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Short-term effects of yoghurt containing a novel fat emulsion on energy and macronutrient intakes in non-obese subjects

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BACKGROUND: The satiating properties of fat remain poorly understood, particularly with reference to its physicochemical characteristics.
OBJECTIVE: To investigate the short-term effects of consumption of yoghurt containing either a novel fat emulsion or normal milk fat, on the energy and macronutrient intakes of non-obese subjects.
DESIGN: Two double-blind, placebo-controlled, within-subject crossover studies were conducted three months apart. Twenty-nine (15 F, 14 M) and thirty (16 F, 14 M) subjects participated in Study 1 and Study 2 respectively. In each study, subjects were given in random order, 7 days apart, either a 200 g portion of a test (5 g of a novel fat emulsion + 1 g milk fat) or control (6 g milk fat) yoghurt at 1300 h. At 4 h post-consumption subjects were given *ad libitum* access to a range of foods. Amounts of food consumed by individuals were determined by pre- and post-covert weighing of individual serving dishes.
RESULTS: Mean energy intakes were significantly lower after the test yoghurt compared with the control yoghurt in Study 1 (6.4 *vs* 7.6 MJ; $P < 0.001$), Study 2 (6.9 *vs* 7.9 MJ; $P < 0.001$), and for both studies combined (6.7 *vs* 7.7 MJ; $P < 0.001$). The corresponding fat intakes in Study 1, Study 2 and in the combined studies were all significantly reduced ($P < 0.001$). Protein and carbohydrate intakes were also significantly reduced in Study 1 ($P < 0.05$), Study 2 ($P < 0.01$), and for the combined studies ($P < 0.001$).
CONCLUSIONS: These results suggest that the physicochemical characteristics of small amounts of dietary fat affect short-term satiety.
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Keywords: fat; emulsion; satiety; energy intake

Introduction

There appears to be a hierarchy in the satiating efficiency of the dietary macronutrients. Fat, relative to protein and carbohydrate, is generally regarded as having the weakest effect on satiation (bringing a meal to a close) and on satiety (postponing the next meal), both of which could facilitate passive overconsumption of energy in the short term.[1–4] Nevertheless, the area remains controversial and poorly understood. There is evidence that fats with different physicochemical characteristics may have varying effects on satiety. For example, medium-chain triacylglycerols appear to increase satiety and decrease energy intake to a greater extent than long chain triacylglycerols.[5,6] Furthermore, in normal weight men and in obese men,[7] fats infused into the small intestine in the form of triacylglycerol emulsion have been shown to suppress short-term hunger ratings and food intake to a greater extent than an isoenergetic infusion of carbohydrate.

While there is little doubt that emulsified fats can increase satiety when infused directly into the small intestine,[8] the issue of whether their oral consumption has the same effect on satiety has not been resolved. Recently, a novel fat emulsion (Olibra™), formulated from palm oil and oat oil fractions, has been developed and incorporated into a commercially available yoghurt. The Olibra™ emulsion (5 g) replaces the same quantity of milk fat, the fat normally found in such yoghurts. While consumption of Olibra™ has been shown to decrease short-term energy intake in animal studies, this effect is associated with increased emulsion stability *in vitro* (unpublished data). The aim of the present study is to compare the short-term effects, in non-obese subjects, of consumption of yoghurts containing either Olibra™ or milk fat, on energy and macronutrient intakes 4 h post-consumption.

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Subjects and methods

Subjects

Sixty subjects took part in two separate studies with an identical protocol: thirty subjects (15 F, 15 M) participated in Study 1, and thirty different subjects (16 F, 14 M) participated in Study 2. The subjects were recruited by poster advertisement from the student and staff population at the University of Ulster. The study protocol was explained in detail to each subject, and the subjects who met the eligibility criteria and agreed to take part gave their written informed consent. Exclusion criteria were: body mass index (BMI, kg/m^2) over 30, smokers, vegetarians and those taking any prescriptive medication. The weight, height and percentage body fat (bioelectrical impedance Bodystat 1500, Bodystat Ltd, Isle of Man, IM99 1DQ, UK) of each subject were measured prior to breakfast on the first study day. The studies were approved by the Research Ethical Committee of the University of Ulster.

