Food Research International 100 (2017) 460–467

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

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

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ARTICLE INFO

Keywords:
Smallanthus sonchifolius
Focal group
Yogurt
Satiety

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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http://dx.doi.org/10.1016/j.foodres.2017.07.035
Received 18 May 2017; Received in revised form 11 July 2017; Accepted 16 July 2017
Available online 18 July 2017

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.

and 9: 'liked extremely'). In the same session, panelists expressed their opinion about what they think to be ideal for sweetness and acidity, using a 5-points "just right" scale (Meilgaard et al., 2015). Panelists were also asked to express the purchase intent, if the product was for sale, on a 5-points scale, varying from "certainly would not buy" to "certainly would buy". The order of presentation of the samples followed a balanced order.

2.4. Characterization of yogurt (control) and yogurt with yacon syrup

To support the results indicated by the sensorial analyses and characterize the products, the following analyses were performed in the yogurt (control) and yogurt added to yacon syrup: pH, titratable acidity, total sugars, reducing sugars and color (L*, a*, b*, chroma, hue and ΔE*), as described in the 2.2 item.

2.5. Pilot study: Effects on hunger/satiety in healthy volunteers

The effects of yacon syrup were tested in two different trials. In the first one, namely Test A, the yacon syrup was consumed for 2-week; for the Test B, the yacon syrup was consumed in only a day. For both tests, were chosen volunteers in overall good health (defined as the absence of hyperthyroidism and renal and gastrointestinal diseases; with no previous diagnosis or family history of *Diabetes mellitus*) and not using any medication, particularly antibiotics that could affect digestion and absorption of foods during the study period. Volunteers classified as overweight/obese (body mass index (BMI) ≥ 25 kg m^{-2}) or underweight (BMI ≤ 18.6 kg m^{-2}) according to the criteria of the World Health Organization (WHO, 1998) and those reporting any disease, pregnancy, breastfeeding, or treatment of any kind (including for possible eating disorders) were not included in the study.

The experimental protocol (sensory analyses and pilot study) was submitted to and approved by the Ethical Research Committee of State University of Ceara (UECE) (no 56094516.4.0000.5534), according to the rules of the National Committee for Ethical Research of the Brazilian Health Ministry (CONEP/MS). All volunteers signed an informed consent form before the intervention.

2.5.1. Experimental design: 2-week intervention period of yacon syrup (Test A)

This study was a double-blind, parallel, placebo-controlled trial performed over two weeks. At the end of the intervention, the hunger/satiety and energy consumption were analyzed. Twenty healthy male (*n* = 10/group) and female (*n* = 10/group) volunteers with a mean (± standard deviation) age of 27.6 ± 5.1 years were included in this study. The volunteers were divided into two groups: the Group 1 (G1), who received yacon syrup (40 g), and the Group 2 (G2), who received placebo (40 g of corn syrup, 71°Brix, acidified with 0.1% of citric acid and 0.018% of caramel colorant). All volunteers received 15 individual portions of the yacon syrup or placebo and were instructed to consume the entire amount of the sachet daily, during breakfast. At the end of the 2-week period, the volunteers were invited to an excess day free-choice buffet meal, to perform the hunger/satiety test. The dietary intake of this last breakfast was estimated by means of food registration and the nutritional composition of the meal of energy, proteins, carbohydrates, lipids and dietary fiber, using the Brazilian Table of Food Composition/Unicamp (TACO). This food intake was also used to evaluate the effect of yacon intake on the appetite of the volunteers *versus* the consumption of a meal. Appetite ratings were made on 100 mm Visual Analogue Scale (VAS) with text expressing the most positive and the negative rating anchored at each end. (A) Satiety: 'I cannot eat another bite'; (B) Hunger: 'I have never been more hungry'; (C) Fullness: 'I am totally full'; (D) Prospective food consumption: 'I can eat a lot' (Raben, Tagliabue, & Astrup, 1995). VAS was used to assess satiety, hunger, fullness and prospective food consumption of the test meals. The volunteers recorded their sensations at the beginning of each meal (time 0) and throughout the period after the breakfast (0, 30, 60, 90, 120, 150, and 180-min time points).

