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Starch digestibility and glycemic index of cookies partially substituted with unripe banana flour

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ABSTRACT

The Mexican government declared that overweight and obesity are Mexico's principal public health problems. Because of this problem the development of nutraceutical foods with a low glycemic index is necessary. Cookies with unripe banana flour (UBF) were prepared with very few ingredients in the formulation to avoid fat and digestible carbohydrates. Proximate composition and starch digestibility were carried out. Moisture and dietary fiber content increased, but protein and fat decreased when the UBF level increased in the cookie. Total starch in cookies added with UBF increased when this ingredient was increased in the formulation. A similar pattern was found for available and resistant starch. Resistant starch content is important due to the beneficial effects associated with its fermentation in the colon. Hydrolysis percentage and predicted glycemic index decreased when the UBF increased in the composite that is related with the resistant starch content. When the amount of UBF was increased in the cookies, the rapidly digestible starch decreased and the slowly digestible starch increased. Addition of UBF to simple formulation for cookie preparation is important to obtain a product with high level of indigestible carbohydrates.

1. Introduction

Obesity is an important health public problem. This is of critical importance with children as juvenile obesity can convert into problems such as diabetes, coronary diseases, digestion malfunction, high cholesterol, etc. This is of particular importance in Mexico because it ranks in first place in juvenile obesity in the world. Because of this ranking a national program to increase consumption of healthy foods ongoing (Bonvecchio et al., 2009; Ellingwood, 2010).

From a nutritional point of view, carbohydrates can be classified as digestible or indigestible, glycemic or nonglycemic. There is a nutritional trend to reduce the consumption of glycemic carbohydrates in food products to increase the level of indigestible carbohydrates (WHO/FAO, 2003) or to increase the content of slowly digestible starch due to its beneficial effects. Starch is one of the most important glycemic carbohydrates in cereals, roots, tubers, and unripe fruits that are consumed in the worldwide diet. The rate of digestion and absorption of glucose in the small intestine determines the glycemic index of starchy foods (Englyst & Hudson, 1996; Englyst, Englyst, Hudson, Cole, & Cummings, 1999; O'Dea, Snow, & Nestel, 1981). Starch has been classified into rapidly digestible starch (RDS) which is digested *in vitro* within 20 min, slowly digestible starch (SDS) which is digested starch between 20 and 120 min, and resistant starch (RS) (Englyst, Kingman, & Cummings, 1992). RDS is rapidly digested and absorbed in the duodenum and proximal regions of the small intestine, leading to rapid elevation of blood glucose and usually followed by a subsequent episode of hypoglycemia. SDS may prolong satiety, which is beneficial in products that are utilized by athletes, and could provide a longer, more consistent source of systemic glucose with a low glycemic response (Englyst et al., 1992). SDS also improves overall blood glucose control in patients with diabetes mellitus (Hodge, English, O'Dea, & Giles, 2004) and attenuates total serum cholesterol levels in hyperlipidemic patients (Flight & Clifton, 2006).

RS is not digested in the upper gastrointestinal tract, but is fermented by microorganisms in the colon that produce short chain fatty acids (SCFA). SCFAs provide additional energy to the body along with a high proportion of butyrate that is beneficial to colonic health (Topping & Clifton, 2001). SDS, as an intermediate starch fraction between RDS and RS, is digested slowly throughout the

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entire small intestine providing sustained glucose release, with a low initial glycemia and subsequently a slow and prolonged release of glucose.

There is a considerable interest to improve control of diabetic patients by altering the glycemic impact of ingested carbohydrates. Glycemic index (GI) is used for ranking foods with respect to their potential liberation of glucose toward the blood (Jenkins et al., 1981), which subsequently leads to the preferred selection of "slow carbohydrate" food items/diets (Englyst et al., 1992). Although it cannot be regarded as a general rule, a nutritional variable that may be linked to low GI properties is the RS and SDS content (Truswell, 1992). Low glycemic index (GI) foods may favorably influence blood glucose (Brand-Miller, Hayne, Petocz, & Colagiuri, 2003), insulin sensitivity (Frost, Leeds, Trew, Margara, & Dornhorst, 1998), insulin secretion (Wolever & Mehling, 2002), blood lipids (Frost et al., 1999), cognition (Benton et al., 2003), appetite (Ludwing, 2000) and athletic performance (Thomas, Brotherhood, & Brand, 1991). Research indicates that to prevent chronic diseases one the focuses should be in low glycemic indexes, which result in "slow-release".

Unripe banana flour has exhibited a nutritional/nutraceutical potential (Da Mota, Lajolo, Ciacco, & Cordenunsi, 2000; Englyst et al., 1992; Pacheco-Delahaye, Perez, & Schnell, 2004) and represents an alternative source of indigestible carbohydrates and antioxidants compounds. Several studies have suggested that consumption of unripe bananas provides a beneficial effect on human health, associated with indigestible components such as resistant starch (Faisant, Buléon et al., 1995; Faisant, Gallant, Bouchet, & Champ, 1995). Recently, several authors observed that when unripe banana starch and flour is added to different foods such as pasta (Hernández-Nava, Berrios, Pan, Osorio-Díaz, & Bello-Pérez, 2009; Ovando-Martinez, Sáyago-Ayerdi, Agama-Acevedo, Goñi, & Bello-Pérez, 2009; Rendon-Villalobos, Osorio-Díaz, Agama-Acevedo, Tovar, & Bello-Perez, 2008; Saifullah, Abbas, Yeoh, & Azhar, 2009), bread (Juárez-García, Agama-Acevedo, Sáyago-Ayerdi, Rodríguez-Ambriz, & Bello-Pérez, 2006) and cookies (Aparicio-Saguilán et al., 2007; Fasolin, de Almeida, Castanho, & Netto-Olveira, 2007). All of which presented high resistant starch content, but starch digestion rate was not tested. The objective of this study was to develop a cookie with unripe banana flour and very few additional ingredients in the formulation to evaluate its starch digestibility.

