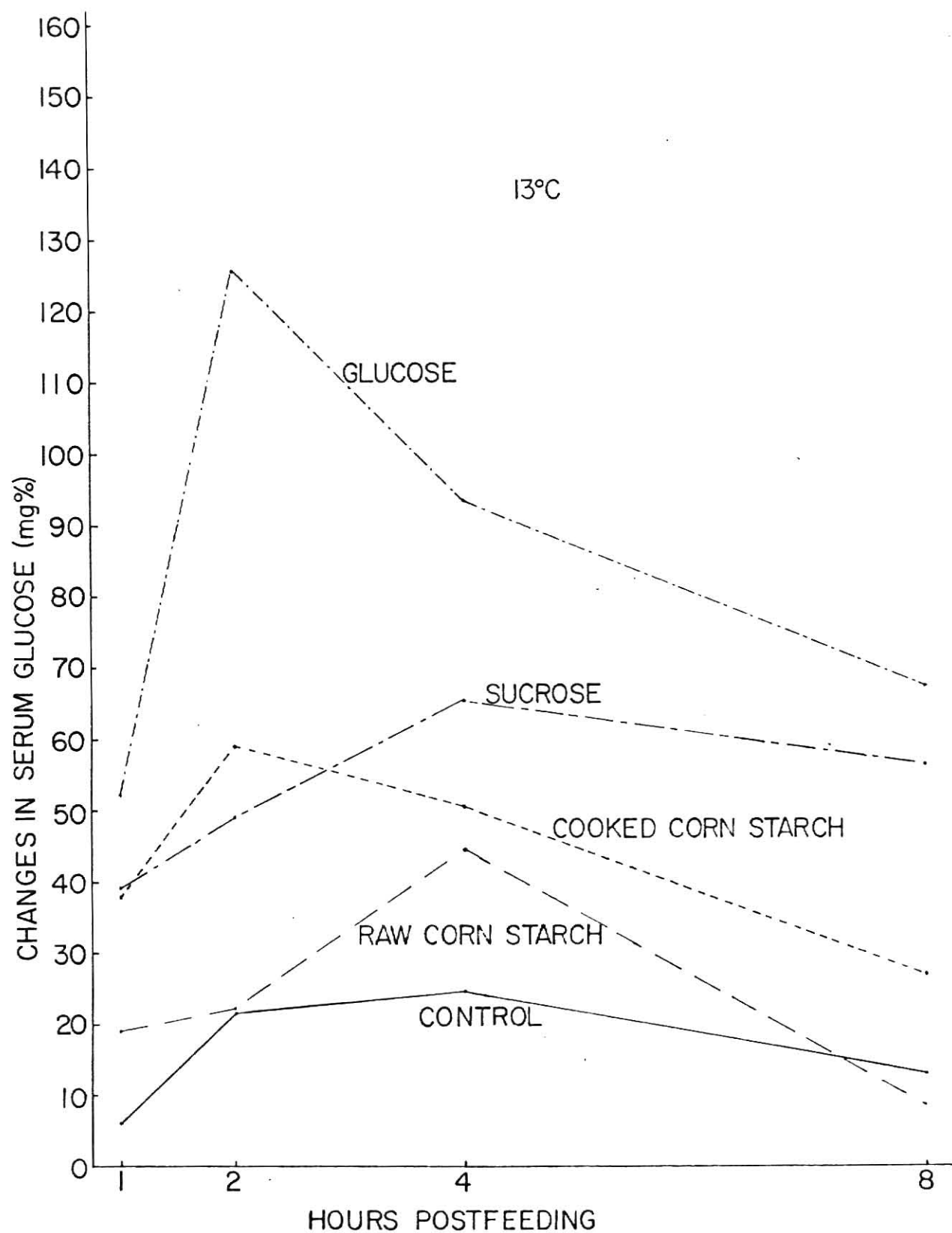


Figure 2: Changes in serum glucose (means of 10 fish each) of control fish and fish force-fed indicated carbohydrates while maintained in water at 13°C.

