Effect of carbohydrate source on lipid metabolism in lactating mice and on pup development*

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The effect of long-term sucrose intake on lipid metabolism and milk composition was examined in lactating mice and correlated with the development of their pups. Female mice were weaned onto semi-purified diets containing 685 g starch or sucrose/kg diet. Food intake was similar on the two diets. At mid-lactation, milk was collected and analysed. Milk from sucrose-fed dams had a lower percentage of linoleic acid (18:2*n*-6) and a higher percentage of oleic acid (18:1*n*-9), although milk fat content was similar. Hepatic fatty acid synthesis (as measured by ^3H_2O incorporation into fatty acid) was three times faster in sucrose-fed than in starch-fed dams. Dietary carbohydrate had no effect on fatty acid synthesis or functional lipoprotein lipase (*EC* 3.1.1.34) activity in mammary gland, nor on plasma triacylglycerol concentration. Pups from first litters were killed at 11–12 d and body composition analysed. Pups born to sucrose-fed dams were significantly heavier with increased body fat and higher levels of plasma glucose and triacylglycerol. Litters of sucrose- and starch-fed dams were cross-fostered at birth and killed at 10–12 d. Analysis of variance indicated that maternal sucrose intake, both during pregnancy and lactation, increased body fat of offspring. The increases in body weight and plasma triacylglycerol of pre-weaning offspring were caused primarily by maternal sucrose intake during lactation.

Sucrose: Milk: Lipid metabolism: Pregnancy: Lactation

Changes in metabolism effected by dietary carbohydrates have been documented in numerous studies in humans and laboratory animals, following the proposal, based on epidemiological evidence, that dietary sucrose may be implicated in the aetiology of maturity-onset diabetes and coronary artery disease (Yudkin, 1964; Cohen *et al.* 1961).

In humans, isoenergetic replacement of dietary starch with sucrose in the short term results in increased plasma triacylglycerol (MacDonald & Braithwaite, 1964; Mann *et al.* 1973; Reiser *et al.* 1979*a*) and cholesterol (Mann *et al.* 1973; Reiser *et al.* 1979*a*) concentrations and impaired glucose tolerance (Reiser *et al.* 1979*b*). Similar adverse effects of high sucrose consumption have been reported for non-human primates and a number of laboratory animals.

In all species tested, however, the metabolic effects of dietary sucrose were governed by interaction with other factors. These include genetic predisposition (Marshall & Hildebrand, 1963; Cohen *et al.* 1972; Reiser, 1982; Cohen, 1986; Yamini *et al.* 1991), sex (Bonnevie-Nielson, 1980) and age of subject (Berdanier *et al.* 1979). They were also affected by the amount of sucrose consumed (Reiser, 1982; McGandy *et al.* 1986; Berdanier, 1987), the length of the feeding period (Reiser, 1982) and other dietary components, especially the type of fat (Baltzell & Berdanier, 1985; Berdanier, 1987). In general, the greatest effects were seen in males in short-term experiments eating diets containing saturated rather than unsaturated fat.

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The present study examined the long-term effects of dietary sucrose on lipid metabolism in female mice, to see whether these changes may affect the growth and development of their offspring. Variation in the components of the maternal diet has long been known to affect the progeny. Restriction of energy and/or protein during pregnancy retards growth and normal development of the fetus and the neonate (Chow & Lee, 1964; Chow *et al.* 1968; Zeman, 1969; Srivastava *et al.* 1974). In rats, maternal sucrose intake has been shown to affect the metabolism of offspring significantly (Berdanier, 1975; Bouillon & Berdanier, 1983). These experiments were performed on the 'carbohydrate-sensitive' BHE rat (Marshall & Hildebrand, 1963). In mice, dilution of maternal stock diet with sucrose before and during pregnancy and lactation has been reported to increase the body weight of female offspring in particular (Davies *et al.* 1972, 1973). However, these experiments would result in changes in dietary fat and protein as well as carbohydrate. In contrast, the present study was performed on female mice from a strain which does not exhibit carbohydrate sensitivity, fed on diets isoenergetic for sucrose or starch.

