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1 **MONOTONOUS CONSUMPTION OF FIBRE-ENRICHED BREAD**  
2 **AT BREAKFAST INCREASES SATIETY AND INFLUENCES**  
3 **SUBSEQUENT FOOD INTAKE**

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20 **ABSTRACT**

21 This study aimed to observe the influence of the monotonous consumption of two  
22 types of fibre-enriched bread at breakfast on hedonic liking for the bread, subsequent  
23 hunger and energy intake. Two groups of unrestrained normal weight participants were  
24 given either white sandwich bread (WS) or multigrain sandwich bread (MG) at  
25 breakfast (the sensory properties of the WS were more similar to the usual bread eaten  
26 by the participants than those of the MG). In each group, two 15-day cross-over  
27 conditions were set up. During the experimental condition the usual breakfast of each  
28 participant was replaced by an isocaloric portion of plain bread (WS or MG). During  
29 the control condition, participants consumed only 10 g of the corresponding bread and  
30 completed their breakfast with other foods they wanted. The results showed that bread  
31 appreciation did not change over exposure even in the experimental condition. Hunger  
32 was lower in the experimental condition than in the control condition. The consumption  
33 of WS decreased energy intake while the consumption of MG did not in the  
34 experimental condition compared to the corresponding control one. In conclusion, a  
35 monotonous breakfast composed solely of a fibre-enriched bread may decrease  
36 subsequent hunger and, when similar to a familiar bread, food intake.

37 **Keywords**

38 Dietary fibre, weight loss, monotony, variety, staple foods, bread, food intake, satiety,  
39 satiation, breakfast

40

41

## 42 **Introduction**

43       Several studies have shown that a high-fibre diet may increase satiety and decrease  
44 energy intake (for recent studies see Lyly et al., 2009; Schroeder, Gallaher, Arndt, &  
45 Marquart, 2009; Willis, Eldridge, Beiseigel, Thomas, & Slavin, 2009). Several  
46 mechanisms have been put forward to explain the lower hunger/energy intake following  
47 the ingestion of dietary fibre (Burton-Freeman, 2000; Heaton, 1973; Howarth,  
48 Saltzman, & Roberts, 2001; Tunglund & Meyer, 2002). Dietary fibre increases  
49 chewing, which is thought to reduce the rate of ingestion (Heaton, 1973). It increases  
50 saliva and gastric juice production and therefore increases gastric volume (Norton,  
51 Anderson, & Hetherington, 2006; Rolls & Roe, 2002). Furthermore, the gel-forming  
52 capacity of soluble fibre increases gastric distension (Burton-Freeman, 2000). This  
53 distension is involved in producing satiation during a meal (de Graaf, Blom, Smeets,  
54 Stafleu, & Hendriks, 2004) and satiety between meals (Wang et al., 2008). Fibre  
55 decreases nutrient absorption in the intestine and thus reduces the metabolisable energy  
56 from available food (Baer, Rumpler, Miles, & Fahey, 1997; Wisker, Maltz, & Feldheim,  
57 1988). Fibre, particularly soluble fibre, also increases chyme viscosity, thereby slowing  
58 transit time in the small intestine which triggers the secretion of Glucagon Like Peptide-  
59 1 (Reimer & McBurney, 1996), of cholecystokinin, of ghrelin (Weickert et al., 2006)  
60 and of peptide YY (Reimer et al., 2010).

61       The aim of the present experiment was to assess whether replacing the usual  
62 breakfast of normal bodyweight participants by an isocaloric portion of fibre-enriched  
63 bread over several days would affect subsequent satiety and food intake. At first sight,  
64 it was expected that a fibre-enriched breakfast would reduce hunger sensation during the

65 morning and decrease food intake during subsequent meals. However, it was unclear  
66 whether or not this effect would persist over several days (e.g. over repeated  
67 consumption) of fibre-enriched bread. In fact, several studies have shown that repeated -  
68 monotonous - consumption of a food induces a decrease in pleasure for that food (Rolls  
69 & de Waal, 1985; Schutz & Pilgrim, 1958; Siegel & Pilgrim, 1958). Thus, the repeated  
70 consumption of fibre-enriched bread may lead to a reduction in pleasure, which in turn  
71 may have an adverse effect on subsequent food intake. This question is obviously of  
72 particular interest to those who wish to promote better weight management through the  
73 consumption of “functional” food such as fibre-enriched foods.

74 This study was conducted using two types of fibre-enriched sandwich bread. In  
75 both types, the quantity of fibre was about five times higher than in a traditional French  
76 baguette. The ratio of soluble/insoluble fibre was similar between the two breads but  
77 the source of the fibre differed. One bread (White Sandwich - WS) was formulated to  
78 look like white sandwich bread because French consumers are used to eat white bread  
79 (75% of the bread eaten in France in 2009 was white bread). The other (Multigrain -  
80 MG) bread actually looked like a multigrain bread with inclusions and was less familiar  
81 to French consumers. The choice of exposing participants to sandwich bread at  
82 breakfast was motivated by the work of de Castro (2007) who observed that a high level  
83 of carbohydrate consumed during the morning reduced total food intake for the rest of  
84 the day.

85 The present experiment aimed to assess whether or not the effect of monotonous  
86 consumption of fibre-enriched bread could influence subsequent satiety and food intake,  
87 and whether such an effect depended on the type of bread eaten by the participants.

## 88 **Materials and methods**

### 89 ***Design***

90       The two types of bread were tested in a between-subject design. For each group,  
91 the study consisted in two periods of 15 days. In one period, the experimental  
92 condition, the participants' breakfast consisted exclusively of fibre-enriched bread (*i.e.*  
93 WS or MG, depending on the group). For each participant, the quantity of bread  
94 consumed provided an energy intake that was similar to that of the participants' usual  
95 breakfast according to food diaries (see below). In the other period, the control  
96 condition, participants ate a small portion of fibre-enriched bread (10 g) and then  
97 completed their breakfast with the food of their choice. The quantity of fibre in such a  
98 small portion was negligible, but it allowed controlling for a possible effect of repeated  
99 exposure to the sensory characteristics of the bread that was independent from the effect  
100 of the fibre. For each condition, liking, hunger and food intake were measured and  
101 recorded at regular intervals (see below).

