Nutritional Effects of Enzymatically Modified Soybean Oil with Caprylic Acid versus Physical Mixture Analogue in Obese Zucker Rats

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Enzymatically modified soybean oil with caprylic acid (SL), a physical mixture of tricaprylin and soybean oil (PHY), and soybean oil as control were fed (20% of diet weight) to female obese Zucker rats. Both lipids (SL and PHY) have similar total fatty acid composition containing 23.4 mol % caprylic acid (C8:0) but have different lipid structures. After 21 days of feeding, the body weight gain was 36.4% in the SL-fed group and 35.2% in the PHY-fed group, respectively; whereas the body weight of the control group increased 41.6%. Significant differences in the respiratory exchange ratio were observed between the SL and PHY groups. However, the contents of glucose, total and high density lipoprotein (HDL) cholesterol, and very low density and low density lipoprotein (VLDL + LDL) cholesterol in serum were not significantly different between the SL- and PHY-fed groups or among the three dietary groups (control, SL, and PHY) ($p < 0.05$). On the other hand, plasma total cholesterol and plasma triacylglycerol (TAG) were significantly higher in SL- and PHY-fed groups than in the control group. In the liver and inguinal adipocyte TAG, C8:0 was found in the SL-fed group, whereas it was not observed in the liver and inguinal adipocyte TAG of the PHY-fed group, which suggests that positional distribution of C8:0 of the TAG molecule is an important consideration in the metabolism of lipids. This study showed that different positional distribution in TAG molecules lead to different metabolic fates, resulting in the change of fatty acid composition in liver and inguinal adipose TAG in female Zucker rats.

Keywords: *Structured lipids; serum lipids; cholesterol; fatty acid composition*

INTRODUCTION

Enzymatically or chemically modified lipids, known as structured lipids (SL), are triacylglycerols (TAG) restructured or modified to change the fatty acid composition and/or their positional distribution in glycerol molecules by chemical or enzymatic process. SL may provide the most effective means of delivering the desired fatty acids for nutritive or therapeutic purposes (Akoh, 1995).

It seems that the regiospecific positions of fatty acids in the TAG molecules are important for the metabolic and physical properties of SL. For example, linoleic acid at the *sn*-2 position of 2-linoleyl-1,3-didecanoyl glycerol was better absorbed than trilinolein (1,2,3-trioctadecadienoyl glycerol) in rats, and the hypocholesterolemic effects of mono- or polyunsaturated fatty acid were reduced significantly when these fatty acids were not positioned at the *sn*-2 position (Ikeda et al., 1991; Kubow, 1996). Therefore, enzyme-catalyzed transesterification is a viable alternative to chemical synthesis because it is possible to selectively incorporate a desired acyl moiety onto a specific position of TAG through enzyme-catalyzed reactions (Lee and Akoh, 1998).

Medium-chain triacylglycerols (MCT) containing C6−C12 saturated fatty acids may not be metabolized via the lymphatic system like long-chain triacylglycerols (LCT), but rather metabolized via the portal vein to provide quick energy. The use of medium-chain fatty acids (MCFA) for quick energy may lead to a decrease in glucose requirements. Because MCFA may not be incorporated into chylomicrons, they are less likely to be stored in adipose tissue. Rather, they may be oxidized preferentially in the liver. Therefore, smaller molecular size and relatively high solubility of MCT in water result in different digestive and absorptive metabolic pathways compared with LCT (Bray et al., 1980; Bach and Babayan, 1982; Babayan, 1988). However, MCT alone cannot provide essential fatty acids. Thus, SL containing both essential fatty acids and MCFA in a triacylglycerol molecule may be useful to target specific diseases, metabolic conditions, and optimal nutrition (Akoh, 1995).

Genetically obese Zucker rats are good animal models for explaining certain types of human obesity, and they have several metabolic characteristics in common with obese human subjects (Bray, 1976). Hypercholesterolemia, hyperlipidemia, obesity, and other diseases related to excess fat consumption might be modulated by structurally and compositionally modified lipids (Swift et al., 1992). In this study, the dietary effects of

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the SL along with the physical mixture (PHY) and soybean oil as control on calorimetry, serum lipids, glucose level, and fatty acid composition in liver and inguinal adipocytes were studied in obese female Zucker rats after 21 days of feeding. The physical mixture was compared because it has a fatty acid composition analogous with a different fatty acid distribution in lipid molecules.