The effect of dietary components on pups may be reflected in the milk composition. The incorporation of dietary fatty acids into milk lipids has been frequently reported in various species including humans (Smith *et al.* 1969; Mellies *et al.* 1979). Milk composition was altered significantly when lactating rats were fed on a high-fat cafeteria diet, with both milk fat content increased and its fatty acid composition resembling that of the food consumed (Rolls *et al.* 1981; Van Duijvervoorde & Rolls, 1985). In the present study we have examined the effect of the carbohydrate source in the maternal diet on milk composition and on the development of the pre-weaning offspring. During lactation, the mammary gland assumes a major lipogenic role to effect milk production. Therefore we also studied the effects of long-term sucrose consumption on the lipid metabolism of the lactating mouse in general and on the mammary gland in particular.

MATERIALS AND METHODS

Animals and diets

BALB/c mice (Harlan Olac Ltd., Shaws Farm, Blackthorn, Oxon) were maintained as an inbred colony on a commercial diet (No. 3 breeding diet; B.P., Witham, Essex). All mice were maintained under a 12 h light/dark cycle (light 08.00–20.00 hours) at an ambient temperature of $22 \pm 2°$ and allowed free access to food and water. Experimental animals (taken from litters of six to eight pups) were weaned onto semi-purified diets in which 64·5% energy was provided by starch or sucrose (Table 1). Mice were mated with litter mates at 7–8 weeks. Their litters were standardized at birth to five pups. Any litter having fewer than five was supplemented using surplus pups born on the same day. Any dam with fewer than five pups on the day of the experiment was excluded. Milk composition was studied from dams with six pups per litter. In cross-over experiments, pups of starch- and sucrose-fed dams were killed at 11–12 d, before they ate solid food (Babicky *et al.* 1970), for measurement of plasma glucose and triacylglycerol concentrations and analysis of body composition. Pregnant mice were killed on approximately the 18th day of pregnancy, and lactating mice at mid-lactation, for measurement of plasma glucose and triacylglycerol concentrations, fatty acid synthesis *in vivo*, lipoprotein lipase (LPL; *EC* 3.1.1.34) assay *in vitro* and analysis of tissue fatty acid profiles by GLC.

Milk collection and composition

Dams were milked at mid-lactation, days 11–12, parturition being taken as lactation day zero. Pups were removed from the dam 4–5 h before milk collection by a method modified by Rath & Thenen (1979). Dams were injected intraperitoneally (i.p.) with 1 IU oxytocin

Table 1. *Composition of semi-purified diets*

Component	g/kg diet	kJ/kg	Energy (%)
Starch/sucrose	684·55	11311	64·5
Casein	210	4025	22·7
Maize oil (Mazola)	60	2278	12·8
Mineral mix*	35·4	—	—
Vitamin mix†	10·0	138	—
DL-α-Tocopherol acetate	0·05	—	—

* The mineral mix had the following composition (g/kg): $K_3C_6H_5O_7.H_2O$ 290·09, $CaH_4(PO_4)_2.H_2O$ 275·77, $CaCO_3$ 241·58, $MgSO_4.7H_2O$ 139·18, NaCl 37·33, $Fe(C_6H_5O_7).3H_2O$ 6·079, $MnCO_3$ 3·027, $ZnCO_3.2ZnO.3H_2O$ 0·614, $Na_2SiO_3.5H_2O$ 0·53, $NiSO_4.7H_2O$ 0·39, $CuCO_3.Cu(OH)_2.H_2O$ 0·278, $SnCl_4.5H_2O$ 0·08293, NaF 0·0648, NH_4VO_3 0·0323, $CrCl_3.6H_2O$ 0·0276, $Na_2SeO_3.5H_2O$ 0·00958, KI 0·005557 (Wise, 1982).