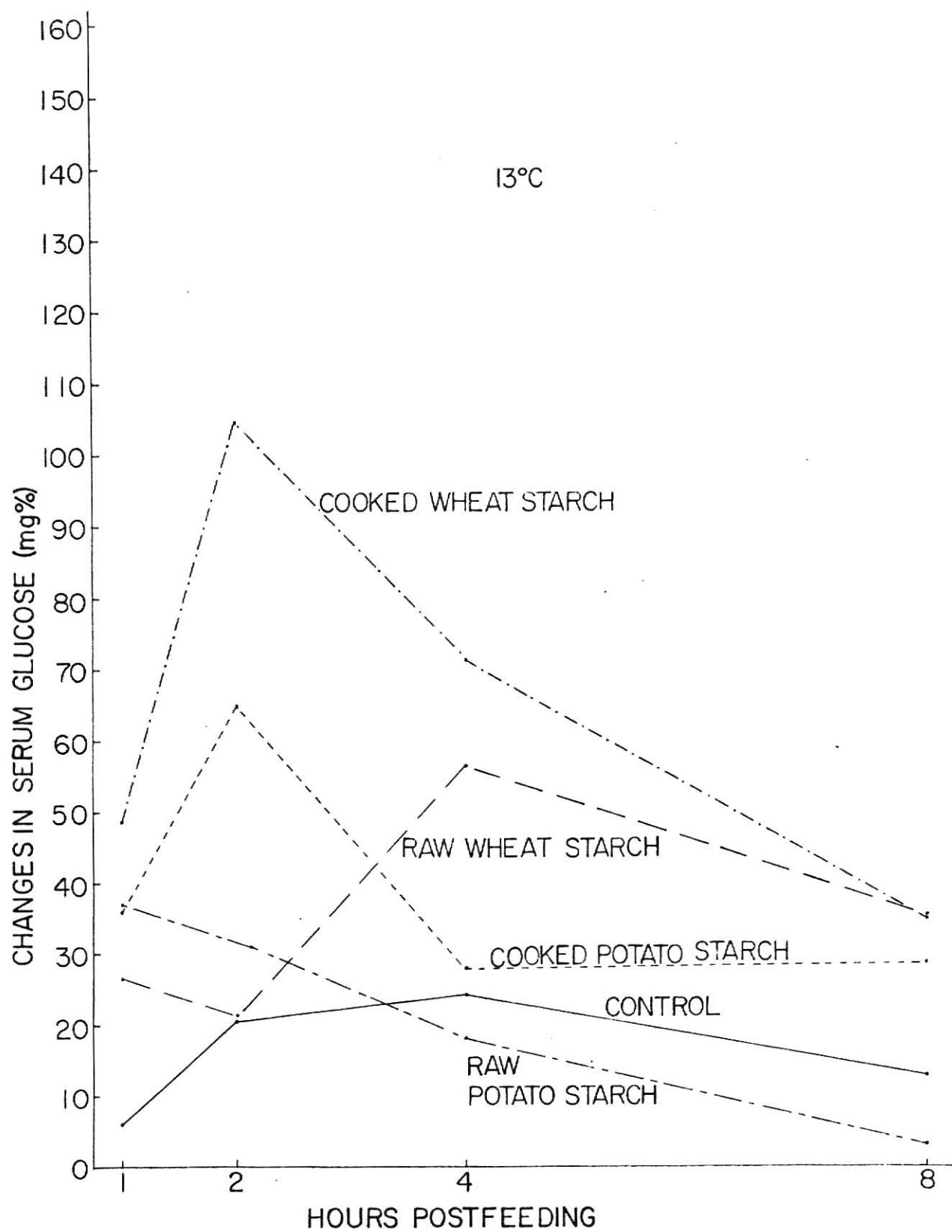


Figure 3. Changes in serum glucose (means of 10 fish each) of control fish and fish force-fed indicated carbohydrates while maintained in water at 13°C.

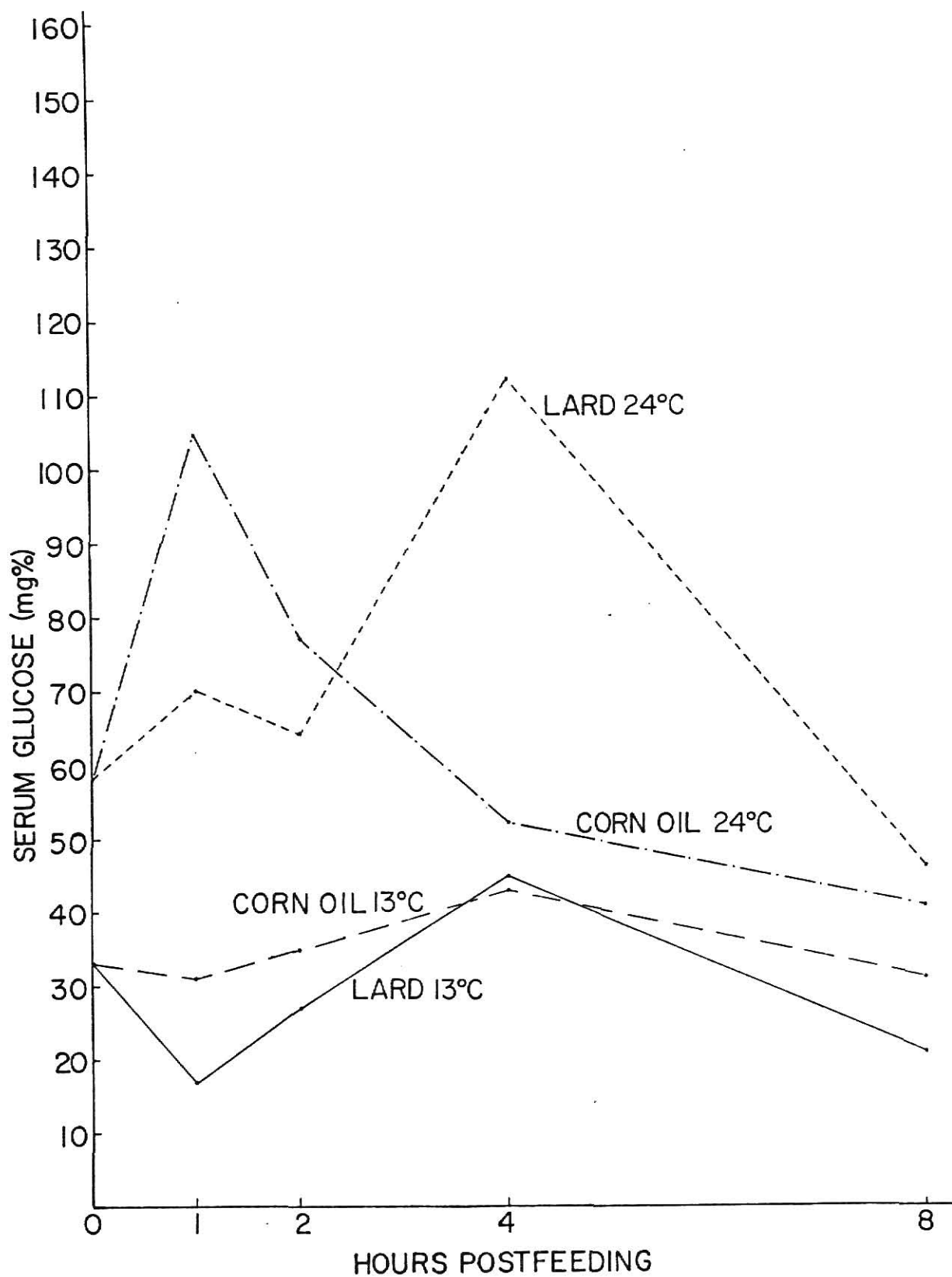


Figure 4: Serum glucose (means of two groups of five fish) of control fish and fish force-fed corn oil or lard while maintained in water at 13 or 24°C.