MATERIALS AND METHODS

Materials. Tricaprylin (1,2,3-trioctanoyl glycerol, 97−98%) and caprylic acid (C8:0) were obtained from Sigma Chemical Company (St. Louis, MO). Lypozyme IM60 was a gift from Novo Nordisk Biochem North America, Inc. (Franklinton, NC).

Synthesis of Structured Lipid. SL was synthesized with soybean oil and caprylic acid (C8:0) in the presence of immobilized enzyme, Lypozyme IM 60 (from *Rhizomucor miehei*), and purified for usage in this study. Twenty grams of soybean oil was mixed with 28.8 g of C8:0 in batches and transesterified by incubation with IM 60 (4.9 g) in hexane (45 mL) at 55 °C in water bath (250 rpm) using 125-mL Erlenmeyer flasks as the bioreactor. After several batches of reaction, the products were pooled and filtered to remove enzyme; hexane was evaporated. Short-path distillation was used for the isolation of synthesized SL from unreacted C8:0. The distillation conditions were 400 m Torr and 215 °C at a feed flow rate of 10 mL/min. After distillation, 1.9 kg of SL was obtained.

Animals. Female obese Zucker rats ($n = 8$) (approximately 6 weeks old and weighing approximately 200−300 g) were used. The Zucker rat may be an ideal model for dietary effects on obesity because it maintains a constant body weight against perturbations in food intake or energy expenditure. Besides, its genetic influence underlies some types of human obesity (Bouchard and Perusse, 1993). The rats were randomly assigned to SL, PHY, and control groups and housed individually in hanging wire cages. Animal care and use were performed in accordance with the Institutional Animal Care and Use Committee guidelines of The University of Georgia. The temperature of the animal room was maintained at approximately 23 ± 2 °C, and the room light was 12 h/day light (0700−1900 h) and dark cycle. Rats were fed diets and water ad libitum for 21 days. The experimental diet contained soybean oil, SL, or the PHY (20% of diet weight) as a lipid source. The diet composition of each group is described in Table 1. Every morning, the residual diet was discarded and fresh diets were provided. Rats were weighed daily except when placed in chambers for calorimetry analysis. After 21 days of diet experiment, rats were killed by CO_2 inhalation. Rats were fasted before being killed. Blood (2 mL) was collected in heparin-containing tubes from the heart and was delivered to Athens Regional Hospital for analysis of serum lipids (catalog no. 450026 for cholesterol, no. 450039 for HDL-cholesterol) and glucose (no. 450058) using Boehringer Mannheim Hitachi 911 automatic system (San Jose, CA) (Boehringer, 1992). The liver and adipose tissue from inguinal fat pads were removed and stored in a freezer (−96 °C) for fatty acid composition analysis.

Calorimetry Analysis. Analysis was performed for two consecutive 24-h periods. After 14 days, rats were moved to open-circuit respiration chambers for calorimetry analysis. Computerized automatic recording indirect calorimeters (Oxymax Deluxe Calorimetry System, Columbus Instrument Inc., Columbus, OH) were used to measure oxygen consumption, carbon dioxide production, respiratory exchange ratio, and heat production of each diet group. Diet intake, water consumption, and dry feces were also measured.

Fatty Acid Composition of Liver and Adipocytes. The liver from each rat was weighed. Approximately 1 g of liver or adipose tissue was homogenized with 12 mL prechilled chloroform/methanol (2:1, v/v) containing 0.005% butyl hydroxyl toluene (BHT). After homogenization with Polytron (Brinkmann Instruments, Inc., Westbury, NY) for 2−3 min, the extract was filtered and 4 mL of 0.88% KCl solution was added. The lower chloroform phase was collected and the solvent was evaporated. Lipid was methylated with 3 mL of 6% HCl in methanol at 75 °C for 2 h, extracted with hexane (2 mL) and 0.1 M KCl solution (1 mL), centrifuged (1000 rpm, 3 min), concentrated under nitrogen, and analyzed by gas chromatography. The running condition was reported previously (Lee and Akoh, 1996). Pancreatic hydrolysis was performed for analysis of fatty acid composition at the *sn*-2 position of SL. One milliliter of 1 M Tris-HCl buffer (pH 7.6), 0.25 mL of bile salt solution (0.05%), 0.1 mL of 2.2% $CaCl_2$ solution, and 10 mg of pancreatic lipase were mixed and incubated at 37 °C for 2 min. A Hewlett-Packard 5890 Series II gas chromatography equipped with a flame-ionization detector (Avondale, PA) was used for fatty acid composition. Extraction of the *sn*-2 monoacylglycerol, methylation for GC analysis, and analysis conditions were described in our previous article (Lee and Akoh, 1996).