### 102 ***Participants***

103       Participants were recruited by a local advertisement. All were bread eaters. To  
104 participate, candidates had to be aged between 20 and 45, have a Body Mass Index  
105 (BMI) between 19 and 25 kg/m<sup>2</sup> and be in the habit of eating breakfast, including at  
106 least one solid food, every day. Candidates also had to obtain a restriction score equal  
107 to or below 9 (Stunkard & Messick, 1985). Finally, any candidates with food allergies,  
108 or who were undergoing medical treatment, or who smoked more than five cigarettes a  
109 day were excluded. The characteristics of both groups are presented in Table 1.

110 Individual informed consent was obtained before the experiment. The protocol was  
111 approved by the ethics committee of Dijon, France (CPP-Est-I). Participants received a  
112 €100 fee for their participation.

### 113 ***Breads***

114 The bread WS was enriched with fibres from wheat bran and formulated to look  
115 like a white sandwich bread. The bread MG was enriched with fibres from other cereals  
116 (oat, rye) and formulated to look like a multigrain bread with inclusions. Both breads  
117 were provided by Gustalis (Longvic, France). Their composition is shown in Table 2.

118 Prior to the study, a Flash Profile (Dairou & Sieffermann, 2002) was carried on the  
119 two breads and on four branded breads belonging to the same product range with 32  
120 participants different from the participants of the present study. Results showed that the  
121 sensory characteristics of WS and MG breads were similar to the ones of the branded  
122 breads. Specifically, the WS bread was characterized by a light colour, a soft texture  
123 and a slightly sweet taste, while the MG bread was characterized by a slightly darker  
124 colour and a larger number of inclusions corresponding to the grain particles. Given the  
125 habits of French participants and the results of the Flash Profile, the WS bread  
126 corresponded more to a "white bread" while the MG bread corresponded more to a  
127 "multigrain bread".

### 128 ***Procedure***

#### 129 ***Food diaries***

130 Before the study, participants recorded and weighed all foods and beverages  
131 consumed at three consecutive regular breakfasts eaten at home (precision required was

132 ± 1g). These diaries were then analysed using Bilnut software (S.C.D.A. Nutrisoft,  
133 Cerelles, France) in order to calculate the usual energy intake for each participant at  
134 breakfast and subsequently to determine the amount of bread (WS or MG) to be  
135 consumed by each individual during the experimental period.

### 136 *Phases of exposure*

137 For each group (WS or MG), there were two periods of a fortnight each. During  
138 the experimental condition, participants were required to consume the equivalent in  
139 bread (WS or MG) of their usual energy intake. Participants were requested to eat the  
140 bread plain, without butter or jam in order to avoid inter-individual differences. In fact,  
141 without this constraint, some participants would have chosen to eat the bread with jam,  
142 others with butter (or margarine) or with both jam and butter. In addition to the bread,  
143 the participants were allowed to drink their usual beverage (e.g. coffee or tea). It should  
144 be noted that in the experimental condition, the mean breakfast intake of dietary fibre  
145 was not different between the WS group (M=14.9;  $\sigma$ =6 g) and the MG group (M= 21.6;  
146  $\sigma$ =10 g). During the control condition, participants were required to consume 10 g of  
147 WS or MG bread at each breakfast. They could complete their breakfast with their  
148 usual food and drink choices.

149 The participants received their daily bread ration in separate freezing bags. They  
150 were instructed to thaw the bread by placing it at room temperature the evening before  
151 consumption. Breakfasts were eaten at home and participants were instructed not to  
152 share their rations with other family members. They were also instructed to consume all  
153 the bread provided at breakfast. In order to check compliance, participants were asked  
154 to bring back their freezing bags each time they came to the laboratory for new



155 supplying. Six participants (5 for the bread MG; 1 for the bread WS) brought back a  
156 small portion of non-eaten bread during the first days of the experiment but after further  
157 discussion, they adapted themselves to the ration.

158 At each breakfast, participants were required to give a hedonic rating for the bread  
159 at the first mouthful. Participants were also asked to rate their sensation of hunger  
160 before breakfast, immediately after breakfast, at 10 am and at noon. These assessments  
161 were made on visual analogue scales of 10 cm anchored at each end ("Extremely  
162 unpleasant" / "Extremely pleasant" and "I am not hungry at all" / "I am extremely  
163 hungry", respectively). On the second, sixth, tenth and fourteenth day of each phase of  
164 exposure (D2, D6, D10, D14), participants were also required to record and accurately  
165 weigh all foods and beverages consumed during the day (Clatronic KW204 scale,  
166 Kempen, Germany, precision required: 1 g).

#### 167 ***Data analysis***

168 The grades on the scales were converted into scores from 0 to 10 by measuring the  
169 distance between the left anchor and the mark made by the participant. The food diaries  
170 filled in during the two periods were analysed using Bilnut software (S.C.D.A.  
171 Nutrisoft, Cerelles, France) to determine the total energy intake per meal and per day  
172 (breakfast, lunch and dinner).

173 The evolution of various parameters (hunger, pleasure, energy, carbohydrate, fat  
174 and protein intakes) during the periods was modelled using a linear mixed model with  
175 *condition* as a fixed effect, and *exposure* and *participant* as random effects. For the  
176 random element, an appropriate correlation structure was sought to account for possible  
177 correlations between measurements taken at different times for a given participant. A

178 *compound symmetry* (CS) correlation structure was chosen because it led to the lowest  
179 Akaike criterion (AIC) for most of the parameters. Only linear factors were retained in  
180 the final models (Table 3), as the quadratic factors (*exposure*<sup>2</sup> and *exposure*<sup>2</sup> × *condition*)  
181 were not significant. Statistical analyses were performed using the MIXED procedure  
182 of SAS software (SAS Institute Inc., Cary, NC, USA).

