

1 **Coconut oil has less satiating properties than medium chain triglyceride oil**

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3 R. Kinsella T. Maher and M.E. Clegg*

4 Functional Food Centre, Department of Sport and Health Sciences, Faculty of Health and Life

5 Sciences, Oxford Brookes University, **Potential mechanisms** Gipsy Lane, Oxford OX3 0BP, UK

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7 *Corresponding author: Miriam Clegg, Functional Food Centre, Department of Sport and

8 Health Sciences, Faculty of Health and Life Sciences, Oxford Brookes University, Gipsy Lane,

9 Oxford OX3 0BP, UK

10 Email: mclegg@brookes.ac.uk; Ph: +44 1865 484365

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12 Running title: MCT, coconut oil and satiety

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25 **Abstract**

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27 It is well established that the consumption of medium-chain triglycerides (MCT) can increase
28 satiety and reduce food intake. Many media articles promote the use of coconut oil for
29 weight loss advocating similar health benefits to that of MCT. The aim of this study was to
30 examine the effect of MCT oil compared to coconut oil and control oil on food intake and
31 satiety. Following an overnight fast, participants consumed a test breakfast smoothie
32 containing 205 kcal of either (i) MCT oil (ii) coconut oil or (iii) vegetable oil (control) on three
33 separate test days. Participants recorded appetite ratings on visual analogue scales and
34 were presented with an *ad libitum* lunch meal of preselected sandwiches 180 minutes after
35 consumption of the breakfast. The results showed a significant difference in energy and
36 macronutrient intakes at the *ad libitum* meal between the three oils with the MCT oil
37 reducing food intake compared to the coconut and control oil. Differences in food intake
38 throughout the day were found for energy and fat, with the control having increased food
39 intake compared to the MCT and coconut. The MCT also increased fullness over the three
40 hours after breakfast compared to the control and coconut oils. The coconut oil was also
41 reported as being less palatable than the MCT oil. The results of this study confirm the
42 differences that exist between MCT and coconut oil such that coconut oil cannot be
43 promoted as having similar effects to MCT oil on food intake and satiety.

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45 **Keywords:** medium chain triglycerides, coconut oil, satiety, food intake

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49 **Highlights:**

- 50 • It is well established that eating medium-chain triglycerides (MCT) can increase
51 satiety and reduce food intake.
- 52 • Many media articles promote the use of coconut oil advocating similar health
53 benefits to that of MCT
- 54 • The current study examined the effect of MCT oil compared to coconut oil and
55 control oil on food intake and satiety.
- 56 • MCT oil reduced food intake compared to the coconut and control oil. The control oil
57 increased food intake throughout the day compared to the MCT and coconut.
- 58 • Coconut oil cannot be promoted as having similar effects to MCT oil on food intake
59 and satiety

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73 **1. Introduction**

74 It has been shown previously that high fat diets are linked to the weight gain and potentially
75 obesity, but evidence also suggests that the type of fat consumed and not just the amount
76 of fat is a factor influencing adipose tissue stores [21]. Medium chain triglycerides (MCT) are
77 a type of dietary triglycerides with fatty acids that are 6 to 10 carbon atoms in length [4] and
78 pure MCT oil is manufactured by the hydrolysis, filtering and re-esterification of both palm
79 oil and coconut oil. It has been shown that MCT consumption increases energy expenditure,
80 fat oxidation [7, 11, 18] and satiety and lowers energy and food intake [14] in both lean and
81 obese individuals. MCT smaller molecular weight allows them to be more rapidly and
82 completely hydrolysed compared to long chain triglycerides (LCT) and can be absorbed
83 when there are decreased intraluminal concentrations of pancreatic enzymes and bile salts
84 [2]. During digestion MCT are converted to medium-chain fatty acids (MCFA) and
85 transported directly in the portal venous system, as opposed to being transported as
86 chylomicrons in the lymphatic system like LCT [1]. MCT therefore bypass peripheral tissues,
87 such as adipose tissue, which makes them less susceptible to the actions of hormone-
88 sensitive lipase and to deposition into adipose tissue stores [4]. MCFA can also cross the
89 mitochondrial membrane of the liver and muscle independently of the acylcarnitine transfer
90 system, making them a much more readily available energy source [3].

