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1 **Title:** The acute effects of baobab fruit (*Adansonia digitata*) on satiety in healthy adults.

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18 **Abbreviations**

19 ALM, *ad libitum* meal; ANOVA, analysis of variance; AUC, area under the curve; avCHO, available

20 carbohydrate; FCR, Folin-Ciocalteu reagent method; GAE, gallic acid equivalents; VAS, visual

21 analogue scale.

22

23

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26

27 **Abstract**

28

29 Background: The baobab fruit is high in both dietary fibre and polyphenols and therefore may  
30 increase satiety. The aim of the study was to measure the effects of baobab fruit extract on  
31 satiety.

32

33 Methods: The study was conducted on 20 healthy participants. The study was a one day  
34 single blind crossover design. Participants were randomised to either a test smoothie  
35 consisting of 15g of baobab extract or a control smoothie without the addition of baobab.  
36 Subjective ratings of satiety were taken on visual analogue scales immediately pre  
37 consumption and then post consumption, and energy intake at a post *ad libitum* meal was  
38 recorded.

39

40 Results: Subjective measures of hunger were reduced following the test smoothie compared  
41 to the control ( $p < 0.05$ ). There was no significant difference in calorie intake at an *ad libitum*  
42 meal.

43

44 Conclusions: This research has positive implications for the use of baobab for reducing  
45 hunger, possibly having a positive effect on weight maintenance.

46

47 **Key words**

48 *baobab fruit, satiety, polyphenols, fibre*

49

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51

52 **Highlights**

53 1. The baobab fruit is rich in many micro nutrients, fibre and polyphenols.

54 2. Satiety is an areas of interest in human nutrition. Foods that increase satiety may be  
55 beneficial for weight management.

56 3. Polyphenols and fibre have shown benefits for improving satiety.

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60

## 61 **Introduction**

62

63 Baobab (*Adansonia digitate L.*) is an African tree that has attracted significant  
64 attention due to its high nutrient content and potential health benefits (Chadare et al., 2010). It  
65 is estimated that approximately 44% of the baobab fruit is made up of soluble and insoluble  
66 fibre. The polyphenol content of baobab is also high, ranging from 18-34mg/g Gallic Acid  
67 Equivalents (GAE) comprised primarily of flavonoids and tannins (Bamalli et al., 2014).

68

69 It is well established that dietary fibre can affect satiety (Slavin & Green, 2007). Similarly,  
70 polyphenols have shown the potential to increase satiety through improved blood glucose  
71 regulation (Hanhineva et al., 2010). We have previously shown in our laboratories that baobab  
72 can reduce starch digestion *in vitro* and glycaemic response *in vivo* (Coe et al., 2013).

73

74 The aim of this study is to assess the effect of 15g of baobab in a breakfast smoothie  
75 on subjective satiety and energy intake compared to a control smoothie.

76

## 77 **Methods**

78

79 *Polyphenol analysis*

80

81 The polyphenol content of each smoothie was analyzed using the Folin-Ciocalteu reagent  
82 (FCR) method (Sharma and Gujral, 2010). The results were expressed as  $\mu\text{g}$  GAE per ml of  
83 sample.

84

85 *Study Design*

86

87 This was a single blind randomized crossover study. Each participant consumed two separate  
88 smoothies on two separate days followed two hours later by an *ad libitum* meal. Tests were  
89 separated by at least three days.

90

91 *Participants*

92

93 Following obtaining written informed consent, twenty participants (7m, 13f) undertook the  
94 study in the Nutrition laboratory at Oxford Brookes University. On the first test day  
95 measurements of height, weight and body fat percentage were taken and a health  
96 questionnaire and Dutch Eating Behavior Questionnaire (DEBQ) were administered. Those  
97 who met the inclusion criteria (age 18-40years, BMI 18-30kg/m<sup>2</sup>, not on prescription  
98 medication, no genetic or metabolic diseases, not allergic/intolerant to foods in the study, not  
99 pregnant or lactating, unrestrained eaters), were included in the study. Participants were  
100 asked to limit caffeine and alcohol consumption, and refrain from strenuous physical activity  
101 the day before testing. Participants arrived between 8:30 and 10am after an overnight fast. On

102 the first day participants underwent a 24-hour recall and were then asked to follow this diet  
103 on the day before the second visit. The study was approved by Oxford Brookes University  
104 Research Ethics Committee and conducted according to the guidelines laid down in the  
105 Declaration of Helsinki.

106

#### 107 *Preload*

108

109 The control smoothie contained 327ml of orange juice and 100g of frozen mango (Tesco,  
110 Hertfordshire, UK) and contained 776µg/ml polyphenols. The test smoothie contained 15g  
111 baobab powder (Minvita superfruit powder, Watford, UK), 300ml of orange juice and 100g  
112 of frozen mango. This smoothie contained 1914µg/ml polyphenols. Both smoothies  
113 contained 44.2g of available carbohydrate and were matched for total energy (kcal) and  
114 macronutrient content as much as possible (Table 1). The smoothies were made prior to  
115 consumption using a NutriBullet for 15 seconds. Participants were given 15minutes to  
116 consume the smoothie preload, 250ml of water was provided after the preload.

