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

**Authors:** Rebecca Garvey, Miriam Clegg and Shelly Coe*

**Affiliation:** Functional Food Centre, Oxford Brookes University, Gipsy Lane, Oxford, OX3 0BP, UK.

**Author contributions:**

**Garvey, R**. First author, data collection and analysis, drafting of paper.

Email: regarvey@gmail.com

**Clegg, M.** Design of study, data analysis and drafting of paper.

Email: mclegg@brookes.ac.uk

**Coe, S.** Corresponding author, design of study, data collection and analysis, drafting of paper.

Abbreviations

ALM, *ad libitum* meal; ANOVA, analysis of variance; AUC, area under the curve; avCHO, available carbohydrate; FCR, Folin-Ciocalteu reagent method; GAE, gallic acid equivalents; VAS, visual analogue scale.

*Corresponding author: Dr. Shelly Coe, Functional Food Centre, Oxford Brookes University, Gipsy Lane, Oxford, UK, OX3 0BP; Tel: +44 (0)1865483839; Email: scoe@brookes.ac.uk

**Abstract**

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

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

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

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

**Key words**

*baobab fruit, satiety, polyphenols, fibre*

## Highlights

1. The baobab fruit is rich in many micro nutrients, fibre and polyphenols.
2. Satiety is an areas of interest in human nutrition. Foods that increase satiety may be beneficial for weight management.
3. Polyphenols and fibre have shown benefits for improving satiety.

## Introduction

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

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

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

## Methods

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79 *Polyphenol analysis*

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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 μg GAE per ml of
83 sample.

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85 *Study Design*

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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.

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91 *Participants*

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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/m², 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

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

*Preload*

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

*Ad libitum meal*

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

127 *Satiety Measurements*

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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.

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

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137 *Statistical Analysis*

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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.

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## Results

*Energy intake*

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

*Appetite scores*

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

*Palatability*

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

## Discussion

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

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

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

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

**Conflict of interest**

Conflict of interest: none.

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