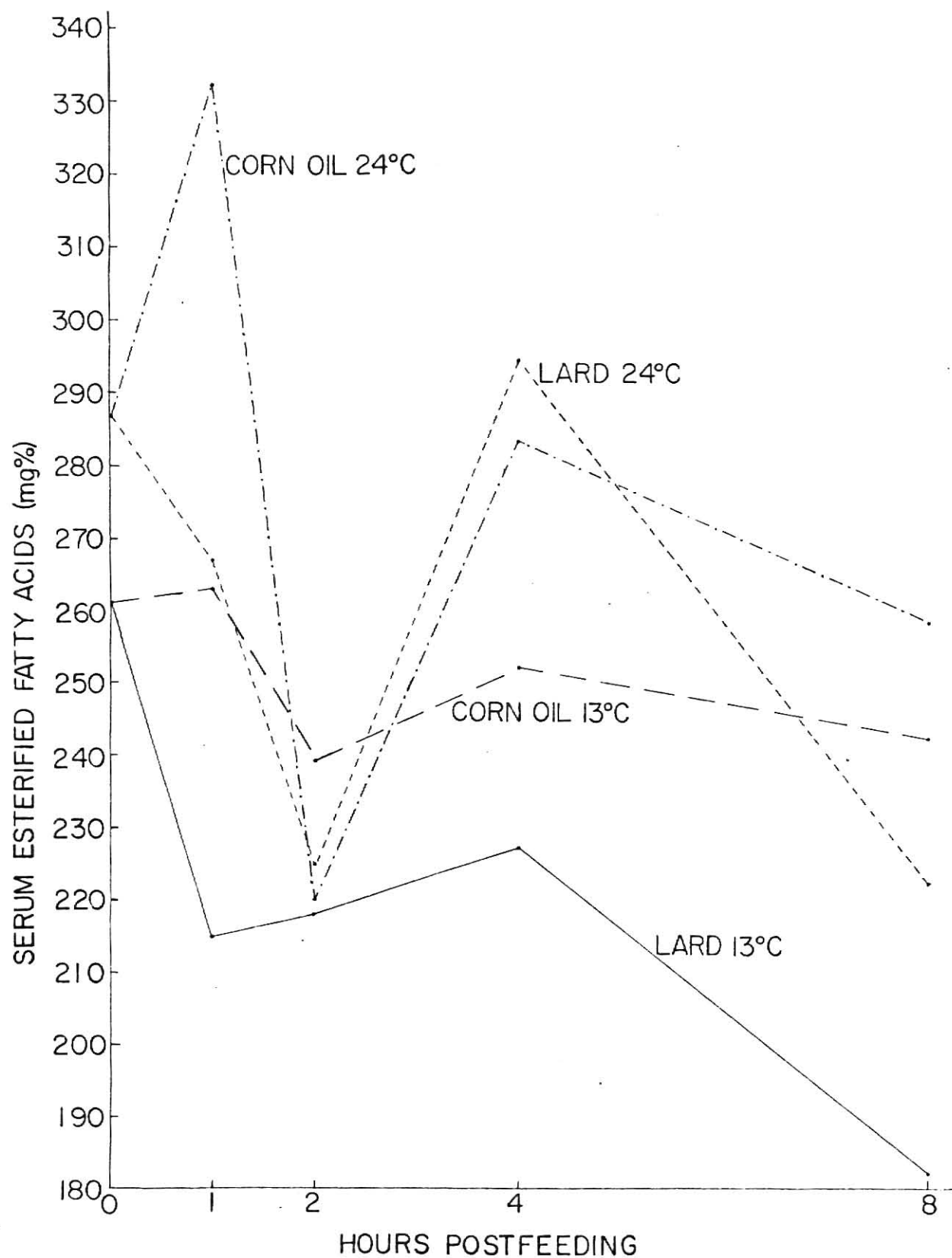


Figure 5. Serum esterified fatty acids (means of two groups of five fish) for control fish and fish force-fed corn oil or lard while maintained in water at 13 or 24°C.

Table 1. Serum glucose levels (mg%) for nonfed fish and fish force-fed soybean meal or egg albumin while maintained at 13 and 24°C.

Protein ingredient	Temperature °C	Levels of serum glucose (mg%) ⁽¹⁾				
		Prefeeding	Hours postfeeding			
		0	1	2	4	8
Soybean	13	33.33	18.80	35.47	32.48	25.21
Soybean	24	58.33	72.22	68.80	48.72	46.15
Albumin	13	33.33	32.48	38.03	47.43	22.65
Albumin	24	58.33	38.03	44.44	56.84	82.48

⁽¹⁾ Each observation represents one analysis of the pooled sera from 10 fish.

Table 2. Essential amino acid levels contained in soybean meal. Individual and total essential amino acid levels and total nonessential amino acid levels in the sera of fish force-fed soybean meal while maintained at 13 and 24° C.

Essential amino acids	Amino acid levels in soybean meal (moles /100moles of feed)	Temperature °C	Levels of amino acids (micromoles/ml sera) ⁽¹⁾				
			Prefeeding		Hours postfeeding		
			0	1	2	4	8
Arginine	6.308	13	.032	.076	.068	.051	.070
		24	.030	.090	.084	.106	.122
Histidine	2.429	13	.028	.044	.026	.019	.028
		24	.030	.046	.032	.038	.044
Isoleucine	4.081	13	.076	.178	.184	.094	.146
		24	.099	.236	.225	.222	.220
Leucine	6.925	13	.137	.332	.334	.178	.244
		24	.159	.326	.344	.330	.334
Lysine	4.696	13	.114	.426	.360	.210	.222
		24	.164	.300	.350	.298	.374
Methionine	0.826	13	.012	.004	.002	.005	.004
		24	.008	.004	.002	.002	.002
Phenylalanine	3.572	13	.048	.086	.076	.046	.074
		24	.070	.100	.114	.380	.120
Threonine	3.736	13	.113	.220	.214	.116	.163
		24	.139	.206	.202	.206	.194
Valine	4.186	13	.102	.240	.244	.118	.184
		24	.239	.302	.308	.300	.304
Total essential	42.459	13	.662	1.606	1.508	.837	1.135
		24	.938	1.610	1.662	1.882	1.714
Total nonessential		13	1.405	2.378	2.150	1.253	1.364
		24	2.298	2.665	2.701	2.730	2.397
Total amino acids		13	2.067	3.984	3.658	2.090	2.499
		24	3.236	4.265	4.363	4.612	4.111

⁽¹⁾ Each observation represents one determination from a pooled sera sample from 10 fish.