Study design

The two separate studies were conducted three months apart in the metabolic suite at the University of Ulster. The design of each study was a randomized double-blind, placebo-controlled, within-subject crossover. Each subject was studied on two occasions, on the same day of each week, and with a one-week interval between crossover. Within each study, subjects were randomly assigned to two groups; Group 1 received the test yoghurt on the first study day, and Group 2 received the test yoghurt on the second study day. Each subject was requested to fast from 2000 h on the evening before each study day and to refrain from moderate-to-heavy exercise on the day prior to, and on each study day. At 0900 h on each study day, each subject consumed the same defined breakfast in the metabolic suite. Subjects then followed their normal routine until 1300 h but were only permitted to drink water, if required. At 1300 h subjects returned to the metabolic suite and were given a 200 g portion of either the test or control yoghurt, both of which were lemon flavoured and presented in identical unmarked white containers. After eating the yoghurt, subjects resumed their normal routine for the afternoon, during which time they were instructed not to consume anything other than water, if required. At 1700 h subjects returned to the metabolic suite and were given *ad libitum* access to a wide range of familiar sweet and savoury foods (which had previously been established to form part of the subject's normal diet). Uncarbonated water was available to drink. All foods were covertly weighed prior to the meal, and all uneaten food was weighed after the meal when the subjects had left the metabolic suite. Intakes were assessed by difference. For the remainder of the day subjects were permitted to eat and drink as they wished, but were instructed to keep a weighed record of all food and beverages consumed. Each subject was provided with a set of weighing scales (Digital Scale, Model 308, Ravencourt Ltd, UK) and a food diary to record intakes.

Test foods

Breakfast Prior to the first study day, subjects were presented with a menu of foods from which to make their breakfast choices. The menu included fruit juices, fruit, cereals, cheese, bacon, eggs, breads, preserves, milks, tea and coffee. Each subject indicated which foods they would prefer to eat at breakfast. The same defined breakfast was served to each subject on both study days. The energy content provided 25% of estimated daily energy expenditure, calculated as 1.4 times estimated basal metabolic rate.[9] The macronutrient composition of the breakfast, expressed as percentage of energy contributed by carbohydrate, fat and protein was 46%, 37% and 17% respectively.

Test yoghurt The composition of both yoghurts was matched for energy and macronutrient content (800 kJ, 6.8 g protein, 6.0 g fat, 28.8 g carbohydrate per 200 g portion). However the control yoghurt contained only milk fat, while in the test yoghurt 5 g of milk fat was replaced by 5 g of fat as Olibra™ emulsion (ScotiaLipid Teknik AB, Stockholm, Sweden). Olibra™ is a food ingredient containing fractionated palm oil and fractionated oat oil in the proportions 95:5, dispersed in water to give a total fat content of 42% (w/w). The percentage fatty acid composition of Olibra™ compared to milk fat is as follows: palmitic (16:0), 42.1 *vs* 26.8; stearic (18:0), 4.3 *vs* 11.5; other saturates, 2.1 *vs* 25.8; oleic (18:1), 40.1 *vs* 28.7; linoleic (18:2), 10.4 *vs* 1.4; and other unsaturates, 1.0 *vs* 5.8. The test and control yoghurts were supplied by Skåne Mejerier, Lunnarp, Sweden.

Evening meal The evening meal was a buffet-style, self-selection meal that allowed *ad libitum* consumption of a variety of foods that varied in macronutrient composition (Table 1). All foods were served in larger than estimated average portions so that choice was not restricted by quantity. All foods were served in individual serving dishes so as not to influence food combination choices and subjects were instructed to eat to comfortable fullness. Unlimited eating time was given to each subject. Uncarbonated water was available to drink at all meals.

Assessment of appetite

Subjects rated their hunger, desire to eat and preoccupation with thoughts of food on visual analogue scales (VAS; in mm) by the pen and paper method.