† The vitamin mix had the following composition (g/kg); choline chloride 134, inositol 20, niacin 3, retinol palmitate (250000 IU/g) 1·6, Ca pantothenate 1·6, pyridoxine HCl 0·7, thiamin HCl 0·6, riboflavin 0·6; pteroylmonoglutamic acid 0·2, menadione 0·05, biotin 0·02, cholecalciferol 0·0025, cyanocobalamin 0·001, maize starch 837·67. (Wise, 1982).

(Sigma Ltd., Poole, Dorset) in 0·1 ml saline (9 g NaCl/l). This dose was repeated after 5–7 min. Water and lipid contents of milk were analysed gravimetrically as described previously (Rath & Thenen, 1979). Protein content of milk was measured by the Kjeldahl method, using alanine as a standard. Milk samples (up to 0·3 ml) to be analysed for fatty acid profiles were made up to 1 ml with distilled water. Chloroform (5 ml) containing 0·05 g BHT (butylated hydroxytoluene; 2,6-di-tert-butyl-p-cresol, supplied by Sigma Ltd.)/l was added before storage for a maximum of 6 weeks at −20°.

Body composition, glucose and triacylglycerol assays

Mice were weighed, anaesthetized in diethyl ether and blood samples were collected into heparinized syringes by cardiac puncture. Plasma glucose was determined by the glucose oxidase (*EC* 1.1.3.4) method (Krebs *et al.* 1964) and triacylglycerol by the method of Van Handle (Van Handle & Zilversmit, 1957). Body composition of pups was determined gravimetrically as previously described for water and lipid content (Rath & Thenen, 1979). Protein content was measured using the Kjeldahl method.

Fatty acid and sterol synthesis in vivo

^3H incorporation from ^3H_2O into tissue fatty acids was measured as previously described (Rath *et al.* 1979). Incorporation into non-saponifiable lipids (sterols) was also measured using the discrimination factor of Fears (1978). Mice were injected i.p. with $7·4 \times 10^7$ Bq ^3H_2O in 0·1 ml saline. After 55 min they were anaesthetized in diethyl ether and bled by cardiac puncture. Tissues were rapidly excised, rinsed in ice-cold saline, blotted and weighed, before lipid extraction. Mammary gland was removed from the inguinal and subclavian regions.

Lipoprotein lipase assay

Heparin-releasable LPL activity of the inguinal region of the mammary gland was assayed *in vitro* by a modification of the method of Vrana *et al.* (1974). Tissue was excised, weighed and rapidly placed in Krebs Ringer bicarbonate buffer (1 g tissue/10 ml) containing heparin (BDH Chemicals, Romford, Essex) at 3 U/ml. The tissue was incubated at 37° for 1 h. The tissue was then removed, rinsed in saline, blotted and stored at −20° before assay of protein content by the Kjeldahl method. The heparin-releasable LPL activity in 0·5 ml

of medium was assayed using Intralipid (UK Kabivitrum Ltd., London) as a substrate, in the presence of mouse serum prepared according to the method of Salaman & Robinson (1966). The assay medium consisted of 0·4 ml Intralipid (200 ml/l), 0·4 ml dialysed mouse serum, 0·6 ml 0·05 M-Tris-HCl buffer, pH 8·5, 0·4 ml defatted bovine serum albumin (300 g/l), fraction V (Sigma) in Tris-HCl buffer. The final volume was adjusted to 2·0 ml with distilled water. Samples (0·5 ml) of the assay mixture were removed at time zero and after 1 h of incubation at 37° after stopping the reaction with an equal volume of perchloric acid (300 g/l). After centrifugation, 0·35 ml portions were mixed with an equal volume of 1 M-hydrazine hydrate (pH 9·8) to adjust the pH of samples to 9·2–9·5. The glycerol content was then assayed according to the method of Wieland (1963).

