Food Research International 42 (2009) 1034–1039

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Acute metabolic responses to butter, margarine, and a monoglyceride gel-structured spread

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ARTICLE INFO

Article history:
Received 29 October 2008
Accepted 24 April 2009

Keywords:
Coagel
Insulin
Liquid crystal
Monoglyceride gel
Postprandial
Hypertriglyceridemia
Serum lipids
Butter
Margarine

ABSTRACT

Cardiovascular and metabolic health concerns have led to interest in development of saturated- and trans fat-free margarines, spreads, and other foods. We have recently characterized a novel monoglyceride gel (MAG GEL) that can structure liquid oil into a semi-plastic solid consistency in the absence of saturated and trans fats. Consumption of this MAG GEL resulted in tempered postprandial metabolic responses compared to those resulting from consumption of a compositionally equivalent but unstructured oil suspension, suggesting a structure-dependent metabolic response. The current study was designed to test the hypothesis that postprandial blood lipid and metabolite responses to MAG GEL would be tempered compared to the responses after ingestion of butter and tub-margarine of equal total fat content. Indeed, blood triglyceride response was tempered in MAG GEL compared to butter, margarine, and unstructured oil trials, all of which produced similar triglyceride responses. The blood free fatty acid, glucose, and insulin responses were not different in MAG GEL compared to butter or margarine trials; and interestingly, there were no differences between butter and margarine trials for any of the metabolic response variables. The MAG GEL is a useful structure for many applications, and produces salubrious postprandial metabolic effects compared to other spreadable fats.

1. Introduction

The primary dietary fat sources for adult Canadians are butter, margarine, and oil (Johnson-Down, Ritter, Starkey, & Gray-Donald, 2006). Butter maintains its spread consistency and structure primarily due to its saturated fat content, and traditional manufacturing processes for other spreads, margarines, and shortenings utilize hydrogenation and/or saturated fats to achieve the desired structuring of liquid oil into semi-solid plastic pastes. The risk of myocardial infarction scales significantly with chronic dietary content of butter and margarine (Lockheart et al., 2007) primarily due to saturated and/or trans fat in these products. Related cardiovascular and metabolic health concerns (Ascherio, Katan, Zock, Stampfer, & Willett, 1999; Kuller, 2006; Rader, 2007; Stender & Dyerberg, 2004) have led to the development of margarines, spreads, and food products that are lower in saturated and trans fats, including 'trans fat free' and 'low in saturated fats' preparations. Marketplace surveys, however, indicate that there is an inverse relationship between the price of margarines and the content of saturated and trans fats that they contain (Albers, Harnack, Steffen, & Jacobs, 2008; Ricciuto & Tarasuk, 2005). Thus, currently available products that are lower in saturated and trans fats tend to cost more, and this may be a significant barrier to their use by price-conscious, and lower income consumers. Thus, there is interest in developing novel semi-solid plastic structures that are capable of encapsulating edible oil for food preparation applications without the use of saturated or trans fats, and that can be cost-effectively produced (Flickinger & Huth, 2004; Marangoni et al., 2007; Upritchard, Zeelenberg, Huizinga, Verschuren, & Trautwein, 2005).

We have recently characterized a novel monoglyceride gel (MAG GEL) structure which encapsulates high volume fractions of liquid oil in a water matrix stabilized by multilamellar monostearin multilayers (Batte, Wright, Rush, Idziak, & Marangoni, 2007a, 2007b; Marangoni et al., 2007), created by utilizing the properties of gel phases (alpha gel and coagel) of long-chain saturated monoglycerides (Batte et al., 2007a, 2007b; Heertje, Hendricks, Knoops, Royers, & Turksma, 1991; Heertje, Roijers, & Hendrickx, 1998; Marangoni et al., 2007). Initial feeding studies of a spread produced using the MAG GEL structure revealed that it could be physically manipulated in simple food preparation in a manner similar to margarine, and that it had mouthfeel similar to margarine. Furthermore, the postprandial responses of serum triglyceride, free fatty acid, and insulin were lower after MAG GEL ingestion than after ingestion of a compositionally equivalent oil–water mixture, lacking the MAG GEL structure (Marangoni, Idziak, & Rush, 2008; Marangoni et al., 2007).

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doi:10.1016/j.foodres.2009.04.013

Considered together, these previous results suggest that MAG GELs are a potentially practical and novel approach toward the goal of structuring unsaturated oils into plastic semi-solid structures for food applications without using saturated or trans fats. Further added potential value in considering MAG GELs as a solution for this food oil structuring problem comes from preliminary reports of salubrious acute metabolic responses to MAG GELs (Marangoni et al., 2007, 2008). In order to more fully understand the potential health and metabolic advantages and disadvantages of MAG GELs in food applications, however, the similarities and differences between metabolic responses to MAG GEL and traditional fat-based spreads such as butter and margarine must be systematically studied.