Table 1 Nutrient composition (per 100 g) of foods offered to subjects at the evening meal

Menu items	*(g provided)*	*kJ (kcal)*	*Protein (g)*	*CHO (g)*	*Fat (g)*
Vegetable soup	(205 g)	89 (45)	1.6	6.3	1.7
Bread rolls	(90 g)	1139 (268)	10.0	51.8	3.8
Butter	(30 g)	3031 (737)	0.5	0.0	81.7
Tortilla chips	(60 g)	1927 (459)	7.6	60.1	22.6
Salsa	(60 g)	144 (34)	1.0	7.5	0.2
Cheddar cheese	(200 g)	1679 (405)	25.1	0.1	33.8
Chicken curry	(400 g)	635 (151)	20.0	4.4	6.1
Beef stew	(400 g)	331 (80)	5.2	3.4	4.8
Bolognaise sauce	(400 g)	407 (97)	6.6	4.0	6.2
Fish in breadcrumbs	(150 g)	983 (235)	12.4	15.2	14.3
Lettuce	(20 g)	53 (13)	0.7	1.9	0.3
Tomatoes	(60 g)	73 (17)	0.7	3.1	0.3
Cucumber	(30 g)	40 (10)	0.7	1.5	0.1
Spring onion	(12 g)	98 (23)	2.0	3.0	0.5
Coleslaw	(90 g)	939 (258)	1.2	4.2	26.4
Savoury rice	(100 g)	599 (142)	2.9	26.3	3.5
Potato salad	(120 g)	553 (132)	1.8	14.7	7.8
Tuna salad	(90 g)	614 (147)	7.2	8.3	9.8
Carrots	(60 g)	93 (22)	0.6	4.4	0.4
Peas	(60 g)	291 (69)	6.0	9.7	0.9
Sweetcorn	(60 g)	470 (111)	4.2	19.6	2.3
Oven chips	(200 g)	687 (162)	3.2	29.8	4.2
Creamed potato	(200 g)	463 (110)	1.8	14.0	5.7
Boiled rice	(140 g)	587 (138)	2.6	30.9	1.3
Pasta	(180 g)	442 (104)	3.6	22.2	0.7
Lemon cheesecake	(120 g)	1139 (274)	2.6	21.2	20.4
Fruit salad	(200 g)	237 (55)	0.7	13.8	0.1
Ice-cream	(120 g)	751 (179)	3.5	24.7	8.0
Cream	(60 g)	1539 (373)	2.0	3.1	39.3
Fruit yoghurt	(150 g)	382 (90)	4.1	17.9	0.7
Iced sponge cake	(180 g)	1717 (407)	3.8	68.8	14.9
Chocolate biscuits	(125 g)	2197 (524)	5.7	67.4	27.6
Swiss rolls, chocolate	(48 g)	1421 (337)	4.3	58.1	11.3
Semi-sweet biscuits	(125 g)	1925 (457)	6.7	74.8	16.6
Chocolate digestive	(80 g)	2071 (493)	6.8	66.5	24.1
Sandwich biscuits	(48 g)	2151 (513)	5.0	69.2	25.9

For example, hunger was rated on a 100 mm line preceded by the question 'How hungry do you feel?' and anchored on the left by 'not at all hungry' and on the right by 'as hungry as I have ever felt'. The other anchors for the questions on desire to eat and preoccupation with thoughts of food consisted of the phrases 'very weak . . . ' against 'very strong . . . ' and 'no thoughts . . . ' against 'very preoccupied . . . ' for each of the questions respectively. Subjects were instructed to make a single vertical mark at the appropriate point between the two anchors on each scale to indicate their subjective feelings of hunger, desire to eat and preoccupation with thoughts of food respectively at defined time points (immediately before and after eating the yoghurt, and thereafter at hourly intervals until after the evening meal on both study days). Yoghurts were rated for pleasantness using a VAS form 15 min post-consumption of both test and control yoghurts.

