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Expected satiation alone does not predict actual intake of desserts

Étienne Guillocheau, Olga Davidenko, Agnès Marsset-Baglieri, Nicolas Darcel,
Claire C. Gaudichon, Daniel Tomé, Gilles Fromentin

► **To cite this version:**

Étienne Guillocheau, Olga Davidenko, Agnès Marsset-Baglieri, Nicolas Darcel, Claire C. Gaudichon, et al.. Expected satiation alone does not predict actual intake of desserts. *Appetite*, 2018, 123, pp.183-190. 10.1016/j.appet.2017.12.022 . hal-01783985

HAL Id: hal-01783985

<https://hal.science/hal-01783985v1>

Submitted on 19 Sep 2019

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3 **1 Expected satiation alone does not predict actual intake of desserts**
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3 Etienne Guillocheau, Olga Davidenko, Agnès Marsset-Baglieri, Nicolas Darcel, Claire

4 Gaudichon, Daniel Tomé, Gilles Fromentin

6 (i) UMR Physiologie de la Nutrition et du Comportement Alimentaire, AgroParisTech, INRA,

7 Université Paris-Saclay, 75005, Paris, France

9 **Corresponding author:** Olga Davidenko, Physiologie de la Nutrition et du Comportement

10 Alimentaire, AgroParisTech, INRA, Université Paris-Saclay, 16 rue Claude Bernard, F-

11 75 005 Paris - E-mail: olga.davidenko@agroparistech.fr – Phone number +331 44 08 86 37

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61
62 **ABSTRACT**
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64 The degree to which consumers expect foods to satisfy hunger, referred to as expected
65 satiation, has been reported to predict food intake. Yet this relationship has not been
66 established precisely, at a quantitative level. We sought to explore this relationship in detail
67 by determining whether expected satiation predicts the actual intake of semi-solid desserts.
68
69 Two separate experiments were performed: the first used variations of a given food (eight
70 apple purées), while the second involved a panel of different foods within a given category
71 (eight desserts). Both experiments studied the consumption of two products assigned to
72 volunteers based on their individual liking and expected satiation ratings, given *ad libitum* at
73 the end of a standardised meal. A linear model was used to find predictors of food intake and
74 included expected satiation scores, palatability scores, BMI, age, sex, TFEQ-R, TFEQ-D,
75 water consumption during the meal, reported frequency of eating desserts, and reported
76 frequency of consuming tested products as explanatory variables. Expected satiation was a
77 significant predictor of actual food intake in both experiments (apple purée: $F(1,97) = 18.60$,
78 $P < 0.001$; desserts: $F(1,106) = 9.05$, $P < 0.01$), along with other parameters such as product
79 palatability and the volunteers' age, sex and food restriction (variation explained by the
80 model/expected satiation in the experiments: 57%/23% and 36%/17%, respectively).
81 However, we found a significant gap between expected and actual consumption of desserts,
82 on group and on individual level. Our results confirm the importance of expected satiation as
83 a predictor of subsequent food intake, but highlight the need to study individual consumption
84 behaviour and preferences in order to fully understand the role of expected satiation.
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109 **KEYWORDS:** Expected satiation; Food intake; Palatability.
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121 **36 INTRODUCTION**
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123 37 It has been shown that most people are able to plan their meals in terms of portion size (Fay et
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125 38 al., 2011; Hinton et al., 2013). Consumers can predict the degree to which foods are expected
126
127 39 to satisfy hunger when compared on a calorie-for-calorie basis, which is referred to as
128
129 40 expected satiation (Brunstrom & Rogers, 2009). What is less studied today is whether
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131 41 expected satiation is quantitatively related to actual food intake. It was reported that the
132
133 42 “perceived fullness” score was the best predictor of actual food intake among military
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135 43 personnel, since it could explain half of the variance associated with food intake (Pilgrim &
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137 44 Kamen, 1963). In addition, expected satiation was found to be significantly correlated with
138
139 45 the ideal portion size estimated by subjects (Brunstrom & Rogers, 2009; Brunstrom &
140
141 46 Shakeshaft, 2009). Despite this, very little work has been done to connect expected satiation
142
143 47 with real food intake: only one study by Wilkinson and colleagues (2012) suggested that
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145 48 among factors such as liking, appetite, food reward, body mass index (BMI) and food
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147 49 restriction and disinhibition scores, expected satiation might be a good predictor of food
148
149 50 intake. However, this study was performed using only one food (pasta with sauce), and it
150
151 51 would be difficult to generalise such findings to other commonly consumed foods. Expected
152
153 52 satiation is also dependent on context. Indeed, expected satiation is more important when
154
155 53 people are hungry than when sated (Brogden & Almiron-Roig, 2010). Given this, desserts
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157 54 present several interests to study expected satiation: first, they constitute a particular food
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159 55 group which is well-understood by the general public yet offers a variability of sensory and
160
161 56 nutritional characteristics; second, because desserts are consumed at the end of a meal when
162
163 57 people are already starting to experience satiation, a situation that allows to control the
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165 58 nutritional state of volunteers in ecological conditions. Despite this, little work has yet been
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167 59 done on desserts (Forde, Almiron-Roig, & Brunstrom, 2015). The objective of this study was
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180 therefore to expand our knowledge by studying the correlation between expected satiation and
181
182 actual food intake using a range of desserts in the context of a meal.
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184 This study had two objectives: (1) to confirm whether expected satiation could predict the
185
186 actual food intake of desserts, and whether the accuracy of this predictor depends on the
187
188 satiating power of the dessert or on its sensory characteristics; (2) to study the degree to which
189
190 expected satiation can be considered as a measure of the amounts of food actually consumed,
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192 at both the group and individual levels.
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196 197 **MATERIALS AND METHODS** 198

199 We present here the data resulting from two independent experiments which shared the same
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201 experimental design but featured different sets of products. The first study used eight apple
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203 purées only varying in texture (“apple purée” experiment), while the second used eight
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205 desserts commonly found on the French market (“dessert” experiment), which were more
206
207 dissimilar. The objective of this second experiment was to verify whether the results obtained
208
209 in the first experiment are generalisable to a larger group of foods. According to French law,
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211 the experimental protocols were approved by the French National Agency for Medicines and
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213 Health Products Safety (ANSM) and the Ethics Committee for Research Ile de France VII
214
215 (“apple purée” experiment: #2013-A00339-36; “dessert” experiment: #2015-A00089-40). All
216
217 participants received financial compensation for their participation.
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222 **Participants** 223

224 Two different panels of volunteers were recruited for the experiments in Paris (France) and its
225
226 surrounding area. All subjects were healthy non-smokers, aged from 18 to 60 years, with a
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228 normal weight (BMI ranging from 18 to 25 kg/m²) and not on a diet. They did not display any
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230 food allergies or dislikes regarding the foods proposed, and were not taking any medications
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239 85 known to affect appetite. Pregnant or breast-feeding women, athletes in training, people with
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241 86 a score ≥ 9 on the restraint subscale (TFEQ-R) or ≥ 8 on the disinhibition subscale (TFEQ-D)
242
243 87 of the Three-Factor Eating Questionnaire (Lesdema et al., 2012; Stunkard & Messick, 1985)
244
245 88 were excluded from the study. Moreover, since both experiments involved foods usually
246
247 89 consumed as desserts, we only recruited volunteers who stated that they were generally used
248
249 90 to eating a dessert at the end of their meals. The power calculation estimated that 54 subjects
250
251 91 were necessary for each experiment to show a 33-g difference in food intake (1/3 of a
252
253 92 standard portion) between the least and most satiating products with a power of 0.80. In order
254
255 93 to ensure spontaneous and natural behaviour during the sessions, the true purpose of the study
256
257 94 was not disclosed to the participants; instead they were told that the aim was to adjust the
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259 95 recipes of the products (apple purées or desserts).