GLC

GLC was used to analyse the fatty acid profiles of lipids in parametrial white adipose tissue (WAT) and milk. Lipids of WAT were extracted and purified using the method of Folch *et al.* (1957). Diluted milk samples containing BHT were extracted with chloroform–methanol (2:1, v/v) and washed twice with aqueous KCl (7·5 g/l). Dried lipid extracts were dissolved in 5 ml reflux reagent (concentrated H_2SO_4–toluene–methanol, 1:10:20 by vol.) and refluxed at 70° for 1 h. Methylated fatty acids were extracted with 5 ml hexane and washed twice with distilled water to remove any traces of H_2SO_4. Samples were analysed by GLC (Pye 104, Cambridge, Cambs). A column of 10% Cp-Silicon 58 on Chromosorb WHP (100–120) was used with the temperature programmed at 100° for 7 min, then increased by 4°/min to 212°. The area of each fatty acid peak detected by flame ionization was used to calculate its ratio by mass. Peaks were identified by comparison with standards (NHI mixture, Supelco, supplied by Radley & Co. Ltd., Sawbridgeworth, Herts.) and confirmed by GC-mass spectrometry carried out by the University of London Research service at King's College, Kensington.

Statistical analysis

Comparisons of means for the two semi-purified diets were made using Student's unpaired *t* test. Two-way ANOVA was used to analyse the results of the cross-over experiment.

RESULTS

The possibility that the source of dietary carbohydrate may affect the reproductive performance of dams was examined. The dietary carbohydrate source had no effect on the ability of female mice to produce litters, nor did it influence litter size or neonatal weight (Table 2). The survival rate of the pups born to dams fed on either starch or sucrose was similar and the ability of dams to bring litters to full term was not altered. These findings are in line with similar studies in carbohydrate-sensitive rats (Berdanier, 1975; Bouillon & Berdanier, 1983).

The source of carbohydrate in the maternal diet during pregnancy had no significant effect on body weight of pups at 11–12 d of age. However, sucrose intake during lactation increased significantly the body weight of pups. Furthermore, sucrose intake during pregnancy and during lactation resulted in a significant increase in body fat of the pups (Table 3).

Sucrose in the maternal diet also affected the concentrations of plasma glucose and triacylglycerol (TAG) in pre-weaning pups (Table 4). Plasma glucose levels in pups were increased when sucrose was present in the maternal diet, whether during pregnancy or lactation. Plasma TAG levels were increased by maternal sucrose intake during lactation alone (Table 4).

Table 2. *Reproductive performance of female mice fed on high-starch and high-sucrose diets**

(Mean values with their standard errors; number of litters is given in parentheses)

		Litter size/dam					
		At birth		At 11–12 d		Wt of neonates (g)†	
Diet	Dams (*n*)	Mean	SE	Mean	SE	Mean	SE
Starch	15	4·8 (15)	0·52	4·6 (15)	0·46	1·32 (3)	0·23
Sucrose	14	5·4 (14)	0·47	4·5 (14)	0·40	1·48 (3)	0·16

* For details of diets, see Table 1.

† Neonate weight quoted is that of the litter weight obtained immediately after birth (before being suckled) divided by the number of neonates.

Table 3. *Effect of maternal diet on body weight and composition of mouse pups at 11–12 d of age**

(Mean values with their standard errors)

		Body weight (g/pup)		Body composition (g/kg)					
				Fat		Protein		Water	
Maternal diet† (*in utero*/lactation)	*n*	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Starch/starch	10	5·7	0·15	127	4	129	3	701	4
Sucrose/starch	14	6·0	0·26	151	7	126	3	681	5
Starch/sucrose	16	6·9	0·14	148	7	123	3	683	6
Sucrose/sucrose	10	6·7	0·26	159	4	127	2	675	3
Analysis of variance, *P* value									
In utero diet		NS		0·025		NS		0·025	
Lactation diet		0·001		0·05		NS		0·05	
Interaction		NS		NS		NS		NS	

* For details for diets, see Table 1.