## 183 **Results**

### 184 *Effect of repeated consumption of a fibre-enriched bread at breakfast on the hedonic* 185 *liking of this bread*

186 Fig. 1 shows the evolution of liking scores during consumption of the first  
187 mouthful of bread at breakfast, according to the condition and the bread consumed.  
188 Marginal ANOVA obtained with the general linear model did not reveal any *condition*  
189 effect for the WS bread (Table 3). No difference in liking for the first mouthful of bread  
190 at breakfast between the experimental condition and the control condition for the WS  
191 bread (experimental condition:  $M = 5.1$ , S.D. = 2.6; control condition:  $M = 4.9$ , S.D. =  
192 2.6) was observed. In contrast, a significant *condition* effect was observed for the MG  
193 bread: participants appreciated this bread less in the experimental condition ( $M = 5.1$ ,  
194 S.D. = 2.7) than in the control condition ( $M = 6.0$ , S.D. = 2.7). As, in both conditions,  
195 participants gave their hedonic rating at the first mouthful, this difference may be  
196 related to what they have to eat. So, their expectations were lower when they had to eat  
197 a large quantity than when they had to eat just a mouthful. Liking for the breads did not  
198 decrease over repeated consumptions: in fact regardless of the bread consumed, the

199 *exposure* effect was not significant. Moreover, the *exposure\*condition* interaction was  
200 not significant.

201 ***Effect of repeated consumption of a fibre-enriched bread at breakfast on subsequent***  
202 ***sensation of hunger***

203 Fig. 2 shows the evolution of the sensation of hunger at four times of the day:  
204 before breakfast, after breakfast, at mid-morning and at noon, for both the WS and MG  
205 bread. For the WS bread, ANOVA did not reveal any significant condition effect before  
206 breakfast: the sensation of hunger in the experimental condition ( $M = 4.9$ , S.D. = 2.7)  
207 was not different from that in the control condition ( $M = 5.0$ , S.D. = 2.7). In contrast, a  
208 *condition* effect was observed immediately after breakfast, at 10 am and at noon. At  
209 each of these times, the sensation of hunger was rated lower in the case of the  
210 experimental condition (after breakfast:  $M = 1.0$ , S.D. = 1.5; at 10 am:  $M = 1.7$ , S.D. =  
211 1.7; at noon:  $M = 4.4$ , S.D. = 3.9) than for the control condition (after breakfast:  $M =$   
212 2.0, S.D. = 2.2, at 10 am:  $M = 2.7$ , S.D. = 2.5; at noon:  $M = 5.2$ , S.D. = 2.8). A  
213 significant *exposure* effect was also observed for measurements at 10 am and at noon,  
214 showing an increase in hunger ratings at both of these times over subsequent days of the  
215 study.

216 For the MG bread, a condition effect was observed before breakfast: the hunger  
217 rating was slightly lower in the experimental condition ( $M = 5.3$ , S.D. = 2.4) than in the  
218 control condition ( $M = 5.6$ , S.D. = 2.8). This effect was nonetheless slight compared to  
219 the significant *condition* effect observed at 10 am and at noon. Once again, at each of  
220 these times, the sensation of hunger was rated lower in the experimental condition (at 10  
221 am:  $M = 2.4$ , S.D. = 2.4; at noon:  $M = 6.0$ , S.D. = 2.7) than in the control condition (at

222 10 am:  $M = 3.5$ , S.D. = 2.7; at noon:  $M = 6.8$ , S.D. = 2.1). An *exposure* effect was also  
223 observed for the evaluations before breakfast, immediately after breakfast and at noon,  
224 showing a decrease in hunger ratings just before and just after breakfast over subsequent  
225 days of the study on the one hand, and an increase at noon on the other.

226 *Effect of repeated consumption of a fibre-enriched bread at breakfast on energy*  
227 *intake throughout the day*

228 Fig. 3 shows the evolution of the total energy intake at breakfast and for the rest of  
229 the day during each period of exposure (D2, D6, D10 and D14). For intake at breakfast,  
230 marginal ANOVA did not reveal any significant *condition*, *exposure* or  
231 *exposure\*condition* effect, regardless of the group considered (Table 3). The energy  
232 intake for the experimental condition (WS bread:  $M = 392$  kcal, S.D. = 173; MG bread:  
233  $M = 393$  kcal; S.D. = 148) was not different from the energy intake for the control  
234 condition (WS bread:  $M = 394$  kcal; S.D. = 241; MG bread:  $M = 354$  kcal; S.D. = 207).  
235 These results therefore demonstrated that at breakfast, energy intake for the  
236 experimental condition was equivalent to the energy intake for the control condition,  
237 during which participants supplemented the required consumption of 10 g of bread with  
238 their usual food and beverage choices.

239 Regarding the energy intake calculated for the rest of the day, data analysis  
240 revealed a significant *condition* effect for both the WS bread and the MG bread, but  
241 these effects were opposite (Table 3 and Figure 3). In fact, for the WS bread the  
242 experimental condition reduced energy intake for the rest of the day compared to the  
243 control condition (mean 4 days values  $M = 1263$  kcal; S.D. = 120 and  $M = 1424$  kcal;  
244 S.D. = 120 respectively). In contrast, for the MG bread the experimental condition

245 increased energy intake for the rest of the day compared to the control condition ( $M =$   
246 1408 kcal; S.D. = 85 and  $M = 1261$  kcal; S.D. = 85 respectively). The *exposure* and  
247 *exposure\*condition* effects were not significant for either type of bread. The same  
248 pattern of results was observed when intakes were analysed per meal (lunch, dinner)  
249 (data not shown).

## 250 **Discussion**

251 In accordance with the hypotheses, replacing the participants' breakfast with a  
252 monotonous consumption of fibre-enriched bread (WS or MG) led to a decrease in the  
253 sensation of hunger during the morning. However, the decrease in hunger coincided  
254 with a decrease in subsequent energy intake for the WS bread, but an increase in energy  
255 intake for the MG bread. Results also showed that repeated consumption of these types  
256 of bread at breakfast did not lead to decreased liking for the breads over the course of  
257 the study, even in the experimental condition.

