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ABSTRACT

Effects of dietary fats and carbohydrates on lipid metabolism in rats were studied. Male and female 4-week-old rats were divided into 8 groups and fed 4 fat-carbohydrate combinations (beef tallow or safflower oil, each with either sucrose or rice starch). After 4 weeks, animals were killed by exsanguination through the abdominal aorta and livers were removed. Plasma and liver cholesterol and phospholipids were determined qualitatively and quantitatively. Liver moisture, protein, and lipid and the fatty acid composition of the total liver lipid were determined quantitatively. Variations in growth, food efficiency, and lipid metabolism, particularly as manifested by the fatty acid composition of the liver lipid, were apparent between males and females and among groups of each sex as a result of dietary treatment.

INTRODUCTION

Several studies have shown that metabolic responses of male weanling rats to the type of dietary carbohydrate are in part dependent upon the type of dietary fat (Carroll 1963). Other investigators have reported that males and females differ in their response to dietary carbohydrate (Macdonald 1972), and this response can be modified by the type of fat in the diet. The purpose of this experiment was to determine the effects of certain dietary fats and carbohydrates on various metabolic functions in male and female rats.

MATERIALS AND METHODS

Twenty male and 20 female 4-week-old rats of the Sprague-Dawley strain were divided into 8 groups (4 of males and 4 of females). The initial average body weights of the males and females were 72 grams and 100 grams, respectively. Rats were fed nutritionally adequate diets containing one of four dietary fat-carbohydrate combinations. The carbohydrate was either sucrose or rice starch and the fat was either beef tallow or safflower oil. After 4 weeks, animals were killed by exsanguination through the abdominal aorta and the liver and plasma were retained for assay.

Criteria for determining the metabolic responses of male and female rats to the diets were levels of plasma cholesterol and phospholipid, total lipid, cholesterol, phospholipid, and protein in the liver. Also, the fatty acid composition of the liver lipid was determined. Data were examined by analysis of variance.

RESULTS AND DISCUSSION

Weight gain was significantly greater in males than in females. This difference seems to have been due to the greater food consumption and food efficiency ratio of the male rats. Rats fed sucrose had a slight depression in growth in comparison with those fed rice starch.

Accumulated data show that males had higher levels of plasma cholesterol and phospholipid than did females. Contrary to the findings of others (Macdonald 1972), plasma cholesterol was not significantly affected by the type of fat or carbohydrate in the diet. The qualitative responses of plasma phospholipids to the type of dietary fat and carbohydrate were the same in both sexes. Rice starch and safflower oil were associated with a depression in plasma phospholipids.

Regardless of the dietary treatment, males had higher relative liver weights (g liver/100 g body weight) than did females (Table I). The beef tallow—rice starch diet produced lower relative liver weights than did the other diets.

On the basis of absolute amounts (mg/100 mg liver nitrogen), the amount of liver lipid was greater in females fed the safflower oil—rice starch diet than in females fed any of the other diets, but this amount was less than that found in males fed the safflower oil—rice starch diet (Table II). The absolute amount of liver cholesterol and phospholipid increased when rice starch rather than sucrose was the dietary carbohydrate. The cholesterol in the liver lipid was quantitatively higher in males than in females. Also, liver cholesterol was higher in rats fed safflower oil than in those fed beef tallow. On the basis of absolute values, liver phospholipids apparently were more resistant to dietary change than liver cholesterol.

Comparison of the fatty acid composition (Table III) of the liver lipids of rats fed beef tallow with that of rats fed safflower oil reflects the differences in the fatty acid composition of the two dietary fats. Lipids from rats fed beef tallow contained higher proportions of saturated and monounsaturated fatty acids and lower proportions of polyunsaturated fatty acids than did those from rats fed safflower oil. However, both the type of carbohydrate and the sex of the animal exerted significant influences on the fatty acid composition of the liver lipid, which were superimposed on the basic effect of the fat source.

In females, sucrose increased the percentage of stearic (18:0), arachidonic (20:4), and the third fatty acid eluted after arachidonic acid in comparison with rice starch. Also, these fatty acids were more concentrated in the liver lipid of females than in that of males. The percentages of palmitic (16:0), oleic (18:1), and linoleic (18:2) acids were greater in males than in females. Female rats had less palmitic (16:0) and more stearic (18:0) acid than did male rats. Therefore, there appears to be a significant sex difference in the elongation of palmitic acid to stearic acid, and this finding agrees with the work of other investigators (Pudelkewicz et al. 1968).

In this experiment, both males and females fed the safflower oil—rice starch diet had higher percentages of linoleic acid (18:2) and greater accumulation of lipid in the liver than did other dietary groups. However, females on this diet had less linoleic acid and less lipid accumulation in the liver than did males. Female rats seem to have a greater capacity not only for the elongation of palmitic to stearic acid, but also for the conversion of linoleic acid to long-chain polyunsaturated fatty acids.

Carroll and Williams (1971) found severely fatty livers and disproportionally large amounts of linoleic acid in males rate fed a polyunsaturated fat (corn oil). They suggested that the ingesion of large amounts of linoleic acid could be detrimental. However, this harmful effect may be reduced if fructose (or sucrose) is included in the diet.

