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Paula Lynn Yates
University of Arkansas, Fayetteville

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METABOLIC RESPONSES OF WHITE RATS TO GLUCOSE OR FRUCTOSE FED WITH TWO SAFFLOWER OILS CONTAINING DIFFERENT PROPORTIONS OF FATTY ACID[1]

Paula Lynn Yates[2]
University of Arkansas

Several studies have shown that metabolic responses of weanling rats to the dietary source of carbohydrate are paritally dependent on the type of fat in the diet, i. e., saturated or unsaturated. For example, in rats fed rations containing 15% of corn oil, more liver lipid accumulated if the dietary carbohydrate was glucose than if it was fructose. But in rats fed 15% of hydrogenated coconut oil, the amount of liver lipid was greater when the dietary carbohydrate was fructose (1).

The purpose of this experiment was to investigate the responses of various components of carbohydrate and lipid metabolism to changes in the type of carbohydrate and in the proportions of fatty acids in the diet. Comparisons were made of the effects of the type of carbohydrate in the diet (glucose or fructose) with oils containing different proportions of fatty acids (high-oleic safflower oil or regular safflower oil). Criteria for determining metabolic responses to the diets were levels of total lipid, cholesterol, phospholipid, glycogen, and nitrogen in the liver; and proportions of individual fatty acids in liver lipids. Also, amount of lipid and fatty acid composition of the lipid from epididymal fat pads were determined.

Thirty-two male weanling rats, weighing approximately 51 grams each initially, were divided into 4 groups. The rats were fed nutritionally adequate diets, the only variables being the type of carbohydrate and the oils containing different proportions of fatty acids (table 1). These oils have an almost complete reversal in percentages of linoleic and oleic acids. Regular safflower oil contains approximately 12% oleic acid and 79% linoleic acid. High-oleic safflower oil contains 80% oleic acid and 15% linoleic acid. Rations for groups I and II contained high oleic safflower oil; rations for groups III and IV contained regular safflower oil. Glucose was the carbohydrate in rations for groups I and III, and fructose in rations for groups II and IV.

At the end of a three-week feeding period, the rats were sacrificed and tissues analyzed. Substituting high-oleic safflower oil for regular safflower oil or replacing glucose with fructose in the rations had no significant effect on growth, food intake, or food efficiency ratio.

TABLE 1

Fatty acid composition of oils in diets containing different carbohydrates and regular or high oleic safflower oil

Fatty acid*	Safflower	High oleic
Palmitic	7	5
Stearic	2	trace
Oleic	12	80
Linoleic	79	15

* Per cent of total fatty acids by Gas Liquid Chromatography of the methyl esters.

Relative liver weights (g of liver/100 g body weight) of rats fed fructose and high oleic oil were more than those of rats fed diets containing glucose and high oleic oil. No significant differences were attributable to dieary fat. No dietary influences on the concentration of glycogen in liver were observed, nor were any differences in protein content noted when values were expressed as percentages of liver weight. However, percentages of lipid in the liver were altered by the carbohydrate-fat combinations fed. Livers of rats fed diets containing glucose and regular safflower oil contained more lipid than those of rats fed either fructose and regular safflower or glucose and high oleic oil (fig. 1a). Types of carbohydrate in diets containing high oleic oil had no significant effect on percentage of lipid in liver. Decrease in amount of liver lipid of rats fed fructose rather than glucose in rations containing safflower oil is consistent with previous studies at this laboratory. When rats were fed diets containing 15% of corn oil (53% of total fatty acids from linoleate) for 4 weeks, lipid accumulated liver to a greater extent when dietary carbohydrate was glucose than when it was fructose (1). In another study (2), with diets containing only 5% of corn oil, lipid did not accumulate in livers of rats fed the corn oil with either glucose or fructose.

High levels of oleate in the high oleic safflower oil fed with either carbohydrate did not cause an increase in liver lipid (fig. 1a). It seems that feeding high levels of linoleate, as in corn oil or in regular safflower oil, with glucose causes an accumulation of lipid in liver. These rats fed fructose with safflower oil accumulated less lipid in the liver, but tended to deposit more lipid in fat pads

than those fed glucose and safflower oil (fig. 1b). Also, proportions of linoleate were greater in fat-pad lipid of rats fed diets containing fructose and safflower oil than in that of rats fed glucose and safflower oil. These observations suggest that, under the conditions of this study, fructose may have facilitated transport of lipid high in linoleate from the liver to the adipose tissue.