Table 3. Essential amino acid levels contained in albumin. Individual and total essential amino acid levels and total nonessential amino acid levels in the sera of fish force-fed egg albumin while maintained at 13 and 24° C.

Essential amino acids	Amino acid levels in albumin (moles/100 moles of feed)	Temperature °C	Levels of amino acids (micromoles/ml sera) ⁽¹⁾				
			Prefeeding	Hours postfeeding			
			0	1	2	4	8
Arginine	4.695	13	.032	.042	.042	.050	.040
		24	.030	.048	.050	.046	.046
Histidine	2.844	13	.028	.027	.020	.017	.022
		24	.030	.058	.042	.036	.030
Isoleucine	5.228	13	.076	.110	.136	.104	.104
		24	.099	.210	.162	.119	.126
Leucine	8.688	13	.137	.210	.244	.184	.198
		24	.159	.332	.268	.180	.192
Lysine	4.951	13	.114	.224	.222	.178	.178
		24	.164	.440	.406	.264	.270
Methionine	3.495	13	.012	.012	.012	.013	.006
		24	.008	.016	.018	.012	.016
Phenylalanine	4.511	13	.048	.048	.052	.040	.076
		24	.070	.118	.104	.088	.072
Threonine	4.677	13	.113	.146	.188	.132	.134
		24	.139	.296	.214	.142	.136
Valine	8.136	13	.102	.144	.152	.116	.254
		24	.239	.270	.220	.152	.022
Total essential	47.225	13	.662	.963	1.076	.822	1.012
		24	.938	1.740	1.484	1.039	.910
Total nonessential		13	1.405	2.104	1.485	1.307	2.042
		24	2.298	3.655	2.930	2.267	2.161
Total amino acids		13	2.067	3.067	2.561	2.129	2.054
		24	3.236	5.395	4.414	3.306	3.071

⁽¹⁾ Each observation represents one determination from a pooled sera sample from 10 fish.

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APPENDIX

Table I. Analysis of variance of serum glucose levels obtained from fish fed various carbohydrates while maintained at 13 and 24°C.

Source	Degrees of Freedom	Mean Square	Probability
Ingredient	4	66220.5000	0.0000* ⁽¹⁾
Time	3	18859.1523	0.0000*
Temperature	1	4953.9765	0.0292*
Ingredient X time	12	3861.0930	0.0000*
Ingredient X temperature	4	1793.1142	0.1418
Time X temperature	3	9624.5664	0.0000*
Ingredient X time X temperature	12	922.2588	0.5555
Residual	360	1034.0827	
Total	399		

(1) Statistically significant at the 0.05 level

Table II. Duncan's Multiple Range Test, with 0.05 protection level, of serum glucose levels obtained from fish fed various carbohydrates while maintained at 13 and 24°C.

Ingredient	Means
Glucose	94.0543
Sucrose	51.1377* ⁽¹⁾
Cooked corn starch	44.3161*
Raw corn starch	31.4102
Control	18.1410
Time (hours)	Means
2	63.6195
4	50.9529*
1	46.2905*
8	30.3845
Temperature °C	Means
24	51.33
13	44.29

(1) Means joined by a column of asterisks are not significantly different.

Table II. (Continued)

Ingredient	Time (hours)	Means	
Glucose	2	142.9058	(1)
Glucose	4	93.9955	*
Glucose	1	77.0084	**
Glucose	8	62.3076	**
Cooked corn starch	2	60.4272	***
Sucrose	4	59.0169	***
Sucrose	2	57.4358	****
Sucrose	1	52.8631	****
Cooked corn starch	4	48.8461	*****
Cooked corn starch	1	42.9058	*****
Raw corn starch	1	39.5726	*****
Raw corn starch	4	38.5255	*****
Sucrose	8	35.2349	*****
Raw corn starch	2	31.4315	*****
Nonfed (control)	2	25.8974	*****
Cooked corn starch	8	25.0854	****
Nonfed (control)	1	19.1025	***
Raw corn starch	8	16.1100	**
Nonfed (control)	4	14.3803	*
Nonfed (control)	8	13.3837	*

Temperature °C	Time (hours)	Means	
24	2	71.5725	*
24	1	61.5554	**
13	4	55.8631	**
13	2	55.6665	**
24	4	46.0426	**
13	8	34.6153	**
13	1	31.0255	*
24	8	26.1538	*

(1) Means joined by a column of asterisks are not significantly different.

Table III. Analysis of variance of serum glucose levels obtained from fish fed various carbohydrates while maintained at 13°C.

Source	Degrees of freedom	Mean square	Probability
Ingredient	8	19847.4475	0.0000* ⁽¹⁾
Time	3	13924.2968	0.0000*
Ingredient X time	24	2389.8908	0.0000*
Residual	324	777.6643	
Total	359		

(1) Statistically significant at the 0.05 level.

Table IV. Duncan's Multiple Range Test, with 0.05 protection level, of serum glucose levels obtained from fish fed various carbohydrates while maintained at 13 and 24°C.

Ingredient	Means	
Glucose	84.8182	
Cooked wheat starch	65.0212	
Sucrose	52.5533	* (1)
Cooked corn starch	44.1131	**
Cooked potato starch	39.5619	*
Raw wheat starch	35.1815	**
Raw corn starch	23.5897	**
Raw potato starch	20.9080	*
Control	16.3888	*
Time (hours)	Means	
2	55.6788	*
4	50.3939	*
1	33.0436	*
8	30.7216	*

Table IV. (Continued)