Statistical analysis

Energy (MJ), macronutrient (g) intakes, and the weight (g) of the food consumed at the *ad libitum* evening meal and subsequent evening snacks were analyzed using Compeat 4.0 (Nutrition Systems, 21 Craven Hill, London, W2 3EN). The data were analyzed using analysis of variance with a mixed effect model. Subjects were treated as random and the fixed effects were 'carry-over', treatment and treatment-order, with sex, bodyweight, BMI, age and percent body fat as covariates. The 'carry-over' term represents the effects of subject group (Group 1 *vs* Group 2), differences in 'carry-over', and treatment × treatment-order interaction, all of which were analyzed in this cross-over design. The treatment-order effect compared the intakes of the subjects who received the test yoghurt on the first study day (Group 1) with those who received the test yoghurt on the second study day (Group 2). The possibility of an interaction between the treatment effect, and sex or bodyweight was considered by including the appropriate interaction terms in the model and testing them for statistical significance. Nonsignificant ($P > 0.05$) interaction terms were omitted from the model when testing treatment and treatment-order effects. The percentage difference in energy and macronutrient intakes after the test and control yoghurts was calculated as: test energy intake − control energy intake/control energy intake × 100. The energy and macronutrient intakes for the remainder of the evening were analyzed by nonparametric statistics in order to reduce the influence of subjects who consumed no food for the remainder of the evening.

The visual analogue ratings were analyzed using analysis of variance (ANOVA) by calculating a mean rating for each 5 h (pre- and post-yoghurt, 1400 h, 1500 h, 1600 h and 1700 h) period with treatment and sex as factors, and subject as a blocking factor. Under conditions where data were not normally distributed, a square root transformation was used for the analysis. Real mean values were used for reporting hunger ratings. Analysis of energy and macronutrient intakes were performed using the SAS statistical program (SAS Institute Inc. Cary, NC, USA). Analysis of VAS was performed using the Genstat 5 statistical program (Genstat, Rothamsted Experimental Station, Harpenden, UK).

Results

No subject reported any ill effects or discomfort after consumption of either test or control yoghurts. One male subject withdrew from Study 1 between study days due to ill health, which was unrelated to the study. The females in both Study 1 and Study 2 had significantly ($P < 0.01$) lower heights and weights but higher percentage body fat than the males (Table 2). However, there were no other significant differences in other characteristics between females and males. Males in Study 2 had significantly greater ($P < 0.01$) BMI than in Study 1. However there were no significant differences between Study 1 and Study 2 for any other characteristics (Table 2). In light of this, results are presented for Study 1 and Study 2 and for the combined studies.

Energy and macronutrient intakes

Energy, macronutrient intakes and total weight of food eaten 4 h post-consumption of the test and control yoghurts for all subjects in Study 1, Study 2 and for both studies combined are presented in Table 3. Energy, protein, fat, carbohydrate and the total weight of food consumed were all significantly lower 4 h post-consumption of the test yoghurt, relative to the control yoghurt for subjects in Study 1, Study 2 and for the combined studies (Table 3). A consistent treatment effect for all measured variables was observed in the two separate studies and for the combined studies. Data for males and females separately are shown in Table 4. Although females

Table 2 Physical characteristics of subjects[a]

	Females			*Males*		
	Study 1 (n = 15)	*Study 2 (n = 16)*	*Combined Studies (n = 31)*	*Study 1 (n = 14)*	*Study 2 (n = 14)*	*Combined Studies (n = 28)*
Age (y)	22.7 ± 2.6	24.5 ± 4.8	23.6 ± 4.0	23.9 ± 4.0	25.6 ± 5.2	24.7 ± 4.6
Height (m)	1.64 ± 0.1	1.64 ± 0.1	1.64 ± 0.1	1.77 ± 0.1	1.77 ± 0.1	1.77 ± 0.1
Weight (kg)	60.8 ± 8.9	60.8 ± 8.3	60.8 ± 8.5	70.7 ± 8.5	79.4 ± 13.6	75.0 ± 12.0
BMI (kg/m^2)	22.3 ± 2.0	22.4 ± 1.8	22.4 ± 1.8	22.4 ± 1.9	25.2 ± 3.0	23.8 ± 2.8
Body fat (%)	25.5 ± 4.9	24.9 ± 3.8	25.2 ± 4.3	14.6 ± 2.6	16.5 ± 3.2	15.5 ± 3.0

[a]Mean ± s.d.