262
263 96 Fifty-four participants (14 M, 40 F) were recruited for the “apple purée” experiment between
264
265 97 January and June 2014, according to the recruitment criteria described above. Their mean
266
267 98 (SEM) ages and BMI values were 25.0 (0.6) years and 20.9 (0.3) kg/m², respectively, and
268
269 99 their mean (SEM) restriction and disinhibition scores were 4.6 (0.2) and 4.9 (0.3),
270
271 100 respectively.

273 101 Fifty-seven participants (13 M, 44 F) were recruited for the dessert experiment between
274
275 102 February and June 2015, according to the recruitment criteria described above. Their mean
276
277 103 (SEM) ages and BMI values were 24.1 (0.5) years and 21.1 (0.2) kg/m², respectively, and
278
279 104 their mean (SEM) restriction and disinhibition scores were 5.2 (0.3) and 5.1 (0.3),
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281 105 respectively.

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286 107 **Study products**

288 108 For each experiment, a set of eight products was designed so that products within the set
289
290 109 would match two criteria: (1) similar energy content (maximum difference of 20 kcal/100 g

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297
298 110 among products), and (2) possibility to visually discriminate the products. The “apple purée”
299
300 111 experiment used eight apple purées obtained from one initial preparation (chunky apple purée
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302 112 with no added sugar from Andros®). The purees were adjusted in a way similar to that used
303
304 113 during a previous study by our team (Parizel et al., 2016) and varied in terms of particle size,
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306 114 pulp content and the addition of apple fragments (see Table 1 for details), which resulted in
307
308 115 perceived visual and texture differences. The “dessert” study used a set consisting of eight
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310 116 desserts selected from those commonly available in France and described during the same
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312 117 previous study (Parizel et al., 2016). This assortment was based on a free sorting test carried
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314 118 out by 32 untrained subjects (who were not the same as the participants in the present study)
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316 119 that allowed us to choose the most dissimilar desserts among a set of 16 products. These
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318 120 desserts included fruit purees, dairy products, custards and puddings; these differed with
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320 121 respect to several sensory modalities (colour, texture, flavour) but had similar nutritional
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322 122 contents (see Table 2 for details).
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328 124 **Evaluation of expected satiation**

329
330 125 Expected satiation was evaluated using a variation of the method developed by (Wilkinson et
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332 126 al., 2012). For each test food, 16 photographs were taken using a high-resolution digital
333
334 127 camera. The lighting conditions and viewing angles were identical for all photographs. The
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336 128 test foods were arranged in identical transparent bowls (Duralux®, 135 mm diameter). The
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338 129 portion size displayed on the photographs increased linearly in 25 kcal steps, from 25 kcal in
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340 130 photograph 1 to 400 kcal in photograph 16. Photograph 4 corresponded to a standard (100
341
342 131 kcal) portion. Each photograph was identified by a random three-figure number, and the 16
343
344 132 photographs of each test food were gathered in a single picture displayed on a tablet
345
346 133 (Samsung® Galaxy Tab 2 10.1, Android 4.1.2). During the evaluation of expected satiation,
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348 134 the participants were asked to look simultaneously at the 16 pictures, and then to “select the
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357 135 picture corresponding to the portion which they thought they needed to eat in order to feel full
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359 136 at the end of lunch”. In addition, the volunteers were given the bowl that had been used for
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361 137 the pictures of each test food, thus enabling them to estimate the real quantity associated with
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363 138 each picture.
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366 139

368 140 **Experimental procedure**

369
370 141 Each experiment consisted in four sessions that took place at lunch time. The participants
371
372 142 were asked to attend at the same time for all sessions, between 11.30 a.m. and 1.30 p.m., with
373
374 143 a one-week minimum gap between each session. They were instructed to eat the same evening
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376 144 meal the day before each test day and the same breakfast on each test day, and were asked to
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378 145 consume no food or drinks, except for plain water, between their breakfast and the session.
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380 146 During the sessions, the volunteers were served lunch in a quiet room free of any food
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382 147 references or other sources of distraction. Each participant was seated alone at a table, and
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384 148 visual contact between the volunteers was not possible. At the start of each session, the
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386 149 participants were first asked to indicate, on a 100-mm unmarked visual analogue scale (VAS),
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388 150 how they were feeling at the time they completed the following questions: How hungry do
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390 151 you feel now? (VAS anchors: not hungry at all–extremely hungry); How full do you feel
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392 152 now? (not full at all–extremely full); How strong is your desire to eat now? (very weak–very
393
394 153 strong); How much food do you think you could eat now? (nothing at all–a large amount);
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396 154 How thirsty do you feel now? (not thirsty at all–extremely thirsty) (using a French translation
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398 155 of the questions recommended by Blundell et al., 2010).

402 156 *Session 1: Expected satiation*

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404 157 After answering the appetite questionnaire, the participants were first of all served a main
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406 158 course composed of pasta with tomato sauce (Penne Tomate Basilic, Panzani®) and 500 mL
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408 159 water. The pasta dish was served *ad libitum* and the participants were instructed to eat as
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416 160 much as they wanted. The amounts of pasta and water consumed were then weighed and
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418 161 recorded with 0.1 g accuracy. Once the participants had eaten the pasta to fullness, they were
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420 162 asked to score its palatability using a 100-mm VAS (question: “How much do you like this
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422 163 dish?”, anchors: not at all-very much indeed). Next, the participants evaluated the expected
423
424 164 satiation associated with the set of products used during the experiment to which they
425
426 165 belonged (apple purées or desserts). The products were presented using a sequential monadic
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428 166 procedure, following a Williams Latin square design (Williams, 1949). First, a 25g sample of
429
430 167 the test food was served to the subjects and they were instructed to taste it and score its
431
432 168 palatability using a 100-mm VAS similar to that used for the pasta. Next, the subjects scored
433
434 169 the expected satiation of the product, as described previously.
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436