2.5.2. Experimental design: one day intervention period of yacon syrup (Test B)

The volunteers were instructed to visit the laboratory after 10 h of fasting, and then to consume a breakfast of known composition [sandwiches with cheese and ham (1027 kJ or 244 kcal $unit^{-1}$) and commercial natural yogurt (324.6 kJ or 77 kcal 100 mL^{-1})], added to yacon syrup (Group 3 – G3) or placebo (Group 4 – G4). The individuals composed by the G3 and G4 were unalterable. However, the tests were applied in two consecutive weeks (in the first week, the volunteers received the yacon syrup; and in the next one, received the placebo). Before and after consumption of a breakfast of known composition, the volunteers answered the 100-mm VAS at the 0, 30, 60, 90, 120, 150, and 180-min time points, similar to applied in the Test A (item 2.5.1).

2.6. Statistical analysis

Results are expressed as mean ± standard error of the mean. The effects of yacon syrup and placebo were compared by ANOVA using repeated measures model with fixed factors of treatment, time, time treatment interaction, and a random factor of voluntary. Energy intake and macronutrients between test meals were compared using an independent *t*-test, SPSS 20.0 for Windows system (SPSS, Chicago IL, USA). The level of significance was set at $P < 0.05$.

3. Results and discussion

3.1. Yacon syrup characterization

The chemical, physical and physicochemical composition of the yacon syrup is shown in Table 1. Results from the color measurements (L*, a* and b*) for yacon syrup coordinates were 47.50 ± 0.38, 1.43 ± 0.03 and 21.81 ± 0.23, respectively. Lachman, Fernández, and Orsák (2003) reviewed the chemical composition of yacon, and shown that the tuberous root presents carotenoids – a class of compounds responsible for the yellow-to-red coloration of many fruits and vegetables – in a concentration of 0.13 mg of β-carotene 100 g^{-1}. These compounds, although in low concentration, can contribute to the color of yacon.

The water content of the yacon syrup was 31.46 ± 0.13%, and a water activity (a_w) of 0.78 ± 0.0, as expected for syrup. According to Beuchat et al. (2013), the foods with aw < 0.85 is considered to as low-a_w foods, considering that minimum a_w for growth of most bacteria is approximately 0.87. This result is related to the higher content of total sugars (56.31 ± 2.49%) and soluble solids (71.03 ± 0.06°Brix). The value for soluble solids is in agreement with other works, such as the yacon syrup obtained by Genta et al. (2009) and Manrique, Párraga, and Hermann (2005) with values of 73°Brix for both products.

As expected, the yacon syrup presents low values of pH and high values for acidity and are related to the use of citric acid solution to inactivate the polyphenoloxidases (PPO) enzymes. In addition to prevent the occurrence of enzymatic browning, and preserve their appearance, the acidification step in the process is particularly relevant for yacon, which is rich in polyphenols and highly susceptible to enzymatic browning (Dionísio et al., 2013).

Yacon is rich in polyphenolic antioxidants, including caffeic acid, ferulic acid and chlorogenic acid (CGA) (Dionísio et al., 2015; Takenaka et al., 2003). Besides the phenolic constituents of yacon, the fructooligosaccharides (FOS) are the major bioactive compound, being recognized by the scientific literature due its functional properties, such as prebiotic effects (Dionísio et al., 2015). As described in Table 1, the values obtained for FOS in the yacon syrup was about 22%. Genta et al. (2009) and Geyer, Manrique, Degen, and Beglinger (2008) obtained values for yacon syrup about 40% and 32% of FOS, respectively.

Table 2
List of descriptors frequencies named by panelists during the focal group session of the yacon syrup.

