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Intestinal absorption and lipolysis of safflower oil and other unsaturated vegetable oils in rats

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INTESTINAL ABSORPTION AND LIPOLYSIS OF SAFFLOWER OIL AND OTHER UNSATURATED VEGETABLE OILS IN RATS

BY

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INTESTINAL ABSORPTION AND LIPOLYSIS OF SAFFLOWER OIL AND OTHER UNSATURATED VEGETABLE OILS IN RATS

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ABSTRACT

The intestinal lipolysis and absorption of safflower, corn, peanut, olive, cottonseed and soybean oils were studied in the rat. Oils and pancreatic lipase were injected into the rat jejunum and ileum (ligated *in situ*), and the amount of esterified fatty acids absorbed and free fatty acids present in the gut after 3 hours was determined. Safflower oil was absorbed significantly less than the other oils. There was no significant difference between the absorption rates of the other oils. When the oils were subjected to porcine pancreatic lipase *in vitro*, safflower oil also exhibited the lowest rate of hydrolysis.

The rates of absorption and lipolysis of the oils could not be explained on the basis of degree of saturation of constituent fatty acids. The low rate of hydrolysis of safflower oil represented the most plausible explanation of its low intestinal absorption.

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INTRODUCTION

The main constituents of vegetable oils used in human nutrition are triglycerides, chemical esters of fatty acids and glycerol. Triglycerides of both vegetable and animal origin contain straight chain fatty acids which have an even number of carbon atoms. The most common are fatty acids containing 16 (e.g. palmitic acid) or 18 (e.g. stearic acid) carbon atoms. Fatty acids with the same number of carbon atoms differ in number of unsaturated (double) bonds and in various chemical and physiological properties. Saturated fatty acids (e.g. stearic acid) contain no unsaturated bonds as opposed to nonsaturated fatty acids (e.g. oleic acid) and linoleic acid which have one or two unsaturated bonds respectively. Less abundant in oils and fats are fatty acids containing 3 or 4 double bonds. Vegetable oils contain substantially larger amounts of unsaturated fatty acids, predominantly oleic acid (olive oil) and linoleic acid (safflower oil) in comparison to animal fats, which contain predominantly saturated fatty

acids. The polyunsaturated fatty acids are essential in the diet of higher animals as they cannot be synthesized (Deuel, 1951).

Experimental and clinical data showing the importance of unsaturated fats in nutrition stimulated the marketing and increased the popularity of various polyunsaturated vegetable oils, such as safflower, corn, peanut, olive, cottonseed, and soybean oils. Safflower oil, obtained from a thistle-like plant (Carthamus tinctorius), contains the highest amount of trilinoleate and was often the subject of interest and also controversy.

The number of unsaturated bonds in fatty acids apparently has importance also in metabolism of lipids. Holt and Clark (1969) suggested that the manipulation of metabolism and deposition of body fat solely through the administration of fats of specific composition in the diet could be useful in dietary management of disease states. The effect of polyunsaturated oils on lowering of blood cholesterol in man is believed to play a role in prevention of arteriosclerosis. Safflower oil, one of the most polyunsaturated vegetable oils, has recently been shown to significantly reduce serum cholesterol levels when fed

to chickens (Hegsted, 1960), gerbils (Hegsted, 1967) and humans (Okey, 1960). This reduction of blood cholesterol has generally been attributed to the nature of the fat, especially to the presence of polyunsaturated fatty acids.

As metabolic effects have been attributed to the nature of ingested fats, the intestinal absorption of these fats has long been of interest. Steenbock et al. (1936) compared the intestinal absorption of animal and vegetable fats, including corn, peanut, olive, cottonseed and soybean oils, in feeding studies in rats. Their results showed no relation between the absorption and degree of saturation of the fats. However, a number of workers performing fat feeding studies on rats (Rao, 1947), pigs (Flanzy, 1968) and infants (Holt, 1935) concluded that the absorption of fat depends on its fatty acid composition. They demonstrated that unsaturated fatty acids are absorbed better than saturated fatty acids.

Digestion and absorption of dietary fats under various experimental conditions were reviewed by Deuel (1955), Johnston (1968) and Holt and Clark (1969). The use of different experimental conditions made it difficult to compare results available in the literature; for instance,

feeding experiments had the distinct disadvantage of variables such as stomach emptying.

The objective of the present study was the comparison of intestinal absorption and lipolysis of vegetable oils with special interest in safflower oil, using a method of ligated rat gut *in situ* with pancreatic lipase. This method eliminated individual variability of stomach evacuation and pancreatic secretion.

MATERIALS AND METHODS

Vegetable oils and free fatty acids employed.

1. safflower oil (General Mills; Minneapolis, Minn.)
2. corn oil (Best Food; Englewood Cliff, N. J.)
3. peanut oil (Planters; Suffolk, Va.)
4. olive oil (F. Berio; Lucca, Italy)
5. cottonseed oil (C. F. Sauer; Richmond, Va.)
6. soybean oil (Proctor and Gamble; Cincinatti, Ohio)
7. oleic acid, U.S.P. (Matheson Coleman and Bell; E. Rutherford, N. J.)
8. linoleic acid, technical (Matheson Coleman and Bell; E. Rutherford, N. J.)

Physical-chemical properties of vegetable oils and free fatty acids.

Table 1 gives the typical fatty acid composition of the vegetable oils employed (Weast, 1966). Table 2 shows a comparison of some physical-chemical properties of the oils and free fatty acids employed in the present study

with values for those properties of the same oils found in the literature (Hodgman, 1949; Stecher, 1968).

Specific gravity was determined at 25°C using a light liquid hydrometer.

Index of refraction was measured at 25°C using an Abbe refractometer.

Acid value, indicating essentially the amount of free fatty acids, was determined by titration with 0.1N solution of sodium hydroxide using phenolphthalein as indicator and was expressed as ml of 0.1N sodium hydroxide needed to titrate 10g of substance (Cook and Martin, 1948).

Iodine value was determined iodometrically by the Hanus method, using the iodobromide solution and was expressed as the number of grams of iodine absorbed by 100g of substance (Cook and Martin, 1948).

Sitosterol content was determined colorimetrically by the method of Liebermann and Burchard and was expressed as mg of sitosterol in 1 ml of oil.

Absorption and lipolysis of vegetable oils in the ligated rat jejunum and ileum.