Table 3 Energy and macronutrient intakes 4 h post-consumption of the test and control yoghurts for all subjects in Study 1, Study 2 and combined studies

	Study 1 (n = 29)	*Study 2 (n = 30)*	*Combined Studies (n = 59)*
Energy intake (MJ)*			
Test	6.45 ± 2.4¶	6.90 ± 1.9¶	6.67 ± 2.1¶
Control	7.62 ± 1.8	7.89 ± 1.9	7.75 ± 1.8
% difference	−14.2	−12.5	−13.9
Fat (g)†			
Test	70.8 ± 30.7¶ (41.5%)	71.2 ± 27.4¶ (39%)	70.5 ± 29.0¶ (39.9%)
Control	91.1 ± 25.2 (45.1%)	83.5 ± 28.1 (40.0%)	86.9 ± 26.6 (42.0%)
% difference	−22.3	−14.7	−18.9
Protein (g)†			
Test	58.6 ± 24.5‡ (15.0%)	70.1 ± 27.3§ (17.0%)	64.1 ± 25.9¶ (16.0%)
Control	66.6 ± 24.5 (14.6%)	79.3 ± 30.0 (16.8%)	72.9 ± 27.2 (15.8%)
% difference	−12.0	−11.6	12.1
Carbohydrate (g)†			
Test	175.5 ± 67.6‡ (45.7%)	189.0 ± 38.4§ (46.0%)	181.7 ± 53.0¶ (45.7%)
Control	199.0 ± 49.7 (43.8%)	206.0 ± 38.3 (43.8%)	202.2 ± 44.0 (43.8%)
% difference	−11.8	−8.2	−10.1
Weight of food eaten (g)*			
Test	1162 ± 404‡	1255 ± 324‡	1202 ± 363§
Control	1321 ± 276	1394 ± 308	1358 ± 292
% difference	−12.0	−10.0	−11.5

*Mean ± s.d.; †Mean ± s.d. (% of Energy); ‡Significantly different from control, $P < 0.05$; §Significantly different from control, $P < 0.01$; ¶Significantly different from control, $P < 0.001$.

Table 4 Energy and macronutrient intakes 4 h post-consumption of the test and control yoghurts for females and males in Study 1, Study 2 and combined studies