Appearance/color	(%)	Aroma	(%)	Flavor	(%)	Consistency/viscosity	(%)
Cane syrup	89	Sweet	100	Acid	100	Viscous	100
Caramel pudding	78	Brown sugar	56	Sweet	78	Dense	56
Burnt sugar	78	Sugarcane	56	Molasses	78	Sticky	44
Glucose syrup	78	Fruity	44	Citric	56	Concentrated juice	33
Caramel	67	Burnt sugar	44	Caramelized	56	Thick	11
Glossy	67	Acid	33	Brown sugar	44		
Coppery	44	Caramel	33	Sugarcane	33		
Medicinal herbal syrup	44	Floral	22	Herbs	22		
Fruit syrup	44	Citric	22	Burnt sugar	22		
Yellow	33	Medicinal	22	Refreshing	22		
Limpid	33	Herbs	11	Floral	22		
Brown	33	Fume	11	Astringent	22		
Transparent	22	Green vegetable	11	Fruity	22		
Dark orange	22	Refreshing	11	Dry vegetable	11		
Clarified	11	Coffee	11	Tangy	11		
Burnt	11			Hot	11		
Crystaline	11			Medicinal	11		
Weak coffee	11			Green vegetable	11		
Refrigerant	11			Pungent	11		
Gilded	11			Caramel	11		

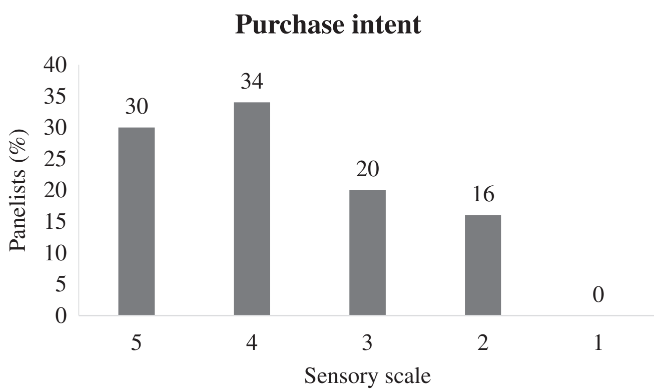

Fig. 1. Percentage distribution of the purchase intent (5 = certainly would buy, 3 = might buy/might not buy and 1 = certainly would not buy) of the yogurt added yacon syrup.

Table 3
Characterization of yogurt (control) and yogurt with yacon syrup.

	Yogurt	Yogurt with yacon syrup
pH	4.53 ± 0.01	4.02 ± 0.01
Titratable acidity (citric acid) (%)	0.64 ± 0.01	1.07 ± 0.03
Total sugars (%)	5.51 ± 0.24	10.96 ± 0.05
Reducing sugars (%)	5.51 ± 0.24	10.96 ± 0.05
L*	74.04 ± 0.69	70.19 ± 1.16
a*	− 1.75 ± 0.04	− 0.82 ± 0.01
b*	11.54 ± 0.11	13.76 ± 0.24
Chroma	11.67 ± 0.11	13.79 ± 0.24
Hue	− 81.36 ± 0.12	− 86.59 ± 0.09
ΔE*	–	4.63 ± 1.26

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

However, Manrique et al. (2005) produce yacon syrup using two different cultivars (CLLUNC118 – Hualqui cultivar, and AMM 5163), and determined values of 10.9 and 47.6% for FOS respectively, showing the dependence of various factors (specially the cultivar), in the FOS amount in different yacon roots.

3.2. Focus group, sensorial acceptance and characterization

Microbiological analyses showed that the yacon syrup was suitable for consumption (*Salmonella* spp., *E. coli*, total coliform, mold and yeast were not detected). After the quality evaluation, a focus group methodology was applied to obtain from the participants' suggestions on foods in which yacon syrup could be used as an ingredient.

Table 4
Comparison of treatments (placebo and yacon syrup) for Test A (2-weeks intervention, and a free-choice buffet meal).