Liver cholesterol values (% of total lipid) of rats fed diets containing fructose and high oleic oil were less than cholesterol values of rats fed diets containing regular safflower oil with either carbohydrate (fig. 2). This suggests that dietary linoleate enhanced cholesterol deposition in the liver. Levels of 18C fatty acids did not differ in the regular and high oleic safflower oils, but the degree of unsaturation was much greater in the regular safflower oil (fig. 3). Other investigators reported that increased levels of unsaturated fatty acids in diets were accompanied by increased amounts of liver lipid and cholesterol (2,3).

Most significant differences in proportions of individual fatty acids were related to dietary fat. Proportions of oleic and linoleic acids in liver lipid were altered markedly by dietary fat. Liver lipid of both groups of rats fed high oleic oil contained approximately three times as much oleic acid as liver lipid of rats fed diets containing regular safflower oil, and percentages of linoleate in liver lipid of rats fed regular safflower oil were six times greater than those in liver lipid of rats fed high oleic oil. Simliar, less striking, relationships were noted in the percentages of fat-pad lipid fatty acids.

The only significant differences in proportions of liver arachidonate (20:4) were due also to dietary fat. Liver lipid of rats fed high oleic oil contained a much smaller proportion of arachidonate than that of rats fed regular safflower oil (fig. 3).

Substrate competition in fatty acid metabolism was evident since the linoleate: oleate ratio in regular safflower oil was sufficient to inhibit the conversion of liver oleate to its 20:3 product, eicosatrienoic acid. But the oleate: linoleate ratio in high-oleic safflower oil did not completely, if at all, repress conversion of liver linoleate to arachindonate. This concept of substrate competition agrees with the assumption by Mohrhauer and Holman (4) that the same or similar metabolic pathways are responsible for all conversions of oleic, linoleic, and linolenic acids to the polyunsaturated fatty acids of their particular series, i. e., characterized by the position of the double bond nearest the methyl end, and that the triene, linolenate, blocks the conversion of the diene, linoleate. Either linoleate or linolenate blocks the conversion of the monoene, oleate. So the affinities for the enzyme sites seem to be linolenate linoleate oleate.

Interesting fatty acid patterns are associated with the different carbohydrate-fat combinations fed. Rats fed glucose and regular safflower oil accumulated more liver lipid than others, but proportions of palmitate, (16:0), the major product of lipogenesis (5), were lower than that in liver lipid of rats fed the three other diets. It seems that accumulation of lipid in livers of these rats is not aided by increased synthesis of fatty acids. It may be possible that levels of safflower oil were sufficient to inhibit fatty acid synthesis, while oversupplying the liver with linoleate. Rats which accumulated more liver lipid did have a slightly greater percentage of liver linoleate and accumulated slightly less fat-pad lipid than rats fed the other rations. Fructose has been shown to stimulate fatty acid synthesis, and may have done so sufficiently to reduce accumulation of lipid in livers below that in rats fed safflower oil with glucose. Liver lipid of rats fed fructose and regular safflower oil contained a larger percentage of palmitate and a slightly lower percentage of linoleate than liver lipid of rats fed glucose and regular safflower oil. Further research should reflect some of the mechanisms involved in these dietary carbohydrate-fat interrelationships.

FOOTNOTES

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[2]Graduate Research Assistant, Department of Home Economics.