	Study 1		*Study 2*		*Combined Studies*	
	Females (n = 15)	*Males (n = 14)*	*Females (n = 16)*	*Males (n = 14)*	*Females (n = 31)*	*Males (n = 28)*
Energy intake (MJ)*						
Test	5.26 ± 1.7	7.66 ± 1.7	5.62 ± 1.5	8.31 ± 1.4	5.45 ± 1.5	7.98 ± 2.3
Control	6.74 ± 1.4	8.55 ± 2.9	6.57 ± 1.2	9.31 ± 1.5	6.65 ± 1.3	8.93 ± 1.6
% difference	−21.9	−10.4	−14.4	−10.7	−18.0	−10.6
Fat (g)†						
Test	58.1 ± 22.6 (41.7%)	83.5 ± 27.0 (41.2%)	55.7 ± 18.5 (37.4%)	90.2 ± 23.3 (41.0%)	55.9 ± 20.4 (38.7%)	86.8 ± 31.3 (41.1%)
Control	79.5 ± 19.6 (44.5%)	103.0 ± 38.4 (45.5%)	66.8 ± 20.0 (38.4%)	101.8 ± 25.9 (41.3%)	72.9 ± 20.5 (41.4%)	102.4 ± 26.0 (43.3%)
% difference	−26.9	−18.9	−16.6	−11.4	−23.3	−15.2
Protein (g)†						
Test	48.8 ± 19.9 (15.5%)	68.5 ± 28.6 (15.0%)	53.8 ± 21.5 (16.0%)	87.9 ± 21.8 (17.7%)	51.4 ± 20.6 (15.8%)	78.2 ± 26.4 (16.4%)
Control	57.8 ± 15.4 (14.4%)	75.9 ± 27.6 (14.9%)	65.7 ± 16.8 (16.8%)	94.3 ± 26.3 (17.0%)	61.9 ± 16.4 (15.6%)	86.0 ± 28.5 (16.1%)
% difference	−15.6	−9.7	−18.1	−6.8	−17.0	−9.1
Carbohydrate (g)†						
Test	137.7 ± 42.6 (43.9%)	214.1 ± 42.6 (46.9%)	170.6 ± 35.4 (50.9%)	209.0 ± 38.4 (42.2%)	154.7 ± 41.8 (47.6%)	211.6 ± 56.8 (44.5%)
Control	180.5 ± 39.8 (44.9%)	219.4 ± 72.2 (43.1%)	185.3 ± 32.1 (47.3%)	228.5 ± 33.7 (41.2%)	183.0 ± 35.5 (46.2%)	224.0 ± 37.9 (42.1%)
% difference	−23.7	−2.4	−7.9	−8.5	−15.5	−5.5
Weight of food (g)*						
Test	955.4 ± 276.3	1373 ± 448.0	1090 ± 308.0	1423 ± 314.6	1025 ± 296.1	1398 ± 380.7
Control	1214 ± 226.0	1435 ± 275.8	1251 ± 212.0	1559 ± 322.0	1233 ± 216.0	1497 ± 300.8
% difference	−21.3	−4.3	−12.9	−8.7	−16.9	−6.6

*Mean ± s.d.; †Mean ± s.d. (% of Energy).

generally decreased intakes more than the males, the treatment effect was independent of either sex or body weight for both Study 1, Study 2 and for combined studies ($P > 0.05$). The corresponding macronutrient intakes were also significantly lower in both Study 1 and Study 2 and in the combined studies. Although not significant, the percentage decreases in fat intake were greater than the decreases in carbohydrate and protein intakes in both studies (Table 3).

A treatment-order effect was observed in Study 1 but not in Study 2. Subjects who had received the test yoghurt on the second study day (Group 2) consumed significantly more energy ($P = 0.025$), protein ($P = 0.049$), and carbohydrate ($P = 0.036$) relative to the subjects who received the test yoghurt on the first study day (Group 1). This treatment-order effect was also apparent for the weight of food eaten in both Study 1 ($P = 0.032$) and Study 2 ($P = 0.007$). When Studies 1 and 2 were analyzed separately, a significant 'carry-over' effect ($P = 0.020$) was observed for energy intakes in Study 2. This 'carry-over' effect is a combination of three different effects, namely: (1) systematic differences between the two groups of subjects, (2) differences in 'carry-over' for the two treatments, (3) treatment × period interaction, all of which; cannot be distinguished from one another in a 2 × 2 cross-over design.

Energy and macronutrient intakes for the remainder of the evening

Approximately 50% of the subjects in Study 1 ($n = 15$) and in Study 2 ($n = 16$) recorded no further intake of food for the remainder of the evening after the test yoghurt. Of these subjects, approximately 50% ($n = 8$ in both studies) recorded no food intake after both test and control yoghurts. Energy and macronutrient intakes reported for the remainder of the evening are presented in Table 5. The energy intakes remained significantly lower during the evenings following consumption of the test yoghurt for subjects in Study 1 ($P = 0.022$) and Study 2 ($P = 0.005$) and for both studies combined ($P < 0.001$). The associated reduction in macronutrient intakes was also significantly lower ($P < 0.01$) in Study 2 and for both studies combined.