The absorption and lipolysis of vegetable oils *in vivo* were studied in the ligated jejunum and ileum *in situ* in fasted rats, using a modified method of Vokac *et al.* (1961). Female Sprague-Dawley rats (average weight of 213g, ranging from 205 to 225g) were randomized into groups of 6 animals each, using random permutation tables (Moses, 1963). Animals were fasted in screen bottom cages for 48 hours with water *ad libitum*. Under light ether anesthesia a silk ligature was placed on the ileum at the ileocoecal valve, care being taken not to obstruct mesenterial blood vessels. The secretion of bile and pancreatic juice into the gut was eliminated by another ligature at the duodenal-jejunal junction. Vegetable oils were injected into the jejunum in a dose of 0.2 ml/200g body weight consisting of 773 μEq esterified fatty acids (EFA) simultaneously with 1 ml (120 Wilson units) of pancreatic lipase suspension and 6 mg of sodium taurocholate in 0.5 ml physiological saline solution (0.85%). The lipase used was porcine pancreatic lipase 3500 (Wilson Laboratories; Chicago, Ill.) containing 3500 Wilson units/gram or 68 Willstatter units/gram. The lipase suspension was prepared in a concentration of 34.4 mg

in 1 ml of 0.1M phosphate buffer (pH 7.2) by means of sonication. In control animals the same phosphate buffer was used without enzyme.

After 3 hours the ligated intestine was removed under light ether anesthesia and the gut contents were washed quantitatively with 50 ml of diethyl ether which inactivates lipase (Mattson et al., 1954). The ether extract was stored at -10°C and analyzed for esterified and free fatty acids.

The amount of undigested vegetable oil in the gut contents after 3 hours was determined as EFA using the method of Stern and Shapiro (1953). The method is based on the alkaline hydroxylaminolysis of carboxylic acid esters to form hydroxamic acids. The colorless hydroxamic acids form highly colored complexes with ferric ions in acid solution. The concentration of the color complex was measured colorimetrically at a wave length of 525 mμ. Triolein was used for construction of the calibration curve, which was linear. The amount of absorbed triglyceride was calculated as the difference between the amount administered and the amount recovered from intestinal contents:

EFA absorbed = EFA administered - EFA recovered.

The amount of free fatty acids (FFA) present in the gut contents at the end of 3 hours was determined by potentiometric titration of the ether extract using an automatic recording pH-stat. The method was a modification of that of Pelot and Grossman (1962). One ml of ether extract was added to 15 ml of solution in a titration vessel. This solution had the following composition as modified from the method of Cherry and Crandall (1932): 10 ml of deionized water, 1 ml of 0.075M calcium chloride, 2 ml of 3M sodium chloride and 2 ml of sodium taurocholate (15 mg/ml). The titrant used was 0.05N sodium hydroxide. The calibration curve constructed with oleic acid was linear.

Absorption of fatty acids in the ligated rat jejunum and ileum.

The absorption of oleic and linoleic acids from the jejunum and ileum was studied as these substances are the main fatty acid constituents of the vegetable oils used in this study. Two groups of female Sprague-Dawley rats, (average weight of 204g, ranging from 190 to 213g) were randomized into two groups of 10 animals each. Animals were fasted and surgically prepared as described above.

Fatty acids were injected into the jejunum in a dose of 0.2 ml/200g body weight. After 3 hours the contents of the ligated jejunum and ileum were washed quantitatively with 50 ml of diethyl ether and stored at -10°C for determination of the remaining fatty acids. FFA in the ether extract were determined by potentiometric titration as described above. The amount of fatty acids absorbed was calculated in μEq/200g rat as a difference between the amount administered and recovered from intestinal contents:

FFA absorbed = FFA administered - FFA recovered.

In vitro lipolysis of vegetable oils by pancreatic lipase.

Lipolysis of the oils was measured *in vitro* by potentiometric titration of FFA as described previously. The mixture, incubated at 37°C had the following composition: deionized water (10 ml), 0.075M calcium chloride (1 ml), 3M sodium chloride (2 ml), sodium taurocholate 15 mg/ml (2 ml). After preincubation, 0.5 ml of test oil and 1 ml of enzyme suspension containing 0.2 mg of pancreatic lipase were added. Samples were incubated at 37°C and at pH 7.2. This pH was found to be optimal for the lipolysis of oils. The samples were continuously stirred and flooded with nitrogen. Released fatty acids were continuously titrated

using an automatic burette; a solution of 0.05N sodium hydroxide was used as titrant. The rate of lipolysis of each oil was determined during the second half of a 10-minute incubation period. The amount of FFA originally present in the oils and released from triglycerides as a result of lipolysis in the first 5-minute period was subtracted from all values. Results were expressed in microequivalents of sodium hydroxide.

Statistical evaluation of data.

The results were evaluated statistically using the Programma 101 (Olivetti-Underwood) for Student t test and the IBM 1800 for linear regressions.

RESULTS

Physical-chemical properties of vegetable oils and free fatty acids.

A comparison of some physical-chemical properties of vegetable oils and FFA (Table 2) indicate that the oils and fatty acids used in the present study are essentially like those reported in the literature.

Iodine value, which increases with degree of unsaturation of fats, was lowest for olive oil (86.8) and highest for safflower oil (138.4). The iodine value of oleic acid was 89.9 and 154.0 for linoleic acid. The sitosterol content of oils ranged from 2.3 to 3.2 mg/ml with the exception of corn oil which contained 10.2 mg/ml.

Absorption and lipolysis of vegetable oils in the ligated rat jejunum and ileum.

In groups of animals dosed intraintestinally with 733 μEq of EFA in the form of vegetable oils, the amount

of EFA absorbed ranged from 298 to 351 μEq (Table 3). This represents 40 to 48% of the total EFA administered. In the group of animals dosed with safflower oil significantly less oil was absorbed than in animals dosed with other oils. The amount of 141 μEq absorbed with safflower oil represents only 19% of the amount administered (Fig. 1). No other significant differences in absorption of EFA were found.

The amounts of FFA recovered (ranging from 71.3 to 105.8 μEq) from the gut contents of rats dosed with various oils were not significant. However, safflower oil exhibited the lowest mean (71.3 μEq). Results are summarized in Table 3 and Figure 2.

Absorption of free fatty acids in the ligated rat jejunum and ileum.

There was no significant difference between the intestinal absorption of oleic and linoleic acids when administered into the ligated jejunum and ileum (Table 4). After the 3 hour incubation period 102 μEq oleic acid had been absorbed as compared to 114 μEq of linoleic acid.

In vitro lipolysis of vegetable oils by pancreatic lipase.

The amount of FFA released from 500 μl of safflower oil by pancreatic lipase *in vitro* was 14 to 29% lower than from any other vegetable oil used as substrate (Fig. 3).

Figure 4 shows the effects of increasing amounts of safflower and olive oils on pancreatic lipase activity. It should be noted that the rate of lipolysis becomes constant at a lower concentration for safflower oil than olive oil. At the highest concentration of substrate 27% less FFA was released from safflower oil than from olive oil.

DISCUSSION

Studies of biological properties of safflower oil have been limited mostly to its effect on blood lipids and cholesterol in chronic nutrition studies. Safflower oil appears to have special significance in fat metabolism, which was attributed to its high content of polyunsaturated linoleic acid. An extensive literature survey revealed no experimental data concerning digestion and absorption of safflower oil in comparison with other dietary vegetable oils.