Ingredient	Time (hours)	Means	
Glucose	2	125.81	*(1)
Cooked wheat starch	2	104.78	**
Glucose	4	93.67	**
Cooked wheat starch	4	71.32	**
Glucose	8	67.65	**
Sucrose	4	65.51	***
Cooked potato starch	2	64.99	****
Cooked corn starch	2	59.65	*****
Cooked potato starch	4	56.66	*****
Sucrose	8	56.28	*****
Glucose	1	52.13	*****
Cooked corn starch	4	50.90	*****
Sucrose	2	49.02	*****
Cooked wheat starch	1	48.50	*****
Raw corn starch	4	44.65	*****
Sucrose	1	39.40	*****
Cooked corn starch	1	38.63	*****
Cooked potato starch	1	36.36	*****
Raw wheat starch	8	35.85	*****
Cooked wheat starch	8	35.47	*****
Raw potato starch	2	31.41	*****
Raw potato starch	1	30.76	*****
Cooked potato starch	8	28.85	*****
Cooked potato starch	4	28.03	*****
Cooked corn starch	8	27.26	*****
Raw wheat starch	1	26.62	*****
Nonfed (control)	4	24.57	*****
Raw corn starch	2	22.22	*****
Nonfed (control)	2	21.62	*****
Raw wheat starch	2	21.58	*****
Raw corn starch	1	18.88	*****
Raw potato starch	4	18.20	*****
Nonfed (control)	8	13.29	****
Raw corn starch	8	8.59	***
Nonfed (control)	1	6.06	**
Raw potato starch	8	3.25	*

(1) Means joined by a column of asterisks are not significantly different.

Table V. Analysis of variance of serum glucose levels obtained from fish fed corn oil or lard while maintained at 13 and 24°C.

Source	Degrees of freedom	Mean square	Probability
Treatment	8	861.7029	0.0077* ⁽¹⁾
Temperature	1	13133.3906	0.0000*
Treatment X temperature	8	532.7578	0.0568
Residual	18	220.0603	
Total	35		

(1) Statistically significant at the 0.05 level

Table VI. Duncan's Multiple Range Test, with 0.05 protection level, of serum glucose levels obtained from fish fed corn oil or lard while maintained at 13 and 24°C.

Treatment		Means	
Ingredient	Time (hours)		
Lard	4	78.6324	* (1)
Corn oil	1	68.0555	**
Corn oil	2	56.1965	***
Corn oil	4	49.0769	**
Corn oil	0	45.8333	**
Control	2	45.5128	**
Lard	1	43.5897	**
Lard	8	36.2179	*
Corn oil	8	33.5469	*
Lard			
Temperature °C		Means	
24		69.7292	
13		31.5289	

(1) Means joined by a column of asterisks are not significantly different.

Table VII. Analysis of variance of serum esterified fatty acid levels obtained from fish fed corn oil or lard while maintained at 13 and 24°C.

Source	Degrees of freedom	Mean square	Probability
Treatment	8	3397.9824	0.0130* ⁽¹⁾
Temperature	1	9354.2578	0.0061*
Treatment X temperature	8	821.4746	0.5761
Residual	18	971.1303	
Total	35		

(1) Statistically significant at the 0.05 level

Table VIII. Duncan's Multiple Range Test, with 0.05 protection level, of serum esterified fatty acid levels obtained from fish fed corn oil and lard while maintained at 13 and 24°C.

Treatment		Means	
Ingredient	Time (hours)		
Corn oil	1	297.7058	* ⁽¹⁾
Control	0	274.1032	**
Corn oil	4	267.8093	**
Lard	4	260.8859	**
Corn oil	8	250.1862	***
Lard	1	241.3746	**
Corn oil	2	230.0455	**
Lard	2	221.8632	**
Lard	8	202.6666	*
Temperature °C		Means	
	24	265.7463	
	13	233.5071	

(1) Means joined by a column of asterisks are not significantly different.

Table IX. Changes in serum glucose levels (mg%) attributed to digestion of carbohydrates by fish maintained at 24°C. Each observation represents the change in serum glucose of one fish.

Ingredient							
Glucose				Sucrose			
Hours postfeeding				Hours postfeeding			
0	2	4	8	0	2	4	8
130.76	147.43	106.41	2.56	72.64	59.40	80.76	1.70
43.16	144.01	193.16	17.09	85.89	55.55	64.10	25.64
92.73	178.20	88.03	21.36	23.40	91.88	29.05	11.96
136.75	52.13	62.82	75.64	63.24	18.65	7.26	-4.70
131.19	384.61	63.67	72.64	78.63	72.64	16.66	43.16
181.19	159.40	145.29	38.88	72.22	114.10	71.79	-9.40
76.49	174.78	28.63	12.39	70.08	47.86	55.98	32.90
131.62	98.71	61.96	74.78	64.52	86.32	50.42	14.10
31.19	141.00	142.73	158.97	64.95	81.62	92.30	8.97
63.67	101.70	50.42	100.42	67.52	38.46	56.83	17.52
avg. 101.88	159.99	94.31	56.96	66.32	65.85	52.52	14.18

Ingredient							
Raw corn starch				Cooked corn starch			
Hours postfeeding				Hours postfeeding			
0	2	4	8	0	2	4	8
51.70	32.17	34.18	14.95	80.76	38.88	91.45	1.28
15.38	32.05	17.09	64.10	62.82	37.17	78.20	56.41
105.55	55.55	52.56	55.98	61.96	104.70	37.17	52.99
83.33	29.48	57.48	35.89	36.83	102.27	40.59	39.74
48.29	27.77	14.95	32.90	30.34	95.72	39.31	44.44
50.00	68.80	22.22	26.06	29.48	31.62	30.34	35.04
49.14	23.93	41.45	10.25	39.31	62.39	61.96	7.69
97.86	46.58	34.18	-10.68	20.08	47.00	26.06	4.70
19.65	42.30	27.77	-10.25	42.73	51.70	29.05	16.66
81.62	42.73	22.22	-17.09	47.43	38.46	33.76	14.52
avg. 60.25	40.64	32.39	23.63	47.17	61.19	46.79	22.90

Table X. Changes in serum glucose levels (mg%) attributed to digestion of carbohydrates by fish maintained at 13°C. Each observation represents the change in serum glucose of one fish.