91

92 MCT have been proposed to affect satiety by a number of mechanisms though a lot is still
93 unknown. Potential mechanisms include the anorexigenic effect through the concomitant
94 production of ketones that is a result of increased acetyl-CoA influx which is necessary to
95 oxidize fatty acids [4, 9, 15]. The results of Van Wymelbeke et al. (2001) and Rolls et al.
96 (1988) indicate pre-absorptive mechanisms pertaining to the rapid rate of absorption of

97 MCT. Where LCT result in two 'peaks' of absorption; that being at the initial point of
98 ingestion and a second delayed peak at the beginning of the next meal, MCT are fully
99 absorbed at the point of ingestion [10]. Therefore, MCT may increase satiation and satiety
100 immediately after the meal as they are all absorbed in one single bolus rather than being
101 delivered later. However it should be noted that some researchers found that the increase
102 in fat oxidation and postprandial energy expenditure associated with MCFA did not result in
103 any significant differences in ad libitum energy intake or perceived appetite sensations [17].

104

105 Many media articles encourage the use of coconut oil for weight loss advocating similar
106 health benefits to that of MCT which has contributed to an increase in consumption of
107 coconut oil in recent years [26]. However MCT oil and coconut oil are not the same. Lauric
108 acid (carbon chain length 12) is found in much larger quantities in coconut oil, making up
109 almost fifty percent of the total fat where no lauric acid is found in MCT oil [26]. Unlike with
110 pure MCT oil containing fatty acids of shorter carbon length (C6-C10) only twenty to thirty
111 percent of lauric acid is taken directly to the liver to be used as energy via the portal vein
112 [8]. Two studies examining the effects of coconut oil compared to LCFAs reported no
113 increase in satiety and no effect on food intake [23, 27]. Poppit et al [23] found no
114 difference in ratings of satiety or food intake at an ad libitum lunch following eating either
115 coconut oil (containing 10g MCT), high short chain triglycerides (3g SCT, 7g MCT) (from soft
116 fraction milk fat) or long chain triglycerides (from tallow). Rizzo et al [27] found that at a
117 dinner meal following ice-cream containing varying amounts of coconut oil there was trend
118 towards a decreased intake following the coconut oil, however this was compensated for
119 later on when snack consumption increased resulting in no overall difference between the
120 ice-creams. To the best of the authors' knowledge there is a lack of data on the effect of

121 coconut oil compared to MCT on food intake and satiety. The aim of this study is to analyse
122 the effect of MCT and coconut oil on food intake and satiety. This study will examine the
123 role that standard MCT and coconut oil play in increasing satiety and reducing food intake
124 over a 24 hour period and will compare them to each other and to a control.

125

126 **2. Materials and methods**

127 This is a randomised, single-blind, repeated measures study that fed participants three
128 different test breakfasts on three non-consecutive days.

129

130 *2.1 Participants*

131 Twenty eight healthy male and female participants were recruited through personal
132 communication and poster advertisements. Prior to inclusion all participants were given
133 detailed information on the study and were then screened for eating behaviour using the
134 Three-factor eating questionnaire for restrained eating [5] as well as a de-identified health
135 questionnaire detailing any food allergies and/or intolerances; any genetic or metabolic
136 disease; medication and smoking habits. They also had their anthropometric measurements
137 (weight, height, fat percentage) taken using a bio impedance scale (Model BC-418 MA,
138 Tanita UK Ltd., Yiewsley, UK) and freestanding stadiometer (Seca 217, Birmingham, UK).
139 Only participants who did not show signs of restrained eating habits (<10 in factor one of
140 the Three Factor eating questionnaire) and satisfied the inclusion criteria were then
141 included in the study. The exclusion criteria were as follows, any metabolic or genetic
142 disease; any medication other than the oral contraceptive pill, any food allergies or
143 intolerances to food included in the study, BMI > 30 kg/m² and ages outside of 18 and 50

144 years. Four participants were excluded from the study at this stage due to being restrained
145 eaters leaving 24 participants that completed the study (table 1).