Subjective hunger, desire to eat and thoughts of food

The mean ratings for hunger, desire to eat and preoccupation with thoughts of food on both test and control study days for Study 1, Study 2 and for both studies combined are presented in Table 6. Subjects in Study 1 had significantly reduced hunger (F (1,27) 11.86; $P = 0.002$), desire to eat (F (1, 27) 8.78; $P = 0.006$) and preoccupation with thoughts of food (F (1, 27) 14.10; $P < 0.001$) after the test yoghurt throughout the day. However no significant effect was seen in Study 2, or for both studies combined, for the

Table 5 Energy and macronutrient intakes for the remainder of the day following consumption of the test and control yoghurts for Study 1, Study 2 and combined studies*

	Study 1 (n = 29)	*Study 2 (n = 30)*	*Combined Studies (n = 59)*
Energy intake (MJ)			
Test	0.7 ± 0.2 †	0.5 ± 0.1‡	0.6 ± 0.1§
Control	1.1 ± 0.3	0.9 ± 0.2	1.0 ± 0.2
% difference	−36.4	−44.4	−40.0
Fat (g)			
Test	5.6 ± 1.9^NS	3.3 ± ‡	4.4 ± 1.0§
Control	7.4 ± 2.1	6.2 ± 1.3	6.8 ± 1.2
% difference	−23.3	−46.8	−35.3
Protein (g)			
Test	2.2 ± 0.7^NS	2.0 ± 0.5‡	2.1 ± 0.4‡
Control	3.3 ± 1.1	3.5 ± 0.7	3.4 ± 0.7
% difference	−33.3	−42.8	−38.2
Carbohydrate (g)			
Test	22.7 ± 7.9^NS	16.0 ± 5.1‡	19.3 ± 4.6§
Control	36.2 ± 10.7	29.6 ± 6.7	32.8 ± 6.2
% difference	−34.6	−45.9	−41.1
Weight of food (g)			
Test	106.9 ± 52.8‡	86.4 ± 52.9†	96.5 ± 37.1§
Control	345.0 ± 103.3	195.1 ± 93.8	268.7 ± 69.8
% difference	−69.0	−55.7	−64.1

*Mean ± s.e.m.; †Significantly different from control, $P < 0.05$; ‡Significantly different from control, $P < 0.01$; §Significantly different from control, $P < 0.001$; ^NS Not significantly different from control, $P > 0.05$.

measured variables. There were no treatment × time or treatment × sex interactions for any parameter measured in Study 1, Study 2 or for combined studies. No significant differences ($P > 0.05$) in the subjectively rated pleasantness of the test and control yoghurts in both Study 1 and Study 2 were observed.

Table 6 Subjective feelings of hunger, desire to eat and preoccupation with thoughts of food between 1300 and 1700 in Study 1, Study 2 and both studies combined*

	Study 1 (n = 29)		*Study 2 (n = 30)*		*Combined Studies (n = 59)*	
Hunger	Test	Control	Test	Control	Test	Control
Pre-yoghurt	65.1	65.3	55.7	57.7	60.3	61.4
Post-yoghurt	37.2†	45.9	30.1	33.0	33.6	39.3
14.00	38.0†	48.6	40.2	37.6	39.1	43.0
15.00	56.8†	57.7	54.9	53.0	55.8	55.3
16.00	67.6†	76.7	71.8	66.2	69.7	71.3
17.00	78.7†	83.8	84.2	79.8	81.5	81.8
Desire to eat	Test	Control	Test	Control	Test	Control
Pre-yoghurt	67.4	67.6	64.6	65.1	66.0	66.3
Post-yoghurt	42.2†	55.8	41.4	39.2	41.8	47.4
14.00	47.9†	51.4	38.9	41.0	43.3	46.1
15.00	61.0†	62.4	57.4	56.9	59.2	59.6
16.00	68.7†	77.8	71.6	69.9	70.1	73.8
17.00	78.7†	84.7	83.9	80.6	81.3	82.6
Preoccupation with thoughts of food	Test	Control	Test	Control	Test	Control
Pre-yoghurt	54.7	58.7	50.7	51.9	52.7	55.3
Post-yoghurt	35.7†	50.6	37.1	34.4	36.4	42.4
14.00	37.5†	44.2	35.7	33.6	36.6	38.8
15.00	47.9†	55.3	48.9	48.3	48.4	51.7
16.00	61.2†	70.5	65.2	65.3	63.2	67.8
17.00	70.0†	76.0	78.8	72.9	74.5	74.5

*Mean; †Significantly different from control, $P < 0.05$.

