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Effects of dietary fat levels and fat sources on growth and trace mineral deposition in young male rats

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The University of North Carolina at Greensboro, 1987

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EFFECTS OF DIETARY FAT LEVELS AND FAT SOURCES ON GROWTH AND TRACE MINERAL DEPOSITION IN YOUNG MALE RATS

by

Thelma Howell Zuniga

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the Faculty of the Graduate School at
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APPROVAL PAGE

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ZUNIGA, THELMA HOWELL, Ph.D. Effects of Dietary Fat Levels and Fat Sources on Growth and Trace Mineral Deposition in Young Male Rats. (1987)
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This study investigated the effects of dietary fat levels and fat sources on growth and trace mineral deposition in young male rats at four weeks. Dietary factors included four levels of fat (2.5, 5, 10, and 20%) and three fat sources for each of two experiments. Fat sources used in the first experiment were coconut oil, lard, and safflower oil, while corn oil, olive oil, and soybean oil were the dietary fat sources for the second experiment. Criteria used to evaluate animal responses to various test diets included weight gain, feed intake, hemoglobin level, hematocrits, and copper, iron, and zinc deposition in the kidneys, liver, spleen and testes.

Analyses of variance (SAS programs) indicated that growth, in the experiment where coconut oil, lard, or safflower oil were the dietary fat sources, was effected significantly by the kilocalorie intake. Animals fed diets high in fat gained the most weight in both experiments. Animals fed dietary corn oil gained significantly more weight versus those fed olive oil or soybean oil. Hemoglobin levels were higher in animals fed coconut oil diets versus those fed lard, and both hemoglobins and hematocrits were higher at the low dietary fat levels.

Kidney copper deposition was greater in animals fed olive oil diets compared to those fed corn or soybean oil diets. A source x level interaction affected kidney iron deposition when coconut oil, lard, and safflower oil were the fat sources. Spleen iron was found to be higher in animals on olive oil diets versus those fed corn oil or soybean oil diets. Tissue zinc deposition was found not to be effected by either dietary fat level or fat sources.

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CHAPTER I

INTRODUCTION

Health professionals and health organizations in the United States are recommending that people reduce their fat intake to 30% of caloric intake and restrict their intake of highly saturated fats. A 1978 FAO/WHO report recommended that dietary fat be reduced and that a balance between dietary polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) be achieved so that a polyunsaturated fatty acid to saturated fatty ratio (P/S) between 0.6-1.0 could be maintained. The higher dietary P/S ratio is considered to be one of the factors which helps to reduce the risk of cardiovascular disease (CVD) (Hamilton & Whitney, 1979, p. 504).

Taylor, Gibney, and Morgan (1979) pointed out that not only the P/S ratio of the diet may be important in CVD, but that the ratio of the different PUFA families (n-6 to n-3) may be just as important. Budowski and Crawford (1985) suggested that a "natural" diet, and one that aids in CVD prevention, should also have a dietary PUFA ratio of n-6 fatty acids to n-3 fatty acids not exceeding five. They have maintained that diets in many western industrialized countries have ratios of linoleic acid (n-6) to linolenic (n-3) well above five, mainly as a result of increased consumption of plant oils.

In order for many people to achieve the recommended dietary balances between dietary lipid components, marked changes in the amount and types of lipids consumed must occur. The typical steak dinner of red meat and potatoes with a salad, has a high percentage of caloric intake from saturated fats. Since changes in a major dietary component can influence the availability and utilization of other nutrients, including trace minerals, information regarding the relationships between various nutrients needs to be considered. The effects of dietary fat on trace minerals have been reported by many researchers (Amine & Hegsted, 1975; Barbatunde, 1972; Bettger, Reeves, Moscatelli, Reynolds, & O'Dell, 1979; Bowering, Masch, & Lewis, 1977; Johnson, Lukaski, & Brown, 1987; Lukaski, Klevay, Bolonchuk, Mahalko, Milne, Johnson, & Sandsted, 1982), but the exact nature of the relationship between dietary fat and trace mineral deposition needs further clarification.

The purpose of this study was to investigate further the effects of fat level and fat source (type) on growth and deposition of the trace minerals, copper, iron, and zinc in young male rats. Fat sources with different fatty acid compositions were chosen in order to determine, if possible, which fatty acid component (P/S ratio or linoleic acid/linolenic acid ratio), along with fat level might have the greatest influence on trace mineral status.

CHAPTER II

REVIEW OF THE LITERATURE

Although interrelationships between dietary fat and the trace minerals, zinc, iron, and copper, in several animal species have been reported, the exact natures of the interrelationships are not clearly defined. The relationship between zinc and dietary fat has been reported by several researchers. Babatunde (1972) reported a direct relationship between dietary levels of lard and zinc required for optimum growth and feed utilization, with the absence of parakeratosis, in young pigs. As the dietary level of lard increased, the amount of zinc needed also increased. Babatunde reported that with a 5% level of lard, 100 ppm of zinc was needed for optimum growth and health of the pig. Bettger, Reeves, Moscatelli, Reynolds, and O'Dell (1979) reported that rats exhibited better growth on diets containing corn oil than on diets containing hydrogenated coconut oil when zinc was limiting. These researchers also found that the effects of zinc deficiency, low growth and dermal lesions were exaggerated by an essential fatty acid deficiency in rats, no matter what the fat source. The corn oil would supply the essential fatty acid, linoleic acid, as compared to the hydrogenated coconut oil with no linoleic acid. Bettger, Reeves, Moscatelli, Savage, and O'Dell (1980) found that chicks fed a zinc deficient diet had higher growth rates when hydrogenated coconut oil was the fat source than when soybean oil was the fat source. Cunnane and Horrobin (1980) reported that supplements of evening primose oil, with a high linolenic acid content, but not olive oil, high in oleic acid, or safflower oil, high in linoleic acid, could prevent dermal lesions and stimulate significant growth in rats fed zinc deficient diets. Frimpong (1982) stated that the effects of dietary fat levels on growth in young rats might be dependent on the type of fatty acids present in the diet.

The effect of dietary fat on the trace mineral iron has also been studied. Amine and Hegsted (1975) reported that rats fed diets with 5% coconut oil exhibited greater iron absorption than did rats fed diets with 5% corn oil. Onderka and Kirksey (1975) also found higher iron concentrations in tissues of rats fed coconut oil as contrasted to rats fed safflower oil. Bowering, March, and Lewis (1977) found that increases in dietary lard (a saturated fat source) were associated with slight increases in total liver iron deposition in male rats as compared to animals fed low levels of corn oil (an unsaturated fat source). Mahoney, Farmer, and Hendricks (1980) reported that rats fed high fat diets incorporated more iron into the liver than did rats fed low fat diets. They also observed that rats fed turkey meat diets, prepared with beef fat, utilized dietary iron for hemoglobin synthesis better than rats fed turkey meat diets prepared with corn oil. Jones (1985) found that liver iron deposition was higher in animals consuming diets high in saturated fats. Increased iron absorption by rats on high fat diets, 30% vs. 5%, was reported by Johnson, Lukaski, and Bowman (1987), as well as higher liver iron deposition and higher hemoglobin levels in animals fed dietary coconut oil compared to safflower oil.

The relationship of dietary fat and the trace mineral copper has also been reported. Lukaski, Klevay, Bolonchuk, Mahalko, Milne, Johnson, and Sanstead (1982) reported that copper retention in humans was impaired by polyunsaturated dietary fat. Sinthusek and Magee (1984) reported that the liver deposition of copper in the rat was increased when coconut oil (a saturated fat source) was used in the diet, while apparent zinc retention was increased when the diets contained corn oil (a polyunsaturated fat source). Lin (1985) also reported that liver copper deposition increased in rats fed diets with coconut oil versus those fed diets with lard. Jones (1985), however, observed that the type of fat had no apparent effect on copper or zinc liver deposition in young rats. Magee, Jones, Lin, Sinthusek, Frimpong, and Wu (1986) concluded that the apparent bioavailability of copper, iron, and zinc may be dependent upon the type and level of fat in the diet, an observation which is supported by the research findings previously mentioned.

Previous studies pertaining to possible effects of dietary fat on trace mineral bioavailability have generally utilized fats which were highly saturated or highly unsaturated, and in most of these studies only one level of fat was used. Information concerning the effects of specific fat composition (polyunsaturated/saturated fatty acid ratio, linoleic/linolenic ratio) as well as low to high levels of dietary fat is particularly limiting. Some of the previous studies also involved mineral deficiency states or focused primarily on the effect of the zinc/copper ratio on lipid profiles and trace mineral status. This study was designed to investigate the effect of dietary fat level and dietary fat composition, in terms of the kind and concentration of fatty acids present, on tissue deposition of copper, iron, and zinc in young male rats fed diets containing adequate amounts of these minerals.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to investigate the effects of different levels of dietary fat and different fat sources on the growth and tissue deposition of copper, iron, and zinc in male weanling rats. Parameters used for evaluating the results included feed intake, weight gain, hemoglobin, hematocrit, and liver, kidney, spleen, and testes concentration of copper, iron, and zinc.

The study was conducted in two experiments. A 4 x 3 factorial design was used for both experiments. The experimental dietary variables for each experiment were four levels of fat (2.5, 5, 10, and 20% by weight) and three fat sources. Three different fat sources, of different fatty acid composition, were used for each experiment. The diets were randomly assigned in a randomized block design involving eight replications.

Animals

Ninety-six weanling male albino Sprague-Dawley rats[1], approximately 21-26 days old and weighing an average of 59 grams, were used for both experiments. The rats were weighed and randomly assigned to a replication according to initial body weight. Eight replications were used, and diets were randomly assigned to individual animals

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[1]Holtzman Company, Madison, Wisconsin.

within a replication. The animals were housed in individual, stainless wire-bottom cages and had free excess to feed and distilled water at all times. They were housed under controlled temperature, 25^{o}C, with a 12-hour light/dark cycle. Feed consumption records were kept, and the animals were weighed weekly for the experimental period of four weeks.

At the end of the experimental periods, animals were fasted for 12 hours and blood was drawn from the tip of the snipped tail for hemoglobin and hematocrit determinations. Animals from five randomly selected replications were anesthetized with ether and sacrificed. The liver, kidneys, spleen, and testes of each animal were removed and weighed. Dry weights were obtained after drying samples to constant weight in an oven at 60^{o}C. The tissues were wet ashed with hot nitric and perchloric acids, and the ash of each sample was dissolved in 3 ml of 0.6N HCL and diluted to 25 ml with redistilled water. Copper, iron, and zinc contents of appropriate aliquots were determined by atomic absorption spectrophotometry.[2]

Diets

The first experiment conducted included coconut oil[3], safflower oil[4], and lard[5] as the sources of fat. These fats were chosen

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[2]Perkin-Elmer Model 272, Norwalk, CT.

[3]ICN Nutritional Biochemicals, Cleveland, OH.

[4]ICN Nutritional Biochemicals, Cleveland, OH.

[5]Armour and Company, Phoenix, AZ.

primarily because of differences in the polyunsaturated/saturated (P/S) ratios and in the linoleic and linolenic acid concentrations. Corn oil[6], soybean oil[7], and olive oil[8] were the sources of fat used for the second experiment and were fed at the levels used for the first experiment. These fat sources were chosen because two had a similar P/S ratio, but different oleic, linoleic, and linolenic acid concentrations. The fat sources were analyzed for fatty acid composition by gas liquid chromatography[9] (Table A-5).

In addition to fat, the diets contained 15% protein[10], 54-72% starch[11], 4% mineral mix[12], 2% vitamin mix, 2% cellulose[13], 2% vitamin A and vitamin D mix[14], and 10 ppm zinc (in the form of zinc sulfate). The composition of all diets, mineral mix, and vitamin mix are given in Appendix A, Tables A-1 through A-5. The diets were ashed and analyzed for copper, iron, and zinc using atomic absorption spectrophotometry

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[6]ICN Nutritional Biochemicals, Cleveland, OH.

[7]Pure soybean oil, A&P, Montvale, NJ.

[8]Spanish pure imported olive oil, Fantis Foods, Inc., NY.

[9]Tracor Instrument Model 222, Austin, TX.

[10]Vitamin free casein, ICN Nutritional Biochemicals, Cleveland, OH.

[11]Cornstarch, Teklad Test Diets, Madison, WI.

[12]Wesson Modified Osborne-Menkel Mineral Mix, Teklad Test Diets, Madison, WI.

[13]Alphacel, ICN Nutritional Biochemicals, Cleveland, OH.

[14]The mix contained 3000 units of vitamin A palmitate/gram and 400 units of vitamin D/gram. The vitamins were purchased from Teklad Test Diets, Madison, WI.

(Table A-4). Diet energy content was calculated using 9 kilocalories (Kcal)/gm fat and 4 Kcal/gm of carbohydrate and protein.

Analytical Methods

Fatty acid composition. The method of Metcalfe and Schmitz (1961), as modified by Wang and Peter (1983), was used for the fatty acid analysis of the oils used in the diets. An aliquot of 250 mg of the oil being analyzed was placed in a 25 ml volumetric flask and 5 ml of 0.5 M methanolic sodium hydroxide was added. The mixture was heated on a hot plate at 100^{o}C for about 15 minutes or until the solution was homogenous. Three ml of methanolic-BF_3 was added to this solution and heated for about five minutes.

The mixture was allowed to cool, and the fatty acid methyl esters were extracted with 5 ml of heptane. The heptane layer was pushed into the neck of the volumetric flask with a saturated sodium chloride solution. The flask was shaken, and the phases were allowed to separate. The heptane layer was removed and placed into a small vial with anhydrous sodium sulfate. After standing, the heptane solution of fatty acid methyl esters was removed and injected into the gas liquid chromatograph for analysis.

The GC profiles of the fatty acid methyl esters were obtained on a Tracor instrument model 222 using a glass column, 6 ft. by 1/4 in. O.D., packed with 12% DEGS on anakron ABS, 90/100 mesh (Analab, Inc.) with a flame ionization detector (FID). The carrier gas was nitrogen with a flow rate of 30 ml per minute. The initial column temperature was 170^{o}C and the final temperature was 200^{o}C, with a program rate change of 2^{o} per minute. The injector port and detector temperature was $210^{o}C$. The peaks were integrated using a Hewlett Packard 3380 or 3392 integrator[15], and peak percentages are percentages of the total area integrated. The fatty acid compositions of fat sources are given in Table A-5.

