Physiology & Behavior 164 (2016) 40–46

Contents lists available at ScienceDirect

Physiology & Behavior

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

Coconut and sunflower oil ratios in ice cream influence subsequent food selection and intake

G. Rizzo [a,*], U. Masic [b], J.A. Harrold [b], J.E. Norton [a], J.C.G. Halford [b]

[a] Centre for Formulation Engineering, Department of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
[b] Department of Psychological Sciences, University of Liverpool, L69 7ZA, UK

HIGHLIGHTS

- The effect of different triglycerides on appetite and food intake was investigated.
- Medium chain triglycerides reduced fat intake at an *ad-libitum* dinner.
- Long chain triglycerides reduced later food intake in *ad-libitum* snacking.
- These differences were attributed to the absorption and metabolism of these lipids.

ARTICLE INFO

Article history:
Received 12 March 2016
Received in revised form 17 May 2016
Accepted 22 May 2016
Available online 25 May 2016

Keywords:
Ice cream
Medium chain triglycerides
Long chain triglycerides
Food intake
Appetite

ABSTRACT

The effect of coconut oil (CO, containing mainly medium chain triglycerides - MCTs) and sunflower oil (SO, containing mainly long chain triglycerides - LCTs) used as fat source (10% fat ice cream) in different ratios (25% CO and 75% SO - 25CO:75SO, 50% CO and 50% SO - 50CO:50SO, 75% CO and 25% SO - 75CO:25SO) was investigated to assess differences in appetite and *ad-libitum* (evening and snack) food intake using a single blind design. 36 healthy female participants consumed a fixed portion (150 g) of ice cream 45 min before an *ad-libitum* dinner and snacks. Appetite sensations were tracked across the day. Participants ate significantly less fat after 75CO:25SO than 25CO:75SO ($p = 0.007$) and there was also a trend for lower fat intake in this condition as compared to 50CO:50SO ($p = 0.068$). High fat savoury snack intake significantly decreased after 75CO:25SO in comparison with both 25CO:75SO ($p = 0.038$) and 50CO:50SO ($p = 0.008$). Calorie intake from snacks was also found to be significantly lower after 25CO:75SO and 50CO:50SO than 75CO:25SO ($p = 0.021$ and 0.030 respectively). There was no effect of condition on appetite or desire ratings over the day. Eating a standard portion of ice cream containing different ratios of MCTs and LCTs can modestly influence acute food selection and intake, with MCTs manifesting their effect earlier and LCTs later due to differences in the absorption and metabolism of these lipids. However, the differences evident in the present study were small, and require further research before firm conclusions can be drawn.

1. Introduction

Fats are an important source of energy and should account for 30% of daily calorie intake [49] due to their essential role in the absorption of fat-soluble vitamins. Most fatty foods are energy dense and palatable, but they exert a weak effect on satiety and satiation compared with protein- and carbohydrate-rich foods ([11,19,27,28]). The consumption of a high fat diet may therefore contribute to weight gain and obesity, which is linked to a variety of co-morbidities [32]. One means of preventing the potential for weight gain from fat sources is by replacing or reducing the amount of fat in food. This usually leads to a considerable reduction in palatability which is likely to reduce consumption [18]. Another possible approach may be to maintain the fat content and vary instead the type of fat consumed to one that may enhance satiation and satiety. For instance, using fats with different carbon chain lengths or saturation levels may influence pre- and post-absorptive mechanisms [4,13,30,39,44,45]. This would maintain palatability and intake while altering satiety and satiation properties to potentially reduce subsequent intake.

Low fat diets are a generally accepted means of weight loss, but recent meta-analyses suggest they are a poor means of weight loss maintenance [43] due to their low palatability which may contribute to low levels of satisfaction and therefore adherence [22,25]. Instead, it may be more useful to maintain healthy levels of functional fats within the diet which are palatable and act to increase satiation and satiety whilst also decreasing food intake. For instance, it has been shown that

* Corresponding author.
E-mail address: 86riga@gmail.com (G. Rizzo).

http://dx.doi.org/10.1016/j.physbeh.2016.05.040
0031-9384/

unsaturated fats, in comparison to saturated fats, lead to a greater release of satiety-related gastrointestinal hormones such as GLP-1 and CCK [4,26] and are absorbed and oxidised faster than saturated fats [40]. However, fat saturation has rarely been shown to have an effect on food intake [30], with many more experiments finding no such effect [9,14,41]. Fats with different chain lengths are also absorbed and metabolised differently. In particular, medium chain triglycerides (MCTs) are hydrolysed faster and more completely than long chain triglycerides (LCTs) due to their smaller molecular weight, thus increasing lipase efficiency and allowing them to be absorbed intact. Unlike LCTs, which are packed into chylomicrons and enter the lymphatic system, MCTs enter the portal system and reach the liver more rapidly where they are readily oxidised, causing the production of Ketone bodies [1]. A decrease in food intake has been associated both with hepatic fat oxidation [29] and the presence of Ketone bodies [31], suggesting that MCTs may reduce food intake more than LCTs. Indeed, a variety of studies have shown that an intestinal infusion [13], a preload [39] or a meal [44,45] containing MCTs led to a reduction in food intake in a subsequent meal as compared to LCTs. Nevertheless, other authors have failed to show an effect of carbon chain length on food intake and appetite after a substantial delay (210–300 min) between the manipulation and subsequent meal; this is likely due to hunger overriding any observable effect [5,38].

