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

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A R T I C L E   I N F O

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- Smallanthus sonchifolius
- Focal group
- Yogurt
- Satiety

A B S T R A C T

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 glyceria (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, Ceará 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 cm³) 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) and 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:

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

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

Water activity (aw) 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, 1976a, 1976b) and from the relation between a and b, 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 (Byama 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>
<thead>
<tr>
<th>Table 1</th>
<th>Yacon syrup characterization.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± standard deviation</td>
</tr>
<tr>
<td><strong>Centesimal composition</strong></td>
<td></td>
</tr>
<tr>
<td>Water (%)</td>
<td>31.46 ± 0.13</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>2.11 ± 0.10</td>
</tr>
<tr>
<td>Proteins (%)</td>
<td>1.61 ± 0.05</td>
</tr>
<tr>
<td>Lipids (%)</td>
<td>0.07 ± 0.01</td>
</tr>
<tr>
<td>Carbohydrates (%)</td>
<td>64.90 ± 0.25</td>
</tr>
<tr>
<td><strong>General characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>47.50 ± 0.38</td>
</tr>
<tr>
<td>a*</td>
<td>1.43 ± 0.03</td>
</tr>
<tr>
<td>b*</td>
<td>21.81 ± 0.23</td>
</tr>
<tr>
<td>Water activity</td>
<td>0.78 ± 0.00</td>
</tr>
<tr>
<td>pH</td>
<td>3.71 ± 0.02</td>
</tr>
<tr>
<td>Titratable acidity (citric acid) (%)</td>
<td>2.82 ± 0.04</td>
</tr>
<tr>
<td>Soluble solids (°Brix)</td>
<td>71.03 ± 0.06</td>
</tr>
<tr>
<td>Total sugars (%)</td>
<td>56.31 ± 2.49</td>
</tr>
<tr>
<td>Fructooligosaccharides and total phenolics</td>
<td></td>
</tr>
<tr>
<td>Fructooligosaccharides (%)</td>
<td>21.84 ± 1.31</td>
</tr>
<tr>
<td>Total phenolics (μg gallic acid eq. g⁻¹)</td>
<td>1202.25 ± 30.02</td>
</tr>
</tbody>
</table>

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. Characterisation 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 AE*), 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 under-weight (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 Ceará (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.

The experimental protocol (sensory analyses and pilot study) was 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 volunteer. 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

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 (CQA) (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.
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 (specifically 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.

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

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

<table>
<thead>
<tr>
<th>Appearance/color (%)</th>
<th>Aroma (%)</th>
<th>Flavor (%)</th>
<th>Consistency/viscosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane syrup</td>
<td>89</td>
<td>Sweet</td>
<td>Acid</td>
</tr>
<tr>
<td>Caramel pudding</td>
<td>78</td>
<td>Brown sugar</td>
<td>Viscous</td>
</tr>
<tr>
<td>Burnt sugar</td>
<td>78</td>
<td>Sugarcane</td>
<td>Sweet</td>
</tr>
<tr>
<td>Glucose syrup</td>
<td>78</td>
<td>Fruity</td>
<td>Molasses</td>
</tr>
<tr>
<td>Caramel</td>
<td>67</td>
<td>Burnt sugar</td>
<td>Citric</td>
</tr>
<tr>
<td>Glossy</td>
<td>67</td>
<td>Acid</td>
<td>Caramelized</td>
</tr>
<tr>
<td>Coppery</td>
<td>44</td>
<td>Caramel</td>
<td>Brown sugar</td>
</tr>
<tr>
<td>Medicinal herbal syrup</td>
<td>44</td>
<td>Floral</td>
<td>Sugarcane</td>
</tr>
<tr>
<td>Fruit syrup</td>
<td>44</td>
<td>Citric</td>
<td>Herbs</td>
</tr>
<tr>
<td>Yellow</td>
<td>33</td>
<td>Medicinal</td>
<td>Burnt sugar</td>
</tr>
<tr>
<td>Lignip</td>
<td>33</td>
<td>Herbs</td>
<td>Refreshing</td>
</tr>
<tr>
<td>Brown</td>
<td>33</td>
<td>Fume</td>
<td>Floral</td>
</tr>
<tr>
<td>Transparent</td>
<td>22</td>
<td>Green vegetable</td>
<td>Astringent</td>
</tr>
<tr>
<td>Dark orange</td>
<td>22</td>
<td>Refreshing</td>
<td>Dry vegetable</td>
</tr>
<tr>
<td>Clarified</td>
<td>11</td>
<td>Coffee</td>
<td>Tangy</td>
</tr>
<tr>
<td>Burnt</td>
<td>11</td>
<td></td>
<td>Hot</td>
</tr>
<tr>
<td>Crystalline</td>
<td>11</td>
<td></td>
<td>Medicinal</td>
</tr>
<tr>
<td>Weak coffee</td>
<td>11</td>
<td></td>
<td>Green vegetable</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>11</td>
<td></td>
<td>Pungent</td>
</tr>
<tr>
<td>Gilded</td>
<td>11</td>
<td></td>
<td>Caramel</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Yogurt</th>
<th>Yogurt with yacon syrup</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.53 ± 0.01</td>
<td>4.02 ± 0.01</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>0.64 ± 0.01</td>
<td>1.07 ± 0.03</td>
</tr>
<tr>
<td>Total sugars (%)</td>
<td>5.51 ± 0.24</td>
<td>10.96 ± 0.05</td>
</tr>
<tr>
<td>Reducing sugars (%)</td>
<td>5.51 ± 0.24</td>
<td>10.96 ± 0.05</td>
</tr>
<tr>
<td>L*</td>
<td>74.04 ± 0.69</td>
<td>70.19 ± 1.16</td>
</tr>
<tr>
<td>a*</td>
<td>-1.75 ± 0.04</td>
<td>-0.82 ± 0.01</td>
</tr>
<tr>
<td>b*</td>
<td>11.54 ± 0.11</td>
<td>13.76 ± 0.24</td>
</tr>
<tr>
<td>Chroma</td>
<td>11.67 ± 0.11</td>
<td>13.79 ± 0.24</td>
</tr>
<tr>
<td>Hue</td>
<td>-81.36 ± 0.12</td>
<td>-86.59 ± 0.09</td>
</tr>
<tr>
<td>ΔE*</td>
<td>-</td>
<td>4.63 ± 1.26</td>
</tr>
</tbody>
</table>

Results are expressed as mean and standard deviation of the triplicate determinations.
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 Staffole, 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 ΔE* > 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 fibers 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.

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 food added with yacon syrup (yogurt with yacon syrup).

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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 (yacan 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 6-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, & Qvyy, 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 showed 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 other 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.

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