Dietary intake	Placebo (n = 10)	Yacon (n = 10)	P-value[a]
Energy, kcal/day	581.0 ± 218.2	603.6 ± 282.1	0.844
Protein, % energy	16.5 ± 4.2	14.1 ± 6.2	0.327
Carbohydrate, % energy	52.0 ± 12.7	54.8 ± 16.0	0.681
Total fat, % energy	31.5 ± 9.2	31.1 ± 11.3	0.926
Dietary fiber, g/day	4.5 ± 1.7	3.7 ± 1.4	0.265

Results are expressed as mean and standard deviation.
[a] Student's t-test.

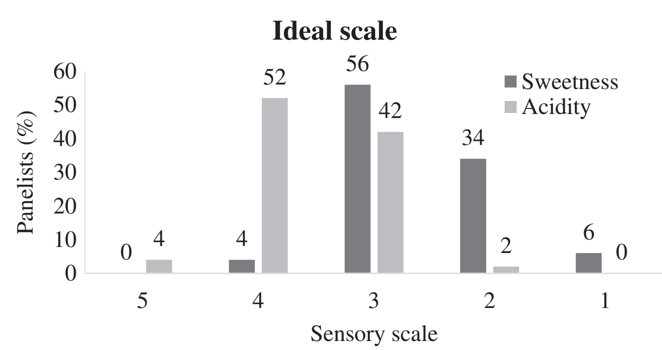

Fig. 2. Percentage distribution of the sweetness and acidity (5 = much more than the ideal, 3 = ideal and 1 = much less than the ideal) of the yogurt added yacon syrup.

After yacon syrup consumption by each participant, the initial step was to brainstorm and develop a list of applications. All participants feel comfortable with each other and engage the discussion. At the end of the session, the terms that received higher scores on appearance/color, aroma, flavor and consistency/viscosity were, respectively: appearance of sugarcane syrup (89%); sweet aroma (100%); acidity flavor (100%) and viscous (100%) (see Table 2 for the complete list). For the applications of yacon syrup, the main suggestions obtained by the focus group include yogurt, fruit salad and beverages. According to Tomic et al. (2017), yogurt is a very accepted product and can be added with a fiber ingredient, as a way to increase the fiber consumption by consumers. In addition, inulin and its hydrolysates (oligofructans with