146

147 On the day prior to all three test days participants were asked to avoid consumption of
148 caffeine, alcohol and nicotine and refrain from unusual strenuous physical activity that was
149 not part of their normal daily life. The participants were also asked to fast from 9pm the
150 night before (10-12 hours before testing). Water was allowed. The participants were
151 required to keep a standardised food diary the day prior to the first test day and their diet
152 and physical activity was repeated the day prior to both of the succeeding test days.
153 Researchers provided instructions, scales and food diaries for participants to complete.
154 Ethical approval was granted by the Research Ethics officer in the Department of Sport and
155 Health Sciences in Oxford Brookes University according to the guidelines laid down in the
156 Declaration of Helsinki. Written informed consent was obtained from all participants.

157

158 *2.2 Study design*

159 Participants took part in a randomised, repeated measures, single blind study where they
160 were fed a breakfast high in MCT, coconut oil or a control (vegetable) oil on three non-
161 consecutive days with at least one day between tests. The minimum number of days
162 between tests was one and the maximum was 14. Participants had baseline measurements
163 taken and then had fifteen minutes to consume the test breakfast. Following this their
164 satiety and appetite was measured over a period of three hours.

165

166 *2.3 Test Breakfast*

167 The test breakfast was 250ml of a mango and passion fruit smoothie (Tesco stores Ltd,
168 Cheshunt, UK, 143 kcal (606 kJ); 0.3g fat; 31.8g carbohydrates; 1.3g protein) with one of the
169 following three lipids: (1) coconut oil (Vita Coco organic extra virgin coconut oil, All Market
170 Europe Ltd, London, UK, 26g (lauric acid 48%, Caprylic acid 8% and capric acid 7%), (2) MCT
171 oil (Muscleform, Norfolk, UK, 25g (caproic acid 2%, caprylic acid 50-60%, capric acid 30-45%
172 and lauric acid 3%), (3) vegetable oil (rapeseed oil, Tesco stores Ltd, Cheshunt, UK, 23g). The
173 three test oils were isocaloric containing 205 kcal (858 kJ) and initial pilot testing noted little
174 taste or texture difference between the smoothies. Each test breakfast contained 348 kcal
175 (1456 kJ). The smoothie and fats were mixed for 60 seconds using a food blender and
176 consumed immediately afterwards to avoid oil separation.

177

178 *2.4 Subjective satiety and appetite feelings*

179 Subjective ratings for hunger, fullness, desire to eat and prospective food consumption were
180 recorded using one-hundred-millimetre continuous line visual analogue scales (VAS).
181 Participants completed the VAS before and after consumption of the test breakfast and
182 every 30 minutes for the following 3 hours until they were presented with the ad libitum
183 lunch and the final VAS was completed after they had consumed the lunch.

184

185 *2.5 Palatability*

186 Palatability (how much they liked the drink) was measured directly after consuming the
187 smoothie using a 100mm visual analogue scale.

188

189 *2.5 Food Intake*

190 Three hours after participants consumed their test breakfast they were presented with an
191 ad libitum sandwich lunch. The lunch consisting of sandwiches was given ad-libitum to
192 measure food intake similar to that used by Ranawana et al [24] and Clegg and Thondre
193 [25]. Prior to testing, participants were given a choice of sandwiches from a list and asked to
194 choose which ones they liked. All the sandwich recipes were formulated to contain the same
195 energy content per portion (Table 2). The lunch consisted of three weighed plates each
196 containing two sandwiches cut into quarters. Participants were given all the sandwiches at
197 once so that it was in excess and asked to eat until they felt comfortably full. Participants
198 were given the same sandwiches for each test. The subjects were presented with the meal
199 under identical conditions on each test day. They ate in the same laboratory on their own
200 with no distractions and were given 20 minutes in which to eat their *ad libitum* meal.

201

202 When participants finished eating the remaining food leftover was weighed to measure
203 food intake. A weighed food diary was used to measure food intake for the rest of the day.
204 Volunteers were provided with a food scales and food diary and were given training and
205 instruction on how to complete it. Food diaries were analysed using the software package
206 Nutritics Professional (Est. 2011, Dublin, Ireland).