In preliminary studies using rats with the gut ligated in situ, safflower oil was absorbed significantly less than olive oil. It was therefore of interest to find out how safflower oil compared with other vegetable oils used for human consumption. The rat was considered a suitable experimental animal for these absorption studies as it has been previously shown that fat transport in the rat was similar qualitatively and quantitatively to that in man (Kayden, 1967). The ligated gut technique appeared preferable

for this purpose since influence of variable rates of gastric emptying was eliminated. Similar ligated gut methods were used also for study of fat absorption by others (Krondl et al., 1962; Greenberger et al., 1966; Gallagher and Playoust, 1969).

Under the experimental conditions of the present study the safflower oil was absorbed significantly less than any other oil tested. This finding was in apparent disagreement with literature results which show increased absorption of oils containing unsaturated fatty acids (Rao et al., 1947; Flanzy et al., 1968). The other oils were absorbed at essentially the same rates in spite of considerable differences in the degree of saturation of constituent fatty acids. The content of the polyunsaturated linoleic acid ranged from 4% in olive oil to 50% in soybean oil. Steenbock et al., (1936) also studied the intestinal absorption of corn, peanut, olive, cottonseed and soybean oils in rats, and found little difference in absorption and no correlation between degree of saturation and absorption.

In the experiment where oleic acid and linoleic acid were injected into the ligated jejunum and ileum, there was no significant difference between the rates of absorption

of these fatty acids. However, linoleic acid was absorbed 8% more than oleic acid, a finding which was in agreement with results of Gallagher and Playoust (1969) and Tomarelli et al. (1968). Gallagher, using a comparable technique of isolated rat jejunum, found linoleic acid to be absorbed 7% more than oleic acid in 3 hours. Tomarelli found in fat feeding experiments in rats that the absorption of linoleic acid was higher than that for oleic acid. He also found that the nature of the fat fed to the animal does not affect the absorption rate of individual fatty acids.

During the lipolysis of vegetable oils in the intestine a considerable portion of fatty acids is released. These FFA originate from the conversion of triglycerides to di- and monoglycerides, rather than from complete cleavage of the triglycerides (Frazer, 1961). In the present study animals dosed with vegetable oils containing 733 μEq EFA, over 40% of the total amount of fat was absorbed in 3 hours. This suggests that at least part of the fat was absorbed as mono- or diglycerides rather than FFA since only approximately 15% of FFA was absorbed after administration of 660 μEq FFA under similar conditions.

Based on these studies it was concluded that the significantly slower absorption of safflower oil was not due to differences in absorption of component fatty acids. Therefore, as a next step the rate of lipolysis of safflower oil was compared to that of other oils *in vitro*. In this study, the lipolysis of safflower oil and olive oil by pancreatic lipase was determined *in vitro*. Safflower oil was lipolyzed substantially slower (27%) than olive oil (Fig. 4). The lipolysis of other oils was compared to that of olive oil and was found to be substantially higher than safflower oil (Fig. 3).

As shown previously in this study, intestinal absorption of oleic and linoleic acids was not significantly different. Therefore, it could be expected that the amount of FFA recovered from the small intestine of rats dosed with oils (Table 3) would correlate with the rate of lipolysis of the same oil *in vitro*. When compared in order of increasing lipolysis, there was a definite linear relationship between these two parameters, although it was not significant ($p>0.05<0.10$, Fig. 5). No relationship was found between the amount of EFA absorbed and the amount of FFA recovered from the intestinal content (Table 3).

The results suggest that the slow rate of safflower oil hydrolysis represented the most plausible explanation of low safflower oil absorption from the rat small intestine. This may be due to the presence of a lipase inhibitor in safflower oil. However, a comparison of the ratio of lipolysis of oils *in vitro* with the intestinal absorption of EFA in rats did not show a direct relationship (Fig. 6). Safflower oil was absorbed substantially less than could be expected based on the rate of lipolysis. It can be speculated that safflower oil contained substances effective not only as lipase inhibitors but also as inhibitors of intestinal absorption.

SUMMARY

1. The absorption of safflower oil in the rat jejunum and ileum within a 3 hour period was significantly lower in comparison with five other unsaturated vegetable oils (corn, peanut, olive, cottonseed, and soybean oils).

2. No significant difference was found in the amount of free fatty acids recovered from jejunal-ileal content after 3 hours in animals dosed with these oils. Animals dosed with safflower oil had the lowest concentration of free fatty acids in the gut.

3. There was no significant difference in the intestinal absorption of oleic and linoleic acids for a 3 hour period in the rat.

4. Safflower oil was lipolyzed by pancreatic lipase *in vitro* substantially slower in comparison with other oils which exhibited no outstanding differences from one another.

LITERATURE CITED

Cherry, I. S. and L. A. Crandall, Jr. The specificity of pancreatic lipase; its appearance in the blood after pancreatic injury. Amer. J. Physiol. 100: 266, 1932.

Cook, E. F. and E. W. Martin. Remington's Practice of Pharmacy, 9th ed. Easton: Mack, 1948, p. 1054.

Deuel, H. J. The Lipids. New York: Interscience, 1951, vol. 1, p. 8.

Deuel, H. J. The Lipids. New York: Interscience, 1955, vol. 2, p. 3.

Flanzy, J., A. Rerat and A. C. Francois. Etude de l' utilisation digestive des acides gras chez le porc. Ann. Biol. animale, Biochem. Biophys. 8: 537, 1968.

Frazer, A. C. Role of lipids in normal metabolism. Fed. Proc. 20: 146, 1961.

Gallagher, N. D. and M. R. Playoust. Absorption of saturated and unsaturated fatty acids by rat jejunum and ileum. Gastroenterology 57: 9, 1969.

Greenberger, N. J., J. B. Rodgers and K. J. Isselbacher. Absorption of medium and long chain triglycerides: factors influencing their hydrolysis and transport. J. Clin. Invest. 45: 217, 1966.

Hegsted, D. M., A. Gotsis and F. J. Stare. Influence of dietary fats on serum cholesterol levels in cholesterol-fed chicks. J. Nutr. 70: 119, 1960.

Hegsted, D. M. and A. Gallagher. Dietary fat and cholesterol and serum cholesterol in the gerbil. J. Lipid Res. 8: 210, 1967.

Hodgman, C. D. ed. Handbook of Chemistry and Physics, 31st ed. Cleveland: Chemical Rubber, 1949, pp. 964, 1266.

Holt, L. E., Jr., H. C. Tidwell, C. M. Kirk, D. M. Cross and S. Neale. Studies in fat metabolism. I. Fat absorption in normal infants. J. Pediat. 6: 427, 1935.

Holt, P. R. and S. B. Clark. Dietary triglyceride composition related to intestinal fat absorption. Amer. J. Clin. Nutr. 22: 279, 1969.