Hemoglobin and hemotocrits. Hemoglobin was determined by the method of Shenk, Hall, and King (1934). The tips of the rats' tails were cut with a sharp razor blade, and blood was drawn into a graduated diluting pipette to the first mark. A freshly prepared solution of 0.1% sodium carbonate was then drawn into the pipette to the second mark. The diluted blood was then drained freely into culture tubes. The optical density of each sample was then determined at a wavelength of 542 nm against a distilled water reference on the Spectronic 20 spectrophotometer.[16] The hemoglobin (Hb) concentration was determined from the optical density by the following equation: optical density (OD) x 28.58 = grams Hb per 100 ml blood.

For the hematocrit determinations, blood was drawn from the tail at the same time as the blood for the hemoglobin was drawn. The heparinized hematocrit capillary tubes were filled, plugged with critoseal, and centrifuged in the hematocrit centrifuge. The hematocrit percentage was then read from the Lancer Critocap Manual reader and recorded.

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[15]Hewlett Packard, Palo Alto, CA.

[16]Bausch & Lomb, Rochester, NY.

Tissue minerals. As already noted, the copper, iron, and zinc concentrations of the animal tissues were determined after ashing by atomic absorption spectrophotometry. A commercial analytical AA standard for each mineral was diluted and used as known standards for the determinations. All glassware was acid washed, and only redistilled water was used in diluting standards or tissue samples. The copper determinations were read at 324.8 nm, iron at 248.3 nm, and zinc at 213.9 nm, using an air-acetylene flame.

Statistical Methods

The analysis of variance (SAS program) was used to analyze the data of experiments 1 and 2, and the reported significant effects were based on the 0.05 level of probability. Covariant analyses were done on the weight gain data to see the effect of diet on weight gain adjusted for feed consumption, or kilocalories, and on the tissue mineral data to adjust for weight gains and/or dry weights. Two-way analysis of variance was used to determine fat source and fat level interactions. The least significant differences (LSD) were provided as an indicator of differences between individual means which were needed to show significance at the 0.05 and 0.01 levels of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The raw data obtained in this study are presented in Appendix B. The results of the statistical analyses of the data are given in Appendix C.

Growth, Feed Intake, and Feed Efficiency

Weight gains of young male rats fed diets with coconut oil, lard, or safflower oil (Experiment 1) are shown in Table 1. A significant source x level interaction ($p < 0.05$) was detected (Appendix C, Table C-1). The data indicated that at low fat levels the animals fed lard diets grew less than those fed coconut or safflower oil diets, but at high fat levels animals fed lard diets gained the most weight followed by those animals fed safflower oil diets, while the animals fed coconut oil diets gained the least. Increasing levels of dietary fat were associated with highly significant ($p < 0.01$) increases in weight gains. It appeared, however, that this occurred only when lard was the source of fat. The growth of animals fed diets with coconut oil or safflower oil was essentially the same over all fat levels.

Feed intake of animals fed coconut oil, lard, or safflower oil diets decreased as the level of fat in the diet increased (Table 2). Animals fed coconut oil diets showed a marked decrease in feed intake at a 10% fat level, whereas animals fed lard and safflower oil diets showed a marked decrease only at the 20% fat level. Analysis of the

Table 1

Growth of Young Male Rats Fed Different Levels and Sources of Fat

Source	Fat Level (%) 2.5	5	10	20	Mean
		4 weeks weight gain (gm)[a]			
Experiment 1					
Coconut oil	184 ± 8	193 ± 12	187 ± 3	197 ± 7	190
Lard	173 ± 6	182 ± 5	213 ± 4	215 ± 9	196
Safflower oil	192 ± 7	201 ± 6	201 ± 10	201 ± 5	199
Mean	183	192	201	205	
$LSD^{b}_{0.05}$	17				
0.01	23				
Experiment 2					
Corn oil	164 ± 7	169 ± 5	195 ± 7	191 ± 6	180
Olive oil	149 ± 3	155 ± 4	161 ± 6	179 ± 5	161
Soybean oil	156 ± 4	168 ± 6	161 ± 7	186 ± 7	168
Mean	157	164	173	186	
$LSD_{0.05}$	16				
0.01	21				

[a]Each value is the mean of 8 animals ± standard error of the mean (SEM).

[b]Least significant differences at specified probability levels.

Table 2

Feed Intake of Young Male Rats Fed Different Levels and Sources of Fat

Source	Fat Level (%) 2.5	5	10	20	Mean
			4 weeks feed intake (gm)[a]		
Experiment 1					
Coconut oil	466 ± 10	456 ± 17	419 ± 7	380 ± 11	430
Lard	441 ± 8	440 ± 11	467 ± 9	411 ± 14	439
Safflower oil	444 ± 17	440 ± 8	443 ± 8	381 ± 9	427
Mean	450	445	443	390	
$LSD^{b}_{0.05}$	28				
0.01	37				
Experiment 2					
Corn oil	457 ± 18	405 ± 14	437 ± 14	373 ± 12	418
Olive oil	418 ± 9	406 ± 9	389 ± 13	375 ± 6	397
Soybean oil	420 ± 8	415 ± 6	382 ± 7	365 ± 10	395
Mean	431	408	402	371	
$LSD_{0.05}$	30				
0.01	40				

[a]Each value is the mean of 8 animals ± SEM.

[b]Least significant differences at specified probability levels.

data (Appendix C, Table C-3) revealed a highly significant ($p < 0.01$) source x level effect on feed intake. At low fat levels the animals fed coconut oil diets consumed significantly more feed, but at high fat levels the animals on lard diets consumed more feed. There was a significant ($p < 0.01$) level effect on feed intake. The higher fat level, 20%, led to a significantly lower feed intake as compared to the 2.5% or 5% dietary fat levels.

Covariant analysis of the growth data (Appendix C, Table C-1) indicated that the effects of diets were significant ($p < 0.01$) after adjusting for feed intake (grams). However, when the growth data were adjusted for feed intake in terms of kilocalories (Table C-1) no significant effects of diets were shown. The differences in weight gains appear to be due to differences in kilocalories consumed by the animals.

Animals fed safflower oil diets had significantly higher ($p < 0.05$) feed efficiency ratios (weight gain/feed intake) than animals fed either coconut oil or lard diets (Table 3, Appendix C, Table C-4). The highest feed efficiency was observed in animals fed a 20% level of fat, while the lowest occurred in animals on 2.5% fat level diets.

These results from Experiment 1 suggest that the degree of saturation or polyunsaturation of the fat in the diet, the P/S ratio, is less important with respect to four weeks growth than the level of dietary fat as the statistical analysis showed on a significant dietary fat level/kilocalorie effect on weight gain. However, when diets are

Table 3

Feed Efficiency Ratios of Young Male Rats Fed Different Levels and Source of Fat

Source	Fat Level (%) 2.5	5	10	20	Mean
Experiment 1					
Coconut oil	0.40 ± 0.01	0.42 ± 0.02	0.45 ± 0.01	0.52 ± 0.02	0.45
Lard	0.39 ± 0.01	0.41 ± 0.01	0.46 ± 0.01	0.52 ± 0.01	0.45
Safflower oil	0.44 ± 0.02	0.46 ± 0.01	0.45 ± 0.02	0.53 ± 0.01	0.47
Mean	0.41	0.43	0.45	0.52	
LSD[b] 0.05	0.02				
0.01	0.03				
Experiment 2					
Corn oil	0.37 ± 0.03	0.42 ± 0.02	0.45 ± 0.02	0.52 ± 0.01	0.44
Olive oil	0.36 ± 0.01	0.38 ± 0.01	0.42 ± 0.01	0.48 ± 0.02	0.41
Soybean oil	0.37 ± 0.01	0.41 ± 0.01	0.42 ± 0.02	0.51 ± 0.02	0.43
Mean	0.37	0.40	0.43	0.50	
LSD[b] 0.05	0.04				
0.01	0.05				

[a]Each value is the mean of 8 animals ± SEM.

[b]Least significant differences at specified probability levels.

low in fat (2.5%), the highly unsaturated fat, safflower oil, with a P/S of 8, supported better growth.

Increased growth of young male rats fed corn oil, olive oil, and soybean oil diets (Experiment 2) was observed as the fat level of the diets increased (Table 1). Animals fed a 10% corn oil diet had essentially the same amount of growth by four weeks as animals fed olive oil or soybean oil diets at a 20% level. Analysis of the data (Appendix C, Table C-2) revealed that both source and level of fat had highly significant ($\underline{p} < 0.01$) effects on weight gains. Animals fed corn oil diets had significantly greater weight gains than animals fed olive oil or soybean oil diets, and those fed the 20% fat level diets showed weight gains significantly higher than those fed the 2.5% fat level diets.

Similar to the results of Experiment 1, the amount of feed consumed by the animals in Experiment 2 decreased as the level of fat in the diets increased (Table 2, Experiment 2). Analysis of the feed intake data (Appendix C, Table C-3) revealed a significant ($\underline{p} < 0.05$) source x level interaction. Animals fed corn oil at a 2.5% level and at a 10% level consumed significantly more feed than animals fed either 2.5% or 10% olive oil or soybean oil. At the 10% and 20% levels of dietary fat, animals fed soybean oil diets consumed the least amount of feed. At the 20% dietary fat level, animals fed olive oil and corn oil diets consumed essentially the same amount of feed. The highly significant ($\underline{p} < 0.01$) effect of corn oil and of the 2.5% and 20% fat levels on feed intakes were also noted on analysis.

Analysis of covariance (Appendix C, Table C-2) revealed that the effects of fat source and level were still highly significant ($p < 0.01$) after adjustment of weight gains for feed intake or kilocalorie intake. The differences in weight gains observed in this experiment appeared not to be due to differences in feed intake or kilocalorie intake.

In Experiment 2, fat level had a highly significant effect ($p < 0.01$) on feed efficiency, while fat source had a significant ($p < 0.05$) effect (Table 3, Appendix C, Table C-4). The highest feed efficiency was observed in animals fed the 20% fat level diets, while animals on the 2.5% fat level diets had the lowest, as in Experiment 1. Animals fed corn oil and soybean oil diets had higher feed efficiency ratios than did animals fed olive oil diets. The animals fed diets with polyunsaturated fat sources, corn oil and soybean oil, and higher P/S ratios had the higher feed efficiency ratios.

These data show that the corn oil diets supported weight gain in the young male rats better than olive or soybean oil diets at four weeks. Corn oil has a higher linoleic/linolenic acid ratio than the other two fat sources. The feed efficiency ratios of corn oil and soybean oil were, however, about the same, with olive oil having the lower feed efficiency ratio.

Hemoglobin and Hematocrits

Hemoglobin concentrations and hematocrits of animals fed coconut oil, lard, and safflower oil diets are shown in Table 4. Analysis (Appendix C, Table C-5) showed a highly significant ($p < 0.01$) source and a significant ($p < 0.05$) level effect on hemoglobin concentration.

Table 4

Hemoglobin Levels and Hematocrits of Young Male Rats Fed Coconut Oil, Lard, and Safflower Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			gm/dl[a]		
Hemoglobin					
Coconut oil	14.3 ± 0.5	13.5 ± 0.3	14.0 ± 0.4	14.2 ± 0.4	14.0
Lard	13.6 ± 0.3	13.6 ± 0.4	13.0 ± 0.3	12.5 ± 0.1	13.2
Safflower oil	14.5 ± 0.7	12.9 ± 0.2	13.1 ± 0.3	13.5 ± 0.4	13.5
Mean	14.1	13.3	13.4	13.4	
$LSD^{b}_{0.05}$	1.1				
0.01	1.4				
			Percent[a]		
Hematocrit					
Coconut oil	46 ± 2	51 ± 1	46 ± 2	48 ± 2	48
Lard	52 ± 2	50 ± 1	46 ± 2	47 ± 2	49
Safflower oil	49 ± 1	46 ± 2	49 ± 1	45 ± 1	47
Mean	49	49	47	47	
$LSD_{0.05}$	4				
0.01	5				

[a]Each Value is the mean of 8 animals ± SEM.

[b]Least significant differences at specified probability levels.

Rats fed coconut oil tended to have higher hemoglobin levels than did rats fed either lard or safflower oil diets. With the exception of animals fed coconut oil diets, increased dietary fat was associated with decreased hemoglobin concentrations. Correlation analysis also revealed a negative correlation of weight gain and hemoglobin concentration. Analysis of the hematocrit data (Appendix C, Table C-5) indicated there was a significant ($p < 0.05$) source x level interaction. Increased dietary fat was associated with decreased hematocrits of animals fed either lard or safflower oil, but with slight increases in hematocrits of animals fed coconut oil. In general the effects of fat source and level of fat on hemoglobin and levels and hematocrits were small.

Hemoglobin levels and hematocrits of animals fed corn oil, olive oil, and soybean oil diets are presented in Table 5. Analyses indicated that neither fat source nor fat level had any significant effects (Appendix C, Table C-6) on hemoglobin levels or hematocrits. Hemoglobin levels of animals fed olive oil diets tended to be higher than hemoglobin levels of animals fed corn oil or soybean oil diets. As noted in Experiment 1, the more saturated fat was associated with higher hemoglobin levels, but these animals also had lower weight gains. Hemoglobin levels also tended to decrease slightly as the level of fat in the diet was increased. Hematocrits of animals fed these three fat sources showed little variation.

Table 5

Hemoglobin Levels and Hematocrits of Young Male Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			gm/dl[a]		
Hemoglobin					
Corn oil	13.0 ± 0.4	12.8 ± 0.3	12.7 ± 0.4	12.7 ± 0.3	12.8
Olive oil	13.4 ± 0.5	13.1 ± 0.6	12.8 ± 0.3	13.5 ± 0.3	13.2
Soybean oil	12.6 ± 0.4	13.0 ± 0.3	12.7 ± 0.3	12.2 ± 0.2	12.6
Mean	13.0	12.9	12.7	12.8	
$LSD^b_{0.05}$	0.9				
0.01	1.2				
			Percent[a]		
Hematocrit					
Corn oil	48 ± 2	46 ± 1	43 ± 1	44 ± 1	45
Olive oil	48 ± 2	46 ± 2	45 ± 1	47 ± 1	46
Soybean oil	44 ± 2	46 ± 1	46 ± 2	43 ± 1	45
Mean	47	46	45	45	
$LSD_{0.05}$	4				
0.01	5				

[a]Each value is the mean of 8 animals ± SEM.