Table 1. Composition of Soybean Oil, Structured Lipid (SL), and Physical Mixture (PHY) Diets

ingredients	SL (g/kg)[a]	PHY (g/kg)[b]	LCT (g/kg)[c]
casein	200	200	200
sucrose	100	100	100
corn starch	400	400	400
cellulose[d]	50	50	50
minerals[e]	35	35	35
vitamin mix[f]	12	12	12
d,*l*-methionine	3	3	3
lipid source			
SL	200	0	0
PHY	0	200	0
soybean oil	0	0	200
kcal/kg	3800	3800	3800

[a] Enzymatically modified soybean oil with caprylic acid. [b] Physical mixture of soybean oil and tricaprylin. [c] LCT, 100% soybean oil as fat source for control group diet. [d] Celufil, a nonnutritive bulk (United States Biochemical, Cleveland, OH). [e] AIN Mineral Mixture 76 contains the following compounds (g/100 g): calcium phosphate dibasic 50.0, sodium chloride 7.4, potassium citrate monohydrate 22.0, potassium sulfate 5.2, magnesium oxide 2.4, manganous carbonate 0.35, ferric citrate 0.6, zinc carbonate 0.16, cupric carbonate 0.03, potassium iodate 0.001, sodium selenite 0.001, chromium potassium sulfate 0.055, sucrose 11.8 (United States Biochemical, Cleveland, OH). [f] AIN Vitamin Mixture 76 contains the following compounds (mg/100 g): thiamine hydrochloride 60.0, riboflavin 60.0, pyridoxine hydrochloride 70.0, nicotinic acid 300.0, D-calcium pantothenate 160.0, folic acid 20.0, D-biotin 2.0, cyanocobalamin 0.1, retinyl palmitate 80.0, DL-a-tocopheryl acetate 2.0, cholecalciferol 0.25, menaquionine 0.5, sucrose 97.0 (United States Biochemical, Cleveland, OH).

Statistics. The Statistical Analysis System (Cary, NC) was used to perform statistical computations. Data are expressed as means ± standard deviation. The Bonferroni *t* test was performed as a post hoc test. Significance was determined at $p < 0.05$ (SAS, 1996).

RESULTS

The fatty acid composition of soybean oil and SL and the physical mixture of tricaprylin and soybean oil (PHY) are presented in Table 2. SL and PHY have similar total fatty acid compositions but have different lipid structures (Scheme 1). Only significantly different contents were observed on C16:0 and C18:0. PHY has more C16:0 (about 3.5 mol %), whereas SL has more C18:0 (1.3 mol %). Both SL and PHY contained approximately 23.4 mol % C8:0 and 43.4−44.7 mol % C18:2 n-6. C8:0 was not found in soybean oil.

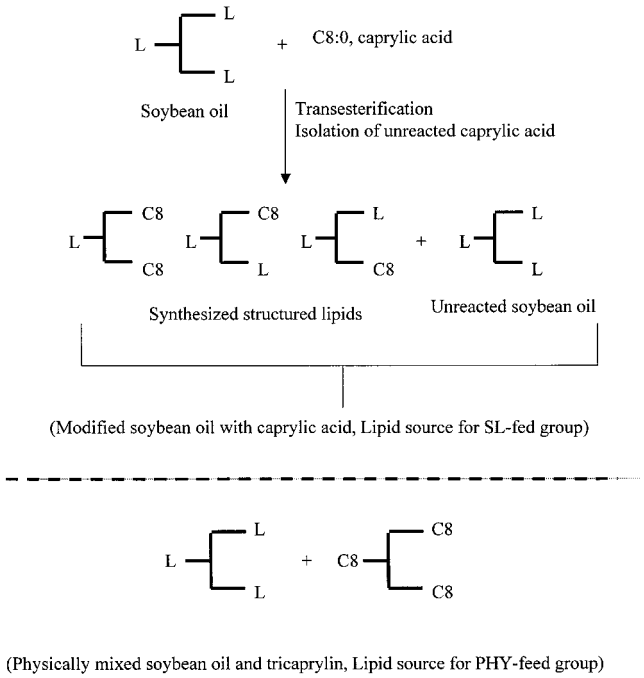
After pancreatic hydrolysis analysis, it was found that the major fatty acid at the *sn*-2 position of each lipid was C18:2 n-6. C8:0 content of both lipids at *sn*-2 position, however, was significantly different. PHY contained 8.1 mol % of C8:0, whereas SL contained 2.5 mol % at the *sn*-2 position of lipid molecules. In SL, the