258 Data in the literature has shown that repeated - monotonous - consumption of a  
259 food generated a decrease in intake and/or in liking for that food (Cabanac & Rabe,  
260 1976; Rolls & de Waal, 1985; Zandstra, de Graaf, & van Trijp, 2000). For instance,  
261 Cabanac and Rabe (1976) observed a reduction of 25 to 50% in food intake when  
262 normal weight subjects were given a complete liquid diet everyday, at each meal, for  
263 three consecutive weeks. In an unpublished study conducted in our laboratory, ten  
264 unrestrained participants of normal weight ate the same food exclusively - ravioli - at  
265 every meal for three consecutive days (for breakfast, lunch and dinner). The results  
266 showed a significant reduction in overall food intake (-33% on the third day) compared

267 to a control situation. Zandstra et al. (2000) observed that consumption of a savoury  
268 sauce once a week for ten consecutive weeks resulted in a decrease in the amount of  
269 sauce consumed, even though the participants could combine the sauce with the food of  
270 their choice. Concurrent with this decrease, Zandstra and colleagues (2000) observed a  
271 decrease in hedonic liking for these sauces. However, several authors have observed  
272 that repeated consumption of “staple foods” did not affect their hedonic liking  
273 (Hetherington, Pirie, & Nabb, 2002; Kamen & Peryam, 1961; Meiselman, de Graaf, &  
274 Leshner, 2000). The FAO defines staple foods as foods that are eaten regularly and in  
275 such quantities as to constitute the dominant part of the diet and supply a major  
276 proportion of energy and nutrient needs. Staple foods are generally cereal products that  
277 constitute a major part of a diet and are culture-specific (e.g., bread in France, rice in  
278 Southeast Asia). Meiselman et al (2000) focused on the evolution in liking for a food  
279 which is initially highly palatable - chocolate - compared to a moderately palatable food  
280 belonging to the *staple food* category - buttered bread - over the course of repeated  
281 consumption (once a day for 22 days). The results showed that liking for chocolate  
282 decreased greatly over the course of subsequent consumption, while liking for buttered  
283 bread remained close to its initial level. Consequently, Meiselman and colleagues  
284 suggested characterising staple foods as “staple components of a diet [that] are resistant  
285 to monotony effects”. Due to their predominance in a population’s diet and to their  
286 resistance to the monotony effect, it has been suggested that staple foods could be used  
287 to fight against certain food disorders. Bouis (2000) and Welch and Graham (2004)  
288 suggested enriching staple foods with macronutrients in order to combat nutritional  
289 deficiencies caused by under-nutrition. Conversely, improving the nutritional quality of  
290 staple foods could be a useful means to prevent and/or treat diabetes and obesity (Franz

291 et al., 2002; Thompson et al., 2005). The present study confirmed that repeated  
292 consumption of a large quantity of bread did not induce lassitude for bread. These  
293 results substantiate the advantages of bread as a way to improve the nutritional quality  
294 of diets for French people.

295       The decrease in hunger after the consumption of the two breads and the lower  
296 intake after the WS bread could be attributed to the presence of dietary fibre. In fact,  
297 some studies have shown that repeated consumption of a fibre-enriched food can lead to  
298 a reduction in energy intake and weight in obese patients (Rössner, Von Zweigbergk,  
299 Öhlin, & Rytting, 1987; Stevens et al., 1987). Pasma and colleagues (Pasma, Saris,  
300 Wauters, & Westerterp-Plantenga, 1997) showed that the consumption of orange juice  
301 containing a guar gum supplement (soluble fibre) for a week led to a decreased  
302 sensation of hunger, resulting in reduced energy intake, compared to a control situation  
303 where participants received orange juice without added fibre. In accordance with these  
304 results, we observed that replacing a standard breakfast with an isocaloric amount of  
305 WS bread led to a decreased sensation of hunger during the morning and a reduction in  
306 subsequent energy intake. In contrast, while replacing breakfast with an isocaloric  
307 amount of MG bread also led to a decreased sensation of hunger, this decrease did not  
308 result in a reduced caloric intake. On the contrary, in the experimental condition for this  
309 bread, participants slightly increased their caloric intake during subsequent eating  
310 events.

311       The difference between the effect of WS and MG bread consumption on  
312 subsequent food intake, albeit a similar decrease in hunger sensation in both conditions,  
313 underlines the fact that measurement of the sensation of hunger (as performed here with  
314 visual analogue scales) does not always predict actual food intake. A number of studies

315 have shown relationships between measurements of hunger and food intake (e.g. de  
316 Castro & Elmore, 1988) but Mattes (1990) noted that rating the sensation of hunger is a  
317 learned rather than an innate reflection of the systems that control appetite. Beyond this  
318 methodological aspect, several hypotheses can be proposed to explain why the  
319 decreased sensation of hunger induced inconsistent reductions in energy intake.

320 One possible explanation relates to the nature of the fibre used to formulate WS  
321 and MG bread. In fact, some authors evidenced that the origin of fibre might play a role  
322 in the decrease in hunger sensation or caloric intake. For example, Hlebowicz et al.  
323 (2007) did not observe any difference in hunger ratings after ingestion of cereal bran  
324 flakes, wholemeal oat flakes or corn flakes. On the contrary, Willis et al. (2009)  
325 observed that participants were less hungry after ingestion of a preload of muffins with  
326 resistant starch or corn bran than muffins with barley oat. Furthermore, some authors  
327 observed that an ingestion of fibre led to a dissociation between hunger and food intake  
328 (e.g., Schroeder et al., 2009) whereas others observed that a decrease in hunger  
329 sensation led to a decrease in subsequent energy intake (e.g., Lee et al., 2006). Another  
330 possible explanation to explain the differential effect of the two breads on energy intake  
331 could be related to the difference in liking between the experimental and the control  
332 conditions that was observed for the MG bread but not for the WS bread. It is possible  
333 that having to eat a relatively large amount of the MG bread induced a feeling of  
334 "discomfort" among participants. Participants may then have compensated for this  
335 "discomfort" by increasing their subsequent food intake. A last explanation relates to  
336 cognitive associations related to the appearance of the bread. Participants may have  
337 associated the MG bread with a high fibre-content (in fact, it was formulated to look  
338 like multigrain bread), and, in turn, to low caloric foods. Thus, it is possible that



339 subjects ate more on the rest of day as they erroneously believed that they had a low  
340 energy breakfast when they had MG bread in comparison to WS bread. However, those  
341 hypotheses deserve further evaluation. A better understanding of the physiological  
342 and/or psychological mechanisms responsible or not of the decrease of subsequent food  
343 intake after fibre ingestion could be a challenge for future studies.