[b]Least significant differences at specified probability levels.

Tissue Dry Weights

Tissue dry weights of the kidney, liver, spleen and testes for animals of Experiment 1 are given in Table 6. Statistical analyses of the tissue data revealed that diet had highly significant ($p < 0.01$) effects only on the liver dry weight (Appendix C, Table C-7). Analysis showed that the 10% dietary fat level significantly increased the liver dry weights. It was noted, however, that animals fed safflower oil diets tended to have the higher tissue dry weights and the higher weight gains. Animals on coconut oil diets generally had the lower tissue dry weights and the lower weight gains. Animals fed the 2.5% dietary fat level had the lower tissue dry weights, while animals fed the 10% fat level had the higher tissue dry weights. Animals fed coconut oil and safflower oil diets had the higher liver dry weights at a 10% level of dietary fat, while those fed lard diets showed increased dry weights with increased dietary fat. Animals fed coconut oil and safflower oil diets had decreased, or the same, tissue dry weights at the 20% level of dietary fat.

The kidney, liver, spleen, and testes dry weights for the animals of Experiment 2 are presented in Table 7. Statistical analyses of this dry weight data revealed only a highly significant ($p < 0.01$) effect of fat source on spleen dry weight and a significant effect ($p < 0.05$) of level (Appendix C, Table C-8). The animals fed corn oil diets had the higher spleen dry weights, and animals on the low, 2.5%, level of dietary fat had the lower spleen dry weights. In this experiment the animals fed olive oil diets tended to have the lower tissue

Table 6

Dry Tissue Weights of Young Male Rats Fed Coconut Oil, Lard, and Safflower Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			grams[a]		
Kidneys					
Coconut oil	0.45 ± 0.02	0.46 ± 0.03	0.50 ± 0.02	0.44 ± 0.02	0.46
Lard	0.45 ± 0.01	0.50 ± 0.03	0.48 ± 0.02	0.48 ± 0.02	0.48
Safflower oil	0.46 ± 0.02	0.51 ± 0.01	0.51 ± 0.02	0.46 ± 0.02	0.49
Mean	0.45	0.49	0.50	0.46	
$LSD^b_{0.05}$	0.06				
0.01	0.08				
Liver					
Coconut oil	1.96 ± 0.12	1.80 ± 0.09	2.09 ± 0.05	2.00 ± 0.09	1.97
Lard	1.65 ± 0.07	1.98 ± 0.07	2.21 ± 0.08	2.28 ± 0.09	2.03
Safflower oil	1.87 ± 0.04	2.05 ± 0.06	21.9 ± 0.06	2.12 ± 0.06	2.06
Mean	1.82	1.95	2.17	2.14	
$LSD_{0.05}$	0.29				
0.01	0.35				
Spleen					
Coconut oil	0.16 ± 0.02	0.13 ± 0.05	0.17 ± 0.01	0.15 ± 0.01	0.15
Lard	0.14 ± 0.01	0.16 ± 0.02	0.18 ± 0.02	0.18 ± 0.01	0.16
Safflower oil	0.15 ± 0.01	0.16 ± 0.01	0.16 ± 0.02	0.15 ± 0.02	0.16
Mean	0.15	0.15	0.17	0.16	
$LSD_{0.05}$	0.04				
0.01	0.05				
Testes					
Coconut oil	0.38 ± 0.02	0.37 ± 0.03	0.39 ± 0.01	0.39 ± 0.01	0.38
Lard	0.35 ± 0.01	0.36 ± 0.02	0.40 ± 0.01	0.41 ± 0.01	0.38
Safflower oil	0.39 ± 0.01	0.38 ± 0.01	0.38 ± 0.01	0.39 ± 0.01	0.39
Mean	0.37	0.37	0.39	0.40	
$LSD_{0.05}$	0.03				
0.01	0.05				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

Table 7

Dry Tissue Weights of Young Male Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source	Fat Level (%)				
	2.5	5	10		Mean
			grams[a]		
Kidneys					
Corn oil	0.49 ± 0.03	0.49 ± 0.04	0.52 ± 0.03	0.53 ± 0.04	0.51
Olive oil	0.48 ± 0.02	0.46 ± 0.03	0.45 ± 0.02	0.50 ± 0.01	0.47
Soybean oil	0.50 ± 0.02	0.57 ± 0.04	0.51 ± 0.01	0.53 ± 0.02	0.53
Mean	0.49	0.51	0.49	0.52	
$LSD^{b}_{0.05}$	0.08				
0.01	0.10				
Liver					
Corn oil	2.08 ± 0.15	2.20 ± 0.14	2.49 ± 0.23	2.30 ± 0.13	2.27
Olive oil	1.94 ± 0.04	2.04 ± 0.11	1.91 ± 0.08	2.52 ± 0.24	2.10
Soybean oil	2.06 ± 0.10	2.22 ± 0.14	2.20 ± 0.08	2.11 ± 0.25	2.15
Mean	2.03	2.15	2.20	2.31	
$LSD_{0.05}$	0.45				
0.01	0.59				
Spleen					
Corn oil	0.18 ± 0.02	0.19 ± 0.01	0.21 ± 0.03	0.23 ± 0.01	0.20
Olive oil	0.15 ± 0.01	0.17 ± 0.02	0.19 ± 0.01	0.17 ± 0.02	0.17
Soybean oil	0.15 ± 0.01	0.19 ± 0.02	0.19 ± 0.01	0.17 ± 0.02	0.17
Mean	0.16	0.18	0.20	0.19	
$LSD_{0.05}$	0.04				
0.01	0.05				
Testes					
Corn oil	0.39 ± 0.02	0.35 ± 0.01	0.37 ± 0.01	0.38 ± 0.01	0.37
Olive oil	0.37 ± 0.01	0.38 ± 0.01	0.35 ± 0.02	0.38 ± 0.91	0.37
Soybean oil	0.34 ± 0.01	0.36 ± 0.02	0.36 ± 0.02	0.36 ± 0.02	0.36
Mean	0.37	0.36	0.36	0.37	
$LSD_{0.05}$	0.04				
0.01	0.05				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

dry weights, especially lower kidney and liver dry weights. As noted before, these animals also had the lower weight gains. Animals fed corn oil and soybean oil diets tended to have the higher tissue dry weights, and these animals also had higher weight gains. Overall the dietary fat level did not appear to effect the animal dry tissue weights, except that at the higher fat levels, higher dry weights were observed.

Tissue Copper

Tissue copper concentrations in animals fed coconut oil, lard or safflower oil diets are given in Table 8, and the statistical analysis of the data is presented in Appendix C, Table C-9. Analysis of the data revealed that diet apparently had little effect on kidney copper deposition. It was observed, however, that kidney copper levels tended to be highest in animals fed 10% fat level diets, and increasing the fat level to 20% resulted in a decrease in kidney copper concentration. A decrease in kidney dry weights was also observed at the 20% dietary fat level for animals fed coconut oil and safflower oil diets.

Animals on the 20% fat level diets in this experiment had lower liver copper levels than did the animals on the three other levels of dietary fat. Tissue copper levels appear not to be greatly effected by any of these fat sources--coconut oil, lard, or safflower oil. There is a tendency, however, for the high fat level, 20%, to be associated with lower tissue copper concentrations and lower tissue dry weights.

Table 8

Tissue Copper Levels of Young Male Rats Fed Coconut Oil, Lard, and Safflower Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			mcg/gm dry weight[a]		
Kidneys					
Coconut oil	25.1 ± 2.8	25.6 ± 2.3	39.4 ± 9.5	21.7 ± 1.3	28.0
Lard	26.0 ± 2.2	22.3 ± 1.0	34.8 ± 7.3	22.9 ± 1.5	26.5
Safflower oil	29.6 ± 1.7	23.8 ± 1.0	32.4 ± 10.2	28.8 ± 4.7	28.2
Mean	26.2	23.9	35.5	24.5	
$LSD^b_{0.05}$	13.8				
0.01	17.9				
Liver					
Coconut oil	18.8 ± 0.7	19.5 ± 0.7	20.6 ± 1.3	19.1 ± 1.8	19.5
Lard	20.4 ± 0.2	19.5 ± 0.5	19.9 ± 0.4	16.5 ± 1.0	19.1
Safflower oil	19.1 ± 0.5	19.0 ± 0.7	18.3 ± 0.5	17.0 ± 1.2	18.3
Mean	19.4	19.4	19.6	17.5	
$LSD_{0.05}$	2.6				
0.01	3.4				
Spleen					
Coconut oil	7.1 ± 2.5	7.1 ± 1.5	4.3 ± 0.8	7.5 ± 1.8	6.5
Lard	6.5 ± 1.3	6.4 ± 1.5	6.1 ± 1.9	4.6 ± 0.8	5.9
Safflower oil	6.3 ± 1.3	5.5 ± 0.7	6.3 ± 1.3	6.9 ± 1.9	6.3
Mean	6.6	6.3	5.6	6.4	
$LSD_{0.05}$	2.6				
0.01	3.3				
Testes					
Coconut oil	12.6 ± 0.5	13.2 ± 0.9	13.2 ± 0.6	12.4 ± 0.7	12.8
Lard	13.1 ± 0.5	12.7 ± 0.3	12.9 ± 0.6	12.3 ± 0.6	12.8
Safflower oil	13.0 ± 0.4	13.0 ± 0.3	13.3 ± 0.4	12.5 ± 0.5	13.0
Mean	12.9	13.0	13.1	12.4	
$LSD_{0.05}$	1.4				
0.01	1.8				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

The tissue copper levels of the animals fed corn oil, olive oil, and soybean oil diets are given in Table 9. Kidney copper levels were significantly higher ($p < 0.01$) in animals fed olive oil diets versus those fed corn oil or soybean oil diets. Statistical adjustment of the data for the dry tissue weight or for weight gain did not change the significance effect of the fat source, olive oil, on kidney copper deposition (Appendix C, Table C-10). An increase of the dietary fat level from 2.5% to 5% was associated with an increase in kidney copper concentration, but at the 20% fat level a decrease was noted. This trend of increasing tissue copper overall with fat level to the 10% fat level and then decreasing at the 20% level was also noted in Experiment 1. Neither fat source nor fat level had any significant effect on liver, spleen, or testes copper deposition in young male rats at four weeks.

Tissue Iron

Tissue iron levels of the animals fed diets containing coconut oil, lard, and safflower oil are given in Table 10, and the statistical analyses are given in Appendix C, Table C-11. Increases in dietary fat were associated with increases in kidney iron deposition; the analysis revealed a significant ($p < 0.05$) source x level interaction. Further analysis of the data with adjustment for weight gains or for dry tissue weight did not change the significance of the source x level effect. Kidney iron levels of animals fed lard and safflower oil diets generally increased as the level of dietary fat increased. In the case

Table 9

Tissue Copper Levels of Young Male Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source	Fat Level (%)[a] 2.5	5	10	20	Mean
	mcg/gm dry weight[a]				
Kidneys					
Corn oil	26.1 ± 1.8	31.9 ± 3.7	25.4 ± 0.5	26.5 ± 2.4	27.4
Olive oil	31.6 ± 4.5	37.9 ± 3.7	40.3 ± 3.2	37.7 ± 4.4	36.9
Soybean oil	27.7 ± 2.5	29.3 ± 4.2	27.3 ± 1.2	25.2 ± 1.3	27.4
Mean	28.4	33.0	31.0	29.8	
LSD[b] $_{0.05}$	7.3				
0.01	9.5				
Liver					
Corn oil	16.7 ± 0.6	18.9 ± 0.5	16.5 ± 0.9	16.0 ± 0.7	17.0
Olive oil	16.3 ± 1.3	16.5 ± 0.8	18.1 ± 0.6	15.4 ± 0.9	16.6
Soybean oil	17.4 ± 0.4	17.0 ± 0.4	16.2 ± 0.2	16.7 ± 2.2	16.8
Mean	16.8	17.5	16.9	16.0	
$LSD_{0.05}$	2.7				
0.01	3.5				
Spleen					
Corn oil	4.9 ± 0.8	6.7 ± 0.8	7.8 ± 0.8	7.6 ± 0.7	6.7
Olive oil	8.7 ± 1.5	8.5 ± 0.9	7.5 ± 0.9	5.7 ± 0.8	7.6
Soybean oil	7.3 ± 0.8	6.4 ± 0.3	6.8 ± 0.7	6.9 ± 0.9	6.9
Mean	7.0	7.2	7.4	6.7	
$LSD_{0.05}$	2.7				
0.01	3.5				
Testes					
Corn oil	15.0 ± 0.8	15.6 ± 0.7	16.0 ± 0.5	14.9 ± 0.5	15.4
Olive oil	14.4 ± 1.2	14.3 ± 1.0	17.1 ± 0.7	14.7 ± 0.6	15.1
Soybean oil	16.8 ± 0.4	15.8 ± 1.8	15.5 ± 0.4	15.0 ± 1.1	15.8
Mean	15.4	15.2	16.2	14.9	
$LSD_{0.05}$	2.0				
0.01	2.6				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

Table 10

Tissue Iron Levels of Young Male Rats Fed Coconut Oil, Lard, and Safflower Oil

Source	Fat Level (%)				
	2.5	5	10	20	Mean
			mcg/gm dry weight[a]		
Kidneys					
Coconut oil	260 ± 20	362 ± 42	355 ± 42	265 ± 36	311
Lard	338 ± 65	286 ± 54	280 ± 38	405 ± 69	327
Safflower oil	301 ± 67	284 ± 48	392 ± 54	449 ± 65	356
Mean	300	311	342	37	
LSD[b] 0.05	125				
0.01	162				
Liver					
Coconut oil	517 ± 63	554 ± 41	559 ± 68	590 ± 51	555
Lard	665 ± 46	476 ± 27	428 ± 15	477 ± 34	511
Safflower oil	549 ± 47	430 ± 16	454 ± 17	429 ± 48	466
Mean	577	487	480	499	
LSD 0.05	126				
0.01	164				
Spleen					
Coconut oil	491 ± 59	480 ± 56	537 ± 59	611 ± 117	530
Lard	574 ± 105	427 ± 60	398 ± 67	489 ± 77	472
Safflower oil	514 ± 47	412 ± 46	438 ± 90	404 ± 54	442
Mean	526	440	457	501	
LSD 0.05	193				
0.01	252				
Testes					
Coconut oil	174 ± 21	154 ± 26	152 ± 3	157 ± 12	159
Lard	152 ± 7	165 ± 8	140 ± 10	140 ± 12	150
Safflower oil	198 ± 49	155 ± 6	179 ± 35	147 ± 7	170
Mean	175	158	157	148	
LSD 0.05	53				
0.01	69				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

of animals fed lard and safflower oil diets generally increased as the level of dietary fat increased. In the case of animals fed coconut oil diets, an increase in kidney iron was seen as the fat level increased for 2.5 to 5% or 10%, but at the 20% level the iron level decreased as did the tissue dry weight. At the higher fat level (20%), animals fed safflower oil diets had the highest kidney iron concentrations, and those fed coconut oil the lowest.