Johnston, J. M. Mechanisms of fat absorption. In: Handbook of Physiology, edited by W. Heidel and C. F. Code. Baltimore: Waverly, 1968, vol. 3, p. 1353.

Kayden, H. J., J. R. Senior and F. H. Mattson. The monoglyceride pathway to fat absorption in man. J. Clin. Invest. 46: 1695, 1967.

Krondl, A., A. Vokac and H. Vavrinkova. Influence of chlortetracycline and neomycin on digestion and absorption of fat in rats. Amer. J. Physiol. 202: 437, 1962.

Mattson, F. H., J. H. Benedict and L. W. Beck. Composition of intestinal lumen lipides following the feeding of triglycerides, partial glycerides or free fatty acids. J. Nutr. 52: 575, 1954.

Moses, L. E. and R. V. Oakford. Tables of random permutations. Stanford: Stanford Univ. Press, 1963, p. 17.

Okey, R., M. Lee, M. C. Hampton and P. Miljanich. Effect of safflower and coconut oils upon plasma cholesterol and lipid fractions. Metab. Clin. Exptl. 9: 791, 1960.

Pelot, D. and M. I. Grossman. Distribution and fate of pancreatic enzymes in small intestine of rat. Amer. J. Physiol. 202: 285, 1962.

Rao, V. R. B., D. Venkatappiah and C. P. Anantakriahnan. The relative rates of absorption of different oils and fats. Indian J. Vet. Sci. 17: 221, 1947.

Stecher, P. G. ed. The Merck Index, 8th ed. Rahway: Merck, 1968, pp. 621, 763.

Steenbock, H., M. H. Irwin and J. Weber. Comparative rate of absorption of different fats. J. Nutr. 12: 103, 1936.

Stern, I. and B. Shapiro. A rapid and simple method for the determination of esterified fatty acids in blood. J. Clin. Path. 6: 158, 1953.

Tomarelli, R. M., B. J. Meyer, J. R. Weaber and F. W. Bernhart. Effect of positional distribution on the absorption of fatty acids of human milk and infant formulas. J. Nutr. 95: 583, 1968.

Vokac, V., A. Krondl and H. Vavrinkova. Die wirkung von chlortetracyklin und neomycin auf die fettspaltung bei ratten. Deut. Z. Verdauungs-u. Stoffwechselkrankh. 21: 76, 1961.

Weast, R. C. ed. Handbook of Chemistry and Physics, 47th ed. Cleveland: Chemical Rubber, 1966, p. D-99.

TABLE 1

PERCENT FATTY ACID COMPOSITION OF VEGETABLE OILS
(Weast, 1966)

Oil	Oleic Acid	Linoleic Acid	Palmitic Acid	Stearic Acid
Safflower	18.6	70.1	(6.8)	
Corn	49.6	34.3	10.2	3.0
Peanut	56.0	26.0	8.3	3.1
Olive	84.4	4.6	6.9	2.3
Cottonseed	22.9	47.8	23.4	1.1
Soybean	28.9	50.7	9.8	2.4

TABLE 2

A COMPARISON OF PHYSICAL-CHEMICAL PROPERTIES OF VEGETABLE OILS USED IN THE PRESENT STUDY WITH THE LITERATURE (Hodgman, 1949; Stecher, 1968)

Oil or FFA[1]	Specific Gravity[2] 25°C±0.5	Index of Refraction 25°C±0.5	Acid Value ml 0.1N NaOH	Iodine Value[3] g. iodine	Sitosterol mg/ml
Safflower oil	0.929 (0.925-28)	1.4745 (1.4769)	0.15 (0.60)	138 (122-141)	3.25
Corn oil	0.927 (0.921-28)	1.4733 (1.4733)	0.26 (1.37-2.02)	125 (111-128)	10.16
Peanut oil	0.921 (0.917-26)	1.4693 (1.4620-53)	0.26 (0.80)	96 (88-98)	2.52
Olive oil	0.920 (0.915-20)	1.4678 (1.4657-67)	1.17 (0.30-1.00)	87 (79-88)	2.26
Cottonseed oil	0.926 (0.917-18)	1.4727 (1.4743-52)	0.08 (0.60-0.90)	118 (103-111)	3.24
Soybean oil	0.924 (0.924-27)	1.4723 (1.4723-56)	0.11 (0.30-1.80)	111 (122-134)	3.12
Oleic acid	0.881 (0.895)	1.4597 (1.4630)	345.00 (198.60)	90 (90)	
Linoleic acid	0.904 (0.903)	1.4671 (1.4683)	345.00 (-)	154 (181)	
Deionized water	0.997 (0.999)	1.3327 (1.3327)			

[1]FFA: Free Fatty Acids
[2]Specific gravity values standardized with water.
[3]Iodine values standardized with water.
Figures in parentheses indicate literature values.

TABLE 3

ABSORPTION OF VEGETABLE OILS IN THE LIGATED SMALL INTESTINE OF RATS

Oil	No. Rats	Dose ml/rat	EFA[1] μEq	EFA[1] Absorbed in 180 min. μEq ± S.E.	% Absorbed	FFA[2] Recovered from gut at 180 min. μEq ± S.E.
Safflower	6	0.2	733	141.3 ± 11.1 $p<0.001$	19.3	71.3 ± 14.3 $p>0.05$
Corn	6	0.2	733	317.8 ± 38.8 $p>0.05$	43.4	97.9 ± 11.0 $p>0.05$
Peanut	6	0.2	733	323.4 ± 27.1 $p>0.05$	44.1	79.3 ± 9.6 $p>0.05$
Olive	6	0.2	733	298.2 ± 20.5 (ref.)[3]	40.7	105.8 ± 15.6 (ref.)[3]
Cottonseed	6	0.2	733	302.1 ± 22.8 $p>0.05$	41.2	105.8 ± 9.4 $p>0.05$
Soybean	6	0.2	733	351.6 ± 20.5 $p>0.05$	48.0	94.9 ± 15.3 $p>0.05$

[1]EFA: Esterified Fatty Acids
[2]FFA: Free Fatty Acids
[3](ref.): Olive oil used as reference for statistical evaluation.

TABLE 4

ABSORPTION OF FREE FATTY ACIDS IN THE LIGATED SMALL INTESTINE OF RATS

Fatty Acid	No. Rats	Dose ml/rat	FFA[1] μEq	FFA[1] Absorbed in 180 min. μEq ± S.E.		% Absorbed
Oleic	12	0.2	660.7	102.1 ± 8.6	p>0.05	15.4
Linoleic	11	0.2	686.0	114.4 ± 5.9		16.7

[1]FFA: Free Fatty Acids

FIGURE 1

ESTERIFIED FATTY ACIDS ABSORBED FROM THE LIGATED SMALL INTESTINE OF RATS AFTER ADMINISTRATION OF VEGETABLE OILS

Oils were administered in a dose of 0.2 ml/200g rat, containing 733 μEq EFA.

