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Yacon syrup: Food applications and impact on satiety in healthy volunteers

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ABSTRACT

Syrup obtained from yacon roots could be well positioned as a nutritional product due to its high fructooligosaccharides (FOS) content. Considering this, we examined the potential food applications of yacon syrup, using the focal group methodology, and its sensorial acceptability when incorporated in yogurt. The beneficial effects of the consumption of yacon syrup were studied over a 2-week period in a double-blind placebo-controlled experiment (namely Test A) and other consistent of only one day of yacon syrup consumption (namely Test B) were also evaluated. The doses of yacon syrup for both experiments were 8.74 g of FOS/day. Energy intake, hunger, satiety, fullness and prospective food consumption were assessed with analogue scales at the end of each test. The results indicate that the yogurt was the food most suggested by the focus group, and the average of the scores given to the attributes when the yacon syrup was incorporated into a yogurt were: 7.78 for appearance; 7.72 for aroma; 7.02 for flavor and 6.96 for overall acceptability, corresponding to "like very much" and "like moderately". Furthermore, the results indicate that yacon syrup has a positive effect on appetite and its effect was dependent on gender and period of intervention, being statistically significant ($P < 0.05$) in women, after 2-week period. These findings suggested that increasing FOS intake could help to increase satiety, and consequently, be helpful in the management of type 2-diabetes or control of the current high prevalence of overweight or obesity.

1. Introduction

Yacon [*Smallanthus sonchifolius* (Poepp. et Endl.) H. Robinson] is a tuberous root that is regarded as a functional food given that it contains fructooligosaccharides (FOS), a dietary fiber with prebiotic properties (Castro, Vilaplana, & Nilsson, 2017) and chlorogenic acid (CGA) (Russo, Valentão, Andrade, Fernandez, & Milella, 2015). The consumption of FOS improves the growth of beneficial microorganisms in the colon (mainly *Bifidus* and *Lactobacillus*), enhances mineral absorption and gastrointestinal metabolism and plays a role in the regulation of serum cholesterol and glycemia (Delgado, Thomé, Gabriel, Tamashiro, & Pastore, 2012). Furthermore, the literature reports that the consumption of some prebiotics could promote a positive modulation of a number of biomarkers related to the digestive tract (*e.g.*, ghrelin) or the energy reserve (*e.g.*, insulin and leptin) and suppressing these hormones can contribute to the energy balance (Cani, Joly, Horsmans, & Delzenne, 2006; Genta et al., 2009).

The appetite, central point of the energy balance, can be divided into the followed components: hunger, satiation, and satiety. Hunger is related to the sensations that promote the consumption of food and involves metabolic, sensory and cognitive factors. Satiation is related to the decrease of appetite and can be measured by the duration or size of the current meal. Thus, satiety is defined as the sensation of fullness as a consequence of eating and which inhibits the resumption of eating in the short term, and is related to the next meal, and may reduce its volume or decrease the time interval between them, those being some of the satiety parameters assessed (Amin & Mercer, 2016; Clark & Slavin, 2013; Giuntini, Dan, Lui, Lajolo, & Menezes, 2015).

The FOS-yacon syrup is a product obtained by several technological processes, comprising acid and enzymatic treatment, followed by microfiltration and concentration of the FOS. This product could be well positioned as a functional product due to its high amounts of these prebiotic compounds. However, the effects of the yacon syrup need to be studied. Thus, the aim of the present work was to investigate the

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potential use of the yacon syrup in food, using the focus group methodology, and the benefits related to satiety after short and long-term yacon syrup intervention, in healthy volunteers.

2. Material and methods

2.1. Yacon syrup

The raw yacon (*S. sonchifolius*) was obtained in a local market in Fortaleza, Ceara State, Brazil. Then, yacon pulp was processed as reported previously by Dionísio et al. (2013). Briefly, after washing and sanitizing, the yacon skin was removed manually and the edible portion was cut (1 cm^3) and immersed in citric acid solution (2.4% w/v) for 8 min to inactivate polyphenoloxidases enzymes. These small pieces were homogenized in an industrial blender to obtain the yacon pulp, and stored at -18 ± 1 °C. The yacon syrup was produced in a food processing pilot plant (Embrapa Tropical Agroindustry, Fortaleza, Ceará – Brazil). Briefly, the yacon pulp was treated with Celluclast® 1.5 L and Pectinex® Ultra SP-L (500 mg L^{-1} of each enzyme), and filtered in a microfiltration system. Thus, the clarified material was concentrated to 71°Brix under vacuum (560 mm Hg) and temperature of 60 ± 5 °C. The syrup was portioned into 40 g sachets (corresponding to 8.74 g of FOS, 71.74 kcal or 300.30 kJ), stored at 5 °C, and samples were evaluated in chemical, physical, physicochemical and microbiological analyses.