The liver iron data analyses revealed that source and level of dietary fat after adjustment for weight gains and/or dry tissue weights had no significant effects on liver iron deposition in the rats in this study. Liver iron levels were, however, highest in animals fed coconut oil diets at all but the 2.5% dietary fat level. As the fat level of the diet increased, liver iron concentration tended to increase in these animals fed dietary coconut oil. At the low (2.5%) fat level, the animals on lard and safflower oil diets had the higher liver iron depositions and the lower liver dry weights.

The spleen and testes iron levels were not significantly effected by dietary fat source or fat level. Animals on coconut oil diets did, in general, show increased spleen iron levels with increased fat, while those animals on safflower oil diets tended to have decreased spleen iron levels with increased dietary fat.

The tissue iron levels of animals fed corn oil, olive oil, and soybean oil are shown in Table 11. Analyses of the data (Appendix C, Table C-12) revealed no significant effects of diet on kidney iron levels. Animals fed corn oil diets generally had lower kidney iron

Table 11

Tissue Iron Levels of Young Male Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			mcg/gm dry weight[a]		
Kidneys					
Corn oil	198 ± 7	159 ± 12	147 ± 11	145 ± 10	162
Olive oil	162 ± 7	181 ± 18	192 ± 14	212 ± 17	187
Soybean oil	200 ± 22	188 ± 21	193 ± 22	183 ± 21	191
Mean	187	176	177	180	
LSD[b] 0.05	45				
0.01	59				
Liver					
Corn oil	408 ± 30	475 ± 71	242 ± 48	372 ± 49	374
Olive oil	384 ± 66	402 ± 107	441 ± 24	432 ± 65	415
Soybean oil	487 ± 65	357 ± 61	473 ± 108	313 ± 31	407
Mean	426	411	385	372	
LSD 0.05	156				
0.01	203				
Spleen					
Corn oil	900 ± 66	687 ± 52	573 ± 5	655 ± 48	704
Olive oil	745 ± 31	1229 ± 131	887 ± 97	858 ± 9	930
Soybean oil	790 ± 49	668 ± 66	762 ± 62	721 ± 35	735
Mean	812	861	741	745	
LSD 0.05	181				
0.01	236				
Testes					
Corn oil	168 ± 15	141 ± 19	168 ± 9	166 ± 14	161
Olive oil	175 ± 6	159 ± 12	164 ± 12	185 ± 17	171
Soybean oil	186 ± 21	150 ± 11	177 ± 20	172 ± 11	171
Mean	176	150	170	174	
LSD 0.05	42				
0.01	54				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

levels than those animals on olive oil or soybean oil diets, but animals fed soybean oil diets had the higher kidney dry weights. Increased dietary fat levels led to decreased iron deposition in animals on the polyunsaturated fats, but to increased iron deposition in the animals on olive oil, a saturated fat.

Increases in dietary fat were also associated with decreases in liver iron levels in animals fed corn oil or soybean oil diets, and with increases in liver iron levels in rats fed olive oil. Statistical analysis of the liver iron data revealed no significant effects of fat source or fat level on liver iron.

Analysis of the spleen iron data (Appendix C, Table C-12) revealed a highly significant ($\underline{p} < 0.01$) effect of fat source and source x level interaction on spleen iron concentration, even after adjustment of the data for weight gains and/or spleen dry weights. Spleen iron levels of the animals on olive oil diets increased with increased dietary fat level. In contrast, those animals on corn oil diets generally showed a decrease in spleen iron levels with increased dietary fat, and a significantly increased tissue dry weight. At the low fat level, 2.5%, these animals had the highest spleen iron levels. Spleen iron levels of rats fed soybean oil diets were esstentially the same regardless of dietary fat level. Testes iron levels of young male rats at four weeks were essentially the same at all fat levels and for all fat sources--corn oil, olive oil, and soybean oil. In general, it would appear that increased dietary polyunsaturated fat leads to decreased tissue iron levels while saturated dietary fats lead to increased iron deposition.

Tissue Zinc

The zinc concentration of the kidneys, liver, spleen, and testes of the animals fed coconut oil, lard, and safflower oil diets are presented in Table 12. Analysis of the data (Appendix C, Table C-13) revealed that these three fats had no significant influence on the deposition of zinc in these organs at four weeks. Animals fed lard diets tended to have the higher kidney and liver zinc depositions at low fat levels, but the lowest spleen and testes zinc concentrations. The tissue zinc concentrations of the animals fed corn oil, olive oil, and soybean oil are given in Table 13. As shown in the analysis (Appendix C, Table C-14), neither dietary fat source nor dietary fat level had a significant effect on tissue zinc deposition.

Table 12

Tissue Zinc Levels of Young Male Rats Fed Coconut Oil, Lard, and Safflower Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			mcg/gm dry weight[a]		
Kidneys					
Coconut oil	86 ± 4	83 ± 4	84 ± 2	90 ± 5	86
Lard	90 ± 7	89 ± 1	90 ± 2	86 ± 3	88
Safflower oil	86 ± 3	82 ± 3	82 ± 5	91 ± 2	85
Mean	87	84	86	89	
$LSD^b_{0.05}$	10				
0.01	13				
Liver					
Coconut oil	102 ± 4	98 ± 5	107 ± 11	108 ± 8	103
Lard	117 ± 8	114 ± 9	115 ± 2	121 ± 9	117
Safflower oil	103 ± 5	115 ± 8	119 ± 14	120 ± 8	114
Mean	107	109	114	116	
$LSD_{0.05}$	24				
0.01	32				
Spleen					
Coconut oil	93 ± 3	94 ± 12	96 ± 7	95 ± 7	95
Lard	94 ± 5	91 ± 5	96 ± 4	95 ± 4	94
Safflower oil	102 ± 2	107 ± 6	97 ± 7	103 ± 9	102
Mean	96	98	96	98	
$LSD_{0.05}$	16				
0.01	21				
Testes					
Coconut oil	176 ± 9	172 ± 8	182 ± 10	175 ± 5	176
Lard	165 ± 7	174 ± 7	165 ± 5	163 ± 1	167
Safflower	174 ± 9	169 ± 3	168 ± 7	173 ± 7	171
Mean	172	172	172	170	
$LSD_{0.05}$	19				
0.01	24				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probability levels.

Table 13

Tissue Zinc Levels of Young Male Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source	Fat Level (%) 2.5	5	10	20	Mean
			mcg/gm dry weight[a]		
Kidneys					
Corn oil	87 ± 1	91 ± 5	88 ± 3	83 ± 2	87
Olive oil	91 ± 2	90 ± 2	87 ± 4	86 ± 3	88
Soybean oil	86 ± 4	80 ± 3	87 ± 3	86 ± 2	85
Mean	88	87	87	85	
$LSD^b_{0.05}$	8				
0.01	11				
Liver					
Corn oil	85 ± 3	96 ± 4	88 ± 7	81 ± 7	88
Olive oil	84 ± 8	89 ± 6	90 ± 7	78 ± 4	85
Soybean oil	92 ± 3	85 ± 7	81 ± 5	92 ± 10	87
Mean	87	90	86	83	
$LSD_{0.05}$	17				
0.01	23				
Spleen					
Corn oil	82 ± 3	83 ± 3	74 ± 6	82 ± 1	81
Olive oil	86 ± 2	87 ± 13	79 ± 2	82 ± 3	83
Soybean oil	82 ± 3	86 ± 6	79 ± 1	83 ± 2	83
Mean	83	85	78	82	
$LSD_{0.05}$	14				
0.01	19				
Testes					
Corn oil	153 ± 4	156 ± 3	160 ± 5	155 ± 3	156
Olive oil	157 ± 4	152 ± 5	150 ± 5	152 ± 6	153
Soybean oil	162 ± 4	149 ± 10	153 ± 3	155 ± 2	155
Mean	158	152	154	154	
$LSD_{0.05}$	14				
0.01	19				

[a]Each value is the mean of 5 animals ± SEM.

[b]Least significant differences at specified probabioity levels.

CHAPTER V

GENERAL DISCUSSION

These studies indicated that dietary fat levels had significant effects on feed intakes of young male rats for four weeks. Rats fed low dietary fat levels had the highest feed intakes while the animals consuming diets with 20% fat levels had the lowest animal feed intake. This is in agreement with the results of Frimpong (1982), who reported that animals fed at a 10% fat level consumed more feed than animals on 20% fat level diets. Johnson, Lukaski, and Bowman (1987) also noted a decrease in feed intake with increasing dietary fat levels from 5% to 30%. In Experiment 1, animals fed dietary lard generally consumed more feed than did those fed either coconut or safflower oil diets. Animals on safflower oil diets consumed the least amount of feed. In Experiment 2, animals fed dietary corn oil consumed more feed than did animals fed dietary olive oil or soybean oil. The least amount of feed was consumed by animals fed soybean oil diets.

Increasing dietary fat levels, which resulted in increases in total caloric consumption, were associated with increased growth rates. This trend was most evident when lard or olive oil were the dietary fat sources, but animals fed these two dietary fats at a 2.5 and 5.0% level exhibited the poorest growth. Animals fed diets high in saturated fats (coconut and olive oil) grew less than animals fed polyunsaturated fats with high levels of linoleic acid (safflower and corn oil). Similar growth patterns in young male rats were reported by Sinthusek and Magee (1984) and Lin (1985). Onderka and Kirksey (1975) reported that animals fed dietary safflower oil had higher weight gains and consumed less feed than animals fed coconut oil. These researchers reported an increased liver and spleen size in animals fed safflower oil versus those fed coconut oil. The results of this study also showed increased liver sizes in animals fed safflower oil diets versus those fed coconut oil, but the analysis revealed that the only significant effect on liver dry weights was the fat level. The two higher dietary fat levels, 10 and 20%, resulted in significant increases in liver dry weights compared to the other two dietary fat levels. The other organs in the experiment where the dietary fat sources were coconut oil, lard, and safflower oil showed no significant differences in dry weights. In general, however, the animals fed safflower oil tended to have the largest kidneys and livers, while those on lard diets tended to have the largest spleens and testes. Johnson et al. (1987), however, reported better growth in animals fed dietary coconut oil than in animals fed safflower oil in their 19-week study.

When the dietary fat sources were corn oil, olive oil, and soybean oil, the only organ dry weight which was significantly affected by dietary fat source and fat level was the spleen. Both fat source and fat level had significant effects on spleen dry weight. Animals fed corn oil diets had larger spleens and they were larger at the 20% dietary fat level. Animals fed olive oil and soybean oil had the higher spleen dry weights at the 10% dietary fat level with a decrease in dry weight at the 20% dietary fat level.

Covariant analysis of the growth data from Experiment 1 revealed that weight gains were not significant after adjustment for feed consumption in terms of kilocalories. Thus, it would appear that the differences in weight gains were due to kilocalorie consumption and not to the type or level of dietary fat. In Experiment 2, the effects of fat source and level were still significant after adjustments in weight gains for kilocalories, were made by covariant analysis. These findings suggest that the differences in weight gains were not due to differences in kilocalorie consumption but were the results of differences in the nature of the fat consumed.

Animals consuming diets with fat sources high in linoleic acid had higher feed efficiency ratios than did animals fed diets which were low in linoleic acid. Significantly higher feed efficiency ratios were also observed when the dietary fat level was 20% versus the other dietary fat levels.

Increases in dietary fat from 2.5 to 20% were associated with decreasing hemoglobin levels and hematocrits in both experiments. Animals fed more saturated fats also tended to have the higher overall hemoglobin levels and hematocrits overall, but the effect was statistically significant only where coconut oil, lard, and safflower oil were the fat sources. Similar results have been reported by others (Johnson, Lukaski, & Bowman, 1987; Mahoney, Farmer, & Hendricks, 1980). In this study animals with lower weight gains tended to have higher hemoglobin levels and hematocrits, as the correlation analysis showing a negative correlation of weight gain with hemoglobin confirms.

The effects of fat source or level on tissue copper levels were not statistically significant. In general, tissue copper levels were highest in animals fed 10% dietary fat and lowest in rats fed the 20% dietary fat levels in both experiments. When the dietary fat sources were coconut oil, lard, or safflower oil, the 10% dietary fat level was associated with increased kidney copper levels in the animals. Animals on coconut oil diets tended to have higher kidney and liver copper levels than animals fed the other fats. Onderka and Kirksey (1975) reported higher liver copper levels in rats fed 20% dietary safflower oil than in animals fed 20% dietary coconut oil in their 19-week study. The tissue copper levels reported here are similar to those reported by Cohen, Keen, Lonnerdal, and Hurley (1985) and by Owen (1972).

When the fat sources were corn oil, olive oil, or soybean oil, the more saturated fat source, olive oil, was associated with a significantly higher kidney copper deposition. No significant effects of fat source or fat level on liver, spleen, or testes copper concentrations were observed in these studies. This is in contrast to the findings of Sinthusek and Magee (1984) that increases in the saturation of dietary fat were associated with increases in liver copper. Other researchers (Frimpong, 1982; Jones, 1983) reported no apparent effect of fat sources on liver copper.

When coconut oil, lard, and safflower oil were the dietary fat sources (Experiment 1), animals fed lard and safflower oil diets tended to have increased kidney iron levels with increased dietary fat levels. Analysis of the kidney iron data revealed a significant source x level interaction, which was still significant after covariant analysis of data for weight gains and dry tissue weights. Animals consuming coconut oil diets showed increased kidney iron concentration as the level of dietary fat increased from 2.5% to 10% only. The tissue iron levels generally were highest in the liver, spleen, and testes of animals fed the 2.5% dietary fat level in both experiments, where growth and tissue dry weights were the lowest. These results do not support the findings of Onderka and Kirksey (1975) who found higher kidney iron levels in animals fed 20% coconut oil diets than in animals fed 20% safflower oil diets. The experimental period was 19 weeks in their study.