## 344 **Conclusion**

345 The present study indicates that the consumption of a monotonous enriched-fibre  
346 bread decrease the subsequent sensation of hunger without affecting liking for bread.  
347 However, while this decrease in hunger led to a decrease in subsequent food intake for  
348 the more familiar bread, it did not for the less familiar one. This underlines the  
349 importance of developing healthy staple foods that are not too different from the foods  
350 we are used to; otherwise they may not lead to the expected beneficial effects.

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357 **References**

- 358 Baer, D. J., Rumpler, W. V., Miles, C. W., & Fahey, G. C. (1997). Dietary fiber  
359 decreases the metabolizable energy content and nutrient digestibility of mixed  
360 diets fed to humans. *The Journal of Nutrition*, 127, 579-586.
- 361 Bouis, H. E. (2000). Enrichment of food staples through plant breeding: A new strategy  
362 for fighting micronutrient malnutrition. *Nutrition*, 16, 701-704.
- 363 Burton-Freeman, B. (2000). Dietary fiber and energy regulation. *The Journal of*  
364 *Nutrition*, 130, 272S-275S.
- 365 Cabanac, M., & Rabe, E. F. (1976). Influence of a monotonous food on body weight  
366 regulation in humans. *Physiology & Behavior*, 17, 675-678.
- 367 Dairou, V., & Sieffermann, J.-M. (2002). A comparison of 14 jams characterized by  
368 conventional profile and a quick original method, the flash profile. *Journal of*  
369 *Food Science*, 67, 826-834.
- 370 de Castro, J., M. (2007). The time of day and the proportions of macronutrients eaten  
371 are related to total daily food intake. *British Journal of Nutrition*, 98, 1077-1083.
- 372 de Castro, J. M., & Elmore, D. K. (1988). Subjective hunger relationships with meal  
373 patterns in the spontaneous feeding-behavior of humans - Evidence for a causal  
374 connection. *Physiology & Behavior*, 43, 159-165.
- 375 de Graaf, C., Blom, W. A. M., Smeets, P. A. M., Stafleu, A., & Hendriks, H. F. J.  
376 (2004). Biomarkers of satiation and satiety. *American Journal of Clinical*  
377 *Nutrition*, 79, 946-961.
- 378 Franz, M. J., Bantle, J. P., Beebe, C. A., Brunzell, J. D., Chiasson, J.-L., Garg, A.,  
379 Holzmeister, L. A., Hoogwerf, B., Mayer-Davis, E., Mooradian, A. D., Purnell,  
380 J. Q., & Wheeler, M. (2002). Evidence-based nutrition principles and

381 recommendations for the treatment and prevention of diabetes and related  
382 complications. *Diabetes Care*, 25, 148-198.

383 Heaton, K. W. (1973). Food fibre as an obstacle to energy intake. *The Lancet*, 302,  
384 1418-1421.

385 Hetherington, M. M., Pirie, L. M., & Nabb, S. (2002). Stimulus satiation: effects of  
386 repeated exposure to foods on pleasantness and intake. *Appetite*, 38, 19-28.

387 Hlebowicz, J., Wickenberg, J., Fahlstrom, R., Bjorgell, O., Almer, L.-O., & Darwiche,  
388 G. (2007). Effect of commercial breakfast fibre cereals compared with corn  
389 flakes on postprandial blood glucose, gastric emptying and satiety in healthy  
390 subjects: a randomized blinded crossover trial. *Nutrition Journal*, 6, 22,  
391 doi:10.1186/1475-2891-6-22.

392 Howarth, N. C., Saltzman, E., & Roberts, S. B. (2001). Dietary fiber and weight  
393 regulation. *Nutrition Reviews*, 59, 129-139.

394 Kamen, J. M., & Peryam, D. R. (1961). Acceptability of repetitive diets. *Food*  
395 *Technology*, 15, 173-177.

396 Lee, Y. P., Mori, T. A., Sipsas, S., Barden, A., Puddey, I. B., Burke, V., Hall, R. S., &  
397 Hodgson, J. M. (2006). Lupin-enriched bread increases satiety and reduces  
398 energy intake acutely. *American Journal of Clinical Nutrition*, 84, 975-980.

399 Lyly, M., Liukkonen, K. H., Salmenkallio-Marttila, M., Karhunen, L., Poutanen, K., &  
400 Lahteenmaki, L. (2009). Fibre in beverages can enhance perceived satiety.  
401 *European Journal of Nutrition*, 48, 251-258.

402 Mattes, R. (1990). Hunger ratings are not a valid proxy measure of reported food-intake  
403 in humans. *Appetite*, 15, 103-113.

404 Meiselman, H. L., de Graaf, C., & Leshner, L. L. (2000). The effects of variety and  
405 monotony on food acceptance and intake at a midday meal. *Physiology &*  
406 *Behavior*, *70*, 119-125.

407 Norton, G. N., Anderson, A. S., & Hetherington, M. M. (2006). Volume and variety:  
408 relative effects on food intake. *Physiology & Behavior*, *87*, 714-722.

409 Pasma, W. J., Saris, W. H. M., Wauters, M. A. J., & Westerterp-Plantenga, M. S.  
410 (1997). Effect of one week of fibre supplementation on hunger and satiety  
411 ratings and energy intake. *Appetite*, *29*, 77-87.

412 Reimer, R. A., & McBurney, M. I. (1996). Dietary fiber modulates intestinal  
413 proglucagon messenger ribonucleic acid and postprandial secretion of glucagon-  
414 like peptide-1 and insulin in rats. *Endocrinology*, *137*, 3948-3956.