207

208 *2.6 Statistical Analysis*

209 Statistical analysis was performed using Statistical Package for the Social Sciences (version
210 23.0; SPSS, Chicago, IL, USA) and data and figures were processed using Microsoft Excel
211 (2006, Reading, UK). A power calculation using actual means and standard deviations from
212 previous satiety research in our laboratory showed that our power to test satiety using VAS
213 AUC was 90% with 23 participants [25].

214 Data were tested for normality using Shapiro-Wilk test. Following this, a repeated measures
215 ANOVA with pairwise comparisons was used to analyse total food intake and to determine
216 the differences between MCT oil, coconut oil and control oil on food intake during a 24-hour
217 period. The food intake at the *ad libitum* lunch data and the palatability data were
218 addressed using Friedman's test due to a non-normal distribution. Wilcoxon signed Rank
219 test was used to determine individual differences between MCT oil, coconut oil and control
220 oil on food intake during the *ad libitum* lunch. For the VAS, the areas under the curves (AUC)
221 were calculated using the trapezoidal rule. The data was analysed using an ANOVA, with the
222 baseline value as a covariate in the analysis (Blundell et al., 2010). Values are presented as
223 means \pm standard deviation. The significance value was set at $p < 0.05$.

224

225 **3. Results**

226 *3.1 Food intake at the ad libitum lunch*

227 For the *ad libitum* lunch there were significant differences in the mass of food consumed
228 ($\chi^2(2) = 9.083$, $p=0.011$), energy ($\chi^2(2) = 7.583$, $p=0.023$), carbohydrate ($\chi^2(2) = 7.750$,
229 $p=0.021$), protein ($\chi^2(2) = 9.083$, $p=0.011$) and fat ($\chi^2(2) = 9.000$, $p=0.011$) intake between
230 the three smoothies. The differences were between the control and MCT and between the
231 MCT and coconut oil such that the MCT oil reduced food intake at the *ad libitum* lunch more
232 than the other two oils (table 3).

233

234 *3.2 Total food intake throughout the day*

235 There were significant differences in energy intake ($F(2)=4.548$, $p=0.016$) and fat
236 consumption ($F(2)=4.659$, $p=0.14$) throughout the day between the three oils (table 3).

237 There were no significant differences in carbohydrate and protein intakes for the entire day
238 between the three oils tested.

239

240 The differences in energy intake were between the control oil and the MCT oil ($t(23) =$
241 $2.571, p=0.017$) and between the control oil and the coconut oil ($t(23)=2.124, p=0.045$). The
242 highest energy intake was consumed after the breakfast containing the control oil, an
243 average of 428Kcal (1796kJ) extra were consumed compared with the breakfast containing
244 the MCT oil and an extra 280kcal (1180 kJ) was consumed following the control oil
245 compared to the coconut oil. There was no significant difference between energy intake
246 after the consumption of coconut oil and MCT oil.

247

248 The significant differences found for fat consumption were between the control oil and the
249 MCT oil ($t(23)=2.607, p=0.016$). An extra 14g of fat was consumed after the control oil
250 compared to the MCT oil. There were no significance differences for fat intake between
251 control and coconut oil or between MCT and coconut oil.

252

253 *3.3 Perceived satiety*

254 There were no significant differences for three of the four satiety parameters that were
255 measured using the VAS: hunger, desire to eat and prospective food consumption ($p>0.05$).

256 There were significance differences for the fullness parameter ($F(2)=3.427, p=0.038$), these
257 differences existed between the control and MCT oil ($p=0.021$) and between the MCT and
258 coconut oil ($p=0.037$) (Figure 1). The highest perception of fullness was found after the
259 consumption of MCT oil compared with control and coconut oil. No differences were found
260 for fullness between control oil and coconut oil. In all tests the feelings of satiety increased

261 following the breakfast and then gradually decreased until the ad libitum buffet (Figure 2a-
262 d).

