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Ingestion of thermally oxidized sunflower oil decreases postprandial lipemia mainly in younger individuals

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ABSTRACT

Animal studies have shown that diets rich in thermally oxidized fat increase glucose and decrease insulin and triglyceride (TG) concentrations in the blood. We hypothesized that ingestion of a potato meal rich in thermally oxidized sunflower oil (TOSO) would decrease postprandial concentrations of insulin, incretins, and TG and increase plasma glucose concentrations. Twenty healthy subjects aged 22 to 70 years consumed meals rich in TOSO or unheated sunflower oil and containing paracetamol (1.5 g) in a randomized, crossover trial. Blood samples were taken at baseline and 10, 20, 30, 60, 90, and 120 minutes after the meals and glucose, insulin, TG, nonesterified fatty acids, glucagon-like polypeptide-1, glucose-independent polypeptide, and paracetamol (as a marker of gastric emptying) were measured in plasma or serum. The incremental areas under the curve of glucose, insulin, nonesterified fatty acid, incretins, and paracetamol levels were not significantly different between the meals. Plasma TG incremental area under the curve was 44% lower after the TOSO meal at a marginal level of significance ($P = .06$) in the total study population and was significantly ($P = .04$) and 61% lower in those of median age and younger (n = 11). These data suggest that ingestion of TOSO may acutely decrease plasma TG mainly in younger individuals and does not acutely affect glucose and insulin metabolism or gastric emptying in healthy subjects.

1. Introduction

Deep-fried foods such as French Fries are a popular fast food in many Western countries. These foods are rich in fat and readily digestible starch that contribute to increased risk of obesity and type 2 diabetes [1,2] when they are consumed excessively. The fat in deep-fried foods is enriched in lipid oxidation products. During the deep-frying process, unsaturated fatty acids in the cooking fat undergo a number of chemical reactions including oxidation, hydrolysis, cyclization, isomerization, and polymerization [3]. There is evidence that ingestion of thermally oxidized frying oil impairs glucose metabolism by decreasing circulating insulin concentrations. In mice, a diet rich in oxidized frying oil increases blood glucose concentrations and decreases serum insulin concentrations during an oral glucose tolerance test [4]. In addition, diets rich in thermally oxidized fat also decrease plasma triglyceride (TG) concentrations in rats [5–8].

Abbreviations: ANOVA, analysis of variance; GIP, glucose-independent polypeptide; GLP-1, glucagon-like polypeptide-1; iAUC, incremental area under the curve; NEFA, nonesterified fatty acid; PPAR, peroxisome proliferator–activated receptor; S_f, Svedberg flotation rate; TOSO, thermally oxidized sunflower oil; TG, triglyceride; USO, unheated sunflower oil.

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The gastrointestinal tract plays an important role in regulating postprandial plasma glucose and insulin concentrations. Ingestion of fat, protein, or glucose stimulates the secretion of the gut-derived incretins, namely, glucagon-like polypeptide-1 (GLP-1) and glucose-independent polypeptide (GIP) [9,10], and these molecules enhance glucose-stimulated insulin release from the pancreas [11]. The type of fatty acid in the meal influences the postprandial increase in plasma GLP-1, with a higher increase after ingestion of olive oil compared with butter in the presence of carbohydrate [12]. Whether thermally oxidized fatty acids have a differential effect on GLP-1 release is unknown. The incretins GLP-1 and GIP are released from endocrine cells located in the gut mucosa. When thermally oxidized fats are ingested, fat oxidation products and their metabolites come in direct contact with the intestinal mucosa and alter mucosal gene expression [13] and intestinal metabolic activity. Aldehydic lipid oxidation products are present in thermally oxidized fats and can damage proteins by condensing with their amino groups. Aldehydes are also formed from ingested lipid hydroperoxides in the gut [14] where they undergo the Maillard reaction with proteins [15,16]. Fried foods are rich in thermally oxidized fat and delay gastric emptying in healthy volunteers [17]. Slow gastric emptying reduces the amount of glucose from the meal entering the circulation and thereby decreases postprandial glycemia [18].