437 170 *Product assignment*

439 171 After the session on expected satiation, two foods from the set were assigned individually to
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441 172 each volunteer as a function of their individual expected satiation scores: the product for
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443 173 which the volunteer selected the smallest portion (referred to as “the most satiating product”
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445 174 below), and the product for which the volunteer selected the biggest portion (referred to as
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447 175 “the least satiating product” below). This was done in order to study whether the subjects
448
449 176 behave the same when they consume products providing different levels of expected satiety.
450
451 177 Since it has been shown that palatability may impact satiation (Bobroff & Kissileff, 1986),
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453 178 pairs of products were selected in such a way as to minimise differences in palatability,
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455 179 whenever possible.
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458 180 *Sessions 2, 3 and 4: Food intake*

459 181 During three subsequent sessions, the actual food intake of the two individually assigned
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461 182 products was measured. A single product was provided during each session. Two sessions
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463 183 featured the least satiating product in order to evaluate the stability of each participant’s
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465 184 behaviour. The order of sessions was randomised. In the same way as for the expected
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475 185 satiation session, the volunteers were first asked to complete the appetite questionnaire. Next,
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477 186 they were served the same amount of pasta as they had eaten during the expected satiation
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479 187 session, and were told to clean the plate (all participants complied with the instructions during
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481 188 all sessions). 500 mL water was also available. After cleaning their plates, the volunteers
482
483 189 scored the palatability of the pasta dish, as described above. They were then given a bowl
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485 190 containing 400 kcal of one of the individually assigned products as their dessert, and were
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487 191 instructed to eat it until they felt full. Afterwards, they were asked to score the palatability of
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489 192 the product using the same method as during the expected satiation session. Any remaining
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491 193 amounts of dessert and water (for the “dessert” experiment) were weighed and recorded with
492
493 194 an accuracy of 0.1-g. At the end of the last food intake session, the subjects were asked to
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495 195 state their frequency of consumption of the study desserts. For the “apple purée” experiment,
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497 196 they were asked to answer the question: “How often do you eat apple purée?” They had to
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499 197 choose between four answers: “At least once a week”, “At least once a month”, “At least once
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501 198 a year”, “Less than once a year”. For the “dessert” experiment, the identities of the
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503 199 individually assigned products were disclosed to the participants and they were asked the
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505 200 same question for each dessert separately.
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511 201
512 202 **Data analysis**
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514 203 The effect of the product on palatability scores collected during the expected satiation session
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516 204 was analysed using one-way ANOVA. The effect of product and palatability on expected
517
518 205 satiation scores (expressed as energy (kcal) and volume (in L)) were analysed using
519
520 206 ANCOVA. Bonferroni *post hoc* corrections were applied for multiple comparisons.
521
522 207 For each session, the appetite score of each participant was calculated as follows:
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525 208
$$\text{Appetite score} = \frac{(\text{Hunger} + \text{Prospective consumption} + \text{Desire to eat}) + (100 - \text{Fullness})}{4}$$

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533
534 209 Before further analysis, the stability of food behaviour was assessed using the data acquired
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536 210 during food intake sessions involving the least satiating product. Linear mixed models were
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538 211 used to analyse appetite scores, palatability scores and the amount of product consumed (as
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540 212 energy or as volume). The session, BMI, age, sex, TFEQ-R and TFEQ-D were used as fixed
541
542 213 effects and the participant as a random effect in order to adjust for repeated measures.

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544
545 214 The stability of appetite scores, palatability ratings, and amount of water consumed during the
546
547 215 food intake sessions (“dessert” experiment only) for products during each session was
548
549 216 assessed using linear mixed models with the session, BMI, age, sex, TFEQ-R and TFEQ-D as
550
551 217 fixed effects and the participant as a random effect. Tukey *post hoc* tests were used to
552
553 218 estimate the means.

554
555 219 A linear model was constructed in order to assess predictors of food intake (as energy or as
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557 220 volume). This model included expected satiation scores (as energy or as volume), palatability
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559 221 scores, mean amount of water consumed during the food intake sessions (for the “dessert”
560
561 222 experiment only), BMI, age, sex, TFEQ-R, TFEQ-D, reported frequency of eating a dessert at
562
563 223 the end of a meal, and reported frequency of consuming the test foods as explanatory
564
565 224 variables.

566
567
568 225 Because expected satiation and actual food intake data were not collected using the same
569
570 226 method, these parameters could not be compared using a single procedure. Four linear mixed
571
572 227 models were therefore used to compare (1) expected satiation *vs.* actual food intake
573
574 228 (separately for two individually selected products), and (2) actual food intake of two
575
576 229 individually selected products (separately for expected satiation session and food intake
577
578 230 sessions). All models included BMI, age, sex, TFEQ-R, TFEQ-D, mean amount of water
579
580 231 consumed during the food intake sessions (for the “dessert” experiment only), reported
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582 232 frequency of eating a dessert at the end of a meal and reported frequency consumption of test
583
584 233 foods as fixed factors and the participant as a random factor.

591
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593 234 Individual intake data were studied by computing the difference between actual food intake
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595 235 and expected satiation relative to the two individually assigned products for each subject. We
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597 236 considered there was a match between expected satiation and actual food intake if this
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599 237 difference was less than 1/3 of a portion (33 g).
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601
602 238 All statistical computations were carried out using R 3.2.1. for Windows ([http://www.cran.r-](http://www.cran.r-project.org/)
603
604 239 [project.org/](http://www.cran.r-project.org/)), using the “car” and “lme” packages, and type II tests. P-values <0.05 were
605
606 240 considered to be statistically significant. All data are presented as mean ± SEM.
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608 241

610 242 **RESULTS**

612 243 ***EXPERIMENT 1: APPLE PURÉES***

614 244 **Stability of food behaviour and appetite sensations**

616 245 For food intake sessions involving the least satiating apple purée, there was no significant
617
618 246 effect of the session on appetite status ($\chi^2(1) = 0.003$, NS), palatability scores ($\chi^2(1) = 0.62$,
619
620 247 NS) and the amount of apple purée actually consumed (energy content and volume: $\chi^2(1) =$
621
622 248 0.14 , NS). Therefore, the mean values of the two sessions were used for subsequent analyses.
623
624 249 No significant effect of the session was seen regarding the appetite status of volunteers ($\chi^2(1)$
625
626 250 $= 5.62$, NS) during the four study sessions.
627

628 251

631 252 **Expected satiation session: palatability and expected satiation for the entire apple purée** 632 633 253 **set**

635 254 We found a significant product effect on palatability scores ($F(7,408) = 3.22$, $P < 0.01$), during
636
637 255 the expected satiation session (see Table 1). There was no significant effect of product on
638
639 256 expected satiation scores, expressed as energy ($F(7,407) = 0.72$, NS) or as volume ($F(7,407) =$
640
641 257 0.73 , NS), but the palatability effect on expected satiation was significant (energy and
642
643 258 volume: $F(1,407) = 117.9$, $P < 0.001$).
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260 **Palatability scores for individually assigned apple purées**

261 The most satiating apple purée was rated as being significantly less palatable than the least
262 satiating apple purée during the expected satiation session ($P < 0.001$, see Figure 1A). During
263 the food intake sessions the most satiating apple purée consistently received lower palatability
264 scores than the least satiating apple purée ($P < 0.01$). The volunteers were consistent in their
265 ratings of the least satiating apple purée, since there was no significant difference between
266 ratings given during the expected satiation session and the food intake sessions ($P = 0.87$). By
267 contrast, the most satiating apple purée was significantly more appreciated during the food
268 intake session than during the expected satiation session ($P < 0.001$).