415 Reimer, R. A., Pelletier, X., Carabin, I. G., Lyon, M., Gahler, R., Parnell, J. A., &  
416 Wood, S. (2010). Increased plasma PYY levels following supplementation with  
417 the functional fiber PolyGlycopleX in healthy adults. *European Journal of*  
418 *Clinical Nutrition*, *64*, 1186-1191.

419 Rolls, B. J., & Roe, L. S. (2002). Effect of the volume of liquid food infused  
420 intragastrically on satiety in women. *Physiology & Behavior*, *76*, 623-631.

421 Rolls, E. T., & de Waal, A. W. L. (1985). Long-term sensory-specific satiety: Evidence  
422 from an Ethiopian refugee camp. *Physiology & Behavior*, *34*, 1017-1020.

423 Rössner, S., Von Zweigbergk, D. A. N., Öhlin, A., & Rytting, K. (1987). Weight  
424 reduction with dietary fibre supplements. *Acta Medica Scandinavica*, *222*, 83-  
425 88.

426 Schroeder, N., Gallaher, D. D., Arndt, E. A., & Marquart, L. (2009). Influence of whole  
427 grain barley, whole grain wheat, and refined rice-based foods on short-term  
428 satiety and energy intake. *Appetite*, *53*, 363-369.

429 Schutz, H. G., & Pilgrim, F. J. (1958). A field study of food monotony. *Psychological*  
430 *Reports*, *4*, 559-565.

431 Siegel, P. S., & Pilgrim, F. J. (1958). The effect of monotony on the acceptance of food.  
432 *The American Journal of Psychology*, *71*, 756-759.

433 Stevens, J., Levitsky, D. A., VanSoest, P. J., Robertson, J. B., Kalkwarf, H. J., & Roe,  
434 D. A. (1987). Effect of psyllium gum and wheat bran on spontaneous energy  
435 intake. *American Journal of Clinical Nutrition*, *46*, 812-817.

436 Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure  
437 dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research*,  
438 *29*, 71-83.

439 Thompson, W. G., Rostad Holdman, N., Janzow, D. J., Slezak, J. M., Morris, K. L., &  
440 Zemel, M. B. (2005). Effect of energy-reduced diets high in dairy products and  
441 fiber on weight loss in obese adults. *Obesity*, *13*, 1344-1353.

442 Tungland, B. C., & Meyer, D. (2002). Nondigestible oligo- and polysaccharides (dietary  
443 fiber): Their physiology and role in human health and food. *Comprehensive*  
444 *Reviews in Food Science and Food Safety*, *1*, 90-109.

445 Wang, G.-J., Tomasi, D., Backus, W., Wang, R., Telang, F., Geliebter, A., Korner, J.,  
446 Bauman, A., Fowler, J. S., Thanos, P. K., & Volkow, N. D. (2008). Gastric  
447 distention activates satiety circuitry in the human brain. *Neuroimage*, *39*, 1824-  
448 1831.

449 Welch, R. M., & Graham, R. D. (2004). Breeding for micronutrients in staple food  
450 crops from a human nutrition perspective. *Journal of Experimental Botany*, 55,  
451 353-364.

452 Willis, H. J., Eldridge, A. L., Beiseigel, J., Thomas, W., & Slavin, J. L. (2009). Greater  
453 satiety response with resistant starch and corn bran in human subjects. *Nutrition*  
454 *Research*, 29, 100-105.

455 Wisker, E., Maltz, A., & Feldheim, W. (1988). Metabolizable energy of diets low or  
456 high in dietary fiber from cereals when eaten by humans. *The Journal of*  
457 *Nutrition*, 118, 945-952.

458 Zandstra, E. H., de Graaf, C., & van Trijp, H. C. M. (2000). Effects of variety and  
459 repeated in-home consumption on product acceptance. *Appetite*, 35, 113-119.

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463 Table 1: Characteristics of the participants

	<b>WS Group (n=16)</b>	<b>MG Group (n=22)</b>
Gender (male / female)	8 / 8	12 / 10
Age (mean $\pm$ sem years)	25.9 $\pm$ 1.2	30.2 $\pm$ 1.5
BMI (mean $\pm$ sem kg.m <sup>-2</sup> )	22.8 $\pm$ 0.5	22.3 $\pm$ 0.4
Restriction score (mean $\pm$ sem)	4.6 $\pm$ 0.5	4.5 $\pm$ 0.4

464 Restriction score was determined by the “Three Factors Eating Questionnaire” (Stunkard &  
465 Messick, 1985).

466

467 Table 2: Energy content and composition of the two types of bread.

	<b>WS Bread</b>	<b>MG Bread</b>
Energy content (kcal/100g)	211.4	228.8
Carbohydrates (g/100g)	37.7	36.8
Lipids (g/100g)	3.2	3.8
Proteins (g/100g)	8.0	11.8
Dietary fibre (g/100g)	10.4	12.8
Ratio soluble/insoluble fibre	30/70	33/67

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469



470 Table 3: Hedonic score, hunger and food intake (*F* and *p* values) for the WS group and the MG  
 471 group. Significant effects are in bold characters.