† Pups born to and suckled by their own mothers are referred to as starch/starch or sucrose/sucrose. Pups cross-fostered at birth are referred to as sucrose/starch or starch/sucrose. Litter sizes were adjusted to five at birth.

No discernible difference was detected in the gross composition of milk collected from lactating dams fed on either of the semi-purified diets (Table 5). However, milk obtained from sucrose-fed dams had a significantly higher proportion of oleic acid (18:1*n*-9) and a lower proportion of linoleic acid (18:2*n*-6, Table 6). The same trend in the fatty acid profile was also seen in the parametrial WAT depot in pregnant mice (Table 6).

Lactating mice fed on a sucrose diet were significantly heavier than those fed on starch, although no significant difference in food intake was observed (Table 7). Hepatic lipogenesis of lactating mice was significantly affected by dietary sucrose. Fatty acid synthesis/g liver was doubled in the sucrose-fed mouse. This difference was further accentuated when rates were calculated per liver, due to the 37% increase in liver mass of sucrose-fed mice (Table 7). Rates of sterol (presumably cholesterol) synthesis paralleled those of fatty acid synthesis. In contrast, sucrose feeding had no effect on lipogenesis in

Table 4. *Effect of maternal diet on plasma levels of glucose and triacylglycerol in mouse pups at 11–12 d of age**

(Mean values with their standard errors)

Maternal diet (*in utero*/lactation)	Plasma glucose (mmol/l)			Plasma triacylglycerol (mmol/l)		
	Mean	SE	(*n*)	Mean	SE	(*n*)
Starch/starch	4·9	0·4	(15)	1·2	0·1	(12)
Sucrose/starch	6·1	0·5	(8)	1·2	0·1	(8)
Starch/sucrose	6·8	0·4	(14)	1·5	0·1	(15)
Sucrose/sucrose	6·9	0·3	(21)	1·5	0·1	(19)
Analysis of variance, *P* value						
In utero diet	0·025			NS		
Lactation diet	0·001			0·001		
Interaction	NS			NS		

For details of diets, see Table 1.

Table 5. *Gross composition of milk* from lactating mice maintained on high-starch and high-sucrose diets†*

Diet	*n*	Milk composition (g/l)					
		Water		Fat		Protein	
		Mean	SE	Mean	SE	Mean	SE
Starch	6	454	12	352	14	103	4
Sucrose	4	507	24	334	27	96	4

* Samples (100–300 μl) of milk were obtained from dams at mid-lactation.
† For details of diets, see Table 1.

mammary gland. There were also no significant differences in the activity of heparin-releasable LPL of mammary tissue or in the levels of plasma TAG in mice fed on the two diets (Table 7).

DISCUSSION

Maternal sucrose intake during lactation increased body weight, body fat, plasma glucose and TAG concentrations in the sucking young. These features are normally associated with pups reared in small litters, presumed to be on a high energy intake (Winand *et al.* 1976; Cryer & Jones, 1979). In the present study, differences in milk yield due to maternal carbohydrate source were thought to be unlikely, given that energy intake by the lactating mice was similar. The food intake of virgin mice fed on either of the semi-purified diets was also found to be similar over a 6-week monitoring period (the cumulative energy intakes per mouse after 6 weeks were 2010 (SE 63) and 2091 (SE 179) kJ for starch- and sucrose-fed respectively). Lactational performance and pup growth are reported to be directly related to maternal energy intake during lactation (Babicky *et al.* 1970; Roberts & Coward, 1985). Furthermore, no correlation between litter size and mean milk intake of pups was detected

Table 6. *Effects of sucrose or starch feeding on fatty acid composition (g/100 g total fatty acids) of parametrial white adipose tissue fat depot (WAT) of pregnant mice and milk composition of lactating mice*†