Discussion

These initial studies, which are the first to report the effects of Olibra™ fat emulsion on satiety in non-obese subjects, clearly demonstrate a short-term lowering of energy and macronutrient intakes relative to control conditions. The mean reductions in energy intakes remained consistent across both studies and there were no indications that males and females responded differently to the Olibra™ yoghurt. The reasons for the treatment-order effect which was evident in Study 1 and for the weight of food consumed in Study 2 are unclear, although such a finding is not unusual in study protocols of this kind. Compliance of the subjects to the instruction not to eat between the consumption of the yoghurts and the evening meal was not strictly monitored. Although the study was designed to take account of any such effects, any non-compliance may have contributed to the treatment-order effects observed. Furthermore, although the total weight of food consumed was high, perhaps due to the unusually small lunch, it was still significantly lower after the test yoghurt than after the control yoghurt. Under normal dietary conditions it is reasonable to expect that a yoghurt containing Olibra™ would be co-consumed with other foods, and that there may be interactions with other diet components. However this requires evaluation in further studies.

At this stage it is not possible to generalize about these findings. For example, only non-obese subjects were studied and it is not known if obese subjects would demonstrate a similar response. In view of the evidence which suggests that obese subjects express an increased preference for high-fat foods,[10,11] and that dietary fat is less satiating in this group,[12] it could be hypothesized that the obese would not exhibit the same responses as non-obese subjects. Moreover, it is not known whether the observed reduction in food intakes would be sustained for a longer period of time, or indeed if the same or an even more pronounced effect on food intakes would have been observed in a shorter period of time. This study also offers no evidence on whether these short-term reductions in energy intakes will result in subsequent compensation, and if so, over what time period. Food intakes for the remainder of the evening did not appear to result in any subsequent compensation. However these intakes were self-reported by the subjects and the possibility of mis-reporting of these intakes cannot be excluded.[13]

At this stage it is only possible to speculate on the possible mode of action of this novel fat emulsion. It appears to be a specific and nonaversive effect since there were no reports of nausea following the consumption of the Olibra™ yoghurt in either study. The effects of Olibra™ on short term intake in animal studies are associated with emulsion stability, and thus the fat-induced 'ileal brake' or 'jejunal brake' may be implicated.[14–17] Furthermore, powerful satiety signals arise from the gastrointestinal tract after an eating episode, one of the most important of which is that produced by the interaction of nutrients with receptors in the small intestine[18] which stimulate the release of putative satiety factors. These include apolipoprotein A-IV,[19] and hormones such as cholecystokinin (CCK),[20,21] glucagon-like peptide 1,[22,23] enterostatin[24–26] and leptin.[27] Since the decrease in the intake of fat was particularly pronounced following the consumption of Olibra™, it may be that apolipoprotein A-IV or enterostatin are of particular relevance since they have been shown to inhibit the intake of dietary fat in a number of experimental protocols.[19,24,26]

On the other hand, orosensory factors are important in appetite regulation[28] and subjects could have been responding to different sensory cues from the yoghurts. Although both yoghurts were judged to be equally palatable, full descriptive sensory analyses of the two yoghurts are not available. Finally, although the volume of water consumed in the period between the yoghurt and the presentation of the *ad libitum* meal was not recorded, it seems unlikely that this could have contributed to the reduced energy intake, since it has been shown that drinking water either before or with a meal has no significant inhibitory effect on energy intake.[29]

If these preliminary results can be substantiated in longer term feeding trials in obese subjects as well as non-obese subjects, they have implications for the widely held assumptions about the satiating properties of fat.

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