Few studies have examined the response of circulating glucose, insulin, incretin, and TG concentrations and gastric emptying to ingestion of thermally oxidized polyunsaturated cooking fat plus readily digestible carbohydrate in humans. In this study, we hypothesized that ingestion of a potato meal rich in thermally oxidized sunflower oil (TOSO) would decrease postprandial concentrations of insulin, incretins, and TG and increase plasma glucose concentrations compared with values after a corresponding meal rich in unoxidized sunflower oil (USO). In addition, we evaluated the effect of these meals on gastric emptying.

2. Methods and materials

2.1. *Subjects*

Twenty healthy subjects older than 16 years were recruited from advertisements in the local newspaper (Table 1). Exclusion criteria included serious illness and use of prescription medications. Written and informed consent was obtained from each participant, and the study was approved by the Southern Regional Ethics Committee.

Table 1 – Baseline characteristics of the participants determined at the first visit

No.	20
Age (y)	50 ± 15
BMI (kg/m^2)	26.1 ± 4.1
Glucose (mmol/L)	4.9 ± 0.5
Insulin (pmol/L)	46 ± 16
Cholesterol (mmol/L)	5.21 ± 0.87
TGs (mmol/L)	1.17 ± 0.44
HDL cholesterol (mmol/L)	1.42 ± 0.40
NEFA (mmol/L)	0.43 ± 0.23
GLP-1 (pg/mL)	0.6 (0.3-1.4)
GIP (pg/mL)	34 ± 19

Data are means ± SD, except for GLP-1, which is expressed as median (interquartile range). BMI, body mass index; HDL, high-density lipoproteins.

2.2. *Study design*

The study had a single-blind, randomized, crossover design. Participants were randomized to receive a meal rich in TOSO or a similar meal containing unheated sunflower oil (USO) in place of the TOSO. At least a week later, they consumed the alternate meal. Participants reported to the study center in the early morning (8:00 AM) after an overnight fast. Meals were consumed within 15 minutes, and participants were not allowed to consume other foods or beverages or to engage in strenuous physical activity during the study period. Blood was taken from an indwelling cannula immediately before and 10, 20, 30, 60, 90, and 120 minutes after the meals.

2.3. *Meals*

Sunflower oil was heated in a small electrical domestic deep fryer for 6 hours at 180°C with frying of “chips” from 2 medium-sized potatoes every 30 minutes. The heated oil was stored at 4°C in the dark until it was used in the preparation of the meals. Two batches of TOSO were prepared during the study. Dehydrated potato was reconstituted to mash potato (glycemic index, 108) with hot water and was used as the main source of carbohydrate in the meals. The composition of the meals is shown in Table 2. Paracetamol (1.5 g) was added to the meals as a marker to assess gastric emptying by measuring the appearance of paracetamol in the blood [19]. Ingested paracetamol is poorly absorbed from the stomach but is rapidly absorbed from the small intestine. Gastric emptying is the rate-limiting step in the delivery of paracetamol to the intestine for absorption. Consequently, the rate of appearance of paracetamol in the blood reflects the rate of gastric emptying.

Table 2 – Composition of the meals containing TOSO and USO

	TOSO meal	USO meal
Dehydrated potato (g)	40	40
Hot water (mL)	160	160
TOSO (g)	50	
USO (g)		50
Paracetamol (g) [a]	1.5	1.5
Energy (kJ)	2429	2429
Fat (% energy)	76	76
Carbohydrate (% energy)	21	21
Protein (% energy)	3	3
Conjugated dienes (μmol/g fat)	53 [b]	13
Carbonyls (μmol/g fat)	15 [b]	6

[a] Marker for gastric emptying assessment.
[b] Mean of the 2 batches of TOSO.