Parameter	Time of measurement	Factors	WS Group		MG Group	
			<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>
Hedonic score	First mouthful	Condition	1.81	0.20	<b>56.82</b>	<b>&lt;0.001</b>
		Exposure	0.00	0.98	1.19	0.27
		Condition×Exposure	1.05	0.31	3.58	0.06
Hunger	Before breakfast	Condition	0.29	0.60	<b>4.45</b>	<b>0.05</b>
		Exposure	3.53	0.06	<b>6.03</b>	<b>0.01</b>
		Condition×Exposure	3.04	0.08	0.02	0.90
	After breakfast	Condition	<b>69.7</b>	<b>&lt;0.001</b>	3.26	0.08
		Exposure	0.07	0.78	<b>11.81</b>	<b>&lt;0.001</b>
		Condition×Exposure	3.28	0.07	3.36	0.07
	At 10 am	Condition	<b>49.90</b>	<b>&lt;0.001</b>	<b>39.32</b>	<b>&lt;0.001</b>
		Exposure	<b>11.27</b>	<b>0.009</b>	2.70	0.10
		Condition×Exposure	0.56	0.45	0.15	0.63
	At noon	Condition	<b>14.77</b>	<b>0.002</b>	<b>20.73</b>	<b>&lt;0.001</b>
		Exposure	<b>6.08</b>	<b>0.01</b>	<b>4.16</b>	<b>0.04</b>
		Condition×Exposure	0.22	0.64	1.56	0.21
Food Intake	Daily	Condition	<b>4.56</b>	<b>0.05</b>	<b>10.69</b>	<b>0.004</b>
		Exposure	<b>4.31</b>	<b>0.04</b>	0.44	0.51
		Condition×Exposure	1.81	0.18	2.22	0.14
	Breakfast	Condition	0.01	0.93	3.68	0.07
		Exposure	0.07	0.79	1.01	0.32
		Condition×Exposure	0.22	0.64	0.23	0.63
	Lunch	Condition	2.79	0.12	0.34	0.57
		Exposure	<b>4.49</b>	<b>0.04</b>	0.07	0.80
		Condition×Exposure	0.22	0.64	0.34	0.56
	Dinner	Condition	<b>5.57</b>	<b>0.03</b>	3.02	0.09
		Exposure	0.84	0.36	0.02	0.88
		Condition×Exposure	0.71	0.40	1.46	0.23
	Snack	Condition	0.02	0.89	2.70	0.11
		Exposure	0.23	0.63	1.05	0.31
		Condition×Exposure	0.86	0.36	2.87	0.09
	Daily <i>minus</i> Breakfast	Condition	<b>4.61</b>	<b>0.05</b>	<b>5.89</b>	<b>0.02</b>
		Exposure	0.34	0.56	0.19	0.66
		Condition×Exposure	0.43	0.51	1.85	0.18

472 Condition levels: experimental and control.

473

474

## FIGURES CAPTIONS

475 Fig. 1. Evolution of bread liking scores during the control condition (hatched line)  
476 *versus* the experimental condition (full line) for each type of fibre-enriched bread (white  
477 sandwich bread – WS – on the left; multigrain bread – MG – on the right). Results are  
478 expressed as mean and SEM.

479 Fig. 2. Evolution in hunger sensation before breakfast, after breakfast, at 10 am and at  
480 noon during the control condition (hatched line) *versus* the experimental condition (full  
481 line) for each type of fibre-enriched bread (white sandwich bread – WS – on the left;  
482 multigrain bread – MG – on the right). Results are expressed as mean and SEM.

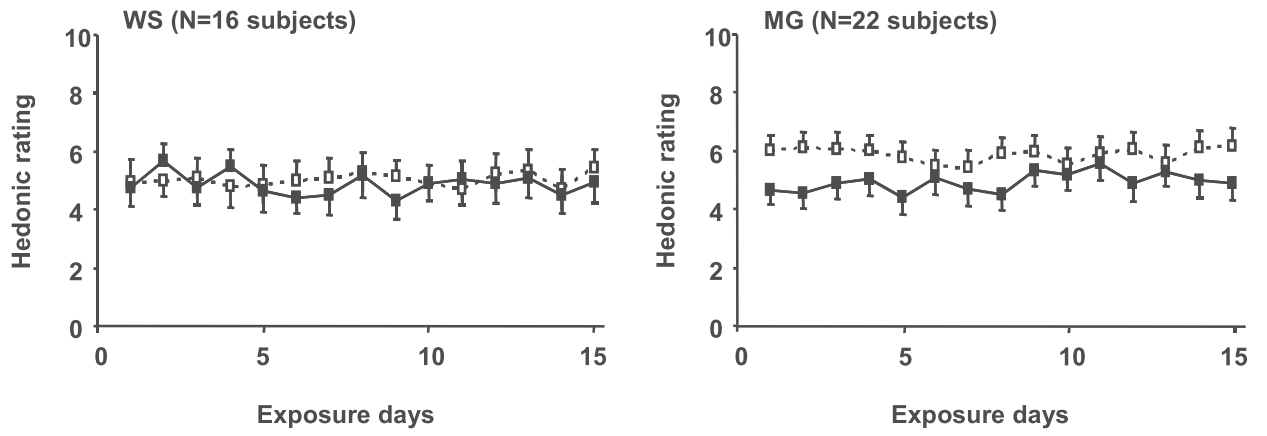
483 Fig. 3. Evolution of the energy intake at breakfast and during the rest of the day (total  
484 daily energy intake *minus* Breakfast energy intake, Table 3) during the control condition  
485 (hatched line) *versus* the experimental condition (full line) for each type of fibre-  
486 enriched bread (white sandwich bread – WS – on the left; multigrain bread – MG – on  
487 the right). Results are expressed as mean and SEM.