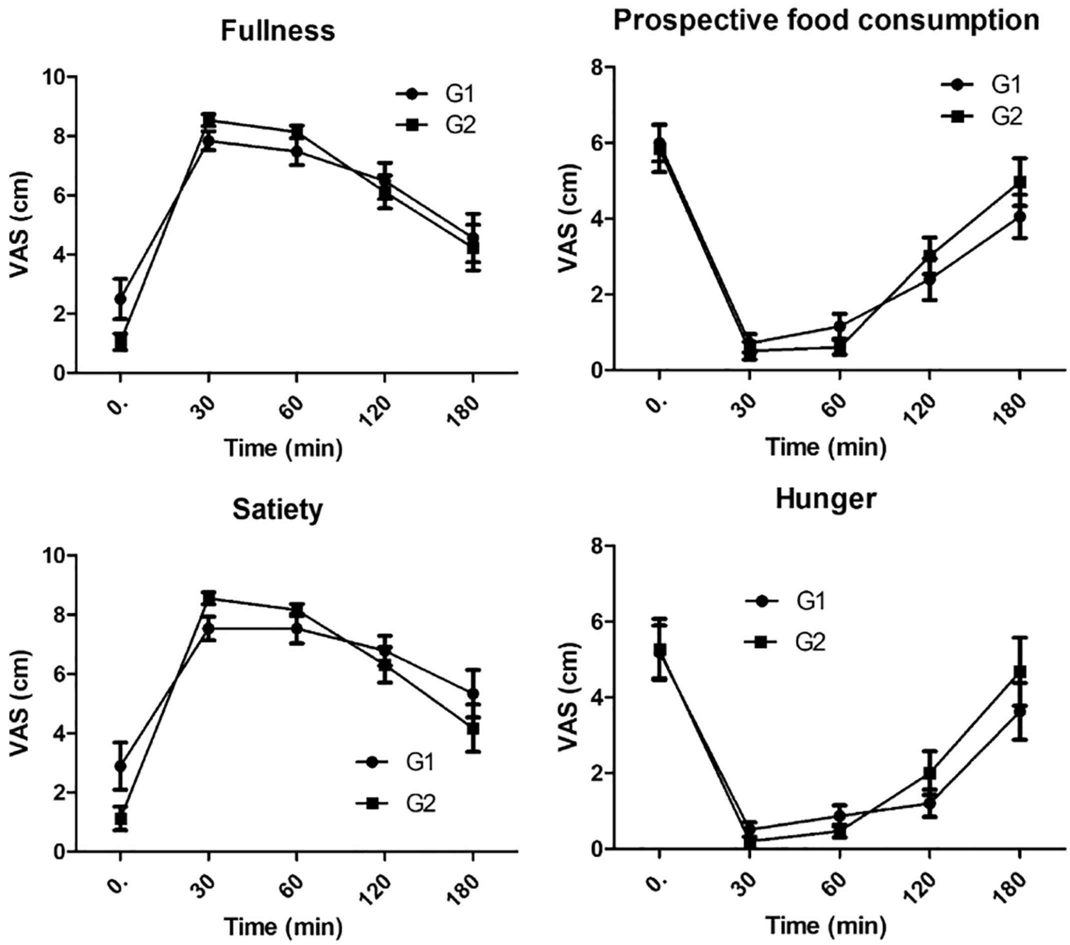

Fig. 3. Variation of the "hunger", "satiety", "fullness" and "prospective food consumption" parameters at fasting (T0) and after consumption of breakfast with yacon syrup (G1) or placebo (G2) (T30, T60, T120 and T180 min) after 2-week intervention period of yacon syrup (G1) and control (G2), in healthy volunteers ($n = 20$). ANOVA using repeated measures model was used for the variable and there results are expressed as the mean and standard error of the mean. Hunger: treatment effect, $P = 0.497$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.607$. Satiety: treatment effect, $P = 0.372$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.063$. Fullness: treatment effect, $P = 0.639$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.251$. Prospective food consumption: treatment effect, $P = 0.672$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.476$.

degree of polymerization from 2 to 8) are also added to dairy products such as yogurt in order to improve textural properties and sensorial acceptance (Castro, Céspedes, Carballo, Bergenståhl, & Tornberg, 2013). Thus, considering the result of the focus group, yogurt was the product selected for the next step of this work, to evaluate the sensory acceptance of a food added with yacon syrup (yogurt with yacon syrup).

The results obtained for the sensory analyses shown high sensory scores for the yogurt added with yacon syrup, considering the score average given by the fifty volunteers. The scores for each attribute evaluate were: 7.78 for appearance; 7.72 for aroma; 7.02 for flavor and 6.96 for overall acceptability, corresponding to "like moderately" and "like very much". In addition, the product would be considered as a possible commercialization success, due the valued obtained by the purchase intention of the product, which showed that 64% of the panelists indicated a positive attitude ("certainly" or "probably would buy the product") (Fig. 1).

The addition of yacon syrup influenced all the parameters evaluated in the yogurt, such as pH, titratable acidity, color (L^*, a^*, and b^* values), total sugars and reducing sugars (see Table 3).