2. Materials and methods

2.1. Banana flour preparation

Commercial hard green (unripe) preclimacteric bananas (*Musa paradisiaca* L.) in the stage 2 (color index) (Aurore, Parfait, & Fahrasmane, 2009) were purchased from the local market in Cuautla, Morelos, México. They were peeled, cut into 1 cm slices and immediately rinsed in citric acid solution (0.3 g/100 mL). The slices were dried at 50 °C and subsequently ground using a commercial grinder (Mapisa Internacional, Distrito Federal, México) to pass a US 50 sieve (0.3 mm) and stored at 25 °C in sealed plastic containers for further analysis.

2.2. Sample preparation

For the preparation of the cookies, raw materials were acquired in local supermarkets and stored in glass/plastic containers at room temperature (25 °C), or under refrigeration (4 °C) depending on the storage requirements of the material. The formulations for the cookies are presented in Table 1. No sugar was added to reduce the amount of glycemic carbohydrates. The ingredients were mixed completely in a Kitchen aid mixer (KitchenAid, Model KPRA, St. Joseph, MI, USA) and the dough was laminated in the same machine at a 0.4 cm height. The dough was cut in circles of 5 cm of diameter and placed on an aluminum mold. The cookies were baked in a household oven (Hotpoint, 6B4411LO, Leisser, San Luis Potosi, México), at an approximate temperature of 180 °C for 25 min. Once baked, the cookies were allowed to cool for 30 min. The cookies were ground using a commercial grinder (Mapisa Internacional, Distrito Federal, México), sieved (300 μm) and stored at room temperature in sealed plastic containers.

Table 1
Formulation of cookies added with unripe banana flour.

Ingredient	Control cookie	Substitution with unripe banana flour		
		Cookie 15-UBF	Cookie 30-UBF	Cookie 50-UBF
Wheat flour (g)[a]	350	297.5	245	175
Banana flour (g)[a]	0	52.5	105	175
Butter (g)	15	15	15	15
Egg (piece)	1	1	1	1
Water (ml)	15	15	15	15

15-UBF = 15 g/100 g Unripe banana flour, 30-UBF = 30 g/100 g Unripe banana flour, 50-UBF = 50 g/100 g Unripe banana flour.
[a] Dry matter basis.

2.3. Chemical composition

Moisture content was determined by gravimetric heating (130°C ± 2 °C for 2 h) using a 2–3 g sample. Ash, protein and fat were analyzed according to AACC (2000) methods 08-01, 46-13 and 30-25 respectively. The dietary fiber method (DF) was tested using 992.16 AOAC (2005).

2.4. In vitro digestibility tests

Total starch content was determined by the Goñi's method (Goñi, García, Mañas, & Saura-Calixto, 1996). In short, a 50 mg sample was dispersed in 2 mol l^{-1} KOH to hydrolyze all the starch (30 min) and subsequently incubated (60 °C, 45 min, pH 4.75) with amyloglucosidase (Roche No. 102 857, Roche Diagnostics, Indianapolis, IN, USA). Glucose content was then determined using the glucose oxidase/peroxidase (GOD/PAD) assay (SERA-PAK® Plus, Bayer de México). Total starch content was calculated as glucose (mg) × 0.9. Potato starch was used as a reference.

Total resistant starch was measured by the Goñi's method (Goñi et al., 1996). This method reports the sum of native indigestible fractions, retrograded fractions, and a substantial part of physically inaccessible starch (Tovar, 2001). In brief, the protocol comprises protein removal with pepsin P-7012 (Sigma Chemical, St Louis, MO, USA) at 40 °C and pH 1.5 for 1 h, incubation with amylase A-3176 (Sigma Chemical) at 37 °C for 16 h to hydrolyze digestible starch, treatment of the precipitate with 2 mol l^{-1} KOH, incubation with amyloglucosidase A-7255 (Sigma Chemical) at 60 °C and pH 4.75 for 45 min and determination of glucose using the GOD/PAD assay (SERA-PAK® Plus, Bayer de México).

Potentially available starch content was determined by the subtracting the difference of total starch by resistant starch.

The *in vitro* rate of hydrolysis was measured using hog pancreatic α-amylase according to Holm et al. (Holm, Björck, Asp, Sjöberg, & Lundquist, 1985). Each assay was run with 500 mg of available starch. Predicted Glycemic Index was calculated from the α-amylolysis curves, using the empiric formula proposed by Goñi et al. (Goñi, Gracía & Saura-Calixto, 1997).