Liver iron levels tended to be lowest in animals fed safflower oil, while the highest liver iron levels were found in animals fed coconut oil diets. These results support results reported by Onderka and Kirksey (1975). An increase in liver iron concentration associated with an increase in dietary fat level has been reported by Johnson, Lukaski, and Bowman (1987). The positive influence of coconut oil, and lard diets, on iron levels has been reported previously by others (Amine & Hegsted, 1975; Bowering, Masch, & Lewis, 1977). The significant effects of diets seen in this study on liver iron were not apparent when the liver iron data were adjusted for weight gains and/or liver dry weights. This indicated that there were no significant effects of fat source or fat level on liver iron concentrations. No significant effects of fat sources or fat level were observed on iron concentrations of the spleens and testes when the animals were fed coconut oil, lard, or safflower oil diets.

When the dietary fat sources were corn oil, olive oil, and soybean oil, animals fed the lower fat levels tended to have the higher tissue iron concentrations and the lower weight gains and dry tissue weights. In general animals consuming polyunsaturated fat sources (corn oil and soybean oil) tended to show decreased iron concentrations with increased dietary fat levels, whereas animals on olive oil diets tended to have increased iron levels with increased fat levels. Animals on corn oil diets, at the higher fat levels, tended to have the lowest tissue iron levels compared to animals fed olive oil or soybean oil diets. These animals had the higher weight gains and generally higher tissue dry weights. These results revealed a tissue iron deposition pattern similar to one reported in rats fed cholesterol (Onderka & Kirksey, 1975). Onderka and Kirksey observed reduced iron deposition in liver, kidney, and spleen in rats fed cholesterol.

Animals fed olive oil diets tended to have the highest tissue iron levels, and the spleen iron levels of these animals were significantly higher than those of animals fed corn oil or soybean oil diets, even after adjustment of the data for weight gain and/or spleen dry weight. Onderka and Kirksey (1975) also found higher spleen iron in animals fed diets high in saturated fats. No significant effects of fat source or fat level on iron levels of the animal tissues, kidney, liver and testes were observed in the animals fed corn oil, olive oil, or soybean oil.

Neither dietary fat source nor dietary fat level had significant effects on the tissue zinc concentrations of the young male rats in these studies. Jones (1985) and Frimpong (1982) also reported that liver zinc deposition in rats was not effected by dietary fat source. Lukaski, Klevay, Bolonchuk, Mahalko, Milne, Johnson, and Sanstead (1982), however, reported that zinc retention in humans decreased with PUFA but increased in the presence of SFA. The tissue mineral values reported here are similar to those reported by Cohen et al (1985) and Hambridge, Casey, and Drebs (1986).

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

Two studies were conducted where three fat sources, with different P/S ratios and/or linoleic/linolenic acid ratios, were fed at four fat levels (2.5, 5, 10, and 20%). Coconut oil, lard, and safflower oil were the dietary fat sources in the first experiment, while corn oil, olive oil, and soybean oil were the dietary fat sources in the second experiment. Parameters used for the evaluation of animal responses to the test diets were feed intake, weight gain, hemoglobin levels, hematocrits, and tissue (kidney, liver, spleen, and testes) copper, iron, and zinc deposition.

Both dietary fat sources and fat level had significant effects on the weight gains of the young male rats. Animals consuming corn oil and safflower oil diets had higher weight gains than the other animals and had the highest feed efficiency ratios. Since these two dietary fats had the higher linoleic acid concentrations, there is the possibility that the presence of this essential fatty acid allowed for higher weight gains and feed efficiency ratios. Polyunsaturated fats also have the higher bond energies and higher heats of combustion. Low weight gains were generally observed by animals fed coconut oil and olive oil diets where the P/S ratio of the fat is low. This effect may be due to the lack of essential fatty acid or to the poor absorption of the fat. There were, however, no other signs of essential fatty deficiency, loss of hair or scaly skin. The higher dietary fat levels also resulted in greater weight gains because the caloric value of the diets increased. Animals fed at the 2.5% fat level consumed the most feed, while those fed the 5 and 10% dietary fat level consumed similar amounts of feed. Animals fed the 20% dietary fat level showed a significant decrease in feed consumption.

When coconut oil, lard, and safflower oil were the dietary fat sources, the only significant effect on tissue dry weights revealed by statistical analyses was the effect of fat level on the liver dry weights. The liver dry weights were higher overall at a 10% dietary fat level. Neither fat source nor fat level significantly affected the other tissue dry weights. When the fat sources were corn oil, olive oil, and soybean oil, statistical analyses revealed that only the spleen dry weights were significantly effected by fat source and fat level. Animals fed corn oil had the higher spleen dry weights, and animals fed the 10% dietary fat level had overall the higher spleen dry weights.

Animals fed coconut oil diets had significantly higher hemoglobin levels than those fed lard diets. Hemoglobin levels also tended to be higher at the low 2.5% fat level. Animals on lard diets had higher hematocrits at the 2.5% fat level, while those fed coconut oil diets had the lower hematocrits. At the 20% fat level animals fed safflower oil diets had the lower hematocrits, and those fed coconut oil diets the higher. Neither dietary fat source nor dietary fat level had any significant effects on hemoglobin levels or hematocrits in the rats fed corn oil, olive oil, or soybean oil. It was noted that at the low dietary fat level, hemoglobin levels tended to be higher and growth was less. Animals on coconut oil and the olive oil diets exhibited the least growth overall and tended to have higher hemoglobin levels and hematocrits. Correlation analysis showed a negative correlation of weight gain with hemoglobin and hematocrits.

No significant effects of dietary fat source or dietary fat level on tissue copper deposition were observed in animals fed coconut oil, lard, or safflower oil. At the 20% dietary fat level, copper concentrations were noted to decrease in all tissues except the spleen. Kidney copper deposition was the highest at the 10% dietary fat level. When corn oil, olive oil, and soybean oil were the dietary fat sources, a significant ($p < 0.01$) effect of fat source on kidney copper was noted. Animals on olive oil diets had the higher kidney copper levels even after the data were adjusted for weight gain. Again, animals on the lower dietary fat levels tended to have the higher tissue copper concentrations with a decrease at the 20% dietary fat level.

In the study where the dietary fats were coconut oil, lard, and safflower oil, a significant ($p < 0.05$) source x level interaction was observed on kidney iron concentration, and when adjusted for dry kidney weights, the effect was still observed. At the 2.5% fat level, animals fed lard and safflower oil diets had the higher kidney iron deposition, but at the 5% fat level, animals fed coconut oil diets had the higher kidney iron concentration. At the 10 and 20% dietary fat level, animals fed safflower oil diets had higher kidney iron levels. The significant effects of dietary fat source and fat level on liver iron deposition were not apparent when the data were adjusted for weight gain and tissue dry weight, indicating that liver iron levels were not effected by these dietary fat sources or levels. At high dietary fat levels the more saturated fat sources, coconut oil and lard, were associated with higher liver iron levels, versus safflower oil, a polyunsaturated fat source with a high linoleic/linolenic ratio. The spleen and testes iron levels were not significantly effected by dietary fat levels or dietary fat sources.

In the study where corn oil, olive oil, and soybean oil were the dietary fat sources, there were no statistical effects of diet on kidney, liver, or testes iron deposition. However, corn oil was associated with the lower tissue iron levels especially at the two higher fat levels, 10 and 20%, where growth was highest. Correlation analysis showed a negative correlation between weight gain and liver and kidney iron in those animals fed corn oil diets. Animals fed olive oil diets did have significantly higher spleen iron deposition as compared to animals fed dietary corn or soybean oil diets. Here the two fat sources with the lower linoleic/linolenic ratios--olive oil and soybean oil--were observed to be associated with the higher tissue iron levels and the lower weight gains.

In these studies the deposition of zinc in the tissues of young male rats was not significantly effected by either dietary fat source or dietary fat level. Thus, it would appear that zinc deposition was not affected by the fat sources, coconut oil, lard, safflower oil, corn oil, olive oil, or soybean oil at the fat levels 2.5, 5, 10, and 20%.

In general, better growth was obtained with fat sources that had high P/S ratios and at the higher dietary fat levels. The animals generally consumed the most feed at the 2.5% fat level and the least at the 20% level of dietary fat. Mineral concentration, mcg/gram dry weight, was highest at low fat levels and with saturated fat sources versus polyunsaturated fat sources, especially iron deposition. Dilution effects of weight gain should be considered when reporting tissue concentrations. The interactions are, however, complex with different tissues affected in different ways by each dietary fat source and at each dietary fat level.

Recommendations

The relationship of dietary fat sources and fat levels to tissue mineral deposition in young male rats appears to be dependent on the tissue function and its interrelations to other tissues. It would be of interest to examine the effects of purified fatty acids, stearic, oleic, linoleic and linolenic, as opposed to the extracted plant oils on the parameters examined here. The effects of other test diets where only the linoleic/linolenic acid ratios were varied would also be of interest.

Extracted plant oils also have other sterol components which may have effects of the parameters examined here. An analysis of the sterol components of the dietary fat sources and an examination of their effects on the growth and tissue mineral deposition patterns in young male rats would be of interest.

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APPENDIX A

COMPOSITION OF THE EXPERIMENTAL DIETS

Table A-1

Composition of Basal Diets

	Percent Fat			
	2.5	5.0	10	20
Ingredients	gm/kg			
Fat[a]	25	50	100	200
Cornstarch	719	694	644	544
Casein	166	166	166	166
Mineral Mix	40	40	40	40
Vitamin Mix	20	20	20	20
Cellulose	20	20	20	20
Vitamin A&D Mix	10	10	10	10
Zinc sulfate	0.01	0.01	0.01	0.01

[a]Experiment 1: Coconut Oil, Lard, Safflower Oil
Experiment 2: Corn Oil, Olive Oil, Soybean Oil

Table A-2

Composition of Mineral Mix, Wesson Modified Osborne-Mendel[a]

Constituents	Percent
Calcium carbonate	21.000
Cupric sulfate 5H 0	0.039
Ferric pyrophosphate	1.470
Manganous sulfate (anhydrous)	0.020
Magnesium sulfate (anhydrous)	9.000
Aluminum potassium sulfate 12H 0	0.009
Potassium chloride	12.000
Potassium dihydrogen phosphate	31.000
Potassium iodide	0.005
Sodium chloride	10.500
Sodium fluoride	0.057
Tricalcium phosphate	14.900

[a]Teklad, Madison, WI.

Table A-3

Composition of Vitamin Mix[a]

Constituents	Amount per 2 kg mix
	mg
Vitamin B-12	2
Biotin	20
Folic acid	100
Thiamin HCL	500
Pyridoxine HCL	500
	gm
Menadione (2 methyl-napthaquinone)	1
Riboflavin	1
Nicotinic acid	1
Calcium pantothenate	3
Para-aminobenzoic acid	100
Inositol	100
Choline chloride	150
DL-methionine	600
Cornstarch[b]	1040

[a]All vitamins and methionine were purchased from ICN Nutritional Biochemicals, Cleveland, OH.

[b]Teklad, Madison, WI.

Table A-4

Mineral Analysis of the Diets

Dietary Fat Source	Copper	Iron	Zinc
		mcg/gm	
Coconut Oil	2.7	81	17
Lard	3.6	96	18
Safflower Oil	3.4	96	18
Corn Oil	3.5	82	15
Olive Oil	2.7	84	13
Soybean Oil	2.5	100	14

Table A-5

Dietary Fat FAtty Acid Composition and Ratios

Fatty Acids		Experiment 1 Fats			Experiment 2 Fats		
		Coconut Oil	Lard	Safflower Oil	Corn Oil	Olive Oil	Soybean Oil
		Weight percent of fatty acids present					
Caprylic	C8:0	5.4	--	--	--	--	--
Capric	C10:0	5.3	--	--	--	--	--
Lauric	C12:0	42.6	--	--	--	--	--
Myristic	C14:0	19.0	1.3	--	--	--	--
Palmitic	C16:0	10.8	25.6	6.9	11.8	11.9	10.9
Palmit-oleic	C16:1	--	2.5	--	--	0.9	--
Margaric	C17:0	--	0.3	--	--	--	--
Stearic	C18:0	3.3	17.9	2.5	1.9	3.2	3.7
Oleic	C18:1	11.3	42.3	12.3	27.7	78.6	24.3
Linoleic	C18:2	2.3	9.6	78.3	58.6	5.7	53.6
Linolenic	C18:3	--	0.5	--	--	--	7.4
P/S Ratio		0.028	0.22	8.3	4.3	0.38	4.2
Linoleic/ Linolenic Ratio		2.3	19	78	59	5.7	7.2

APPENDIX B

RAW DATA

Table B-1

Total Feed Consumption in Rats in Experiments 1 and 2.

	Replicates								
Diets	1	2	3	4	5	6	7	8	Mean
				grams					
				Experiment 1					
1	437	495	429	459	450	454	509	492	466
2	390	438	421	540	430	453	510	467	456
3	388	430	430	430	428	430	389	425	419
4	345	389	341	395	430	354	382	400	380
5	390	375	455	525	454	464	458	430	444
6	422	413	424	440	470	468	450	432	440
7	410	450	419	437	460	472	440	459	443
8	344	401	356	363	370	400	400	416	381
9	400	420	439	449	439	450	479	450	441
10	440	493	457	430	430	460	413	397	440
11	418	480	491	465	460	503	460	460	467
12	428	330	390	433	430	453	391	430	410
				Experiment 2					
1	450	420	460	477	441	560	458	386	457
2	322	447	420	446	377	398	420	410	405
3	448	517	388	404	419	440	440	440	437
4	404	347	383	410	335	409	356	336	373
5	407	421	450	440	390	440	402	406	420
6	410	397	443	403	410	410	407	443	415
7	372	387	390	420	384	376	356	370	382
8	381	329	359	376	366	406	323	378	365
9	400	450	410	450	410	390	390	446	418
10	428	446	362	410	384	410	410	398	406
11	372	374	345	385	270	474	390	398	389
12	406	362	380	358	381	379	353	382	375

Table B-2

Total Weight Gain of Rats in Experiments 1 and 2.