Columns represent the mean of 6 animals each ± standard error.

1 safflower oil

2 corn oil

3 peanut oil

4 olive oil

5 cottonseed oil

6 soybean oil

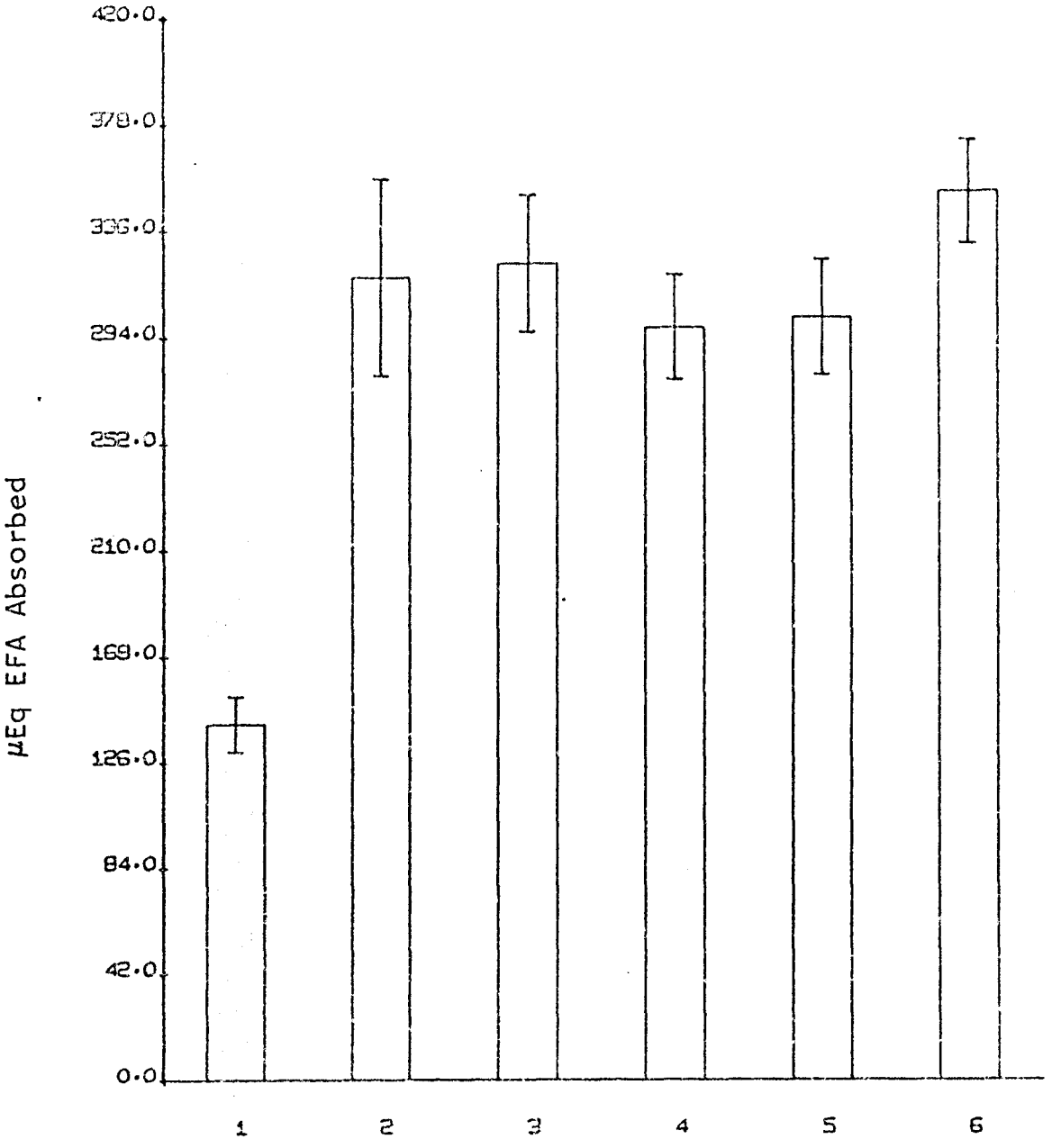

420.0
378.0
336.0
294.0
252.0
210.0
168.0
126.0
84.0
42.0
0.0
μEq EFA Absorbed
1
2
3
4
5
6

FIGURE 2

FREE FATTY ACIDS RECOVERED FROM THE LIGATED SMALL INTESTINE OF RATS AFTER ADMINISTRATION OF VEGETABLE OILS

Oils were administered in a dose of 0.2 ml/200g rat, containing 733 μEq EFA.

Columns represent the mean of 6 animals each ± standard error.