Table 2. Fatty Acid Composition (mol %) of Soybean Oil, Structured Lipids, and Physical Mixture

total (*sn*−2 position)	SL[a]		PHY[b]		LCT[c]	
8:0	23.4 ± 1.2	(2.5 ± 0.4^{e})	23.4 ± 1.1	(8.1 ± 0.4^{d})	nd	(nd)
16:0	6.3 ± 0.2^{f}	(2.6 ± 0.1)	9.8 ± 0.8^{e}	(2.2 ± 0.01^{e})	12.9 ± 0.5^{d}	(2.5 ± 0.2)
18:0	3.1 ± 0.1^{e}	(2.4 ± 0.1^{d})	1.8 ± 0.02^{f}	(1.8 ± 0.02^{e})	4.6 ± 0.2^{d}	(1.5 ± 0.3^{e})
18:1 n-9	16.3 ± 0.8^{e}	(23.1 ± 0.8^{de})	15.2 ± 0.5^{e}	(21.4 ± 0.9^{e})	19.6 ± 0.9^{d}	(24.0 ± 0.6^{d})
18:2 n-6	44.7 ± 1.5^{e}	(62.9 ± 2.1^{de})	43.4 ± 1.8^{e}	(61.0 ± 2.6^{e})	54.4 ± 0.8^{d}	(66.4 ± 0.7^{d})
18:3 n-3	6.2 ± 0.2^{e}	(5.9 ± 0.8)	6.4 ± 0.2^{e}	(4.8 ± 0.2)	8.5 ± 0.8^{d}	(5.1 ± 0.2)

[a] Enzymatically modified soybean oil with caprylic acid. [b] Physical mixture of soybean oil and tricaprylin. [c] LCT, soybean oil. [d−f] Mean values for fatty acid composition (total and *sn*-2 position, respectively) within the same row having a similar superscript do not differ significantly ($p < 0.05$).

Scheme 1



presence of C8:0 at the *sn*-2 position was found unexpectedly, because used lipase, IM 60, is believed to be a *sn*-1, 3-specific or selective lipase. Such lipase is supposed to replace fatty acids at the *sn*-1,3 positions with C8:0. Therefore, we could assume that acyl migration during the processing and analysis of SL contribute to the presence of C8:0 at the *sn*-2 position of the SL.

The body weight gain was 36.4% in the SL-fed group and 35.2% in the PHY-fed group, respectively, whereas the body weight gain of the control group was increased to 41.6%. No significant differences were observed in liver weight and liver/body weight ratio among three different diet-fed groups (Table 3). The amounts of total cholesterol and total TAG in serum in the SL and PHY groups were significantly higher than those in the control group. However, the contents of glucose, total and high density lipoprotein (HDL) cholesterol, and very low density and low density lipoprotein (VLDL + LDL) cholesterol in serum were not significantly different between SL and PHY groups or among three dietary groups (control, SL, and PHY) ($p < 0.05$).

The fatty acid composition of inguinal adipocytes TAG was similar between the two diet groups (SL and PHY) except C16:1. However, C8:0 (0.5 mol %) was found in inguinal adipocyte TAG of SL-fed group, whereas it was not observed in that of the PHY-fed group. In liver, the mol % of C18:1 n-9, C18:2 n-6, and C20:4 n-6 were significantly different between the two groups (SL and PHY), and C8:0 (0.4 mol %) was also observed in liver TAG of the SL-fed group (Table 4). However, the amounts of 18:2 n-6 and 18:3 n-3 in the LCT (soybean oil)-fed group were higher than those in two groups (SL and PHY).