269

270 **Expected satiation and food intake**

271 We found a significant difference in expected satiation ratings between the most satiating and
272 least satiating apple purées (energy: $\chi^2(1) = 51.46$, $P < 0.001$, see Figure 1B; volume: $\chi^2(1) =$
273 52.19 , $P < 0.001$ see Figure 1C). This difference remained throughout the food intake sessions
274 as the most satiating apple purée was significantly less consumed than the least satiating apple
275 purée (analysis in terms of both energy and volume gave the same result: $\chi^2(1) = 4.83$, P
276 < 0.05). However, the actual food intake of the most satiating apple purée was significantly
277 larger (energy: $\chi^2(1) = 48.37$, $P < 0.001$; volume: $\chi^2(1) = 47.51$, $P < 0.001$) than expected,
278 while there was no significant difference between expected satiation and the actual food
279 intake of the least satiating apple purée (energy: $\chi^2(1) = 1.96$, NS; volume: $\chi^2(1) = 1.93$, NS).

280

281 **Predictors of food intake**

282 The linear model revealed that actual food intake (as energy) was predicted by expected
283 satiation ($F(1,97) = 18.60$, $P < 0.001$), sex ($F(1,97) = 17.66$, $P < 0.001$), TFEQ-R ($F(1,97) =$

284 20.95, $P < 0.001$), age ($F(1,97) = 5.50$, $P < 0.05$) and the palatability score given during the
285 food intake session ($F(1,97) = 6.64$, $P < 0.05$). The model accounted for 57% of the variance
286 associated with food intake ($R^2 = 0.57$). **Expected satiation was the first predictor in terms of**
287 **explained variance (23%)**. After adjustment for the reported frequency of eating a dessert at
288 the end of a meal, and the reported frequency of consuming apple purées, these parameters
289 remained significant predictors of food intake. The adjusted model accounted for 58% of the
290 variance in food intake ($R^2 = 0.58$). Comparable results were obtained when expressing food
291 intake as volume. Expected satiation, sex, TFEQ-R, age and palatability scores at the food
292 intake session remained good predictors of actual food intake, even when adjusting for
293 experience parameters. Likewise, the adjusted model accounted for more than the half of the
294 variance associated with food intake when expressed as volume ($R^2 = 0.58$).

296 **Consistency between food intake and expected satiation at an individual level**

297 Individual food intake was plotted against expected satiation (as energy) for the most and
298 least satiating apple purées (see Figure 3). The actual food intake of the most satiating apple
299 purée was higher than the expected satiation in all participants except one. However, some
300 participants consumed less of the least satiating apple purée than expected, and the differences
301 between expected and actual consumption were within a broader range for this product. After
302 matching individual values, we found that only five subjects consumed within 1/3 of a portion
303 (+/- 33 g or +/- 18.7 kcal) of the expected satiation of both products. Four more subjects were
304 within the limits for the most satiating puree only and 11 for the least satiating puree only.

306 **EXPERIMENT 2: DESSERTS**

307 **Stability of food behaviour and appetite sensations**

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769
770 308 There was no significant effect of the session on appetite status ($\chi^2(1) = 0.40$, NS), palatability
771
772 309 scores ($\chi^2(1) = 0.09$, NS) and the amount of the least satiating dessert consumed during two
773
774 310 food intake sessions (energy: $\chi^2(1) = 0.23$, NS; volume: $\chi^2(1) = 0.32$). Therefore, as for the
775
776 311 “apple purée” experiment, the mean values of the two sessions were used for subsequent
777
778 312 analyses. No significant effect of session was found on the appetite status of volunteers ($\chi^2(1)$
779
780 = 5.54, NS) during the four study sessions. No significant effect of session was found on the
781
782 amount of water consumed during the food intake sessions ($\chi^2(2)=1.1092$, NS).
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787 316 **Expected satiation session: palatability and expected satiation for the entire dessert set**

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789 317 We found a product effect on the palatability scores ($F(7,447) = 2.82$, $P < 0.01$, see Table 2)
790
791 318 collected during the expected satiation session. There was no significant effect of product
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793 319 ($F(7,447) = 0.48$, NS) on expected satiation scores when expressed as energy. However, we
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795 320 observed an significant effect of product ($F(7,447) = 4.29$, $P < 0.001$) when expected satiation
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797 321 was expressed as volume. As in the “apple purée” experiment, the effect of palatability on
798
799 322 expected satiation scores was significant (energy: $F(1,447) = 98.70$, $P < 0.001$; volume:
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801 $F(1,447) = 98.22$, $P < 0.001$).
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806 325 **Palatability scores of individually assigned desserts**

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808 326 The most satiating dessert was rated as being significantly less palatable than the least
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810 327 satiating dessert during the expected satiation session ($P < 0.001$, see Figure 2A). The most
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812 328 satiating dessert was consistently associated with a lower palatability score during the food
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814 329 intake sessions when compared to the least satiating dessert ($P < 0.001$). No significant
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816 330 difference in palatability scores was found between the expected satiation session and food
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818 331 intake sessions ($P = 0.99$ and $P = 0.13$ for the least and most satiating desserts, respectively).
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829 332 The mean palatability for each dessert was therefore determined and used for subsequent
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831 333 calculations.
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835 335 **Expected satiation and actual food intake**

836 336 As expected, the expected satiation scores assigned to the most and least satiating desserts
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838 336 As expected, the expected satiation scores assigned to the most and least satiating desserts
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840 337 were significantly different (energy: $\chi^2(1) = 115.24$, $P < 0.001$, see Figure 2B; volume: $\chi^2(1) =$
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842 338 90.97 , $P < 0.001$, see Figure 2C). However, actual intakes did not differ between these two
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844 339 desserts (energy: $\chi^2(1) = 0.32$, NS; volume: $\chi^2(1) = 1.15$, NS). Participants consumed
845
846 340 significantly more of the most satiating dessert than expected (energy: $\chi^2(1) = 24.60$, P
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848 341 < 0.001 ; volume: $\chi^2(1) = 23.16$, $P < 0.001$), while the reverse applied for the least satiating
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850 342 dessert (energy: $\chi^2(1) = 14.03$, $P < 0.001$; volume: $\chi^2(1) = 15.88$, $P < 0.001$).
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854 344 **Predictors of food intake**