Ingredient							
Glucose				Sucrose			
Hours postfeeding				Hours postfeeding			
0	2	4	8	0	2	4	8
28.20	181.19	179.48	-24.53	32.47	38.46	58.97	78.63
120.94	80.34	85.89	43.16	38.88	24.35	63.24	-5.12
64.95	101.28	52.13	136.75	35.89	55.55	53.55	105.12
61.96	67.09	86.75	15.37	91.02	30.34	73.50	114.52
36.32	123.50	140.17	132.47	29.91	55.98	123.59	77.77
30.76	128.20	19.65	128.47	28.63	56.41	19.65	42.73
43.16	113.67	95.29	98.29	20.51	53.84	20.51	65.81
46.15	116.23	106.41	33.33	23.50	85.89	11.53	32.90
40.17	132.05	62.82	44.87	50.85	60.68	81.62	-44.01
48.71	214.52	108.12	67.94	38.46	28.63	119.61	94.44
avg.	52.13	125.81	93.67	39.40	49.17	65.51	56.28

Ingredient							
Raw corn starch				Cooked corn starch			
Hours postfeeding				Hours postfeeding			
0	2	4	8	0	2	4	8
11.11	21.79	35.47	3.41	49.57	64.10	63.67	-2.56
28.63	6.41	32.90	-7.69	57.26	89.31	43.58	15.38
18.23	13.24	48.29	11.53	51.28	73.50	24.78	21.79
17.09	38.88	42.30	26.49	31.19	51.70	38.46	50.42
14.95	5.55	55.12	-37.17	19.65	61.11	59.40	38.46
0.85	5.55	50.00	16.23	28.20	46.58	30.34	22.64
19.23	36.32	38.48	0.42	32.90	65.81	72.22	55.98
13.67	15.38	32.05	-5.98	56.83	31.19	83.76	51.28
38.46	29.48	73.50	0.42	34.61	62.82	28.20	76.49
25.64	49.57	38.88	67.94	27.77	49.57	64.52	18.80
avg.	18.88	22.22	44.65	38.63	59.65	50.89	27.26

Table X. (continued)

Ingredient							
Raw potato starch				Cooked potato starch			
Hours postfeeding				Hours postfeeding			
0	2	4	8	0	2	4	8
7.26	56.84	0.98	1.28	50.83	89.31	37.17	8.11
19.65	41.88	2.13	6.41	99.57	69.20	45.29	36.32
146.58	12.82	11.96	8.11	17.94	59.82	22.22	38.46
23.07	17.94	3.84	-0.42	25.64	34.18	10.25	32.47
0.03	-0.42	13.24	0.00	14.10	48.29	13.67	32.62
23.93	45.72	21.76	-3.41	38.03	161.53	14.10	23.50
30.34	44.44	45.72	3.41	33.33	58.54	68.80	29.48
32.90	35.04	10.68	5.12	26.92	64.52	38.88	16.23
17.52	25.64	20.08	4.27	50.42	37.17	18.80	28.20
3.41	23.18	43.16	7.69	0.85	27.35	11.11	44.01
avg. 30.76	31.41	18.20	3.24	36.36	64.99	28.03	28.84

Ingredient							
Raw wheat starch				Cooked wheat starch			
Hours postfeeding				Hours postfeeding			
0	2	4	8	0	2	4	8
31.19	11.53	36.75	41.02	40.59	70.94	105.12	19.65
14.95	15.81	37.17	36.32	36.75	80.05	129.05	15.81
28.20	20.51	54.27	29.91	43.16	128.20	58.97	20.08
32.90	39.31	52.13	60.25	14.10	97.00	56.83	55.12
16.66	43.58	61.11	21.79	88.88	76.06	128.63	20.51
41.88	21.79	63.24	14.95	46.58	60.68	61.96	92.73
29.11	12.39	96.58	29.91	88.03	208.11	12.39	37.60
28.20	25.64	45.72	50.85	48.71	148.71	30.76	34.61
28.63	3.84	64.10	50.00	44.87	85.89	34.18	24.78
13.67	21.36	55.55	23.50	33.33	90.17	95.29	33.76
avg. 26.62	21.58	56.66	35.85	48.50	104.78	71.32	35.47

Table XI. Changes in serum glucose levels (mg%) attributed to sampling and handling procedures of fish maintained at 13 and 24°C. Each observation represents the change in serum glucose of one fish.

Nonfed 13°C				
Hours postfeeding				
1	2	4	8	
-40.59	-4.27	32.47	9.85	
14.59	7.69	25.64	8.54	
61.96	6.41	51.28	0.85	
-0.85	-2.13	2.13	2.13	
-17.09	31.19	17.94	8.97	
14.52	34.61	35.04	25.64	
-21.79	20.51	21.36	23.07	
7.26	51.28	24.35	15.38	
22.22	44.87	14.10	30.34	
20.08	26.06	21.36	21.36	
avg. 6.06	21.62	24.57	13.29	

Nonfed 13°C				
Hours postfeeding				
1	2	4	8	
84.61	-4.27	-11.96	7.69	
34.18	22.64	7.26	38.46	
53.41	3.84	-2.13	8.97	
0.85	49.14	10.25	28.63	
20.08	40.17	36.32	50.85	
6.83	34.61	-13.67	-8.97	
44.01	5.12	1.70	-20.51	
20.08	82.05	5.12	18.80	
23.07	70.94	-20.08	11.53	
34.18	6.41	29.05	-4.70	
avg. 32.13	30.17	4.18	13.07	

Table XII. Serum glucose levels (mg%) of nonfed fish and fish force-fed various lipids while maintained at 13 and 24°C. Each observation represents the serum glucose level from a pooled blood sample of five fish.

Corn oil 13°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
29.91	39.31	47.00	33.76	
<u>33.33</u>	<u>30.76</u>	<u>39.74</u>	<u>28.63</u>	
avg. 31.62	35.04	43.37	31.19	
Corn oil 24°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
78.20	75.21	50.85	49.29	
<u>130.76</u>	<u>79.48</u>	<u>54.70</u>	<u>34.18</u>	
avg. 104.48	77.35	52.77	41.23	
Lard 13°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
25.64	49.57	50.42	21.36	
<u>31.62</u>	<u>30.76</u>	<u>39.31</u>	<u>20.51</u>	
avg. 28.63	40.16	44.87	20.94	
Lard 24°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
74.35	60.25	102.56	59.40	
<u>65.91</u>	<u>69.23</u>	<u>122.22</u>	<u>32.90</u>	
avg. 70.08	64.74	112.39	46.15	
		<u>13°C</u>	<u>24°C</u>	
Levels of nonfed fish		38.46	50.00	
		<u>28.20</u>	<u>66.66</u>	
avg.		33.33	58.33	

Table XIII. Serum esterified fatty acid levels (mg%) of nonfed fish and fish force-fed various lipids while maintained at 13 and 24°C. Each observation represents the serum glucose level from a pooled blood sample of five fish.