Besides, significant differences were observed in the respiratory exchange ratio (RQ) and water intake ($p < 0.05$) between the SL and PHY groups (Table 5).

DISCUSSION

MCFA have smaller molecular size, more rapid hydrolysis rate, higher solubility in water, and follow a different metabolic pathway than long-chain fatty acids (LCFA). MCT provide quick energy and less calories than LCT. (MCT provide approximately 6.5−8.3 kcal/g, whereas LCT provide 9 kcal/g.) These properties can lead to beneficial effects on hospital patients including altered weight gain, glucose, triacylglycerol, and insulin levels (Bray et al., 1980; Grancher et al., 1987). After hydrolysis by pancreatic lipase and lingual and gastric lipases, MCFA from MCT are transported predominantly via the portal vein to the liver rather than through the lymphatic system, because transport as free fatty acid via the portal vein is favored generally (Swift et al., 1990). However, some reports indicate they may be transported through the lymphatic system under certain conditions, such as consumption of high levels of MCT or the presence of MCFA at the *sn*-2 position. In addition, it was reported that MCFA can be incorporated into chylomicrons and adipose tissue when the diet contains relatively high levels of MCFA (Hill et al., 1990; Jensen et al., 1994). In our results, 0.5 mol % C8:0 was found in adipocytes of SL-fed rats (but not found in PHY-fed rats), which suggests the transportation of MCFA through the lymphatic system to adipocytes.

In the liver, MCFA are readily β-oxidized to form acetyl-CoA end-products that are further oxidized to produce CO_2 in the Krebs cycle. It was reported that C8:0 produces about 10 times more CO_2, than C16:0 (Bach and Babayan, 1982). Acetyl-CoA is used for the synthesis of ketone bodies for energy. Therefore, MCT may enhance ketogenesis and thermogenesis, causing energy dissipation as heat (Chanez et al., 1991) and may lead to reduction of fat deposition (Geliebter et al., 1983). In our calorimetry study, a higher respiratory quotient (RQ) was observed in the SL- and PHY-fed groups than the soybean oil-fed group (control). The RQ is the ratio of carbon dioxide production to oxygen consumption and is used to indicate the type of nutrient being metabolized (RQ is near 1 if all energy comes from carbohydrate and is near 0.7 if fat is the source of all energy) (Blaxter, 1988). Although the diets provided contained 20% of diet weight in fat, the RQ from SL- and PHY-fed groups were near 1, resembling carbohydrate utilization (Table 5). The unusual high RQ with MCT intake was also found in another study (Mok et al., 1984).

Effects of MCFA on cholesterol and TAG concentration in the blood are not clear. Swift et al. (1992)

Table 3. Effects of SL and Physical Mixture Diets on Serum Lipids, Glucose Levels, Body Weight Gain, and Liver Weight in Zucker Rats During 21-Day Feeding

parameters studied	SL	PHY	LCT[a]
glucose (mmol/L)	8.0 ± 1.4	9.3 ± 1.7	9.1 ± 0.4
total cholesterol (mmol/L)	4.2 ± 0.6[b]	4.0 ± 0.8[b]	2.5 ± 0.2[c]
total TAG (mmol/L)	5.9 ± 2.1[b]	5.6 ± 1.5[b]	3.8 ± 0.6[c]
HDL cholesterol (mg/dL)	2.5 ± 0.6	2.3 ± 0.5	1.8 ± 0.2
VLDL + LDL cholesterol (mg/dL)	1.5 ± 0.4	1.4 ± 0.3	0.8 ± 0.3
day-1 body weight (g)	254.2 ± 23.4	267.2 ± 31.9	253.9 ± 36.2
day-21 body weight (g)	399.8 ± 40.2	412.1 ± 38.9	435 ± 40.2
day-21 liver weight (g)	18.7 ± 2.4	19.4 ± 3.6	19.6 ± 3.3
liver/body weight (%)	4.7	4.7	4.5

[a] LCT, control group fed with 100% soybean oil as fat source. [b,c] Mean values within the same row having a similar superscript do not differ significantly ($p < 0.05$).