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857 345 The linear model revealed that actual food intake (expressed as energy) was predicted by
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859 346 palatability ($F(1,105) = 22.56$, $P < 0.001$), expected satiation ($F(1,105) = 7.92$, $P < 0.01$) and
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861 347 TFEQ-R ($F(1,105) = 4.99$, $P < 0.05$). The model accounted for 36% of the variance associated
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863 348 with food intake ($R^2 = 0.36$). Expected satiation was the first predictor (17% expected
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865 349 variance) and palatability explained 11% of the total variance. Expected satiation and
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867 350 palatability, but not the TFEQ-R, remained significant after adjustment for the reported
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869 351 frequency of eating a dessert at the end of a meal, and the reported frequency of consuming
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871 352 both contrasting desserts. The adjusted model accounted for 40% of the variance associated
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873 353 with food intake ($R^2 = 0.40$). When actual food intake was expressed as volume, palatability
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875 354 and expected satiation remained significant predictors of food intake before ($F(1,105) =$
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877 355 16.51 , $P < 0.001$ and $F(1,105) = 4.38$, $P < 0.05$, respectively) and after adjustment ($F(1,105) =$
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879 356 11.92 , $P < 0.001$ and $F(1,105) = 5.56$, $P < 0.05$, respectively), and the mean volume of water
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888 357 consumed during the session became a significant predictor as well (before adjustment:
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890 358 $F(1,105) = 7.59, P < 0.01$; after adjustment: $F(1,105) = 8.15, P < 0.01$). The adjusted model
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892 359 accounted for more than a third of the variance associated with food intake ($R^2 = 0.35$).
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896 361 **Consistency between actual food intake and expected satiation at an individual level**

897 362 Individual differences between actual food intake and expected satiation (as energy) regarding
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899 363 the most and least satiating apple purées are plotted on Figure 4. Most volunteers (75%)
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901 364 consumed more of the most satiating dessert than expected. We observed more mixed results
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903 365 with the least satiating dessert. Only five subjects consumed within 1/3 of a portion (+/- 33 g
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905 366 or +/- 33.4 kcal) from the expected portions of both desserts. Twenty-four more were within
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907 367 the range for one of the products (nine for the least satiating and 15 for the most satiating,
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909 368 respectively).
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913 369 **DISCUSSION**

914 370
915 371 Our experiments studied the relationship between expected satiation and the actual intake of
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917 372 common semi-liquid desserts. We used a set of versions of a single food (the “apple purée”
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919 373 experiment, products varying in texture only) and a set of different foods within a given
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921 374 category (the “dessert” experiment, products varying in different characteristics) in order to
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923 375 generalize the results of the first experiment to a wider food category. Furthermore, the use of
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925 376 individually assigned products allowed us to study the relationship between expected satiation
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927 377 and actual intake using a within-subject design, and to test the robustness of the relationship
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929 378 between these parameters for different levels of expected satiation. During both experiments,
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931 379 we found that expected satiation was a significant predictor of the actual intake of selected
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933 380 products. Nevertheless, the quantities actually consumed were close (within 33 g) to the
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935 381 expected portions in only a small minority of subjects (9%), while actual intakes were stable
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947 382 across the sessions. We must therefore conclude that expected satiation could not be
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949 383 considered as an alternative measure of food intake in the case of spoonable desserts, and
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951 384 other factors should be taken into account.

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953 385 Our study showed that expected satiation is a significant predictor of the actual intake of
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955 386 desserts, alongside palatability and other factors such as age, sex or TFEQ-R scores. Our
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957 387 findings were partly in contradiction with previous results which had shown that expected
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959 388 satiation was the only significant predictor of intake (Wilkinson et al., 2012). Such a
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961 389 difference in the results might have been caused by our choice to work with desserts, products
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963 390 that are more likely to be consumed for their hedonic value than the pasta with sauce used in
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965 391 Wilkinson's study. The variance associated with palatability was therefore higher in our
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967 392 experiment.

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971 393 While expected satiation performed quite well as a predictor of actual intake within the linear
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973 394 model, the results were more nuanced when expected satiation scores and actual intakes were
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975 395 compared quantitatively. With the exception of the least satiating apple purée, a significant
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977 396 difference was observed between mean actual intake and mean expected satiation, in line with
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979 397 the findings of a previous study (P S Hogenkamp, Mars, Stafleu, & de Graaf, 2012). In order
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981 398 to determine the proportion of participants who could be considered as "consistent", we fixed
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983 399 a threshold of congruence between actual intakes and expected satiation. Although this
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985 400 threshold was chosen to be relatively permissive (1/3 of a standard portion), only ten out of
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987 401 111 participants (9%) fell within this threshold for both the most and the least satiating
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989 402 products, and a further 39 (35%) fell within this threshold for only one of the two products.

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991 403 The difference between expected and actual intake could be explained by a significant change
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993 404 in mean palatability scores between sessions for the most satiating apple purée (35 and 52 for
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995 405 the expected satiation session and food intake session, respectively) (Bobroff & Kissileff,
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997 406 1986), because palatability was identified as a predictor of actual intake. But although
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1006 407 palatability remained constant in the “dessert” experiment, we observed even less consistency
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1008 408 between expected and actual intakes during the second study, thus showing that factors other
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1010 409 than palatability might be involved. One of such factors might be the nature of the products
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1012 410 used. Indeed, purées and desserts eaten with a spoon are usually consumed in individual pre-
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1014 411 packaged portions of comparable size. While the intakes recorded *ad libitum* were likely to
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1016 412 reflect a real willingness to eat, they still might have been influenced by previous experiences
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1018 413 with pre-packaged foods. This could explain why we did not observe difference in actual
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1020 414 intake between the most and the least satiating product in the “dessert” study. Previous
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1022 415 experience with such foods might have driven the subjects to consume a portion close to the
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1024 416 habitual portion, disregarding the difference in palatability (high enough in case of desserts).
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1026 417 Besides, it is possible that during the “expected satiation” session, the task of judging eight
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1028 418 products simultaneously led to a more precise categorisation during the expected satiation
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1030 419 session and caused more differentiation in palatability and expected satiation by a process
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1032 420 comparable to a hedonic contrast effect where “good things (here, better liked products) make
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1034 421 less good things even worse” (Hayes, DePasquale, & Moser, 2011; Parizel et al., 2015;
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1036 422 Zellner, Allen, Henley, & Parker, 2006). Compared to this, the food intake sessions involved
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1038 423 a more natural situation of consuming one dessert and partly abolished satiation and
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1040 424 palatability differences. Finally, the amount of water intake displayed a significant influence
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1042 425 on the volume of desserts consumed. Still, since the actual consumption was not
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1044 426 systematically lower than anticipated, water did not suppress the intake, and besides, water
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1046 427 intake was not a predictor of caloric intake.