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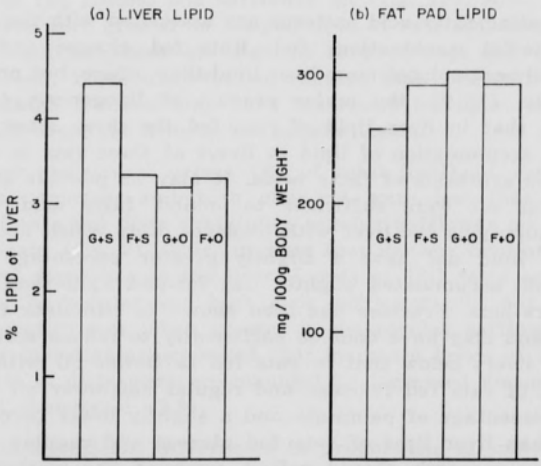

Fig. 1 Percentage of total lipid in liver (a), and mg. fat pad lipid per 100 g body weight (b), in rats fed different carbohydrates and oils containing different proportions of fatty acids for three weeks. G = glucose, F = fructose, S = safflower oil, O = high oleic safflower oil.

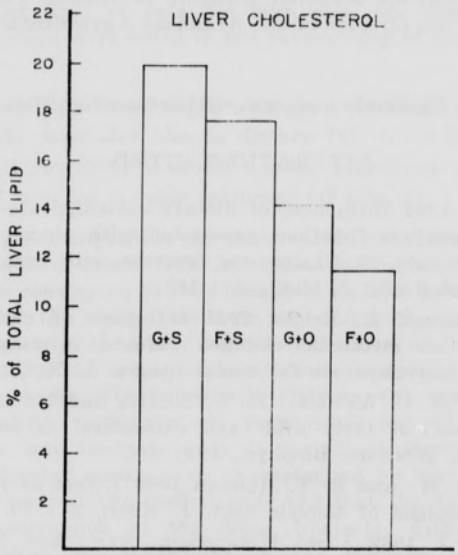

Fig. 2 Percentage of cholesterol in liver lipid of rats fed different carbohydrates of fatty acids for three weeks. G = glucose, F = fructose, S = safflower oil, O = high oleic safflower oil.

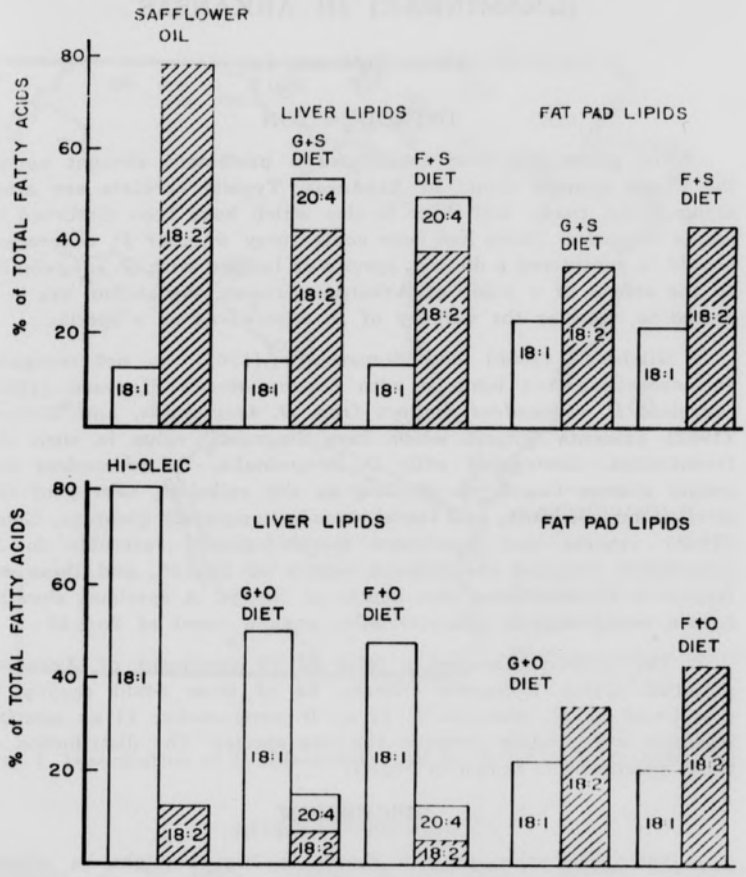

Fig. 3 **Percentages of oleic, linoleic, and arachidonic acids in dietary oils and in tissue lipids of rats fed diets containing each of the oils with glucose and with fructose. G = glucose, F = fructose, S = safflower oil, O = high oleic safflower oil.**