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Impact of resistant starch from unripe banana flour on hunger, satiety, and glucose homeostasis in healthy volunteers

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ABSTRACT

Sources of dietary fibre can induce satiety and impact energy consumption. Herein, healthy volunteers consumed unripe banana flour (UBF), rich in resistant starch (5 g/8 g UBF), non-daily (3 times a week) for six weeks. The resistant starch (15 g/week) significantly reduced hunger and increased satiety parameters, as evaluated by the visual analogue scale (VAS) and area under the curve of ghrelin and peptide YY hormones. Changes in the VAS score and hormone levels were followed by a 14% reduction in energy intake at two subsequent meals in the UBF group. The fasting insulin after intake of UBF showed higher sensitivity by HOMA2-IR or QUICKI when compared to the baseline and control groups. These results suggest that UBF can be considered as a functional food ingredient that may contribute to reduced risks of certain non-communicable diseases owing to its high resistant starch levels.

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Abbreviations: AS, available starch; AUC, area under the curve; BMI, body mass index; DF, dietary fibre; FFA, free fatty acid; GLP-1, glucagon-like peptide 1; GTT, glucose tolerance test; HOMA2-IR, Homeostasis Model Assessment 2-Insulin Resistance; PYY, peptide YY; RS, resistant starch; QUICKI, quantitative insulin sensitivity check index; SCFA, short chain fatty acid; TS, total starch; UBF, unripe banana flour; VAS, visual analogue scale

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1. Introduction

Several foods have shown promising effects on inducing satiety; however, these effects may not always reflect a lower energy intake (Rebello, Greenway, & Dhurandhar, 2014). The consumption of different types of dietary fibre (DF) has been demonstrated to be able to change the profile of gastrointestinal hormone release related to satiety and energy intake (Roberfroid et al., 2010; Sánchez, Miguel, & Aleixandre, 2012). However, the relationships of these carbohydrates with increased satiety and weight control are still being investigated, and have been speculated to be associated with lower energy density, delay of gastric emptying, and/or modulation of gastrointestinal hormones (Smith & Tucker, 2011). Thus, it is important to increase the supply and consumption of food and ingredients that are sources of DF.

Colonic fermentation of some components of DF, such as resistant starch (RS), produces short chain fatty acids (SCFAs); these not only promote local effects on colonocytes (Baboota et al., 2013), but also lead to systemic effects affecting functions such as glucose homeostasis and lipid metabolism (Keenan et al., 2015). As described below, studies with prolonged intake (4–12 weeks) of RS obtained from corn flour, which has high amylose content, have shown variable effects on glucose homeostasis. One study that evaluated the daily intake of 12 g of RS over 6 weeks did not observe alterations in the glucose and fasting insulin levels or in the calculated indices from these values (Penn-Marshall, Holtzman, & Barbeau, 2010). On the other hand, increased insulin sensitivity was observed after RS consumption in other studies (Bodinham et al., 2014; Johnston, Thomas, Bell, Frost, & Robertson, 2010; Maki et al., 2012). For example, cookies with RS from whole grain high-amylose corn flour promoted glycaemic and satiety benefits (Luhovyy et al., 2014). RS acts on the release of gastrointestinal peptides related to satiety and postprandial insulin, and has the ability to reduce lipid storage in adipocytes, indicating that it may have effects on energy balance (Higgins, 2014).

Unripe banana flour (UBF), which is rich in RS (Menezes et al., 2011; Rayo et al., 2015), has been evaluated as a functional ingredient. Its application in short-duration clinical trials with healthy volunteers has been demonstrated to lead to a reduced glycaemic response (Menezes et al., 2010). In a study carried out by Dan (2011), daily UBF consumption for 14 days showed positive effects on gastrointestinal hormones and decreased energy intake at subsequent meals. These positive attributes of UBF point to its possible utility as a food supplement aimed at improving the DF content and at helping to reduce the risk of certain non-communicable diseases, such as overweight/obesity, hyperglycaemia, and hyperlipidaemia. However, there are currently no studies evaluating the effects of UBF intake according to more realistic consumption patterns; that is, as a regular, but not necessarily daily, intake. Thus, the objective of this study was to evaluate the impact of regular, but non-daily, intake of RS from UBF on parameters related to hunger/satiety and glucose homeostasis in healthy volunteers.

2. Methods

2.1. Clinical trial

This study was a double-blind, parallel, placebo-controlled clinical trial performed over 6 weeks. Before the intervention period and at the end of it, the hunger/satiety, energy consumption, and the release profiles of the hormones ghrelin and peptide YY (PYY) were analysed. Additionally, an oral glucose tolerance test (GTT) was performed prior to intervention and afterwards.

2.1.1. Screening of volunteers

Twenty-two healthy male (n = 2/group) and female (n = 9/group) volunteers with a mean (±standard deviation) age of 27.6 ± 5.1 years and a body mass index (BMI) of 22.8 ± 3.5 kg/m^2 (Table S1), who were accustomed to eating frozen meals on a regular basis, were included in this study.

2.1.2. Selection criteria

Subjects who were in good overall health (defined as absence of hyperthyroidism and renal and gastrointestinal diseases; with no previous diagnosis or family history of *diabetes mellitus*) and were not using any type of medication, particularly antibiotics that could affect digestion and absorption of foods during the study period, were included.

2.1.3. Exclusion criteria

Subjects classified as overweight/obese (BMI ≥ 25 kg/m^2) or underweight (BMI ≤ 18.6 kg/m^2) according to the criteria of the World Health Organization (WHO, 2003) and those reporting any disease, pregnancy, breastfeeding, or treatment of any kind (including for possible eating disorders) were not included in the study.

2.1.4. Experimental design

The 22 volunteers were divided into two groups: the Control group, who received a ready-to-eat soup vehicle and individual servings of a placebo (2 g of maltodextrin), and the UBF group, who received a ready-to-eat soup vehicle and individual portions of UBF (8 g). The amount chosen to be evaluated was based on a previous study by our group; 8 g of UBF showed measureable effects without eliciting gastrointestinal side effects (Dan, 2011). Both groups received supplements with similar energy values.

All volunteers received 18 individual portions of frozen ready-to-eat soup (9 units of meat soup with noodles and vegetables, and 9 units of bean and vegetable soup) and 18 portions of supplements, and were instructed to consume 3 servings per week for 6 weeks while alternating the flavours. The volunteers were instructed to add the supplements after thawing and heating the frozen soup (8 min in a microwave).

Blood collections for hormonal assessment and other evaluations were performed before and after the intervention, as shown in Fig. 1.

2.2. Study design

Each volunteer was instructed to visit the laboratory after 10 h of fasting, and had their vein cannulated to collect blood at