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FIGURE 1

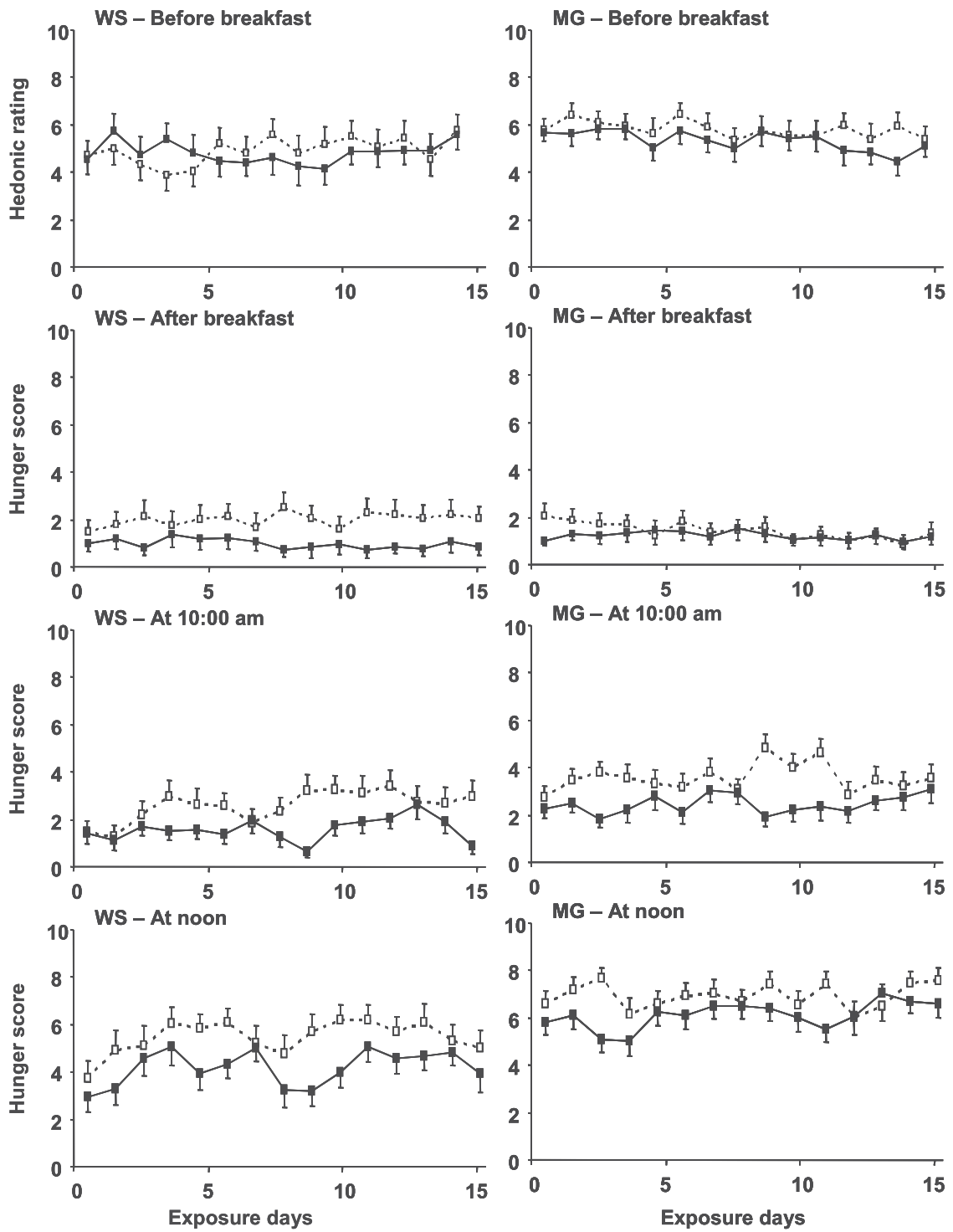
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FIGURE 2

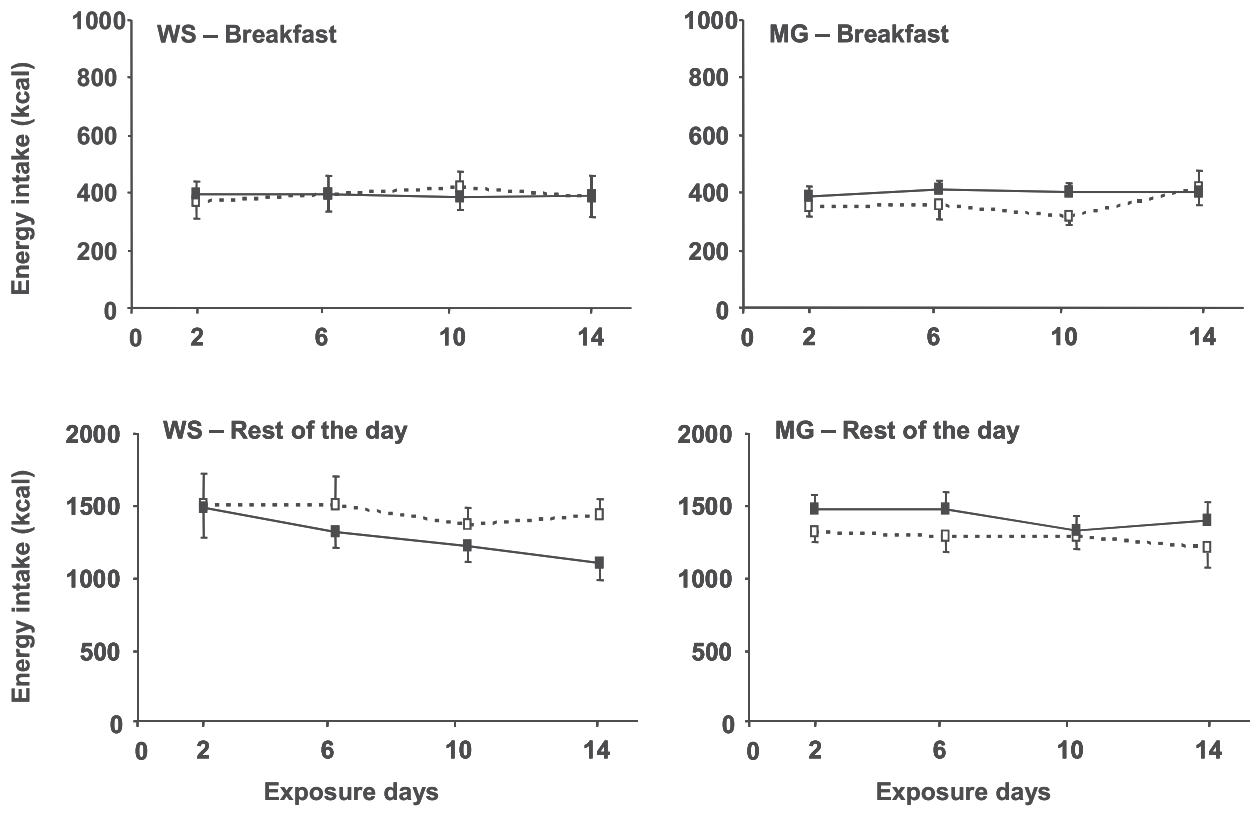


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FIGURE 3



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