2.2. Analyses methods

2.2.1. Color

The color was performed in a Minolta Colorimeter (Model CR-400, Konica Minolta Sensing, Inc., Osaka, Japan), with results based on three color coordinates: L^* (whiteness or brightness/darkness), a^* (redness/greenness), and b^* (yellowness/blueness). Based on the values of L^*, a^* and b^*, the chroma value (c^*), which is the color saturation, was calculated and from the relation between a^* and b^*, the angle of color hue (h^*), which indicates de color tone, was obtained. The ΔE^* (color difference) was defined by the following equation:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (1)$$

2.2.2. Water activity, total and reducing sugars, and soluble solids

Water activity (a_w) was measured at 25 °C using Aqualab equipment (Dacagon Devices, Inc., model CX-2 T, Pullman, WA, USA). The total and reducing sugars were determined by the Antrona (Yemn & Willis, 1954) and 3,5-dinitrosalicylic acid (DNS) method (Miller, 1959), respectively. The soluble solids content (°Brix) was measured with a digital refractometer (Pocket Refractometer PAL-3, ATAGO, Japan) at 20.0 ± 0.5 °C, as recommended by AOAC (2005).

2.2.3. pH and titratable acidity

The pH in the samples were measured using a digital pH meter (Hanna Instruments, Romania) and titratable acidity, expressed as grams of citric acid per 100 g of sample, were determined following AOAC's methods (2000) (942.15 AOAC).

2.2.4. Chemical composition

The proteins were determined using the Kjeldahl method (920.87 AOAC); total lipids contents were determined by Soxhlet extraction method (925.38 AOAC); ash was determined by incinerating at 550 °C in a muffle furnace for 6 h (923.03 AOAC), the moisture was determined by AOAC 925.09 method, and carbohydrate by difference (AOAC, 2000).

2.2.5. Fructooligosaccharides

The fructooligosaccharides were determined as described by Horwitz, Latimer, and George (2005), and the results were expressed as % FOS of sample.

2.2.6. Total polyphenols

The total polyphenols were determined by the Folin–Ciocalteu method (Obanda, Owuor, & Taylor, 1997) and the results were expressed as μg GAE (gallic acid equivalent) per g of sample.

2.2.7. Microbiological analyses

The presence of total coliform and *Escherichia coli* in the samples was evaluated according to the Feng, Weagant, Grant, and Burkhardt (2013). Mold and yeast counts were evaluated according to Tournas, Stack, Mislivec, Koch, and Bandler (2001) and the safety microbial parameters *Salmonella* spp. according to the Andrews, Jacobson, and Hammack (2016). Analyses were carried out according to the methodology described by FDA's Bacteriological Analytical Manual.

2.3. Sensory analyses

2.3.1. Focus group

The focus group was used to obtain suggestions for applications of the yacon syrup on foods, as well as a brief sensory characterization of the product. The test was conducted according to Della Lucia and Minin (2013), with 9 participants, five men, and four women, ranging from 26 to 55 years old, recruited from their involvement with correlated areas, such as gastronomy, food science or food engineering, and agronomy. A moderator and a note-taker also participated, and the discussions were recorded using audio. Panelists also marked on a list of terms described in the literature for honey and syrups (Bayma et al., 2010; García-Quiroga et al., 2015; Marcazzan, Magli, Piana, Savino, & Stefano, 2014) those who were perceived in yacon syrup. The frequencies of each suggested application and the descriptive terms were calculated.

2.3.2. Acceptability of yogurt with yacon syrup

A commercial natural yogurt was used in the sensory acceptance, as defined in focus group. The yogurt was prepared with a 200 g portion of yogurt, as established by RDC 359 (Brasil, 2003), with the addition of 40 g of yacon syrup, totaling approximately 8.74 g of FOS (see Table 1). This value was based on its characterization as a fiber source by FDA regulations for nutrient content claims (FDA, 2008) and being below the tolerable doses (16 g/day) (Grabitske & Slavin, 2009).

The sensory evaluation of acceptance was carried out with fifty untrained panelists, as suggested by Meilgaard, Civille, and Carr (2015), using 9-point structured hedonic scales (1: 'disliked extremely'

Table 1
Yacon syrup characterization.

Yacon syrup	Mean ± standard deviation
Centesimal composition	
Water (%)	31.46 ± 0.13
Ash (%)	2.11 ± 0.10
Proteins (%)	1.61 ± 0.05
Lipids (%)	0.07 ± 0.01
Carbohydrates (%)	64.90 ± 0.25
General characteristics	
L^*	47.50 ± 0.38
a^*	1.43 ± 0.03
b^*	21.81 ± 0.23
Water activity	0.78 ± 0.00
pH	3.71 ± 0.02
Titratable acidity (citric acid) (%)	2.82 ± 0.04
Soluble solids (°Brix)	71.03 ± 0.06
Total sugars (%)	56.31 ± 2.49
Fructooligosaccharides and total phenolics	
Fructooligosaccharides (%)	21.84 ± 1.31
Total phenolics (μg gallic acid eq. g^{-1})	1202.25 ± 30.02

Results are expressed as mean and standard deviation of the triplicate determinations.

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