	Replicates								
Diets	1	2	3	4	5	6	7	8	Mean
					grams				
					Experiment 1				
1	162	203	165	177	199	180	227	162	184
2	153	164	183	225	153	217	232	214	193
3	186	191	202	194	185	188	173	178	187
4	191	172	186	221	192	183	220	214	197
5	230	172	194	188	177	213	189	176	192
6	180	182	203	191	224	229	196	194	201
7	196	218	189	189	141	235	217	224	201
8	192	229	187	182	197	208	206	207	201
9	147	164	180	165	161	180	208	180	173
10	185	201	185	193	174	183	180	157	182
11	201	212	210	222	204	207	224	224	214
12	223	167	190	223	227	252	211	232	216
					Experiment 2				
1	174	158	185	134	157	141	173	192	164
2	167	193	180	175	155	158	174	154	170
3	215	189	177	158	198	208	204	211	195
4	214	171	196	203	176	196	175	199	191
5	146	155	166	174	155	159	150	145	156
6	178	152	188	153	177	149	165	186	169
7	165	168	169	183	176	159	152	117	161
8	186	152	210	175	187	189	182	210	186
9	147	150	155	163	146	140	137	157	149
10	168	173	140	148	150	157	160	164	155
11	147	155	138	171	173	182	175	152	161
12	157	181	186	173	173	200	167	198	179

Table B-3

Blood Hemoglobin Concentration in Rats in Experiments 1 and 2.

	Replicates								
Diets	1	2	3	4	5	6	7	8	Mean
					gm/dl				
					Experiment 1				
1	17.1	13.2	14.6	13.6	14.4	15.3	13.3	12.5	14.2
2	13.7	14.3	12.6	12.3	15.4	13.4	13.7	12.9	13.5
3	13.1	16.3	14.0	14.9	12.7	13.4	14.9	13.0	14.0
4	13.3	14.1	16.5	13.7	15.3	14.9	13.4	12.7	14.2
5	14.5	13.7	17.2	14.0	17.7	11.7	14.5	12.3	14.5
6	13.3	13.0	12.1	12.5	13.3	13.0	13.1	12.4	12.8
7	12.2	14.9	13.9	12.9	13.0	12.5	12.8	12.3	13.1
8	12.9	14.3	15.4	13.0	12.3	12.7	12.5	14.5	13.5
9	14.5	12.6	13.0	13.9	14.9	13.9	12.6	13.1	13.6
10	14.0	12.6	14.9	12.1	14.9	13.7	12.9	13.4	13.6
11	12.3	12.7	14.1	12.7	12.7	14.5	12.6	12.6	13.0
12	12.4	12.9	12.6	11.7	12.3	12.3	13.3	12.1	12.5
					Experiment 2				
1	13.1	13.8	12.1	12.0	14.6	14.6	11.8	12.4	13.0
2	13.0	13.9	13.3	12.5	12.7	13.4	12.7	10.8	12.8
3	13.0	13.8	10.1	13.1	13.4	12.6	12.4	12.9	12.7
4	13.5	12.7	13.4	12.4	12.7	13.0	12.7	11.0	12.7
5	14.4	13.4	13.0	13.6	11.0	13.0	11.4	11.4	12.7
6	13.4	14.0	12.0	12.1	13.7	14.0	12.9	11.7	13.0
7	13.8	11.4	12.4	12.4	12.4	12.9	12.7	14.2	12.9
8	12.0	13.0	11.7	13.2	11.6	12.0	12.0	11.8	12.1
9	13.1	16.0	14.0	14.4	13.5	12.1	11.7	12.1	13.4
10	16.7	14.1	13.4	12.4	11.5	11.4	12.2	13.0	13.1
11	13.0	13.0	12.4	13.0	12.0	13.0	12.0	11.8	12.8
12	14.6	13.5	13.3	14.4	13.7	12.6	12.8	12.9	13.5

Table B-4

Blood Hematocrits of Rats in Experiments 1 and 2.

	Replicates								
Diets	1	2	3	4	5	6	7	8	Mean
					percent				
					Experiment 1				
1	54	42	51	43	40	49	45	40	46
2	50	55	52	49	54	51	50	47	51
3	49	46	58	42	42	49	40	40	46
4	53	52	58	43	41	48	50	41	48
5	51	52	(49)	50	46	49	43	50	49
6	(46)	48	(46)	39	57	46	43	45	46
7	54	(49)	48	45	53	(49)	50	41	49
8	46	48	48	45	40	40	46	49	45
9	55	54	50	47	60	(52)	55	42	52
10	56	51	(50)	49	53	45	(50)	48	50
11	46	57	54	42	43	45	40	45	47
12	47	47	(47)	50	55	(47)	40	42	47
					Experiment 2				
1	48	49	45	43	58	50	48	42	48
2	41	50	45	46	51	49	45	41	46
3	45	44	42	42	42	40	46	46	43
4	52	43	44	44	42	45	45	40	44
5	50	43	42	44	39	46	50	40	44
6	46	46	41	43	52	48	48	43	46
7	50	47	45	43	40	42	51	50	46
8	45	40	39	46	47	41	47	46	44
9	52	55	52	43	49	49	41	45	48
10	48	57	45	45	40	40	43	46	46
11	42	46	40	46	45	48	50	45	45
12	47	45	47	45	49	42	53	45	47

a
() estimated missing plot value.

Table B-5

Kidney Weights of Rats Fed Coconut Oil, Lard, and Safflower Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	1.48	1.97	1.54	2.04	1.79	1.76
2	1.75	1.60	1.57	2.04	1.46	1.68
3	1.80	1.94	1.84	2.10	1.83	1.90
4	1.46	1.74	1.69	1.90	1.96	1.75
5	1.84	1.68	1.67	1.83	1.86	1.78
6	1.83	1.83	1.87	2.00	2.05	1.90
7	1.95	2.01	2.00	1.64	2.03	1.90
8	1.85	2.19	1.77	1.55	1.91	1.80
9	1.56	1.80	1.77	1.77	1.68	1.70
10	1.99	2.20	1.71	1.84	1.67	1.90
11	1.56	2.09	1.97	1.93	1.81	1.90
12	2.09	1.64	1.73	1.92	2.01	1.90
			Dry Weights (grams)			
1	0.38	0.47	0.42	0.49	0.50	0.45
2	0.52	0.41	0.42	0.54	0.40	0.46
3	0.48	0.50	0.53	0.56	0.44	0.50
4	0.38	0.45	0.44	0.46	0.47	0.44
5	0.47	0.45	0.41	0.47	0.51	0.46
6	0.50	0.47	0.50	0.53	0.53	0.51
7	0.57	0.48	0.52	0.43	0.53	0.51
8	0.47	0.53	0.43	0.39	0.50	0.46
9	0.45	0.45	0.49	0.41	0.44	0.45
10	0.57	0.56	0.47	0.49	0.41	0.50
11	0.41	0.52	0.48	0.53	0.45	0.48
12	0.54	0.47	0.42	0.49	0.49	0.48

Table B-6

Liver Weights of Rats Fed Coconut Oil, Lard, and Safflower Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	6.39	8.54	6.25	7.87	8.83	7.58
2	6.50	6.59	6.96	7.55	6.25	6.77
3	7.88	8.35	8.47	8.17	7.45	8.06
4	8.45	7.61	6.80	8.41	7.74	7.80
5	7.07	6.91	7.07	7.76	7.10	7.18
6	6.57	6.84	8.11	7.37	8.50	7.48
7	6.94	8.51	7.45	7.84	10.20	8.14
8	8.53	9.16	7.32	7.67	8.31	8.20
9	5.48	6.45	6.87	6.36	6.71	6.37
10	7.43	7.85	6.82	7.24	6.57	7.18
11	8.04	8.12	7.71	8.52	8.25	8.13
12	9.93	6.73	6.46	9.66	9.63	8.48
			Dry Weights (grams)			
1	1.79	2.20	1.64	1.94	2.25	1.96
2	1.68	1.72	1.85	2.12	1.65	1.80
3	2.08	2.22	2.09	2.13	1.94	2.09
4	2.27	1.86	1.75	2.14	2.00	2.00
5	1.73	1.85	1.91	1.97	1.89	1.87
6	1.77	1.84	2.14	2.03	2.48	2.05
7	1.98	2.27	2.04	2.04	2.64	2.19
8	2.07	2.38	2.04	2.00	2.14	2.13
9	1.39	1.72	1.81	1.66	1.71	1.66
10	2.10	2.18	1.98	1.79	1.85	1.98
11	2.07	2.39	1.98	2.32	2.29	2.21
12	2.58	1.81	1.78	2.80	2.45	2.28

Table B-7

Spleen Weights of Rats Fed Coconut Oil, Lard, and Safflower Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	0.49	0.87	0.58	0.86	0.70	0.70
2	0.48	0.50	0.51	0.74	0.55	0.56
3	0.76	0.73	0.66	0.82	0.73	0.74
4	0.74	0.59	0.73	0.66	0.64	0.67
5	0.67	0.80	0.74	0.57	0.61	0.68
6	0.77	0.49	0.87	0.79	0.66	0.72
7	0.57	0.85	0.56	0.63	0.81	0.68
8	0.60	0.64	0.57	0.81	0.64	0.65
9	0.60	0.55	0.67	0.54	0.66	0.60
10	0.75	0.63	0.55	0.77	0.65	0.67
11	0.65	0.67	0.64	0.92	0.95	0.77
12	1.06	0.52	0.73	0.80	0.85	0.79
			Dry Weights (grams)			
1	0.11	0.18	0.14	0.20	0.16	0.16
2	0.11	0.12	0.12	0.17	0.13	0.13
3	0.17	0.18	0.16	0.18	0.18	0.17
4	0.18	0.13	0.16	0.15	0.15	0.15
5	0.15	0.18	0.17	0.13	0.14	0.15
6	0.18	0.10	0.19	0.18	0.15	0.16
7	0.14	0.19	0.12	0.14	0.20	0.16
8	0.13	0.15	0.12	0.18	0.15	0.15
9	0.13	0.13	0.16	0.12	0.15	0.14
10	0.17	0.14	0.13	0.17	0.17	0.16
11	0.15	0.15	0.15	0.21	0.23	0.18
12	0.25	0.12	0.16	0.18	0.20	0.18

Table B-8

Testes Weights of Rats Fed Coconut Oil, Lard, and Safflower Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	1.99	2.78	2.98	2.98	2.96	2.74
2	2.63	1.77	2.89	3.03	2.74	2.01
3	2.85	2.88	2.88	2.95	2.58	2.83
4	2.53	2.73	2.76	2.62	2.90	2.71
5	2.52	2.20	2.82	2.78	2.88	2.64
6	2.56	2.62	2.64	2.87	2.94	2.73
7	2.53	2.72	2.91	2.88	2.37	2.68
8	2.53	2.92	2.83	2.70	3.15	2.83
9	2.46	2.12	2.55	2.79	2.35	2.45
10	2.63	2.88	2.64	2.51	2.22	2.58
11	2.97	2.61	2.76	2.75	2.83	2.78
12	3.05	2.73	2.69	3.06	3.03	2.91
			Dry Weights (grams)			
1	0.29	0.38	0.42	0.42	0.41	0.38
2	0.36	0.26	0.41	0.42	0.39	0.37
3	0.40	0.39	0.39	0.39	0.36	0.39
4	0.38	0.39	0.39	0.38	0.41	0.39
5	0.38	0.38	0.39	0.39	0.39	0.39
6	0.36	0.38	0.37	0.39	0.42	0.38
7	0.36	0.38	0.40	0.41	0.33	0.38
8	0.35	0.41	0.39	0.36	0.42	0.39
9	0.35	0.31	0.36	0.39	0.35	0.35
10	0.38	0.41	0.36	0.35	0.32	0.36
11	0.45	0.37	0.40	0.38	0.40	0.40
12	0.42	0.38	0.38	0.42	0.43	0.41

Table B-9

Kidney Weights of Rats Fed Corn Oil, Olive Oil, and Soybean Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	2.25	1.69	2.07	1.71	1.69	1.88
2	1.87	2.24	1.83	2.23	1.45	1.92
3	2.38	2.11	1.93	1.79	1.98	2.04
4	2.37	1.75	2.23	2.34	1.74	2.09
5	1.72	2.30	2.00	2.04	1.71	1.95
6	2.25	1.98	2.55	2.03	1.93	2.15
7	2.06	2.04	2.11	2.28	1.92	2.08
8	1.98	2.48	2.33	1.86	2.04	2.14
9	1.92	2.00	1.98	2.00	1.67	1.91
10	2.15	2.18	1.54	1.68	1.68	1.85
11	1.68	1.64	1.64	2.10	1.85	1.78
12	1.89	2.21	1.96	1.98	1.98	2.00
			Dry Weights (grams)			
1	0.59	0.42	0.52	0.45	0.45	0.49
2	0.45	0.58	0.42	0.58	0.40	0.49
3	0.63	0.51	0.45	0.51	0.51	0.52
4	0.62	0.43	0.52	0.63	0.46	0.53
5	0.44	0.57	0.51	0.51	0.46	0.50
6	0.68	0.50	0.64	0.51	0.52	0.57
7	0.50	0.51	0.49	0.55	0.51	0.51
8	0.51	0.54	0.57	0.48	0.54	0.53
9	0.51	0.47	0.50	0.49	0.42	0.48
10	0.52	0.55	0.37	0.42	0.43	0.46
11	0.47	0.42	0.40	0.49	0.48	0.45
12	0.51	0.52	0.48	0.48	0.49	0.50

Table B-10

Liver Weights of Rats Fed Corn Oil, Olive Oil, and Soybean Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	7.66	7.50	10.11	6.57	7.67	7.90
2	8.42	10.36	7.55	8.13	6.43	8.17
3	10.93	8.02	7.29	6.72	9.02	8.41
4	9.01	7.96	8.38	9.03	7.04	8.28
5	6.89	9.12	6.90	8.69	7.64	7.85
6	9.44	8.02	9.68	6.95	7.46	8.32
7	7.33	7.71	7.66	10.15	7.25	8.02
8	8.55	6.10	9.75	7.80	8.28	8.10
9	7.71	6.84	7.60	7.45	7.01	7.32
10	7.06	9.10	7.02	8.48	6.38	7.61
11	6.72	7.13	6.76	7.62	8.13	7.22
12	7.46	10.59	8.20	10.73	9.16	9.20
			Dry Weights (grams)			
1	2.09	1.98	2.63	1.73	1.98	2.08
2	2.15	2.66	2.22	2.21	1.76	2.20
3	3.24	2.32	2.16	1.92	2.81	2.49
4	2.71	2.09	2.35	2.43	1.94	2.30
5	1.77	2.40	2.01	2.09	2.02	2.06
6	2.47	2.04	2.60	1.81	2.15	2.22
7	2.09	2.22	2.13	2.51	2.04	2.20
8	2.38	1.17	2.58	2.14	2.26	2.11
9	2.02	1.86	2.03	1.88	1.92	1.94
10	1.98	2.37	1.90	2.21	1.73	2.04
11	1.75	2.01	1.72	1.97	2.12	1.91
12	2.00	2.65	2.37	3.36	2.20	2.52