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1048 428 Beyond its influence on actual intake, in both experiments palatability also appeared to be
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1050 429 correlated with expected satiation itself, although the study design does not allow to draw a
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1052 430 causality relationship. By contrast, the product effect appeared to be a less important
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1054 431 determinant of expected satiation, particularly in the “apple purée” experiment. This was
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1065 432 contrary to what had been expected, because the apple purées we used varied in texture and
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1067 433 previous studies had shown that texture influences expected satiation (Pleunie S Hogenkamp,
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1069 434 Stafleu, Mars, Brunstrom, & de Graaf, 2011; McCrickerd, Chambers, Brunstrom, &
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1071 435 Yeomans, 2012). However, previous findings were based on much more diverse sets of
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1073 436 products, ranging from solid to liquid, while the apple purées in our experiment were all semi-
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1075 437 solid and varied in density and the amount of chunks rather in terms of their food form. The
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1077 438 same applied to the set of products used in the “dessert” experiment. However, in the second
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1079 439 experiment, differences in expected satiation could be explained by the product factor when it
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1081 440 was expressed in volume rather than in calories. This might signal an adjustment of
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1083 441 consumption for energy rather than for volume, as the product set in the “dessert” experiment
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1085 442 was more variable in caloric density ($SD = 0.094$) than the set used for the “apple purée”
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1087 443 experiment ($SD = 0.005$). How energy density can be detected at the stage of expected
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1089 444 satiation still needs to be studied.

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1091 445 Our experiments used foods that are usually consumed as desserts and they were
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1093 446 served at the end of a lunch. This design served two purposes: first, it was more ecological
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1095 447 because the desserts are chosen and consumed at the end of the meal, and second, the
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1097 448 standardised main course allowed us to control the appetite status of the volunteers, because it
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1099 449 has been shown that appetite status impacts expected satiation (Brogden & Almiron-Roig,
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1101 450 2010). This design differed crucially from that of previous studies involving a variety of test
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1103 451 foods from different categories. For instance, the study by (Brunstrom, Shakeshaft, & Scott-
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1105 452 Samuel, 2008) included main courses (pizza, boiled potatoes), but also snack foods (crackers,
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1107 453 potato crisps) and other types of foods (fresh banana). Our design explains the overall stability
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1109 454 of expected satiation among test foods, as well as that of liking scores and actual intakes.
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1111 455 However, our experiments only used semi-solid foods that could be eaten with a spoon. The
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456 outcomes might have been different if we had included solid desserts such as pies or fruit
457 pieces, or liquids such as milkshakes.

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459 **CONCLUSIONS**

460 Our results may generate conflicting views regarding the importance of expected satiation to
461 food intake in humans. On the one hand, our study confirmed that expected satiation is a
462 predictor of actual intake, which is consistent with previous studies. However, we also
463 showed that other parameters, and especially palatability, were also predictors of intake. **The**
464 **importance of expected satiation could therefore be questioned if it were to be considered as a**
465 **means of controlling food intake, especially in case of highly palatable foods. Reasoning at an**
466 **individual level, taking into account personal preferences, is necessary if the objective is to**
467 **limit the consumption of highly palatable foods such as desserts, for example in order to**
468 **control weight gain.** Further research is now needed to fully understand the role of expected
469 satiation as it relates to food intake, in different individuals and food groups.

470
471 **Funding acknowledgement.** This research did not receive any specific grant from funding
472 agencies in the public, commercial, or not-for-profit sectors.

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TABLE 1Formulation parameters, mean (\pm SEM) palatability scores and expected satiation of the products used during the apple purée experiment.

	Formulation parameters			Energy (kcal/100 g)	Density (100 mm scales)	Palatability		Expected satiation	
	Grinding ¹	Added pulp ²	Apple fragments ³			kcal	L litre??		
Hd	2	-1	0	54.0	0.986	40 \pm 4	61.0 \pm 6.3	0.11 \pm 0.01	
HdF	2	-1	1	56.2	0.986	50 \pm 3	62.7 \pm 6.0	0.12 \pm 0.01	
HC	2	1	0	58.1	0.995	42 \pm 3	64.7 \pm 6.3	0.12 \pm 0.01	
HCF	2	1	1	57.2	0.992	44 \pm 3	56.2 \pm 4.8	0.10 \pm 0.01	
L	1	0	0	56.0	0.993	53 \pm 3	66.2 \pm 5.4	0.12 \pm 0.01	
LF	1	0	1	55.6	1.000	56 \pm 3	68.7 \pm 5.1	0.13 \pm 0.01	
LC	1	1	0	58.9	0.994	51 \pm 3	68.6 \pm 5.5	0.13 \pm 0.01	
LCF	1	1	1	57.6	0.988	53 \pm 3	62.5 \pm 5.2	0.12 \pm 0.01	
Heterogeneity	-	-	-	-	-	$P < 0.01$	$P = 0.72$	$P = 0.73$	

¹An initial apple purée was ground at two levels: weak (1) and strong (2).²Addition of pulp to ground apple purées (1); No added pulp (0); Dilution of ground apple purée (-1).³Addition of apple fragments to ground apple purées (1); No added apple fragments (0).

TABLE 2

Macronutrient and energy content, mean (\pm SEM) palatability scores and expected satiation of the products used during the dessert experiment.

	Energy (kcal/100 g)	Carbohydrates (g/100 g)	Fat (g/100 g)	Protein (g/100 g)	Density	Palatability		Expected satiation	
						(100 mm scales)		kcal	L
Apple purée	94.0	22.0	0.1	0.3	1.23	64 \pm 3	164.0 \pm 9.7	0.14 \pm 0.01	
Chocolate dessert cream	112.0	16.7	3.6	3.1	1.15	56 \pm 4	149.6 \pm 9.2	0.12 \pm 0.01	
Natural yogurt ¹	95.5	12.2	3.4	4.2	1.08	58 \pm 3	145.6 \pm 8.6	0.14 \pm 0.01	
Protein-rich yogurt ²	96.5	9.1	2.4	8.7	1.01	63 \pm 3	152.2 \pm 9.2	0.16 \pm 0.01	
Prune yogurt	97.0	12.0	3.3	3.5	0.97	56 \pm 4	138.2 \pm 8.6	0.15 \pm 0.01	
Raspberry puree	93.0	20.0	0.2	0.8	1.14	63 \pm 4	147.4 \pm 10.1	0.14 \pm 0.01	
Raspberry-blueberry yogurt	108.0	12.0	5.3	2.5	1.08	68 \pm 2	161.0 \pm 7.9	0.14 \pm 0.01	
Rice pudding	113.0	20.7	2.2	2.4	1.21	49 \pm 3	132.5 \pm 9.1	0.10 \pm 0.01	
Heterogeneity	-	-	-	-	-	$P < 0.01$	$P = 0.85$	$P < 0.01$	

¹The nutritional composition takes account of the addition of 6.64 g sugar per 100 g of natural yogurt, in order to obtain an energy density close to 100

kcal/100 g.

²The nutritional composition takes account of the addition of 5.78 g sugar per 100 g of protein-rich yogurt, in order to obtain an energy density close to 100

kcal/100 g.