According to the chemical, physical and physicochemical results (Table 4), the yacon syrup addition into yogurt diminished the clarity (reduced the L^* value when compared to the control) and imparted a yellow-greenish color to the yogurt (increased a^* and b^* values). Sanz, Salvador, Jimenez, and Fiszman (2008) evaluated the effect of fiber extraction method on rheological properties, color, and sensory acceptance of yogurt enrichment with functional asparagus fiber. The authors concluded that the fiber changed the L^*, a^* and b^* values of the yogurt, which also varied depending on the method of extraction and drying, being more colorful the yogurts with water-extracted fibers. Dello Staffolo, Bertola, Martino, and Bevilacqua (2004), adding apple fiber to yogurt, showed color differences compared to the control. The authors concluded that the fibers modified certain rheological characteristics of the yogurt, however, the panelists found the supplemented yogurts acceptable.

With the aim of determining whether the differences in color between the yogurts that were recorded on measuring instruments can be perceived by the human eye, parameter ΔE^* was calculated, with the color parameters of the control yogurt (without added fiber) being taken as the reference point. Yogurt added with yacon syrup had value for $\Delta E^* > 3$, that indicate difference evident to the human eye between the samples (Francis & Clydesdale, 1975). This color behavior was expected because yogurt with this type of fiber differs more markedly from white yogurt in terms of parameters L^*, a^* and b^*.

The changes caused by the yacon syrup addition in the pH and titratable acidity, apart from the increase of total sugars and reducing sugars, were an expected result, considering the characteristics of the yacon syrup (see Table 1). Thus, the results of the sensorial acceptance (see Fig. 2) shown that the yogurt added of yacon syrup presents 56% and 42% of the values located "ideal scale" of sweetness and acidity,