Table 4. Dietary Effect of SL and Physical Mixture on Liver and Adipose Tissue Total Triacylglycerol Fatty Acid Composition (mol %)[a]

	liver			inguinal adipose tissue		
fatty acid	SL	PHY	LCT	SL	PHY	LCT
8:0	0.4 ± 0.2	nd	nd	0.5 ± 0.3	nd	nd
10:0	nd	nd	nd	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.1
12:0	nd	nd	nd	0.3 ± 0.2	0.4 ± 0.2	0.5 ± 0.1
14:0	nd	nd	nd	2.6 ± 0.3[bc]	1.7 ± 0.6[c]	3.3 ± 0.5[b]
14:1	nd	nd	nd	0.6 ± 0.4	0.4 ± 0.3	0.7 ± 0.2
16:0	22.3 ± 1.1	20.1 ± 0.2	23.8 ± 0.8	27.4 ± 1.7[b]	29.4 ± 1.4[b]	25.1 ± 1.5[c]
16:1 n-7	4.3 ± 0.5	3.8 ± 1.3	3.8 ± 0.5	7.3 ± 1.6[b]	4.4 ± 0.9[c]	7.9 ± 0.8[b]
18:0	18.4 ± 1.1	20.1 ± 1.0	18.8 ± 0.8	5.7 ± 0.7	4.9 ± 0.3	5.7 ± 0.5
18:1 n-9	14.2 ± 0.3[b]	12.7 ± 0.4[c]	13.9 ± 0.4[bc]	26.1 ± 1.0	26.0 ± 1.2	28.6 ± 1.0
18:2 n-6	11.3 ± 0.1[c]	15.2 ± 1.7[b]	17.1 ± 1.2[b]	20.2 ± 1.4	23.1 ± 1.0	20.3 ± 1.1
18:3 n-3	1.1 ± 0.8[c]	0.8 ± 0.3[c]	3.3 ± 0.4[b]	3.7 ± 0.3	3.9 ± 0.6	5.2 ± 0.3
20:3 n-6	0.7 ± 0.2	0.7 ± 0.1	0.4 ± 0.1	nd	nd	nd
20:4 n-6	14.7 ± 0.8[c]	17.2 ± 0.4[b]	18.4 ± 1.2[b]	2.6 ± 0.2	2.2 ± 0.7	2.5 ± 0.3
20:5 n-3	0.6 ± 0.3	0.3 ± 0.1	0.7 ± 0.2	nd	nd	nd
22:5 n-6	0.4 ± 0.0	0.5 ± 0.3	0.3 ± 0.2	nd	nd	nd
22:5 n-3	0.6 ± 0.2	0.6 ± 0.4	0.7 ± 0.2	nd	nd	nd
22:6 n-3	6.7 ± 0.8	6.8 ± 0.9	7.1 ± 0.2	1.7 ± 0.5[b]	2.2 ± 1.1[b]	0.9 ± 0.1[c]

[a] Data are expressed as mean ± SD, $n = 8$. [b,c] Mean values for fatty acid composition (liver and inguinal adipose tissue, respectively) within the same row having a similar superscript do not differ significantly ($p < 0.05$).

Table 5. Dietary Effects of SL and Physical Mixture on Calorimetry Parameters[a]

parameters studied	SL	PHY	LCT
oxygen consumption (mL/kg/h)	10.0 ± 1.3	10.1 ± 1.0	9.8 ± 0.4
CO_2 production (mL/kg/h)	9.9 ± 1.3	9.7 ± 0.9	10.1 ± 0.5
respiratory exchange ratio (RQ)	0.99 ± 0.01[b]	0.96 ± 0.01[c]	0.83 ± 0.01[d]
heat production (kcal)	45.4 ± 5.5	45.8 ± 4.5	43.5 ± 3.1
diet intake (g/day)	17.9 ± 2.2	17.4 ± 0.9	17.5 ± 1.0
water intake (g/day)	16.8 ± 2.1[c]	19.1 ± 0.9[b]	18.4 ± 0.6[bc]
dry feces (g/day)	1.7 ± 0.3	1.5 ± 0.3	1.6 ± 0.2

[a] Data are expressed as mean ± SD, $n = 8$. [b–d] Mean values within the same row having a similar superscript do not differ significantly ($p < 0.05$).