The current study was conducted to examine postprandial blood lipid and metabolic responses to the MAG GEL preparation and to ingestion of the same total amount of fat in the form of unstructured oil, butter, and soft tub-margarine, each delivered on a simple toasted bread vehicle as in our previous studies (Marangoni et al., 2007). This experimental design facilitated testing the hypothesis that acute metabolic responses to ingestion of MAG GEL would be tempered compared to those resulting from ingestion of commercially available butter and margarine.

2. Materials and methods

2.1. Experimental design

Volunteers for this study were recruited from a University student population. An interview was conducted to determine age, gender, medical history, and smoking habits. Height and weight measurements were obtained, and body mass index (BMI) calculated (weight in kilograms divided by height in meters squared; kg/m^2). Volunteers older than thirty years of age, smokers, and those with known cardiovascular disease, autoimmune disease, inflammatory conditions, hypertension, diabetes, insulin resistance, or taking medications that affect blood lipids were excluded from participation. A total of ten subjects participated in this study (5 male, 5 female). All procedures involving human subjects were approved by the University of Waterloo Human Research Ethics Committee, and written informed consent was provided by each individual prior to participation.

The postprandial metabolic responses to four conditions were assessed: MAG GEL; a compositionally equivalent but unstructured oil preparation; butter; and margarine. Each of the four trials were separated by one week. Subjects refrained from alcohol and vigorous physical activity for at least 24 h prior to laboratory visits. Subjects reported to the laboratory after an overnight (13 h) fast, and had fasting blood samples taken, after which the test meal was administered. Subjects were permitted to drink 1 L of bottled water every 3 h.

The test meal consisted of two pieces of 100% whole wheat toast with either: (1) 80 g of the MAG GEL preparation, as previously described (Marangoni et al., 2007), consisting of 4.8 g monostearin, 43.2 g canola oil, and 32 g of water (MAG GEL trial); (2) a compositionally equivalent unstructured oil preparation (Oil trial); (3) 60 g of butter containing 48 g of total fat (butter trial); or (4) 60 g of soft tub-margarine containing 48 g total fat (margarine

Table 1
Composition of test meal components and test meals.

	Two pieces of 100% whole wheat bread – commercial sandwich bread							
		E%						
Calories (kcal)	169.0							
Fat (g)	2.2	5						
Polyunsaturated (g)	0.6	2						
Monounsaturated (g)	0.7	2						
Saturated (g)	0.4	1						
Trans (g)	–	0						
Cholesterol (mg)	–	0						
Carbohydrate (g)	34.0	80						
Protein (g)	6.3	15						
Spread	Butter		Margarine		Oil		MAG	
		E%		*E%*		*E%*		*E%*
Calories (kcal)	420		432.0		433.0		433.0	
Fat (g)	48.0	100	48.0	99	48.0	100	48.0	100
Polyunsaturated (g)	1.8	4	19.2	46	14.6	30	14.6	30
Monounsaturated (g	12.6	28	12.6	31	30.3	63	30.3	63
Saturated (g)	30.0	66	9.0	22	3.1	7	3.1	7
Trans (g)	1.2	3	–	0	–	0	–	0
Cholesterol (mg)	150.0		–	0	–	0	–	0
Carbohydrate (g)	–	0	0.6	1	–	0	–	0
Protein (g)	0.1	0	–	0	–	0	–	0
Spread + Bread Sandwich	Butter		Margarine		Oil		MAG	
		E%		*E%*		*E%*		*E%*
Calories (kcal)	589.0		601.0		602.0		602.0	
Fat (g)	50.2	55	50.2	55	50.2	55	50.2	55
Polyunsaturated (g)	2.4	3	19.8	26	15.2	17	15.2	17
Monounsaturated (g	13.3	15	13.3	17	31.0	34	31.0	34
Saturated (g)	30.4	35	9.4	12	3.5	4	3.5	4
Trans (g)	1.2	2	–	0	–	0	–	0
Cholesterol (mg)	150.0		–	0	–	0	–	0
Carbohydrate (g)	34.0	38	34.6	38	34.0	38	34.0	38
Protein (g)	6.4	7	6.3	7	6.3	7	6.3	7

Left side of each double column is the values for the indicated variable in the units specified, right side of each column expresses the content of each variable as a percentage of the total calories (*E%*) for each indicated preparation.