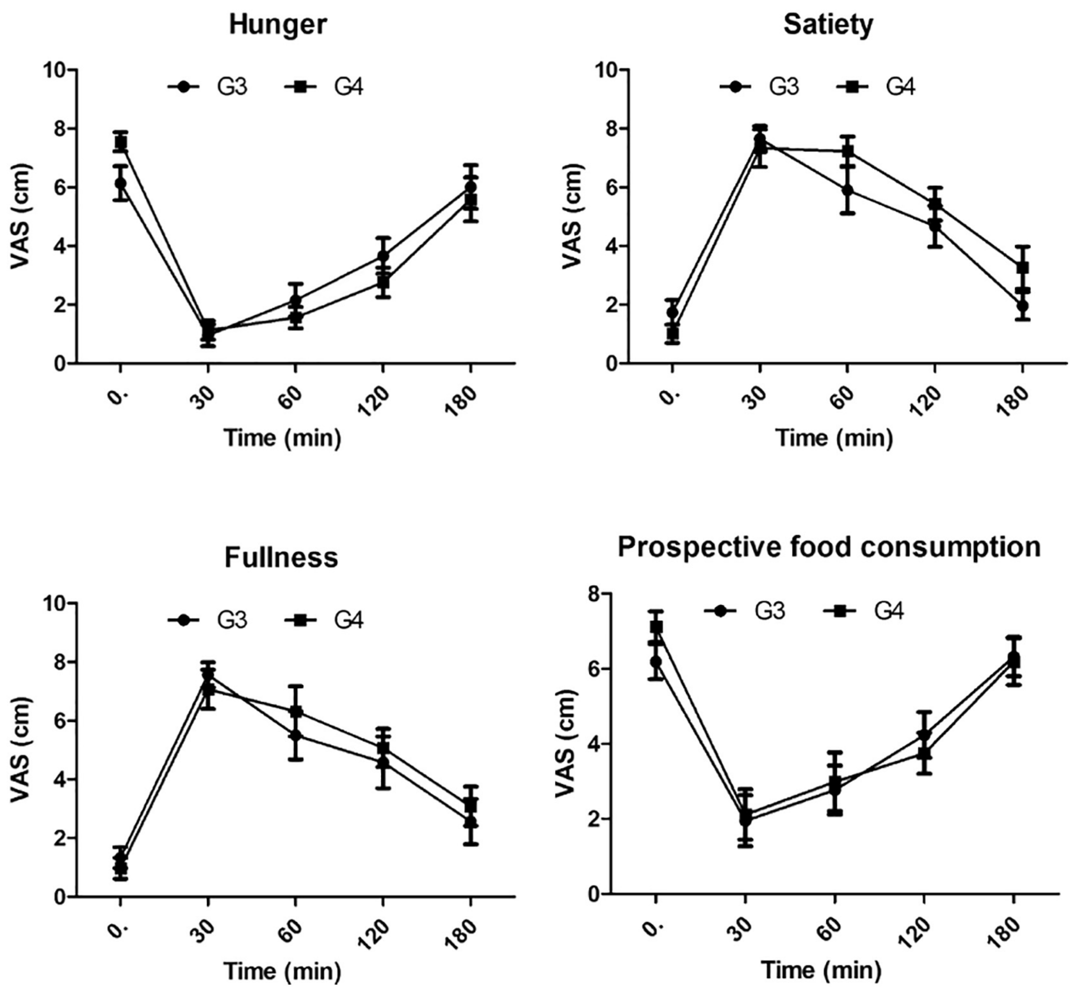

Fig. 4. Variation of the "hunger", "satiety", "fullness" and "prospective food consumption" parameters at fasting (T0) and after consumption of breakfast (T30, T60, T120 and T180 min) after consumption of yacon syrup (G3) and placebo (G4), in healthy volunteers ($n = 10$). ANOVA using repeated measures model was used for the variable and there results are expressed as the mean and standard error of the mean. Hunger: treatment effect, $P = 0.846$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.222$. Satiety: treatment effect, $P = 0.200$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.254$. Fullness: treatment effect, $P = 0.646$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.826$. Prospective food consumption: treatment effect, $P = 0.715$; time effect, $P < 0.001$; time treatment interaction effect, $P = 0.825$.

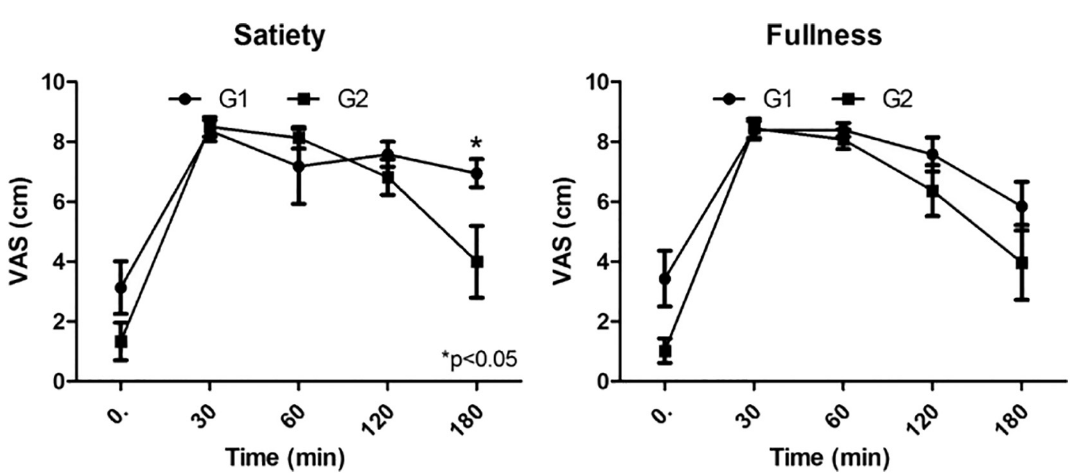

Fig. 5. Variation of the "satiety", and "fullness" parameters at fasting (T0) and after consumption of breakfast (T30, T60, T120 and T180 min) after 2-week intervention period of yacon syrup (G1) and control (G2), in healthy women ($n = 10$).

respectively.

3.3. Effect of yacon syrup on satiety in healthy volunteers

The total fiber and dietary energy and macronutrient intake (protein, carbohydrate, fat) during the free-breakfast at the end of 2-week period (Test A) were equivalent for both groups (yacon syrup and placebo – G1 and G2, respectively) and are presented in Table 4. For Test B, the breakfast was similar for all participants, according to described in 2.4.2. item.