From the findings of this experiment, the mechanisms by which the differences in lipid metabolism between the sexes occur cannot be explained. Yet there are differences in the plasma and liver lipid response of males and females to the type of dietary fat and carbohydrate. It is evident that without consideration of the sex of the individual the evaluation of dietary treatments of such metabolic disorders as hyperlipemia would be incomplete.

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Table I. Means by Analysis of Variance for Relative Liver Weight and Major Liver Components of Male and Female Rats Fed Different Dietary Fat-Carbohydrate Combinations

Source of Variation	g liver/100 g body weight	% protein of liver	mg protein/ 100 g body weight	% moisture of liver	% lipid of liver	mg liver lipid/ 100 mg liver N
Fat (F)[1]						
BT	3.82	16.1^{b}	611^{b}	70.8^{a}	5.25^{a}	205^{a}
SO	3.93	16.7	652	69.7	6.36	241
Carbohydrate (C)						
SUC	3.99^{b}	16.4	650^{b}	70.6^{b}	5.07^{a}	195^{a}
RS	3.76	16.4	613	69.9	6.55	251
Sex (S)						
♂	4.51^{a}	15.4^{a}	638	69.4^{a}	5.99	243^{a}
♀	3.60	17.4	625	71.1	5.63	203
Interactions	F x C^{b}	----	F x S^{b} C x S^{x}	F x C^{b} F x S^{x}	F x C^{a} F x S^{x}	F x C^{a} F x S^{b} F x C x S^{b}

[1] Abbreviations: F = Fat, C = Carbohydrate, S = Sex, BT = Beef Tallow, SO = Safflower Oil, SUC = Sucrose, RS = Rice Starch, ♂ = Male, ♀ = Female.

[a,b,x] a = P≤ 0.005, b = P≤ 0.05, x = P≤ 0.10.

Table II. Means by Analysis of Variance for Composition of Total Liver Lipid of Male and Female Rats Fed Different Dietary Fat-Carbohydrate Combinations

Source of Variation	% cholesterol	mg cholesterol/ 100 g liver N	% phospholipid	mg phospholipid/ 100 mg liver N
Fat (F)[1]				
BT	7.68^{a}	15.6^{a}	38.8^{a}	79.0
SO	10.87	26.5	32.8	75.6
Carbohydrate (C)				
SUC	8.93^{a}	17.4^{a}	37.9^{b}	72.4^{b}
RS	9.62	24.7	33.8	76.9
Sex (S)				
♂	9.25	23.3^{a}	33.0^{a}	77.7
♀	9.30	18.9	38.7	76.9
Interactions	F x C^{a} C x S^{a}	F x C^{a} F x S^{a} F x C x S^{b}	F x C^{b} F x S^{b} C x S^{a}	----

[1] Abbreviations: F = Fat, C = Carbohydrate, S = Sex, BT = Beef Tallow, SO = Safflower Oil, SUC = Sucrose, RS = Rice Starch, ♂ = Male, ♀ = Female.

[a,b] Levels of significance: a = P≤ 0.005, b = P≤ 0.05.

Table III. Means by Analysis of Variance for Fatty Acid Composition of Total Liver Lipid of Male and Female Rats Fed Different Dietary Fat-Carbohydrate Combinations

Source of Variation	Fatty Acids									
	16:0	16:1	18:0	18:1	18:2	18:3	Unidentified[2]	20:4	2nd >20:4	3rd >20:4
	(% of lipid)									
Fat (F)[1]										
BT	19.7^{a}	4.90^{a}	17.1^{a}	35.0^{a}	7.3^{a}	tr	tr	13.4^{a}	tr	tr
SO	14.1	2.01	12.5	10.7	35.7	2.87^{a}	1.13^{a}	17.0	1.60^{a}	2.86^{a}
Carbohydrate (C)										
SUC	17.2	3.82^{a}	15.9^{a}	22.7	19.5^{a}	2.77	0.97	15.3	1.46	3.21^{b}
RS	16.7	3.09	13.8	23.0	23.6	2.98	1.11	15.0	1.67	2.42
Sex (S)										
♂	17.9^{a}	3.80^{a}	12.4^{a}	23.4	23.6^{a}	2.88	1.35^{a}	13.9^{a}	1.70	2.44^{x}
♀	16.0	3.21	17.3	22.3	19.5	2.87	0.73	16.4	1.43	3.19^{x}
Interactions	F x S^{x}	F x C^{a} C x S^{b}	F x C^{b} F x S^{b} C x S^{b}	F x S^{x}	F x C^{b} F x S^{a}	----	----	F x C^{b} C x S^{b}	----	----

[1] Abbreviations: F = Fat, C = Carbohydrate, S = Sex, BT = Beef Tallow, SO = Safflower Oil, SUC = Sucrose, RS = Rice Starch, ♂ = Male, ♀ = Female.

[2] Unidentified peak between 18:3 and 20:4.

[a,b,x] Level of significance: a = P≤0.005, b = P≤ 0.05, x = P≤ 0.10.