Corn oil 13°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
304.43	239.02	257.89	231.47	
<u>221.40</u>	<u>239.12</u>	<u>246.56</u>	<u>252.85</u>	
avg. 263.08	239.17	252.38	242.31	
Corn oil 24°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
330.85	231.47	255.37	252.85	
<u>333.37</u>	<u>210.08</u>	<u>310.71</u>	<u>262.92</u>	
avg. 332.32	220.91	283.22	258.05	
Lard 13°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
201.28	254.11	233.98	168.57	
<u>228.95</u>	<u>182.41</u>	<u>220.15</u>	<u>196.24</u>	
avg. 215.25	218.40	227.21	182.52	
Lard 24°C				
Hours postfeeding				
<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	
226.44	272.98	269.21	201.28	
<u>308.21</u>	<u>255.37</u>	<u>319.53</u>	<u>244.05</u>	
avg. 267.49	225.32	294.55	222.80	
		<u>13°C</u>	<u>24°C</u>	
Levels of nonfed fish		239.02	278.01	
		<u>279.47</u>	<u>295.63</u>	
avg..		261.20	287.00	

Table XIII. Levels of amino acids, ammonia and urea in the sera for nonfed fish and fish force-fed albumin. Blood samples were taken at 1, 2, 4, and 8 hours postfeeding while fish were maintained at 13°C.

Amino acid	Levels of amino acids in sera (micromoles/ml sera) ⁽¹⁾				
	Prefeeding	Hours postfeeding			
	0	1	2	4	8
Phosphoethanolamine	.005	.007	.004	.001	.003
Asparagine	.094	.139	.121	.088	.076
Alpha-amino adipic acid	trace	trace	trace	trace	trace
Cystathionine	.008	.008	.009	.014	.009
Taurine	.524	.737	.484	.410	1.090
Urea	.793	.879	.484	.629	1.176
Hydroxy proline	.055	.118	.092	.092	.056
Aspartic acid	.036	.058	.061	.038	.034
Threonine	.113	.146	.188	.132	.134
Serine	.080	.071	.094	.073	.077
Sarcosine	trace	trace	trace	trace	trace
Proline	.069	.134	.120	.056	.058
Glutamic acid	.092	.101	.089	.038	.048
Citrulline	trace	trace	trace	trace	.107
Glycine	.142	.190	.188	.171	.142
Alanine	.162	.340	.151	.183	.186
Alpha-amino-n-butyric acid	.015	.007	.010	.009	.010
Valine	.102	.144	.152	.116	.254
Cystine	trace	.037	.049	.032	trace
Methionine	.012	.012	.012	.013	.006
Isoleucine	.076	.110	.136	.104	.104
Leucine	.137	.210	.244	.184	.198
Tyrosine	.054	.060	.045	.040	.054
Phenylalanine	.048	.048	.052	.040	.076
Gamma-amino butyric	.002	.005	.003	trace	trace
Ornithine	.050	.063	.056	.049	.057
Ethanolamine + Ammonia	.305	.334	.389	.359	.342
Lysine	.114	.224	.222	.178	.178
l-methyl histidine	.017	.029	.016	.029	.037
Arginine	.032	.042	.050	.038	.040
Histidine	.028	.027	.020	.017	.022
Total	2.067	3.067	2.561	2.129	3.054

(1) Each observation represents one analysis of the pooled sera from 10 fish.

Table XIV. Levels of amino acids, ammonia and urea in the sera for nonfed fish and fish force-fed albumin. Blood samples were taken at 1, 2, 4, and 8 hours postfeeding while fish were maintained at 24°C.

Amino acid	Levels of amino acids in sera (micromoles/ml sera) ⁽¹⁾				
	Prefeeding	Hours postfeeding			
	0	1	2	4	8
Phosphoethanolamine	.006	.012	.008	.006	.004
Asparagine	.121	.142	.196	.116	.166
Alpha-amino adipic acid	trace	trace	trace	trace	trace
Cystathionine	.006	.013	.008	.004	.006
Taurine	1.070	1.029	.808	.940	.904
Urea	.588	1.046	.799	.674	1.089
Hydroxy proline	.067	.222	.174	.077	.065
Aspartic acid	.036	.116	.100	.050	.056
Threonine	.139	.296	.214	.142	.136
Serine	.099	.145	.150	.099	.088
Sarcosine	trace	.055	.033	trace	trace
Proline	.115	.380	.224	.126	.074
Glutamic acid	.101	.203	.169	.124	.095
Citrulline	trace	.012	.010	trace	trace
Glycine	.179	.410	.333	.239	.231
Alanine	.205	.511	.403	.244	.223
Alpha-amino-n-butyric acid	.006	.006	.005	.006	.007
Valine	.239	.270	.220	.152	.022
Cystine	trace	.062	.050	.052	.056
Methionine	.008	.016	.018	.012	.016
Isoleucine	.099	.210	.162	.119	.126
Leucine	.159	.332	.268	.180	.192
Tyrosine	.056	.098	.082	.070	.066
Phenylalanine	.070	.118	.104	.088	.072
Gamma-amino butyric	.005	.010	.005	.004	.005
Ornithine	.007	.149	.140	.094	.090
Ethanolamine + Ammonia	.331	.481	.444	.397	.418
Lysine	.164	.300	.350	.298	.374
l-methyl histidine	.022	.033	.048	.035	.029
Arginine	.030	.048	.050	.046	.046
Histidine	.030	.058	.043	.036	.031
Total	3.236	5.395	4.414	3.306	3.071

(1) Each observation represents one analysis of the pooled sera from 10 fish.

Table XV. Levels of amino acids, ammonia and urea in the sera for nonfed fish and fish force-fed soybean meal. Blood samples taken at 1, 2, 4, and 8 hours postfeeding while fish were maintained at 24°C.