1 safflower oil

2 corn oil

3 peanut oil

4 olive oil

5 cottonseed oil

6 soybean oil

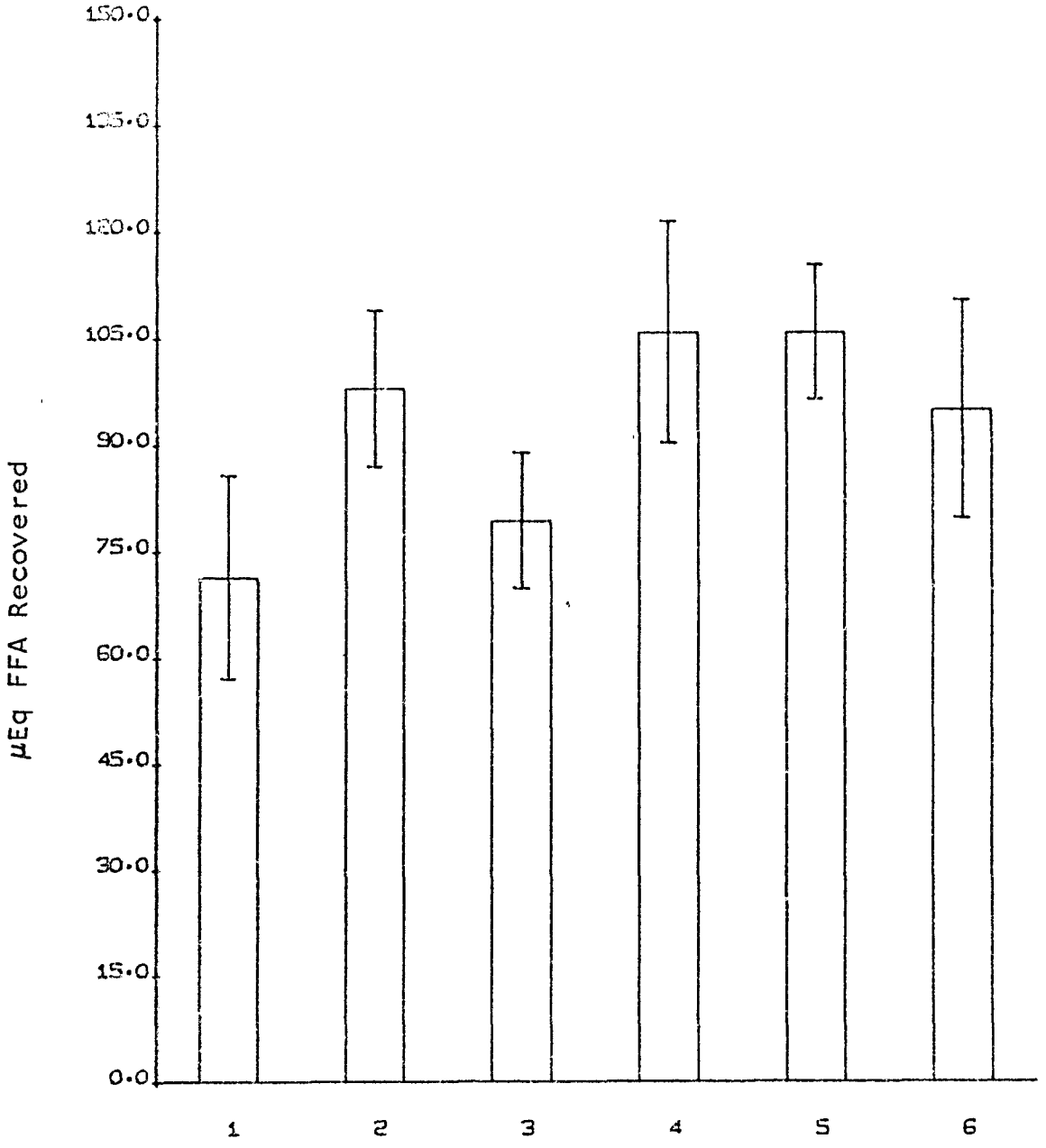

150·0
135·0
120·0
105·0
90·0
75·0
60·0
45·0
30·0
15·0
0·0
μEq FFA Recovered
1
2
3
4
5
6

FIGURE 3

LIPOLYSIS OF VEGETABLE OILS BY PANCREATIC LIPASE IN VITRO

500 µl of each oil was used as substrate

Columns represent the amount of sodium hydroxide required to neutralize free fatty acids and are the mean of duplicate runs.

1 safflower oil

2 corn oil

3 peanut oil

4 olive oil

5 cottonseed oil

6 soybean oil

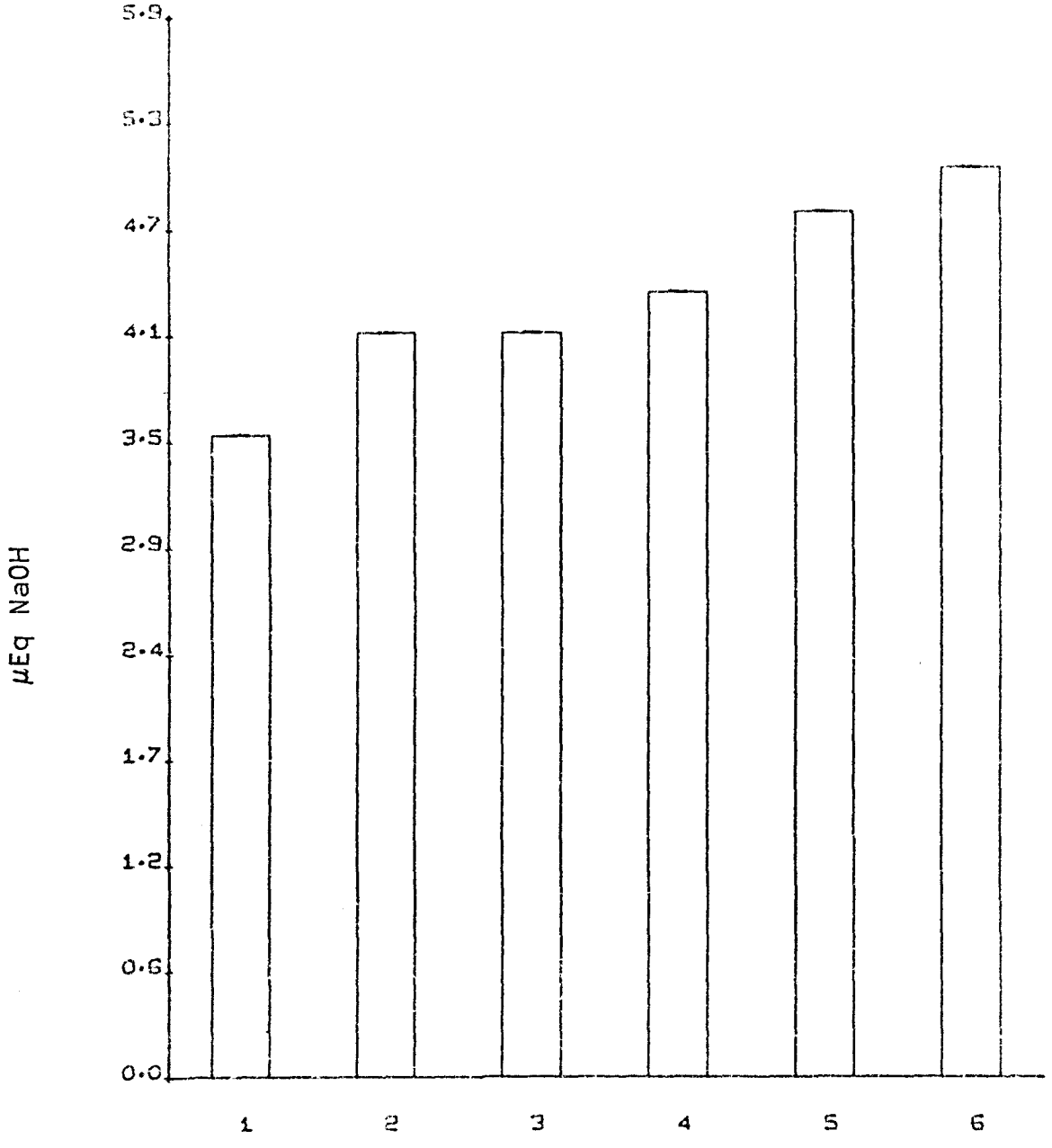

μEq NaOH
5.9
5.3
4.7
4.1
3.5
2.9
2.4
1.7
1.2
0.6
0.0
1
2
3
4
5
6

FIGURE 4

LIPOLYSIS OF SAFFLOWER OIL AND OLIVE OIL BY PANCREATIC LIPASE IN VITRO

The curves were constructed by use of an IBM 1800 computer with an IBM 1627 plotter.