263

264 3.4 Palatability

265 There was a difference in palatability between the three smoothies (control: 72.3±18.7;
266 MCT: 73.0±23.1; coconut: 63.9±22.8; $\chi^2(2) = 6.156, p=0.046$), the difference was between
267 MCT and coconut oil ($Z=-2.221, p=0.026$). The MCT was recorded as being more palatable
268 than the coconut oil.

269

270 4. Discussion

271 To the best knowledge of the authors this is the first study to compare the effects of MCT
272 and coconut oil against each other and to a control LCFA for satiety and food intake. Studies
273 have previously shown that MCT demonstrates beneficial effects by increasing satiety and
274 reducing food intake over a period of a day [6, 13, 16] and this was confirmed in the current
275 study where the MCT oil reduced food intake both at the *ad libitum* meal and throughout
276 the day compared to a control LCFA oil. Differences in food intake following coconut oil are
277 not as well documented despite much media speculation in relation to their satiating
278 properties [26].

279

280 In the current study, the coconut oil did not reduce food intake at the *ad libitum* meal.
281 There were, however significant differences in food intake throughout the day with the
282 coconut oil reducing food intake compared to the LCFA oil though not to the same extent as
283 the MCT oil. Given that the coconut oil contains significantly less MCT and that the MCT has
284 mostly caused the increase in satiety, this is not a particularly surprising effect. It highlights

285 that the distinction between the two oils needs to be made especially in the media. Previous
286 research on the effect of coconut oil is limited however two studies have been completed.
287 Research from Poppitt et al [23] found a lack of difference in visual analogue scale ratings of
288 satiety or ad libitum food intake between dairy fats (MCT and short chain fatty acids),
289 coconut oil and beef tallow (saturated long chain fatty acids). In a later study by Rizzo et al.
290 [27] they found that coconut oil did reduce fat intake and there was a trend towards a
291 reduction in energy intake at an *ad libitum* meal following a high coconut oil ice cream.
292 However this appeared to be compensated for later in the day. It should also be noted that
293 amounts of lipids given in this study were over half that given in the current study.

294

295 The lack of similarity between MCT and coconut oil results may be due to their structure.
296 Coconut oil is a natural source of MCFAs oils and the main MCFA that makes up coconut oil
297 is lauric acid (~50%) [8], while MCT oil has a lower amount of lauric acid (1-3%) [4]. Lauric
298 acid has a chain length 12 carbons and due this it's metabolism can differ to that of MCT oil
299 (caproic fatty acids (C6:0), caprylic fatty acid (C8:0), capric fatty acid (C10:0)) [20]. Some
300 authors such as Denke & Grundly [8] affirm that only 20-30% of lauric acid is absorbed by
301 the portal vein directly to the liver and the rest of lauric acid is absorbed using chylomicrons
302 like LCFAs do [8]. These warrants further research into the metabolism of lauric acid and the
303 similarity to the metabolism of the rest of MCFAs. It should also be noted that overall
304 combination of lauric, caprylic and capric acid present in the coconut oil was only ~63%
305 compared with the remainder being LCFA. The MCT oil consisted of all MCFA.

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307

308 Nausea was not measured during the trial however feelings of nausea were reported by five
309 of the participants of the study after having the MCT oil, while no side effects were reported
310 after the consumption of either the coconut or control oil. These could have affected the
311 participant's food intake and the VAS scores. It has been demonstrated that MCT can cause
312 side effects including stomach cramping and nausea [22] however it has previously always
313 been associated with quite high doses of ~85g given in exercise studies [12]. This shows that
314 even a dose as small as 25g of MCT can have side effects which may have impacted in their
315 food intake. Nonetheless it was the coconut oil smoothies that were found to be the least
316 palatable. This is in contradiction to the hypothesis that MCFA have a repulsive taste and
317 MCT may be broken down into MCFA by lingual lipase early on in digestion causing people
318 to eat less [4, 6], however given it was a smoothie it was unlikely to remain in the mouth for
319 a prolonged period for any reasonable digestion to occur. The dislike of the coconut
320 beverage could potentially have been due to participants disliking the taste of coconut,
321 however this was quite strongly masked by the smoothie drink, as was found in our pilot
322 testing.