Table B-11

Spleen Weights of Rats Fed Corn Oil, Olive Oil, and Soybean Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	0.75	0.80	1.11	0.82	0.58	0.81
2	0.81	1.06	0.87	0.75	0.75	0.85
3	1.18	0.87	1.06	0.54	0.86	0.90
4	0.91	0.93	1.17	1.01	0.89	0.98
5	0.59	0.67	0.57	0.65	0.84	0.66
6	1.04	0.65	1.02	0.73	0.62	0.81
7	0.69	0.89	0.85	0.93	0.69	0.81
8	0.80	0.69	0.92	0.51	0.67	0.72
9	0.54	0.83	0.54	0.61	0.66	0.64
10	0.76	0.94	0.61	0.60	0.63	0.71
11	0.82	0.89	0.84	0.60	0.86	0.80
12	0.67	0.88	0.64	0.80	0.76	0.75
			Dry Weights (grams)			
1	0.17	0.17	0.25	0.18	0.14	0.18
2	0.18	0.24	0.20	0.17	0.17	0.19
3	0.27	0.21	0.25	0.12	0.20	0.21
4	0.22	0.21	0.26	0.23	0.21	0.23
5	0.13	0.15	0.13	0.16	0.20	0.15
6	0.23	0.16	0.24	0.17	0.14	0.19
7	0.16	0.21	0.20	0.21	0.16	0.19
8	0.18	0.16	0.21	0.11	0.17	0.17
9	0.12	0.19	0.13	0.14	0.15	0.15
10	0.16	0.22	0.15	0.15	0.15	0.17
11	0.19	0.20	0.21	0.13	0.20	0.19
12	0.15	0.19	0.15	0.20	0.18	0.17

Table B-12

Testes Weights of Rats Fed Corn Oil, Olive Oil, and Soybean Oil.

	Replicates					
Diets	1	2	3	4	5	Mean
			Wet Weights (grams)			
1	2.91	2.52	2.41	3.00	2.87	2.74
2	2.56	2.57	2.65	2.73	2.21	2.54
3	2.57	2.66	2.59	5.74	2.86	2.68
4	2.93	2.53	2.69	2.80	2.52	2.69
5	2.25	2.40	2.63	2.74	2.41	2.49
6	2.99	2.45	2.70	2.70	2.26	2.62
7	2.64	2.78	2.13	2.88	2.73	2.63
8	2.57	2.34	3.07	2.74	2.45	2.63
9	2.73	2.62	2.04	2.86	2.63	2.58
10	2.56	2.65	2.95	2.85	2.74	2.75
11	2.83	2.41	1.80	2.56	2.74	2.47
12	2.71	2.70	2.78	2.63	2.79	2.72
			Dry Weights (grams)			
1	0.42	0.34	0.35	0.41	0.42	0.39
2	0.37	0.34	0.37	0.36	0.30	0.35
3	0.36	0.37	0.36	0.38	0.39	0.37
4	0.41	0.34	0.39	0.38	0.36	0.38
5	0.32	0.33	0.37	0.36	0.32	0.38
6	0.42	0.34	0.37	0.36	0.32	0.36
7	0.36	0.39	0.30	0.39	0.36	0.36
8	0.36	0.32	0.42	0.36	0.35	0.36
9	0.38	0.36	0.36	0.39	0.37	0.37
10	0.35	0.36	0.41	0.39	0.38	0.38
11	0.40	0.35	0.27	0.36	0.38	0.35
12	0.41	0.37	0.35	0.36	0.39	0.38

Table B-13

Kidney Copper Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	35.9	24.2	24.4	20.9	20.5	25.1
2	19.7	22.2	27.1	33.7	25.6	25.6
3	23.7	65.9	27.9	58.8	20.7	39.4
4	20.9	17.7	25.8	22.2	21.8	21.7
5	26.6	27.8	30.5	21.6	31.2	27.6
6	20.5	26.6	25.0	23.6	23.6	23.8
7	17.9	71.0	35.0	21.1	17.1	32.4
8	36.3	42.9	26.4	20.4	18.2	28.9
9	22.7	25.3	27.8	33.3	20.7	25.9
10	21.9	22.3	21.8	25.5	19.4	22.2
11	49.9	28.4	54.5	23.5	17.7	34.8
12	27.4	19.3	21.6	25.5	20.9	22.9
			Experiment 2			
1	23.3	29.8	21.6	25.0	30.6	26.1
2	27.8	45.3	26.8	34.5	52.0	31.9
3	25.8	24.5	25.0	24.5	27.0	25.4
4	22.1	26.2	24.0	35.7	24.5	26.5
5	22.7	37.3	27.0	27.0	24.5	27.7
6	18.4	42.5	27.3	34.3	24.0	29.3
7	25.0	27.0	25.5	27.3	31.9	27.3
8	27.0	25.5	24.1	28.6	20.8	25.2
9	34.3	45.2	17.5	28.1	32.7	31.6
10	31.2	43.2	27.0	41.7	46.5	37.9
11	39.3	38.7	40.6	45.9	46.9	40.3
12	34.3	45.7	23.4	36.5	48.5	37.7

Table B-14

Kidney Iron Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	273	304	374	299	2365	297
2	385	523	459	463	241	414
3	454	514	472	338	252	406
4	216	421	373	186	319	303
5	342	635	279	279	189	344
6	486	266	300	404	168	325
7	426	505	536	556	216	448
8	691	451	648	495	279	513
9	270	302	350	679	333	387
10	275	357	228	554	218	327
11	270	412	350	391	175	319
12	384	638	289	671	335	463
			Experiment 2			
1	198	212	171	198	210	198
2	173	182	132	125	181	159
3	176	142	111	163	142	147
4	134	181	128	150	133	145
5	202	283	153	196	169	200
6	196	267	165	163	149	188
7	255	153	136	192	229	193
8	174	134	244	220	144	183
9	185	142	156	170	158	162
10	128	192	180	238	168	181
11	166	185	220	227	162	192
12	218	246	150	243	204	212

Table B-15

Kidney Zinc Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	89	87	94	88	73	86
2	70	88	89	87	78	83
3	88	81	82	91	82	95
4	102	75	93	95	84	90
5	93	85	87	83	79	86
6	77	86	85	88	75	82
7	67	82	83	96	83	82
8	93	96	90	82	83	91
9	86	81	79	117	85	90
10	90	85	91	86	90	89
11	97	87	88	90	88	90
12	79	77	95	90	87	86
			Experiment 2			
1	84	90	84	88	88	87
2	108	78	91	91	85	91
3	79	85	97	94	85	88
4	86	86	81	76	84	83
5	96	79	92	83	76	86
6	75	88	74	85	70	80
7	86	78	94	86	89	87
8	83	90	83	92	82	86
9	89	91	87	96	90	91
10	90	89	97	90	83	90
11	79	87	79	91	98	87
12	85	77	92	90	85	86

Table B-16

Liver Copper Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	20.1	18.6	20.7	17.5	16.9	18.8
2	17.9	19.8	22.2	18.0	20.0	19.5
3	20.2	19.4	21.1	25.4	17.0	20.6
4	12.3	20.4	22.9	20.6	19.5	19.1
5	20.2	19.1	19.9	18.8	17.5	19.1
6	19.8	19.6	17.8	21.2	16.9	19.0
7	17.7	20.3	18.1	18.1	17.0	18.3
8	18.4	20.2	17.2	13.5	15.9	17.0
9	20.1	20.3	20.4	21.1	19.9	20.4
10	20.5	19.7	17.7	20.7	19.5	19.6
11	20.3	18.8	21.2	19.0	20.0	19.9
12	12.8	17.1	18.0	16.1	18.4	16.5
			Experiment 2			
1	16.1	16.3	15.1	17.1	18.6	16.7
2	17.9	17.9	19.9	20.0	19.2	18.9
3	14.5	14.5	18.4	19.1	15.7	16.5
4	13.6	16.9	15.6	16.3	17.4	16.0
5	18.3	18.4	16.1	17.6	16.7	17.4
6	16.7	15.9	16.4	18.2	17.8	17.0
7	15.5	16.6	16.6	16.4	15.9	16.2
8	16.1	25.1	15.4	13.7	13.0	16.7
9	14.6	19.8	12.3	16.4	18.4	16.3
10	19.3	15.5	14.7	16.0	17.0	16.5
11	18.5	19.8	16.2	18.7	17.3	18.1
12	16.2	17.8	15.5	12.3	15.4	15.4

Table B-17

Liver Iron Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	539	292	675	571	508	517
2	574	457	560	489	693	554
3	326	563	752	604	552	559
4	503	749	469	467	661	590
5	392	683	524	562	586	549
6	444	485	401	405	418	430
7	415	425	490	438	501	454
8	604	360	333	446	401	429
9	617	560	730	602	815	665
10	544	459	415	539	425	476
11	449	418	451	446	374	428
12	457	572	421	395	539	477
			Experiment 2			
1	359	463	317	436	463	408
2	291	329	563	528	663	475
3	206	198	193	434	178	242
4	246	299	355	446	515	372
5	400	278	539	638	578	487
6	388	388	160	538	310	357
7	239	244	822	531	531	473
8	248	285	226	350	406	313
9	392	269	246	621	391	384
10	274	264	307	830	337	402
11	429	352	484	465	472	441
12	271	393	633	521	341	432

Table B-18

Liver Zinc Concentration of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	111	111	90	97	99	102
2	90	112	85	94	108	98
3	69	103	134	109	120	107
4	79	123	110	115	111	108
5	95	94	120	104	102	103
6	91	142	112	111	112	115
7	173	110	91	114	106	117
8	144	128	96	113	118	120
9	138	114	127	114	92	117
10	103	90	109	124	144	114
11	122	108	114	115	113	115
12	122	129	148	95	109	121
			Experiment 2			
1	96	86	78	82	91	87
2	97	83	101	91	109	96
3	81	79	93	111	74	88
4	74	90	75	82	84	87
5	99	82	93	88	97	92
6	93	78	85	105	66	85
7	82	83	88	63	88	81
8	81	104	79	78	89	92
9	83	81	58	106	91	84
10	97	79	92	72	107	89
11	105	106	67	89	87	90
12	79	88	84	67	72	78

Table B-19

Spleen Copper Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	17.0	6.9	4.5	3.1	3.9	7.1
2	11.4	10.4	5.2	3.7	4.8	7.1
3	7.4	3.5	3.9	3.5	3.5	4.3
4	6.9	14.4	7.8	4.2	4.2	7.5
5	8.3	10.4	3.7	4.8	4.4	6.3
6	6.9	6.3	6.6	3.5	4.2	5.5
7	8.9	9.9	5.2	4.5	3.1	6.3
8	9.6	12.5	5.2	3.5	4.2	7.0
9	9.6	9.6	3.9	5.2	4.2	6.5
10	11.0	8.9	4.8	3.6	3.6	6.4
11	8.3	12.5	4.2	3.0	2.7	6.1
12	7.5	5.2	3.9	3.5	3.1	4.6
			Experiment 2			
1	4.2	4.2	2.9	7.9	5.1	4.9
2	7.9	6.0	7.1	4.2	8.4	6.7
3	10.6	6.8	8.6	6.0	7.1	7.8
4	6.5	10.2	8.2	6.2	6.8	7.5
5	5.5	9.5	5.5	8.9	7.1	7.3
6	3.1	4.5	6.0	8.4	10.2	6.4
7	8.9	6.8	7.1	6.8	4.5	6.8
8	4.0	8.9	6.8	6.4	8.4	6.9
9	11.9	11.3	5.5	10.2	4.8	8.7
10	8.9	9.7	4.8	9.5	9.5	8.5
11	7.5	10.7	6.8	5.5	7.1	7.5
12	4.8	3.8	4.8	7.1	7.9	5.7

Table B-20

Spleen Iron Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	432	708	429	513	375	491
2	659	375	521	500	346	480
3	397	639	703	514	431	537
4	500	981	391	400	783	611
5	567	625	382	423	571	514
6	347	400	500	528	283	412
7	268	474	750	446	250	438
8	538	300	354	528	300	404
9	385	692	656	854	283	574
10	485	482	462	515	191	427
11	550	300	467	488	185	398
12	380	792	453	444	375	489
			Experiment 2			
1	733	1126	868	833	940	900
2	705	779	565	570	814	684
3	556	582	434	750	542	573
4	671	736	479	642	747	655
5	905	831	657	865	692	790
6	461	865	653	733	626	668
7	822	813	542	725	908	762
8	731	756	648	839	652	721
9	712	850	781	692	692	745
10	1327	1017	1508	1462	831	1228
11	984	1085	813	1011	542	887
12	846	850	892	842	859	858

Table B-21

Spleen Zinc Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	96	88	84	99	97	93
2	62	82	133	103	90	94
3	89	101	102	114	74	96
4	86	117	104	86	83	95
5	109	105	96	99	103	102
6	112	129	102	99	96	107
7	92	110	104	108	72	97
8	93	111	129	101	79	102
9	87	82	90	111	101	94
10	80	92	102	102	80	91
11	96	104	93	103	82	96
12	94	94	104	80	91	95
			Experiment 2			
1	81	87	78	91	76	82
2	91	77	83	88	76	83
3	78	53	78	88	80	75
4	83	83	84	83	79	82
5	82	81	94	76	78	82
6	75	110	77	87	83	86
7	81	77	78	81	76	79
8	86	81	77	87	81	83
9	88	80	86	89	86	85
10	95	78	60	69	133	87
11	82	82	71	82	80	79
12	79	83	88	88	73	82