1 olive oil

2 safflower oil

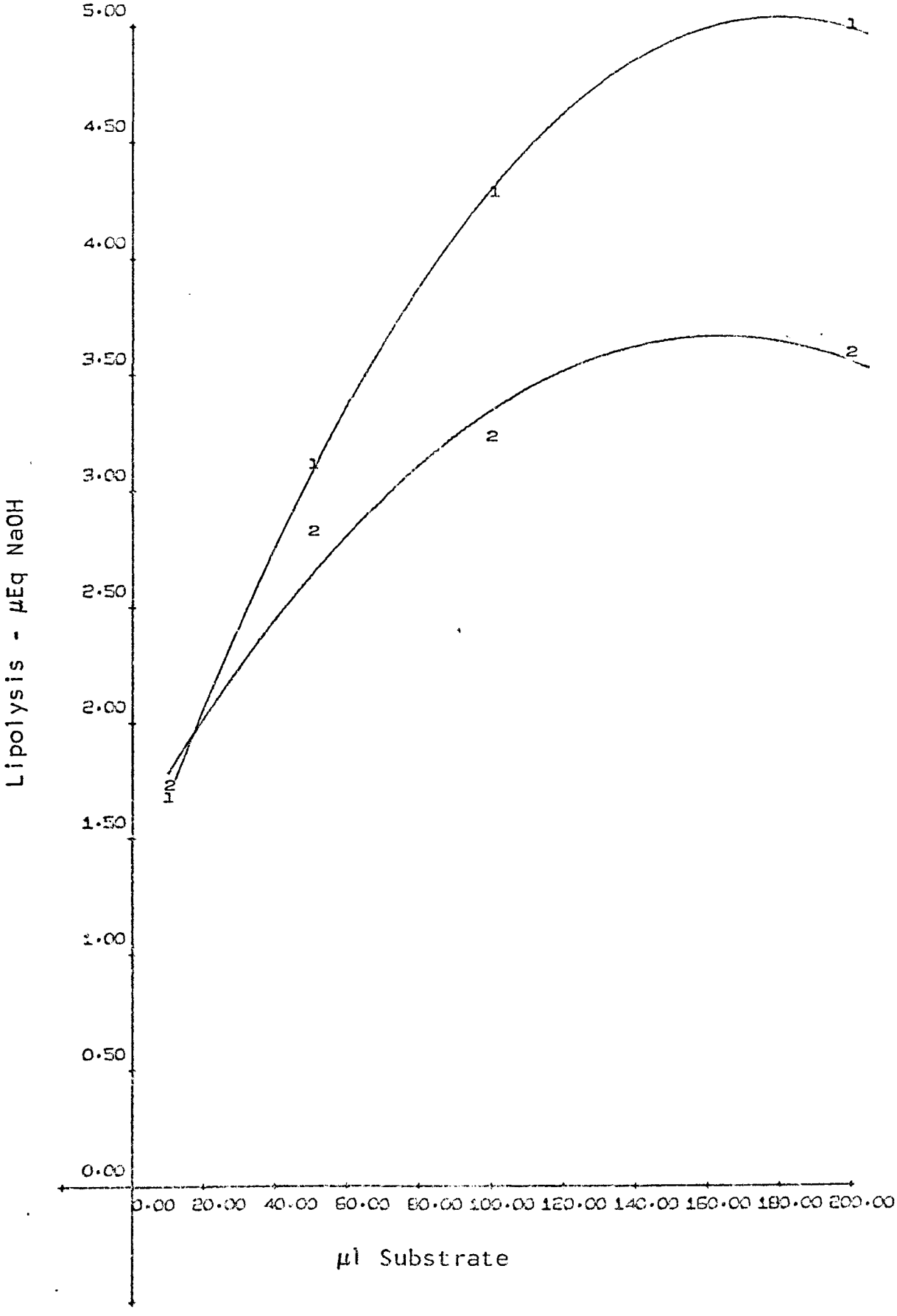

5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Lipolysis - µEq NaOH
0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00 160.00 180.00 200.00
µl Substrate
1
2

FIGURE 5

A COMPARISON OF LIPOLYSIS IN VITRO WITH THE AMOUNT OF FREE FATTY ACIDS RECOVERED FROM THE LIGATED SMALL INTESTINE OF RATS

The linear regression was calculated by an IBM 1800 computer and constructed by an IBM 1627 plotter.

The linear regression is characterized by the equation: $y = 18.3x + 11.2$

Significance of the slope: $p>0.05$.