323

324 There are several limitations to this study. The study excluded obese individuals. This
325 decision was made as it has been shown that MCT may potentially be less effective in obese
326 individuals [11, 19], however this area does warrant further research. The study also used a
327 high dose of fat, and consuming 25g MCT in a single setting would not be pragmatic or
328 recommended, however it was based on similar studies that had shown positive satiating
329 effects of MCT [13, 16]. Future studies should address this by using smaller doses that are
330 more representative of single meals. Participants were aware that their food intake was
331 being measured, however none commented on noticing any differences between the three

332 smoothies so were unlikely to behave differently based on this. Finally female participants
333 were not tested at the same phase of their menstrual cycle.

334

335 **5. Conclusion**

336 Overall the research indicates that the effects seen in for MCT oil are not the same as those
337 found for coconut oil, however given that the coconut oil contains less MCT this is not
338 surprising. The coconut oil given in the current study did reduce food intake throughout the
339 day, however it must be remembered that this was given in a dose of 26g which is likely to
340 be more than an individual would generally consume in one day. Further research is needed
341 using smaller doses of coconut oil in obese and overweight individuals.

342

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- 424
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426 **List of tables**

427 Table 1: Participant characteristics

	Female	Male	Both
	(n=18)	(n=6)	(n=24)
Age (years)	28.1±6.6	24.8±2.7	27.5±6.0
Height (m)	1.66±0.07	1.74±0.05	1.68±0.07
Weight (kg)	62.0±7.4	70.1±9.7	64.5±8.5
BMI (kg.m ²)	22.6±2.5	23.2±2.3	22.9±2.4

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444 Table 2: Nutritional content of sandwiches (*ad libitum* lunch)

Sandwich:	Weight (g)	Energy (kcal (kJ))	Carbohydrate (g)	Protein (g)	Fat (g)
Egg mayo	223	408.20 (1709)	36.68	17.46	19.81
Cheese and tomato	185	406.06 (1700)	36.62	19.73	18.51
Tuna mayo	146	402.79 (1686)	35.30	18.37	19.56
Chicken salad	221	406.48 (1701)	37.51	18.61	18.66
Cheese and pickle	148	404.75 (1695)	38.98	19.03	17.75
Ham and cheese	153	405.43 (1698)	35.62	21.49	18.21
Roast beef and tomato	181	404.30 (1693)	36.55	20.02	18.11

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456 Table 3: Energy and macronutrient intake at the ad libitum lunch and the day's total intake

	Control	MCT	Coconut
<i>Ad libitum lunch</i>			
Energy (kcal)	1680 ± 498	1438 ± 573*	1612 ± 502 [†]
kJ	7023 ± 2084	6011 ± 2397*	6738 ± 2099 [†]
Carbohydrate (g)	155 ± 47	132 ± 54*	149 ± 47 [†]
Protein (g)	78 ± 24	67 ± 27*	75 ± 23 [†]
Fat (g)	77 ± 22	66 ± 26*	74 ± 23 [†]
<i>Total day intake</i>			
Energy (kcal)	2992 ± 714	2564 ± 918*	2712 ± 546*
kJ	12518 ± 2995	10722 ± 3841*	11338 ± 2284*
Carbohydrate (g)	295 ± 69	261 ± 110	269 ± 62
Protein (g)	142 ± 43	125 ± 49	131 ± 33
Fat (g)	132 ± 36	108 ± 37*	118 ± 27

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458 *p<0.05 compared to control

459 [†]p<0.05 compared to MCT

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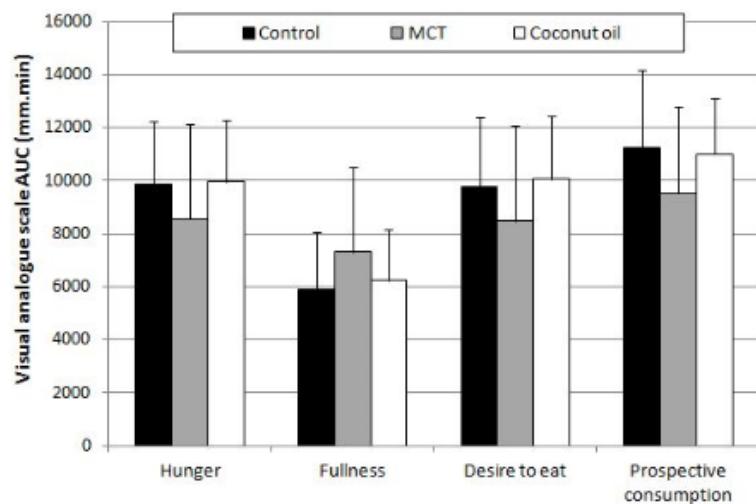
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466 **Figure headings**