(Mean values with their standard errors

	Starch diet			Sucrose diet			
	WAT	Milk		WAT		Milk	
Fatty acid	Mean	Mean	SE	Mean	SE	Mean	SE
10:0	0·07	6·5	0·5	0·24	0·03	6·3	0·3
12:0	0·08	12·0	0·3	0·07	0·01	11·0	0·3
14:0	1·0	17·7	0·5	1·1	0·04	16·0	0·6
16:0	18·0	28·8	0·5	20·4	0·8	27·0	0·7
16:1	5·1	4·0	0·3	6·2	0·2	4·6	0·1
18:0	2·8	1·9	0·1	2·2	0·2	1·7	0·1
18:1	43·4	15·8	0·8	52·2	0·9	22·0**	1·5
18:2	29·0	12·6	0·1	19·9	1·6	10·6***	0·3
20:0	0·8	ND		1·1	0·1	ND	
n	2	6		4		7	

ND, not detectable.
Mean values were significantly different from those for starch-fed dams, ** $P < 0·01$; *** $P < 0·001$.
† For details of diets and procedures, see Table 1 and pp. 822–824.

Table 7. *Effect of sucrose or starch feeding on lipid metabolism in lactating mice*†

(Mean values with their standard errors, and number of observations given in parentheses)

	Starch diet			Sucrose diet		
Variable	Mean	SE	(*n*)	Mean	SE	(*n*)
Body weight (g)	24·5	0·42	(27)	26·5**	0·32	(27)
Food intake (g/d)	5·9	0·35	(3)	6·4	0·46	(3)
Plasma TAG (mmol/l)	0·7	0·06	(5)	0·8	0·08	(6)
Plasma glucose (mmol/l)	9·8	0·80	(8)	11·2	0·80	(8)
Liver						
Liver weight (g)	1·54	0·01	(27)	2·11***	0·05	(27)
FAS (μmol C_2 units/g)‡	58·0	7·0	(10)	127**	15	(10)
Sterol synthesis (μmol/g)§	1·5	0·3	(9)	2·6*	0·4	(9)
Mammary gland						
FAS (μmol C_2 units/g)‡	329	52	(10)	450	46	(10)
Sterol synthesis (μmol/g)§	0·4	0·1	(7)	0·5	0·1	(8)
LPL activity (U/g)‖	13·9	1·5	(6)	11·2	0·8	(7)

TAG, triacylglycerol; FAS, fatty acid synthesis; LPL, lipoprotein lipase (*EC* 3.1.1.34).
Mean values were significantly different from those for starch-fed dams, * $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$.
† For details of diets and procedures, see Table 1 and pp. 822–824.
‡ Expressed as μmol acetyl units incorporated/h per g wet weight of tissue.
§ Rates of sterol (non-saponifiable lipids) synthesis are expressed as μmol cholesterol synthesized/h per g wet weight of tissue.
‖ The heparin-releasable LPL activity is expressed as μmol glycerol released/h (units) per g wet weight of tissue.

up to day 10 of lactation (Rath & Thenen, 1979), the period of this study. Nevertheless, the possibility of difference in energy utilization between starch- and sucrose-fed mice, resulting in enhanced milk yield in the sucrose-fed dams, cannot be ruled out.

Maternal sucrose intake did not appear to alter the gross composition of mouse milk, although this may be masked by inaccurate measurement of the water content. The present values of water and fat content of milk are in disagreement with values reported for other strains (Hanrahan & Eisen, 1970; Rath & Thenen, 1979). Water evaporation during milk collection is the probable reason for the discrepancy observed, as may be the case for earlier reported values (Meier *et al.* 1965).