1 safflower oil

2 corn oil

3 peanut oil

4 olive oil

5 cottonseed oil

6 soybean oil

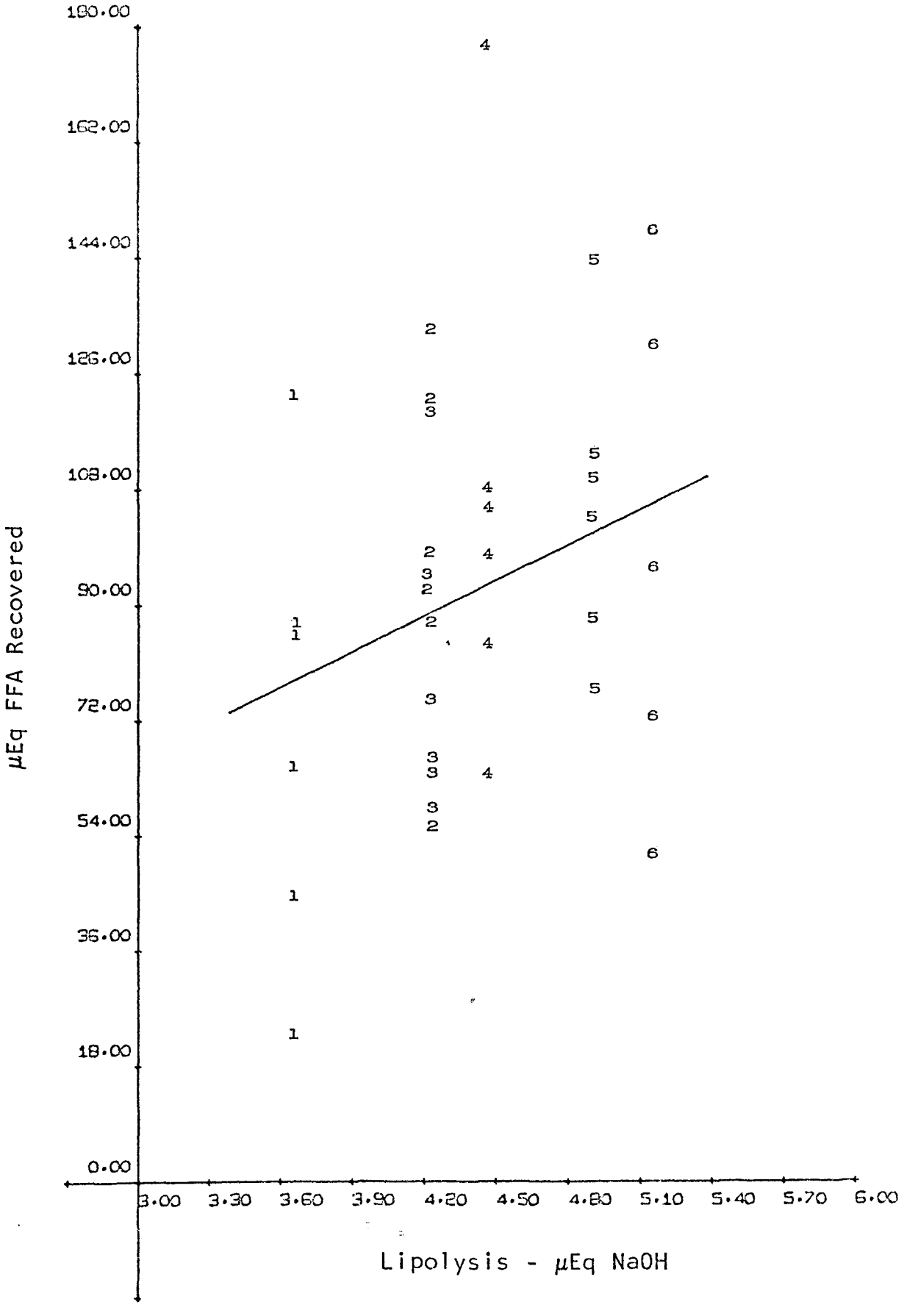

180.00
162.00
144.00
126.00
108.00
90.00
72.00
54.00
36.00
18.00
0.00
µEq FFA Recovered
3.00
3.30
3.60
3.90
4.20
4.50
4.80
5.10
5.40
5.70
6.00
Lipolysis - µEq NaOH

FIGURE 6

A COMPARISON OF LIPOLYSIS IN VITRO WITH THE AMOUNT OF ESTERIFIED FATTY ACIDS ABSORBED FROM THE LIGATED SMALL INTESTINE OF RATS

1 safflower oil

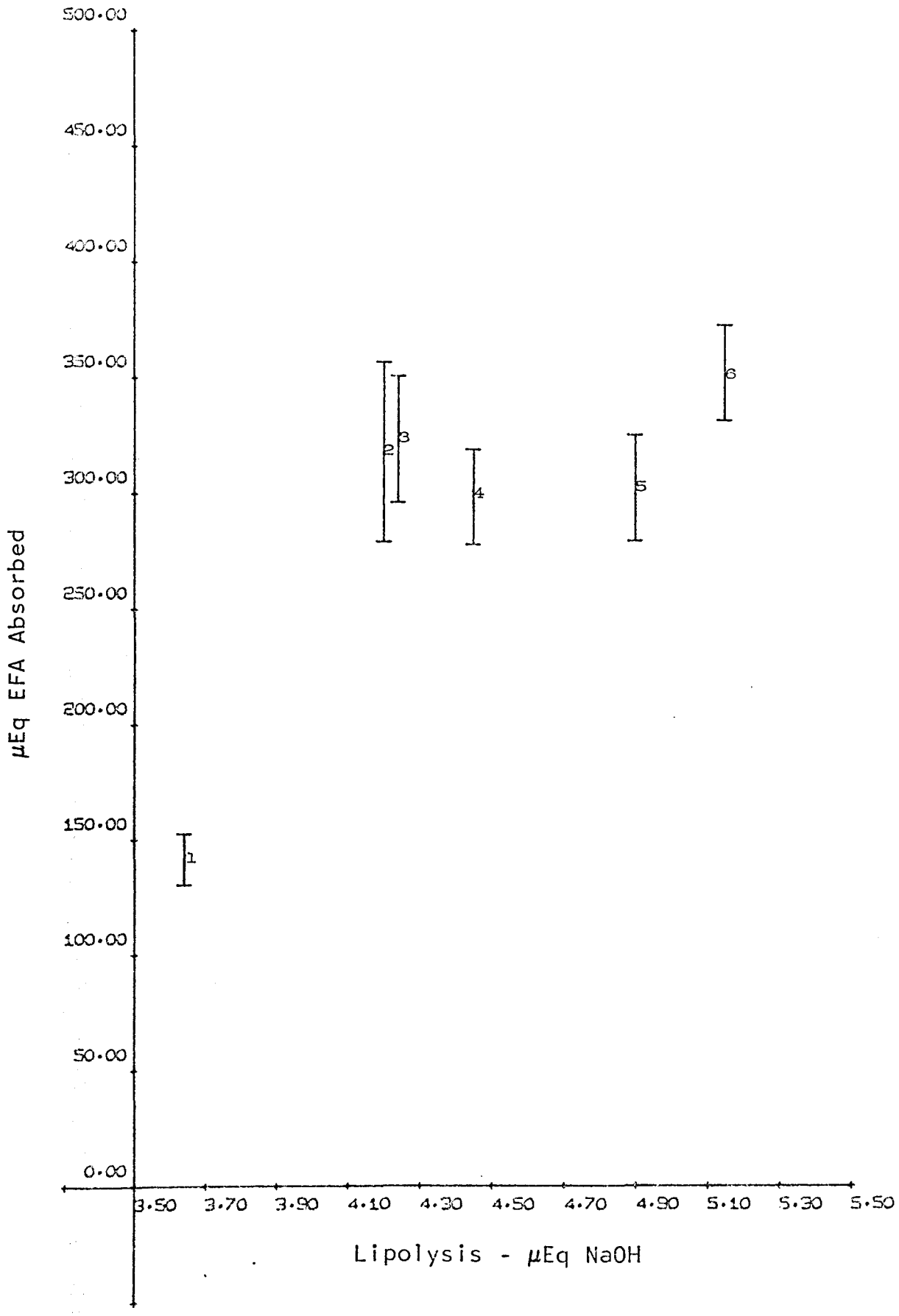
2 corn oil

3 peanut oil

4 olive oil

5 cottonseed oil

6 soybean oil


500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
µEq EFA Absorbed
3.50
3.70
3.90
4.10
4.30
4.50
4.70
4.90
5.10
5.30
5.50
Lipolysis - µEq NaOH
1
2
3
4
5
6

VITA

Robert Leslie Gregory, Jr. was born April 29, 1945 in Newport News, Virginia. He attended Granby High School in Norfolk, Virginia and completed his secondary education in June, 1963. He began his higher education at Elon College in Elon College, North Carolina where he majored in Biology and was graduated in June, 1967 with a B.A. degree. He was married August, 1967 to the former Miss Mary Elizabeth Parker. In October, 1967 he was employed by A. H. Robins Co., Inc. as a research biologist. During his employment he began graduate study at the University of Richmond in September, 1968. While at the University he was initiated into the Beta Beta Beta Honorary Biological Society. He completed his requirements for the Master of Arts degree in August, 1971.