Amino acid	Levels of amino acids in sera (micromoles/ml sera) ⁽¹⁾				
	Prefeeding	Hours postfeeding			
	0	1	2	4	8
Phosphoethanolamine	.006	.044	.035	.028	.017
Asparagine	.119	.163	.110	.157	.163
Alpha-amino adipic acid	trace	trace	trace	trace	trace
Cystathionine	.006	.004	.008	.006	.006
Taurine	1.070	1.047	1.319	1.291	.968
Urea	.588	.766	1.062	.961	.661
Hydroxy proline	.067	trace	trace	trace	trace
Aspartic acid	.036	.099	.059	.096	.093
Threonine	.139	.206	.202	.206	.194
Serine	.099	.206	.125	.173	.140
Sarcosine	trace	trace	trace	trace	trace
Proline	.115	.140	.125	.122	.120
Glutamic acid	.101	.163	.150	.135	.135
Citrulline	trace	trace	trace	trace	trace
Glycine	.179	.167	.156	.182	.180
Alanine	.205	.446	.365	.305	.295
Alpha-amino-n-butyric acid	.006	.010	.011	.008	.010
Valine	.239	.302	.308	.300	.304
Cystine	trace	trace	trace	trace	trace
Methionine	.008	.004	.002	.002	.002
Isoleucine	.099	.236	.225	.222	.220
Leucine	.159	.326	.344	.330	.334
Tyrosine	.056	.079	.084	.084	.088
Phenylalanine	.070	.100	.114	.114	.120
Gamma-amino butyric	.005	.003	.004	.006	.002
Ornithine	.007	.083	.091	.097	.130
Ethanolamine + Ammonia	.331	.506	.378	.391	.464
Lysine	.164	.300	.350	.298	.374
l-methyl histidine	.022	.066	.060	.045	.052
Arginine	.030	.090	.084	.106	.122
Histidine	.030	.046	.032	.038	.044
Total	3.236	4.265	4.363	4.612	4.111

(1) Each observation represents one analysis of the pooled sera from 10 fish.

Table XVI. Levels of amino acids, ammonia and urea in the sera for nonfed fish and fish force-fed soybean meal. Blood samples taken at 1, 2, 4, and 8 hours postfeeding while fish were maintained at 13°C.

Amino acid	Levels of amino acids in sera (micromoles/ml sera) ⁽¹⁾				
	Prefeeding	Hours postfeeding			
	0	1	2	4	8
Phosphoethanolamine	.005	.036	.035	.010	.012
Asparagine	.094	.092	.098	.057	.095
Alpha-amino adipic acid	trace	trace	trace	trace	trace
Cystathionine	.008	.002	.011	.011	.016
Taurine	.524	.916	.717	.594	.542
Urea	.593	.780	1.170	.459	1.076
Hydroxy proline	.055	.049	.020	.020	.039
Aspartic acid	.036	.095	.118	.013	.044
Threonine	.113	.220	.214	.116	.163
Serine	.080	.115	.122	.076	.101
Sarcosine	trace	trace	trace	trace	trace
Proline	.069	.112	.137	.044	.062
Glutamic acid	.091	.149	.151	.031	.058
Citrulline	trace	trace	trace	trace	trace
Glycine	.142	.205	.178	.101	.132
Alanine	.162	.259	.359	.172	.148
Alpha-amino-n-butyric acid	.015	.014	.015	.008	.011
Valine	.102	.240	.244	.118	.184
Cystine	trace	trace	trace	trace	trace
Methionine	.012	.004	.002	.005	.004
Isoleucine	.076	.178	.184	.094	.146
Leucine	.137	.332	.334	.178	.244
Tyrosine	.054	.065	.066	.032	.048
Phenylalanine	.048	.086	.076	.046	.074
Gamma-amino butyric	.002	.009	.004	.003	.002
Ornithine	.050	.019	.093	.058	.025
Ethanolamine + Ammonia	.305	.558	.491	.488	.328
Lysine	.114	.426	.360	.210	.222
l-methyl histidine	.017	.043	.019	.022	.030
Arginine	.032	.076	.068	.051	.070
Histidine	.028	.044	.026	.019	.028
Total	2.067	3.984	3.658	2.090	2.499

(1) Each observation represents one analysis of the pooled sera from 10 fish.

DIGESTIBILITY OF CARBOHYDRATES, LIPIDS, AND
PROTEINS IN CHANNEL CATFISH ICTALURUS PUNCTATUS (Rafinesque)

by

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ABSTRACT

This study determined digestibility of several carbohydrate, lipid and protein feed ingredients in channel catfish, Ictalurus punctatus (Rafinesque) and effects of water temperature and time after feeding on digestion of ingredients. Digestion end-products in the sera were measured to indicate feed ingredient digestibility.

Channel catfish weighing 340 to 570 grams each were maintained at 13 or 24° and sampled for blood at 0, 1, 2, 4, and 8 hours after force-feeding known quantities of ingredients. Levels of blood glucose were determined from sera of fish fed glucose, sucrose, raw and cooked starches (corn, wheat and potato), corn oil, lard, egg albumin, and soybean meal. Esterified fatty acids in the sera were determined for fish fed corn oil and lard. Sera amino acids were determined for fish fed egg albumin and soybean meal.

Results showed that: 1) serum glucose increased with decreases in complexity of the carbohydrate fed; 2) channel catfish digested carbohydrates at 13°C but at a slower rate than at 24°C; 3) cooking starches increased serum glucose more than raw starches; 4) corn oil and lard did not significantly effect serum esterified fatty acids or serum glucose, however, fish maintained at 24°C had higher serum glucose and esterified fatty acids than fish maintained at 13°C; 5) egg albumin and soybean meal had little effect on serum glucose; 6) generally, sera amino acids were greater for fish maintained at 24°C than 13°C; 7) methionine was the limiting amino acid when egg albumin and soybean meal were fed; 8) soybean meal resulted in as high or higher increases in sera amino acids than fish fed egg albumin, however, these higher increases are presumably due to decreased utilization of amino acids because of the lower level of methionine in soybean meal.