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468 Figure 1: Area under the curve for hunger, fullness, desire to eat and prospective

469 consumption following the breakfast containing either control oil, MCT oil or coconut oil.



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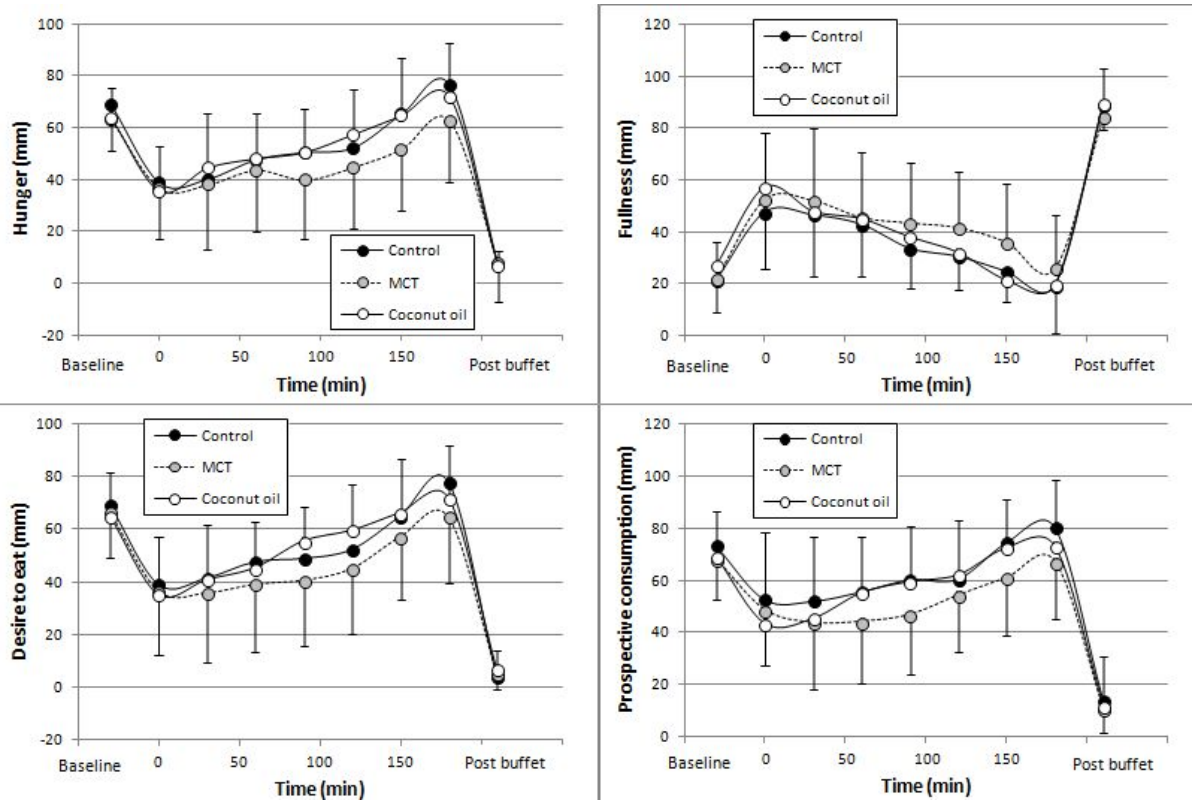
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484 Figure 2: Visual analogue scale data for hunger, fullness, desire to eat and prospective
 485 consumption at baseline (0 min), between the breakfast (of either control oil, MCT oil or
 486 coconut oil) and the ad libitum meal and after the ad libitum meal



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