117

#### 118 *Ad libitum meal*

119

120 The *ad libitum* meal consisted of pre-selected sandwiches. Participants selected three  
121 sandwich types from seven options prior to testing, based on their own preferences. Six  
122 sandwiches consisting of two sandwich types were prepared and served quartered alongside  
123 250ml of water. All sandwiches were matched for calories. Participants had 30minutes to eat  
124 and were instructed to eat until comfortably full. The sandwiches and leftovers were weighed  
125 and calories consumed were calculated.

126

127 *Satiety Measurements*

128

129 Subjective satiety was evaluated using paper 100mm visual analogue scales (VAS; Blundell,  
130 2006). The VAS was administered at 0minutes just before pre load consumption and every 15  
131 minutes for the first hour and then every 30minutes for the remaining hour. The VAS  
132 investigated hunger, fullness, desire to eat and prospective food consumption.

133

134 A VAS was also used to record the palatability and pleasantness of both the control and test  
135 smoothie.

136

137 *Statistical Analysis*

138

139 Data were analysed using SPSS V.22 (Chicago, IL, USA). The subject number was chosen  
140 based on similar research designs and outcomes (Harrold et al., 2014). Prior to statistical  
141 analysis, normality of the data was tested using the Shapiro-Wilks statistic. Values are  
142 mean±SD unless otherwise specified. Appetite area under the curve were analysed using an  
143 one-way ANOVA with baseline values used as a covariate in the analysis. Energy intake at  
144 the buffet meal and palatability scores were analysed using a Wilcoxon Signed Rank test.

145

146

147

148 **Results**

149

150 *Energy intake*

151

152 There was no significant difference between energy intake nor total carbohydrate fat or  
153 protein intake at the buffet meal proceeding consumption of the baobab compared to the  
154 control (kcal;control 1163±467 kcal, baobab 1045±462 kcal; p = 0.052).

155

156 *Appetite scores*

157

158 There was no significant differences in any of the appetite scores with the exception of  
159 hunger (p<0.05). Hunger was increased following the control compared to the baobab  
160 smoothie (Figure 1).

161

162 *Palatability*

163

164 There was no significant differences in scores relating to the palatability and pleasantness  
165 between the baobab and the control (tastiness: baobab: 63.9±23.0mm; control: 70.5±18.2mm;  
166 pleasantness: baobab: 62.0±29.0mm; control: 72.7±19.0mm).

167

168 **Discussion**

169

170 To the author's knowledge this study is the first to examine the effects of baobab on both  
171 subjective satiety ratings and food intake. Hunger was found to be significantly reduced in  
172 the baobab smoothie group however there were no significant differences in food intake.

173

174           Fibre rich foods have been found to slow gastric emptying which in turn can decrease  
175 hunger ratings (Sepple and Read, 1989). Therefore the reduction in hunger in the current  
176 study may be attributed to delayed gastric emptying after consumption of the baobab  
177 smoothie. In the only other study, known to the authors, to test for the effects of baobab on  
178 satiety, Coe et al. (2013) failed to detect any differences in subjective satiety. However in  
179 this study the baobab was given as a drink alongside bread and was not incorporated into the  
180 test meal. Therefore it may not have been possible for the baobab to mix thoroughly through  
181 the bread and slow gastric emptying. Research also indicates that polyphenolic extracts lower  
182 glycaemic response by working as enzyme inhibitors by binding to the enzyme's active site  
183 preventing it from breaking down the substrate and releasing glucose units. The polyphenols  
184 in the baobab may have reduced the glycaemic response of the drink and lower glycaemic  
185 index foods are associated with increased satiety (Bornet et al., 2007)

186

187           A limitation was that the phases of the menstrual cycle was not controlled for in the  
188 current study. Although research from our lab has failed to show differences in food intake  
189 and perceived food intake from VAS across the phases of the menstrual cycle (Campolier et  
190 al., 2016), earlier studies show conflicting results (Dye and Blundell, 1997). Therefore, had it  
191 been controlled for perhaps trends in food intake would have been detected. Previous studies  
192 demonstrate that VAS can be more sensitive to a dietary manipulation than changes in energy  
193 intake (Johnstone et al., 1996) and that reduced feelings of satiety using VAS are not always  
194 accompanied by a reduced energy intake at a subsequent meal (Harper et al., 2007). Previous  
195 studies demonstrate that normal mechanisms of satiety that affect food intake maybe over  
196 ridden by a free meal (Fallaize et al., 2012). In the current study this was also the case, as  
197 ratings of hunger were found to be different even though the energy intake data was only

198 approaching significance. The current study was able to demonstrate the ability of baobab  
199 fruit extract to reduce subjective hunger however more research on baobab is needed to  
200 understand the mechanisms influencing satiety.

201

202

### 203 **Conflict of interest**

204 Conflict of interest: none.

205

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208

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