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1424 **555 FIGURE LEGENDS**
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1428 **557 FIGURE 1**
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1430 558 “Apple purée” experiment: mean (\pm SEM) palatability score (A), mean (\pm SEM) amount
1431 559 (kcal) (B) and mean (\pm SEM) volume (L) (C) for both contrasting apple purées during the
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1433 560 expected satiation session and food intake sessions. The value for the least satiating apple
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1435 561 purée during the food intake session corresponds to the mean intakes during the food intake
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1437 562 sessions that involved this product.

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1439 563 Within-product differences: $P < 0.001$ (***).

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1441 564 Within-session differences: $P < 0.05$ (#), $P < 0.01$ (†), $P < 0.001$ (§).
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1447 **566 FIGURE 2**
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1449 567 Dessert experiment: mean (\pm SEM) palatability score (A), mean (\pm SEM) amount (kcal) (B)
1450 568 and mean (\pm SEM) volume (L) (C) for both contrasting desserts during the expected satiation
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1452 569 session and food intake sessions.

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1454 570 The value for the least satiating dessert during the food intake session corresponds to the
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1456 571 mean intakes during the food intake sessions that involved this product.

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1458 572 Within-product differences: $P < 0.001$ (***).

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1460 573 Within-session differences: $P < 0.001$ (§).
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1466 **575 FIGURE 3**
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1468 576 Analysis of individual consumption (“apple purée” experiment). The actual intakes by
1469 577 participants of individually selected apple purées plotted against the expected satiation of each
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1471 578 of the two products. (•) corresponds to the most satiating apple purée. (°) corresponds to the
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1473 579 least satiating apple purée (for each data point, the mean value of the two intake sessions for
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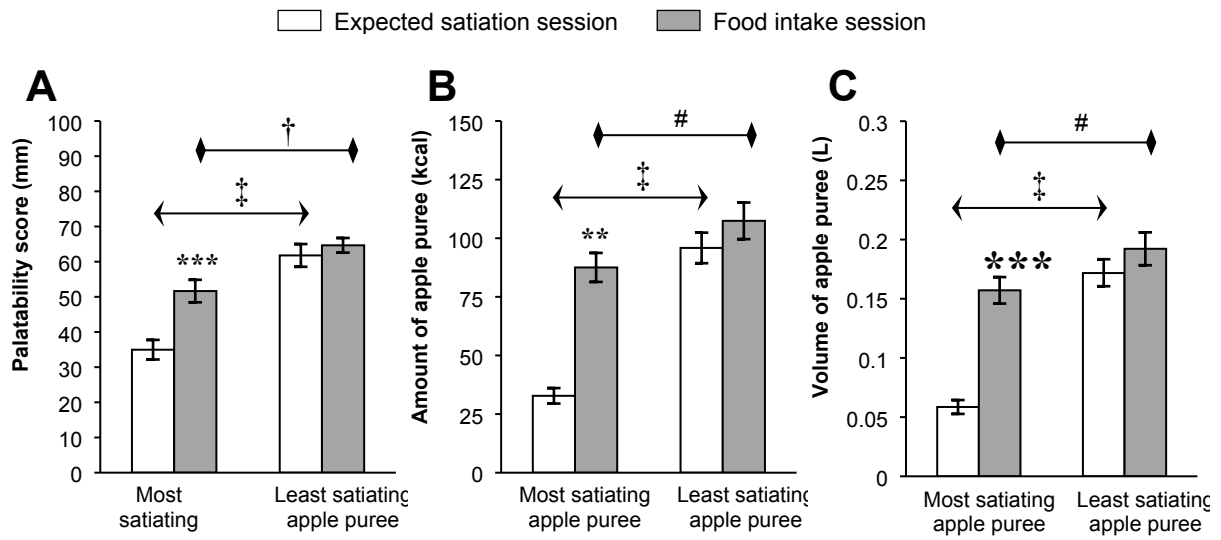
580 this product has been plotted). The solid line represents the area of no differences between
581 food intake and expected satiation. Hatched lines indicate the “consistency threshold” of ± 33
582 g (1/3 of a standard portion; 18.7 kcal for the “apple purée” experiment.

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FIGURE 4
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585 Analysis of individual consumption (“dessert” experiment). The actual intakes by participants
586 of individually selected desserts plotted against the expected satiation of each of the two
587 products. (•) corresponds to the most satiating dessert. (°) corresponds to the least satiating
588 dessert (for each data point, the mean value of the two intake sessions for this product has
589 been plotted). The solid line represents the area of no differences between food intake and
590 expected satiation. Hatched lines indicate the “consistency threshold” of ± 33 g (1/3 of a
591 standard portion; 33.4 kcal for the “dessert” experiment.

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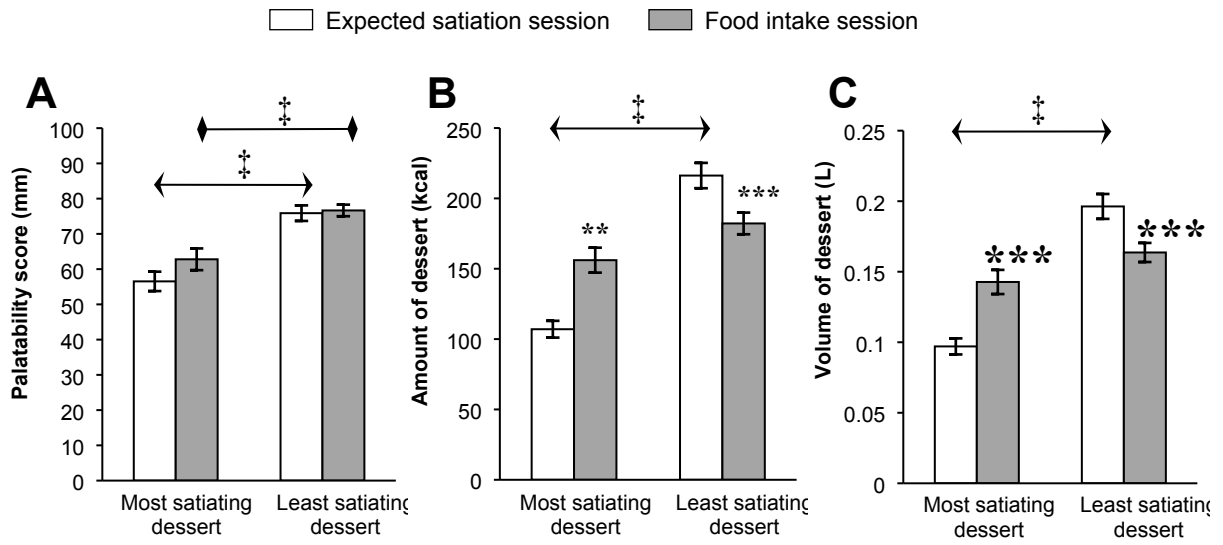
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594 **FIGURE 1**