Figs. 3 and 4 shown no-statistical differences ($P > 0.05$) for hunger, satiety, fullness and prospective food consumption after short term (Test B) or 2-week intervention period of yacon syrup (Test A). After stratification by sex, no-statistical differences ($P > 0.05$) were found in all parameters tested for Test B. However, the opposite profile was observed in Test A. Among women, the variation of the "satiety" observed treatment effect ($P = 0.059$) and difference in time T180 ($P < 0.05$) and treatment effect ($P = 0.010$) in "fullness" (see Fig. 5). Our findings suggest that the ability of the yacon syrup to affect satiety may not be immediate, and dependent on the gender. Gender differences in satiety responses have been noted in previous studies. Cornier, Salzberg, Endly, Bessesen, and Tregellas (2010) suggested that women would have a more robust prefrontal and parietal response to food-related visual cues than men, and also have greater sensitivity to hunger and satiety responses to eating as compared to men, resulting in the ability to better maintain energy balance during an *ad libitum* diet setting. In addition, Scudine et al. (2016) have shown differences in masticatory behavior between men and women. The authors showed that the men have decrease chewing time and fewer chewing strokes than women, and showing their relation with satiety, which is higher in women.

The differences in short and long-term consumption of fibers in satiety responses have been reported in previous studies. In human interventions, a pilot study of 10 healthy individuals who consumed FOS (16 g/d total) twice a day, for 2-weeks, reported increased satiety after breakfast and dinner when compared to placebo (Cani et al., 2006). However, consistent with our findings, individuals consuming FOS (8 g) in a meal-replacement bar for two days, once or twice a day, had not affected the short-term appetite (Peters, Boers, Haddeman, Melnikov, & Qvyjt, 2009).

The hypothalamus is the structure of the nervous system responsible for the control of food intake (short-term regulation of hunger and satiety) and body weight (long-term regulation). It receives many signals in the form of hormones such as ghrelin that stimulates hunger, and adrenaline, insulin, cholecystokinin, leptin and PYY protein that stimulates satiation and/or satiety (Giuntini et al., 2015). Shi and Clegg (2009) review the sex differences of regulation of body weight of humans. The authors shown differences in the way the brains of female and male respond to signals that regulate body fat, and revealed that leptin levels are higher in females compared with males. Carroll, Kaiser, Franks, Deere, and Caffrey (2007) evaluated the effect of gender in postprandial hormone responses, and concluded that men had slightly greater postprandial decline in leptin compared with women.

Thus, our results are corroborated by a number of studies that indicate that FOS were to have an effect on appetite that is more likely to be detected in women and within a study of longer duration. These findings suggested that increasing total fiber intake could help to increase satiety, especially in women, and consequently, be helpful in the management of type-2 diabetes (Venn & Mann, 2004) or control of the current high prevalence of obesity and overweight (Cani et al., 2006). However, these results have to be confirmed by longer studies (> 2 weeks) and assessed in overweight, obese and type 2 diabetes volunteers.

4. Conclusions

The results of this study demonstrate that yacon syrup can be consumed as a single food or as an ingredient of another food, such as yogurt, according to observations made in the focus group. In addition, the yogurt supplemented with yacon syrup showed good sensory acceptance and positive purchase intention. After a medium-term intervention of the yacon syrup in healthy volunteers, the results showed important sex-based differences in appetite responses to foods. In addition, the effect was not observed in a short-term intervention.

Acknowledgements

We thank all the volunteers who participated in this study. In addition, the authors would like to thank the Brazilian Agricultural Research Corporation (EMBRAPA SEG n° 03.14.13.008.00.00) and the National Council for Scientific and Technological Development (*CNPq* n° 447191/2014-4) for the financial support.

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