Table B-22

Testes Copper Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	14.1	12.0	13.0	13.0	11.1	12.6
2	13.9	14.0	13.3	9.7	15.2	13.2
3	14.8	14.0	12.8	12.8	11.4	13.2
4	10.8	14.0	14.0	12.0	11.1	12.3
5	14.4	13.2	12.8	11.7	12.8	13.0
6	13.9	13.2	12.3	12.8	13.0	13.0
7	13.9	14.4	12.5	13.3	12.4	13.3
8	14.3	12.9	12.8	11.4	11.9	12.5
9	14.3	11.7	12.6	14.4	13.0	13.1
10	13.2	13.3	12.6	11.7	12.8	12.7
11	13.1	13.5	14.8	12.0	11.4	12.9
12	14.1	13.2	12.0	10.8	11.6	12.3
			Experiment 2			
1	15.3	16.8	12.2	16.3	14.7	15.1
2	17.4	16.8	13.5	15.9	14.3	15.6
3	17.9	15.4	15.9	16.3	14.7	16.0
4	15.7	14.7	14.2	16.3	13.2	14.9
5	17.9	17.3	15.4	17.2	16.4	16.8
6	18.7	18.9	15.4	17.2	8.9	15.8
7	15.9	14.7	16.7	15.9	14.6	15.5
8	15.9	15.6	15.3	12.2	10.9	15.0
9	18.8	13.9	11.9	14.7	12.9	14.4
10	14.3	17.9	12.2	14.7	12.5	14.3
11	17.9	18.4	18.5	15.9	15.0	17.1
12	15.7	15.4	13.2	15.9	13.4	14.7

Table B-23

Testes Iron Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	203	161	241	131	134	174
2	153	207	213	74	122	154
3	153	151	154	141	150	152
4	168	167	192	132	128	157
5	161	158	388	112	170	198
6	177	145	159	144	152	155
7	142	316	166	143	129	179
8	168	140	138	160	148	147
9	157	161	170	138	136	152
10	184	177	170	150	145	165
11	111	142	172	145	131	140
12	149	174	132	149	99	141
			Experiment 2			
1	149	184	179	122	208	168
2	203	147	135	139	83	141
3	174	135	174	164	191	168
4	183	147	160	132	208	166
5	234	152	135	174	234	186
6	179	147	169	139	117	150
7	173	160	250	128	174	177
8	139	156	179	208	179	172
9	197	174	174	160	168	175
10	179	139	152	192	132	159
11	156	143	185	139	197	164
12	152	203	164	243	160	185

Table B-24

Testes Zinc Concentrations of Rats in Experiments 1 and 2.

	Replicates					
Diets	1	2	3	4	5	Mean
			mcg/gm dry wt			
			Experiment 1			
1	166	205	172	152	185	176
2	175	142	169	189	185	172
3	160	173	185	173	216	182
4	175	183	190	158	169	175
5	166	178	161	157	207	174
6	162	173	168	161	179	169
7	175	185	167	169	146	168
8	190	163	154	175	183	173
9	164	146	190	166	158	165
10	158	165	170	183	197	174
11	154	153	181	171	167	165
12	161	163	161	161	168	163
			Experiment 2			
1	142	157	163	145	159	153
2	154	155	152	168	149	156
3	156	152	180	155	155	160
4	161	160	146	150	160	156
5	167	159	149	166	170	162
6	163	150	145	173	115	149
7	158	151	140	157	156	153
8	149	159	159	158	150	155
9	154	168	156	162	145	157
10	160	151	133	160	157	152
11	156	153	130	156	159	150
12	130	145	164	163	155	152

APPENDIX C

STATISTICAL ANALYSES

Table C-1

Analysis of Variance of Growth Data of Rats Fed Coconut Oil, Lard, and Safflower Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
	Experiment 1		
Total	95	49898	
Replicates	7	5700	814
Diet	11	13680	1244**
Source	2	1176	588
Level	3	6538	2179**
Source x Level	6	5966	994*
Error	77	30517	396
	Covariant Analysis		
Total	95	49898	
Replicates	7	3158	451
Feed Intake	1	9028	9028**
Diet	11	20373	1852**
Source	2	1563	782
Level	3	14794	4931**
Source x Level	6	1835	306
Error	76	21489	283
Total	95	49898	
Replicates	7	3262	466
Kilocalories	1	9300	9300**
Diet	11	4434	403
Error	76	21217	279

* significant ($p<0.05$)
** highly significant ($p<0.01$)

Table C-2

Analysis of Variance of Growth Data of Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source of Variation	Degrees of Freedom		Sum of Squares		Mean Square	
			Experiment 1			
Total	95		40590			
Replicates	7		624		89	
Diet	11		19590		1781**	
Source		2		5680		2840**
Level		3		11090		3697**
Source x Level		6		2820		470
Error	77		20376		265	
			Covariant analysis			
Total	95		40590			
Replicates	7		1173		168	
Feed Intake	1		2790		2790**	
Diet	11		22280		2025**	
Source		2		3051		1526**
Level		3		13323		4441**
Source x Level		6		1339		223
Error	76		17586		231	
Total	95		40590			
Replicates	7		1184		169	
Kilocalories	1		2998		2998**	
Diet	11		9490		863**	
Source		2		3047		1524**
Level		3		6195		2065**
Source x Level		6		1239		207
Error	76		17378		229	

* significant ($p<0.05$)
** highly significant ($p<0.01$)

Table C-3

Analysis of Variance of Feed Intake Data of Rats

Source of Variation	Degrees of Freedom		Sum of Squares		Mean Square	
		Experiment 1				
Total	95		158527			
Replicates	7		20372		2910	
Diet	11		75064		6824**	
Source		2		2753		1377
Level		3		56475		18825**
Source x Level		6		15836		2639**
Error	77		63091		819	
		Experiment 2				
Total	95		150260			
Replicates	7		11711		1673	
Diet	11		68115		6192**	
Source		2		9974		4987**
Level		3		45077		15026**
Source x Level		6		13065		2178*
Error	77		70433		914	

* significant ($p<0.05$)
** highly significant ($p<0.01$)

Table C-4

Analysis of Variance of Feed Efficiency Data

Source of Variation	Degrees of Freedom		Sum of Squares		Mean Square	
		Experiment 1				
Total	95		0.3334			
Replicates	7		0.0182		0.0026	
Diet	11		0.2014		0.0183**	
Source		2		0.0103		0.0051*
Level		3		0.1826		0.0609**
Source x Level		6		0.0086		0.0014
Error	77		0.1138		0.0015	
		Experiment 2				
Total	95		0.3934			
Replicates	7		0.0160		0.0023	
Diet	11		0.2572		0.0234**	
Source		2		0.0134		0.0067*
Level		3		0.2395		0.0798**
Source x Level		6		0.0043		0.0007
Error	77		0.1202		0.0016	

* significant ($p<0.05$)
** highly significant ($p<0.01$)

Table C-5

Analysis of Variance of Hemoglobin and Hematocrit Data of Rats Fed Coconut Oil, Lard, and Safflower Oil

Source of Variation	Degrees of Freedom		Sum of Squares		Mean Square	
		Hemoglobin				
Total	95		142			
Replicates	7		19		3	
Diet	11		33		3**	
Source		2		12		6**
Level		3		9		3*
Source x Level		6		12		2
Error	77		90		1	
		Hematocrit				
Total	95		2352			
Replicates	7		551		79	
Diet	11		444		40*	
Source		2		48		24
Level		3		105		35
Source x Level		6		291		49*
Error	77		1357		18	

* significant ($p<0.05$)
** highly significant ($p<0.01$)

Table C-6

Analysis of Variance of Hemoglobin and Hematocrit Data of Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
	Hemoglobin		
Total	95	108	
Replicates	7	24	3
Diet	11	11	1
Error	77	74	1
	Hematocrit		
Total	95	1519	
Replicates	7	183	26
Diet	11	200	18
Error	77	1136	15

Table C-7

Analysis of Variance of Tissue Dry Weight Data of Rats Fed Coconut Oil, Lard, and Safflower Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
		Kidneys	
Total	59	0.143	
Replicates	4	0.004	0.037
Diet	11	0.032	0.296
Error	44	0.108	0.003
		Liver	
Total	59	4.367	
Replicates	4	0.306	0.076
Diet	11	1.800	0.164**
Source	2	0.093	0.047
Level	3	1.155	0.385**
Source x Level	6	0.552	0.092
Error	44	2.262	0.051
		Spleen	
Total	59	0.054	
Replicates	4	0.005	0.001
Diet	11	0.013	0.001
Error	44	0.036	0.001
		Testes	
Total	59	0.067	
Replicates	4	0.004	0.001
Diet	11	0.012	0.001
Error	44	0.050	0.001

* significant ($p<0.05$)
** highly sighnificant ($p<0.01$)

Table C-8

Analysis of Variance of Tissue Dry Weight Data of Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source of Variation	Degrees of Freedom	Sum of Squares		Mean Square	
		Kidneys			
Total	59	0.241			
Replicates	4	0.027		0.007	
Diet	11	0.061		0.006	
Error	44	0.153		0.003	
		Liver			
Total	59	7.808			
Replicates	4	0.181		0.045	
Diet	11	2.021		0.184	
Error	44	5.605		0.127	
		Spleen			
Total	59	0.085			
Replicates	4	0.009		0.002	
Diet	11	0.028		0.003*	
Source	2		0.014		0.007**
Level	3		0.010		0.003*
Source x Level	6		0.004		0.001
Error	44	0.048		0.001	
		Testes			
Total	59	0.0578			
Replicates	4	0.0065		0.0016	
Diet	11	0.0116		0.0011	
Error	44	0.0398		0.0009	

* significant ($p<0.05$)
** highly sighnificant ($p<0.01$)

Table C-9

Analysis of Variance of Tissue Copper Data of Rats Fed Coconut Oil, Lard, and Safflower Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
		Kidneys	
Total	59	7581	
Replicates	4	808	202
Diet	11	1643	149
Error	44	5130	117
		Liver	
Total	59	287	
Replicates	4	22	6
Diet	11	84	8
Error	44	180	4
		Spleen	
Total	59	617	
Replicates	4	388	97
Diet	11	53	5
Error	44	176	4
		Testes	
Total	59	77	
Replicates	4	21	5
Diet	11	6	1
Error	44	50	1

Table C-10

Analysis of Variance of Tissue Copper Data of Rats Fed

Corn Oil, Olive Oil, and Soybean Oil

Source of Variation	Degrees of Freedom		Sum of Squares		Mean Square
			Kidneys		
Total	59		3852		
Replicates	4		844		211
Diet	11		1574		143**
Source		2		1190	595**
Level		3		171	57
Source x Level		6		212	35
Error	44		1435		33
			Covariant Analysis		
Total	59		3852		
Replicates	4		844		211
Weight Gain	1		42		42
Diet	11		1529		139**
Error	44		1393		32
			Liver		
Total	59		265		
Replicates	4		22		6
Diet	11		50		5
Error	44		192		4
			Spleen		
Total	59		280		
Replicates	4		16		4
Diet	11		67		6
Error	44		198		5
			Testes		
Total	59		244		
Replicates	4		92		23
Diet	11		44		4
Error	44		105		2

** highly sighnificant ($p<0.01$)

Table C-11

Analysis of Variance of Tissue Iron Data of Rats Fed

Coconut Oil, Lard, and Safflower Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
		Kidneys	
Total	59	1135380	
Replicates	4	310874	77719
Diet	11	273691	24881*
Source	2	28018	14009
Level	3	64481	21494
Source x Level	6	181192	30199*
Error	44	550816	12519
		Liver	
Total	59	753869	
Replicates	4	17582	4396
Diet	11	307464	27951**
Source	2	80396	40198*
Level	3	90548	30183*
Source x Level	6	136520	22753*
Error	44	428822	9746
		Covariant Analysis	
Total	59	753869	
Replicates	4	175582	4396
Weight Gain	1	169567	169567
Dry Weight	1	29579	29579
Diet	11	159156	14469
Error	44	377984	9000
		Spleen	
Total	59	155422377	
Replicates	4	270633	67658
Diet	11	261650	23786
Error	44	1010094	22957
		Testes	
Total	59	121670	
Replicates	4	28770	7192
Diet	11	15798	1436
Error	44	77102	1752

* significant (p<0.05)
** highly sighnificant (p<0.01)

Table C-12

Analysis of Variance of Tissue Iron Data of Rats Fed

Corn Oil, Olive Oil, and Soybean Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
		Kidneys	
Total	59	899949	
Replicates	4	8274	2069
Diet	11	26256	2387
Error	44	55419	1260
		Liver	
Total	59	1326220	
Replicates	4	384009	96002
Diet	11	283506	25773
Error	44	658704	14971
		Spleen	
Total	59	2614900	
Replicates	4	139345	34836
Diet	11	1585674	144152**
Source	2	599785	299893**
Level	3	150344	50115
Source x Level	6	835546	139258**
Error	44	889880	20225
		Covariant Analysis	
Total	59	2614900	
Replicates	4	139345	34836
Weight Gain	1	536833	536833**
Dry Weight	1	68329	68329
Diet	11	1136017	103274**
Source	2	26418	132409*
Level	3	88567	29522
Source x Level	6	782633	130439**
Error	44	734375	17485
		Testes	
Total	59	60101	
Replicates	4	2992	748
Diet	11	9331	848
Error	44	47777	1086

* significant ($p<0.05$)
** highly sighnificant ($p<0.01$)

Table C-13

Analysis of Variance of Tissue Zinc Data of Rats Fed Coconut Oil, Lard, and Safflower Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
	Kidney		
Total	59	3708	
Replicates	4	654	164
Diet	11	576	52
Error	44	2479	56
	Liver		
Total	59	19410	
Replicates	4	128	32
Diet	11	3320	302
Error	44	15962	363
	Spleen		
Total	59	10807	
Replicates	4	2284	571
Diet	11	1233	112
Error	44	7289	166
	Testes		
Total	59	13072	
Replicates	4	1307	327
Diet	11	1640	149
Error	44	10124	230

Table C-14

Analysis of Variance of Tissue Zinc Data of Rats Fed Corn Oil, Olive Oil, and Soybean Oil

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
		Kidney	
Total	59	2480	
Replicates	4	163	40
Diet	11	505	46
Error	44	1812	41
		Liver	
Total	59	10104	
Replicates	4	306	77
Diet	11	1553	141
Error	44	8244	187
		Spleen	
Total	59	6259	
Replicates	4	199	50
Diet	11	608	55
Error	44	5452	124
		Testes	
Total	59	6801	
Replicates	4	459	115
Diet	11	798	73
Error	44	5545	126