The main difference that distinguished milk obtained from sucrose-fed dams from that of starch-fed dams was the increase in the proportion of oleic (18:1*n*-9) and decrease in linoleic (18:2*n*-6) acid. Similar decreases in linoleate in response to sucrose or fructose feeding have been reported in other tissue lipid fractions (Alling *et al.* 1973; Worcester *et al.* 1979; Wander & Berdanier, 1985). Other reported changes, such as the increase in stearate (18:0) (Worcester *et al.* 1979), were not observed. The suggestion that such changes in mitochondrial lipid composition may affect function has not explained the effect of maternal sucrose intake on the development of the offspring (Wander & Berdanier, 1985). However recent reports suggest that diet-induced changes in polyunsaturated:saturated ratio of the fatty acid composition of adipocytes (Field *et al.* 1990), liver (Christon *et al.* 1988; Clandinin *et al.* 1993), and muscle membrane (Clandinin *et al.* 1993) may alter insulin binding and insulin responsiveness in rats. This could have a particular implication for glucose transport and utilization particularly during pregnancy.

Linoleic acid is known to be a more effective inhibitor of lipogenesis than oleic acid (Jeffcoat & James, 1977, 1978; Da Silva *et al.* 1993). Hence it is possible that in pups suckled by sucrose-fed dams, lipogenesis is less inhibited. However, it is unlikely that this would be of major significance, given that hepatic lipogenesis in sucking rats and mice is extremely low (Taylor *et al.* 1967; Smith & Abraham, 1970; Kochan & Swierczyński, 1992), the greatest contribution to circulating TAG being maternal supply through the milk. The increase in plasma TAG observed in pups suckled by sucrose-fed dams (in the absence of increased lipid intake) may indicate reduced removal by LPL. The fatty acid composition of the TAG substrate has been reported to modulate LPL activity, but the reduction in linoleate may be expected to reduce the K_m and thus enhance TAG removal by LPL (de Pury & Collins, 1972).

An alternative explanation is the combined effect of milk fat composition and plasma glucose levels on gastric inhibitory polypeptide (GIP) secretion in pups. GIP stimulates insulin release in the presence of moderate hyperglycaemia (e.g. after a meal; Marks, 1988). Pups born to sucrose-fed dams had higher plasma glucose levels. Therefore, during sucking, milk may stimulate a higher GIP response and consequently higher insulin secretion in these pups than in those pups born to and reared by starch-fed dams (starch/starch pups). GIP secretion is also stimulated by long-chain but not medium-chain fatty acids (Kwasowski *et al.* 1985). The proportion of long-chain fatty acids was slightly, but not significantly, higher in milk of sucrose-fed dams, at the expense of medium-chain fatty acids. Enhanced GIP could result in increased body fat, not only by stimulating insulin secretion in response to mild hyperglycaemia, but also by enhancing LPL activity without concomitant insulin secretion (Eckel *et al.* 1979; Wasada *et al.* 1981).

The increase in the proportion of oleic acid in milk fat obtained from sucrose-fed dams reflected changes in fatty acid metabolism in the lactating dam. The rate of fatty acid synthesis in the liver of sucrose-fed dams was three times that in the starch-fed ones. The increased hepatic production of oleic acid is thought to cause the apparent reduction in linoleic acid observed in sucrose-fed rats (Worcester *et al.* 1979). However, an estimation

of the linoleic acid content of parametrial WAT in pregnant mice and in milk during lactation suggests an absolute reduction in the amount of linoleic acid in sucrose-fed dams. Sucrose feeding appears to enhance linoleic acid metabolism.

Bouillon & Berdanier (1983) have clearly demonstrated the effect of maternal sucrose intake by the carbohydrate-sensitive BHE rat on the subsequent response of their offspring to dietary sucrose. Their experiments did not distinguish between the effects on the offspring *in utero* and during lactation. Our experiments indicate that in BALB/c mice, which are not carbohydrate-sensitive, maternal sucrose intake, particularly during lactation, affects the metabolism of the offspring, resulting in increased body weight and body fat before the ingestion of solid food. Experiments are continuing to establish whether this results in obesity and/or altered metabolic responses to dietary sucrose in the mature offspring, that is, to establish whether maternal dietary sucrose predisposes the offspring to increased carbohydrate sensitivity as adults.

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