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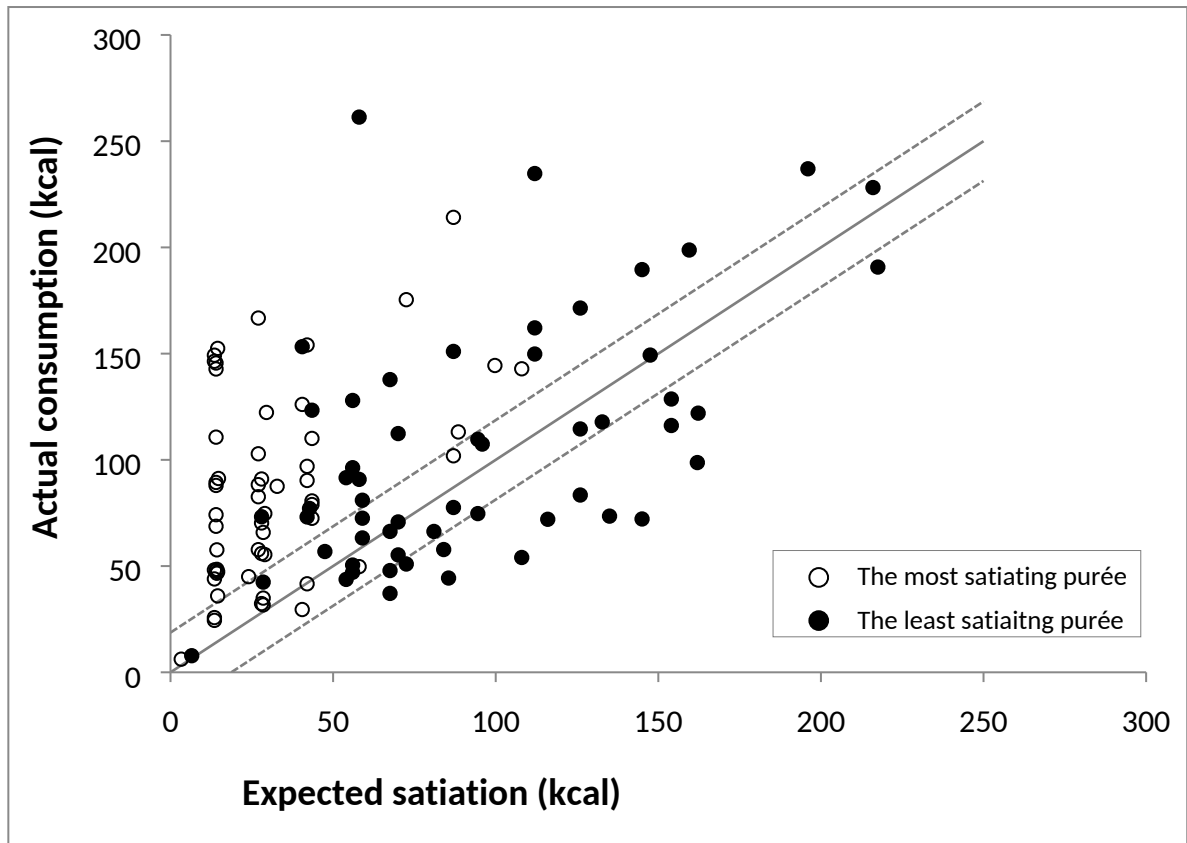
599 **FIGURE 2**



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FIGURE 3

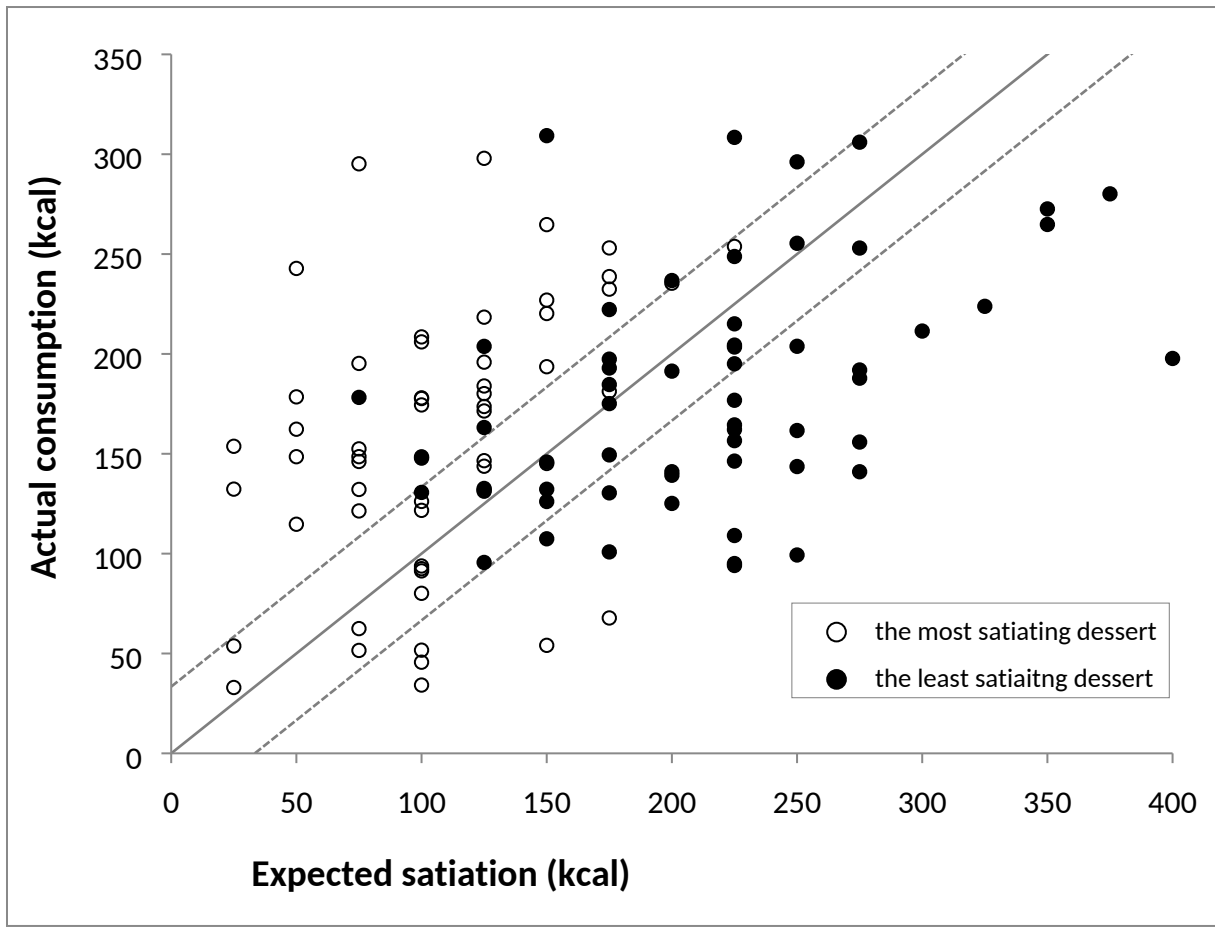


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607 **FIGURE 4**



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