Ice cream is a highly palatable, high-fat dessert comprised of a solid foam made up of air bubbles, ice crystals, and a network of fat globules surrounded by an unfrozen serum of sugars, proteins, polysaccharides and water [20]. The fats used to make up ice cream can be unsaturated or saturated, allowing for a stable food matrix to compare MCTs (such as coconut oil - CO) to LCTs (such as sunflower oil - SO).

In the previous literature, standard quantities of fat were in the range of 30–40 g [30,39,44,45], which exceeds the amounts normally found in foods. This may be problematic as, firstly, such quantities are not realistic to incorporate into everyday use; and secondly, these amounts of fat may be more harmful than helpful in the long term [32]. The present research assesses the effects of different fats (CO, containing mainly MCTs and SO, containing mainly unsaturated LCTs) in different ratios (25% CO and 75% SO - 25CO:75SO, 50% CO and 50% SO - 50CO:50SO, 75% CO and 25% SO - 75CO:25SO) as part of a fixed portion ice cream; a palatable, well accepted, complex food product with 10% (15 g) fat (a standard ice cream fat content) to determine how differing fat ratios influence appetite and *ad-libitum* dinner and snack intake. Such research in this area is novel because it assesses the effect of these fats when ingested in more typical quantities. It is important to highlight that in this study, as well as in other studies [2,39,45], fats with both different chain length (MCTs and LCTs) and saturation (in particular saturated MCTs and unsaturated LCTs) were compared because 1) much research comparing fatty acid saturation levels (when keeping the chain length constant) on appetite and food intake has not shown any difference in effect; 2) MCTs have been shown to reduce food intake in comparison with both unsaturated and saturated LCTs [44] and 3) a variety of food products (including ice cream) use a combination of vegetable-based saturated fat (like CO and palm oil, rich in MCTs) and vegetable-based unsaturated fat (like SO, rich in unsaturated LCTs). Thus understanding the effects of such fats in differing ratios on appetite and energy intake are invaluable. We predicted that due to the faster absorption of MCTs, the high ratio MCT condition would elicit a reduction in appetite and food intake more strongly than the high ratio LCT condition.

2. Material and methods

2.1. Participants

Thirty six healthy female volunteers were recruited to the study through advertisements at the University of Liverpool. Volunteers were asked to provide informed consent and were then screened. Exclusion at the screening session included: volunteers aged <18 years or >55 years; with a BMI < 18.5 kg m^{-2} or >25 kg m^{-2}; who were taking medication known to affect appetite; who disliked >25% of the study foods; who were smokers or had recently stopped smoking; who reported food allergies or intolerances; who were currently dieting or about to embark a diet; who had significantly changed their physical activity in the past 4 weeks or intended to change it during the course of the study; who did not eat breakfast regularly; who dislike coconut flavoured ice cream; and who showed disordered eating behaviours (score > 4 on the Dutch Eating Behaviour Questionnaire Restraint, DEBQ-R [46] or >27 on the Binge Eating Scale, BES [21]). The study was conducted in accordance to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the University of Liverpool Committee on Research Ethics. Written informed consent was obtained from all subjects. Participants were compensated for their time and travel to the laboratory.

2.2. Study foods

2.2.1. Study products

The study products were three fixed quantity ice cream portions (150 g) different in ratios of CO to SO; 25% CO and 75% SO (25CO:75SO), 50% CO and 50% SO (50CO:50SO), 75% CO and 25% SO (75CO:25SO). Ice cream ingredients are shown in Table 1 and the nutritional profile is shown in Table 2. Each ice cream portion provided 270 cal, 6 g of proteins, 15 g of fats and 27 g of carbohydrates. The typical composition of the fats used was as follows; SO is composed of palmitic acid (16:0; 5%), stearic acid (18:0; 6%), oleic acid (18:1; 30%), linoleic acid (18:2; 59%), whereas CO of caproic acid (6:0; 0.4–0.6%), caprylic acid (8:0; 7–9%), capric acid (10:0; 6–8%), lauric acid (12:0; 46–50%), myristic acid (14:0; 17–19%), palmitic acid (16:0; 8–10%), stearic acid (18:0; 2–3%), oleic acid (18:1; 5–7%), linoleic acid (18:2; 1–2%). A separate pilot sensory test with thirty participants showed that the ice creams used were sensory matched for creaminess, thickness, hardness, meltdown speed (time taken to melt in the mouth) and fattiness using VAS scale measures.

2.2.2. Test meals and snack box

All participants were provided with a fixed-load breakfast, fixed-load lunch, fixed-load ice cream and *ad-libitum* dinner and snacks. A preliminary pilot study was conducted to adjust the fixed load and *ad-libitum* meal quantities to ensure the participants could comfortably consume the fixed load meals and that the *ad-libitum* items were more than they could possibly eat in one sitting. The nutritional profile of the fixed-load meals is shown in Table 3. 250 g of water was provided for breakfast (as either tea, coffee or pure water) and lunch and 500 g water was provided for dinner. If participants requested tea or coffee at breakfast they received the same beverage on each study day (with sugar or sweetener if requested). The *ad-libitum* dinner provided a range of high and low fat savoury and sweet options which consisted of pasta with bolognese sauce, medium grated cheese, garlic bread, strawberry jelly and chocolate mousse. After the dinner, participants were given a snack box containing a range of pre-weighed high and low fat sweet and savoury options (see Table 4 for nutritional information of the snacks provided). Participants were instructed to consume as much or little of these foods as they wished for the rest of the evening, to

Table 1
Ice cream composition.

Ingredient	Percentage (wt%)
Fat	10
Skim milk powder	11
Sucrose	18
Guar gum	0.3
Distilled monoglycerides	0.2
Water	60.5