reported that MCT did not change the concentration of plasma cholesterol in humans when they were fed 40% total energy as MCT, LCT, or mixed MCT + LCT. On the other hand, diets containing MCT resulted in the significant elevation of plasma TAG (Carnielli et al., 1996; Cater et al., 1997), lowered serum TAG concentration (Grancher, 1987), or no significant difference (Cohen and Thompson, 1987). Other studies showed hypocholesterolemic effects of MCT (Kaunitz et al., 1958; Hashim et al., 1960; Stewart et al., 1978) or hypercholesteremic effects (Cater et al., 1997). In our study, serum glucose, total and each cholesterol class (HDL or VLDL + LDL), and total TAG in serum were not significantly affected by the different types of dietary lipids (SL vs PHY) which contain 23.4 mol % of C8:0 after 21 days of feeding in female obese Zucker rats. Even though the fatty acid composition of SL and PHY was similar, the amounts of C18:1 n-9, C18:2 n-6, and C20:4 n-6 in liver were significantly different between the two dietary groups, which can not be fully explained at this point. However, total cholesterol and total TAG in SL- and PHY-fed groups were higher than in the control group. This has a negative effect on plasma cholesterol and TAG by substituting soybean oil (control) by the SL or PHY. It can be explained for by the higher content of unsaturated fatty acids in soybean oil, because the higher content reduces blood cholesterol and TAG levels in nonhypertriglyceridemic individuals (Mattson and Grundy, 1985).

The influence of saturated fatty acids on serum lipid levels differs depending on their chain length and the positional distribution of fatty acids in TAG molecules (Kubow, 1996). For that reason, we can expect that the positional distribution of C8:0, even though SL and the PHY contained a similar fatty acid composition in the TAG molecule, is an important consideration in the metabolism of lipids because the stereochemistry of SL and simple PHY mixture are different (Small, 1991). In the study by Ikeda et al. (1991), the lymphatic absorption of 2-octanoyl-1,3-dilinoleoyl glycerol (18:2/8:0/18:

2), 2-linoleoyl-1,3-dioctanoyl glycerol (8:0/18:2/8:0), and tricaprylin (8:0/8:0/8:0), were compared and the lymphatic absorption of C8:0 was in the order 18:2/8:0/18:2 > 8:0/18:2/8:0 > 8:0/8:0/8:0, which may suggest that most C8:0 from tricaprylin was transported to the liver, not into the lymphatic system. However, C8:0 in SL (18:2/8:0/18:2) were well absorbed via the lymphatic system as *sn*-2 monoacyl glycerol. In our results, 0.4−0.5 mol % of C8:0 was found in the liver and in the adipose tissue of SL-fed group, respectively whereas it was not found in the PHY-fed and control (soybean oil) groups. From these results, we could expect that some parts of tricaprylin in the PHY may be hydrolyzed more rapidly by lingual and gastric lipase into MCFA as free fatty acids and absorbed preferentially through the portal vein, and not through the lymphatic system to the liver. Some MCT may be taken up by mucosal cells directly (Hashim and Tantibhedyangkul, 1987) or hydrolyzed by pancreatic lipase and transported mostly into the liver in which the rapid oxidation of C8:0 occurred. However, caprylic acid at *sn*-2 position in SL-TAG seems to be maintained after hydrolysis by pancreatic lipases and transported into liver and adipose tissues. In the LCT (soybean oil)-fed group (control), the higher levels of unsaturated fatty acids (linoleic and linolenic acid) in the liver reflect the dietary fatty acids because soybean oil is a rich source of them.

CONCLUSION

This study showed that enzymatically modified lipids and a physical mixture of lipids, although they have similar total fatty acid compositions, have different metabolic pathways based on the structure due to the different fatty acid composition at the *sn*-2 position of lipid molecules. Caprylic acid (C8:0) was found in the liver and inguinal adipocyte TAG of the SL-fed group, whereas it was not in those of the PHY-fed group, suggesting that positional distribution of C8:0 of TAG molecule is an important consideration in the metabolism of lipids. This may lead to different physiological influences and this is why the enzymatic process should be considered in the design of SL to provide products with specific positional distribution of fatty acids. However, higher levels of plasma cholesterol and TAG were observed when soybean oil (control) was substituted by SL or PHY which contain 23.4 mol % of caprylic acid. The metabolic fate (lymphatic vs portal transport) of SL containing MCFA may indeed depend on the structure of the SL molecular species and this aspect needs further investigation.

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