INTRODUCTION

Yacon (Smallanthus sonchifolius) is a plant native to the Andes, which was introduced in Brazil in the early 90’s. In mid-2000, this root started to be significantly consumed and became popularly known as yacon potato or diabetic potato. Yacon tuberous roots are rich in fructans (fructooligosaccharides and inulin) and insoluble fiber, with potential beneficial effect on health (1,2,3). The energy value of the root is considered low due to the high water content, around 90% of its fresh weight. Carbohydrate is the main component of its dry matter, about 90%; while 40 to 70% is composed of fructooligosaccharides (FOS); 5 to 15% of sucrose; 5 to 15% of fructose; and less than 5% of glucose. The other components (proteins, lipids, vitamins and minerals) are found at lower amounts (4).

In addition to the functional properties, FOS also have desirable technological characteristics, since, as non-reducing sugars, they are not susceptible to the Maillard reaction. As for stability, these compounds are stable at pH values higher than 3 and temperatures up to 140 °C. Besides, they are not degraded in most thermal processes of food industries (6).

Due to its composition, yacon self life is very short, approximately seven days. Therefore, yacon-based products have been developed to be used as ingredients of low-fat and reduced calorie preparations that provide physiological benefits to consumers (7). Jams are easily manufactured, aggregate value and allow food conservation for an extended period of time, thus playing a major role in food industry. They can become an alternative to raw or processed foods that receive the addition of yacon.

Thus, this study aimed to develop yacon jams with and without condiments and evaluate their physical-chemical and microbiological characteristics and sensory acceptability.

MATERIAL AND METHODS

Development of yacon jams

Four formulations of yacon jam were developed, with four different flavors: natural, cinnamon, nutmeg and ginger.
Desarrollo de jalea de yacón de reducido valor calórico: caracterización físico-química, microbiológica y sensorial

El yacón usado en el experimento fue adquirido en un supermercado de la ciudad de Viçosa. Se lavó en agua corriente y se sanitizó con 200 mg L-1 de clorato activo durante 15 minutos. Después, el yacón se huskó y sumergió en una solución de 0.5% ácido sulfúrico (p/v) durante 15 minutos para evitar la enzimática browning (8). Parte del yacón fue triturada (aproximadamente 18% p/p), y el resto fue procesado en una licuadora (ARNO) para el procesamiento de la jalea. Posteriormente, el pH de ambas porciones combinadas se corrigió a 3.9 con ácido cítrico (9,10). Luego, la mezcla fue calentada en un prensa no stick pan hasta que alcanzó 70 °C. Como se previamente, 0.7% p/p pectina fue homogenizada en azúcar para prevenir la formación indeseada de lúpulos (11) y se añadió con 13.6% p/p azúcar (12) al yacón pulpa. Las jaleas se concentraron hasta alcanzar 28 °Brix y la canela, nuez moscada y jengibre secado fueron homogeneizadas en azúcar para evitar la formación indeseada. Después, el yacón se huskó y sumergió en una solución de 0.5% bisulfito de sodio (p/v) durante 15 minutos para prevenir la formación de enzimas. Luego, la jalea fue homogeneizada en una licuadora Stomacher® (Seward, UK). Apropriate diluciones decimales y alícuotas de estas diluciones fueron transferidas a un medio específico para cada grupo de microorganismos. Cada dilución se puso en placas en duplicado.

Sensory analysis of yacón jams

La evaluación del valor sensorial de las cuatro formulaciones de jalea de yacón fue realizada en un supermercado en la ciudad de Viçosa, MG.

El valor de aceptación general de las jaleas se evaluó utilizando una escala hedónica de 9 puntos (21). Grupo de edad, género y frecuencia de consumo de jalea se investigó, además de la evaluación sensorial.

Los resultados de la evaluación sensorial se analizaron en un modelo de bloque aleatorizado, y los consumidores se representaron a través de bloques. Los resultados se calcularon usando el método de predicción mediante el análisis de componentes principales, en el que se basó el método CNNPA 1978 ANVISA (18) para jaleas, el método 963.15 de la AOAC para la extracción en Soxhlet; el método 991.20 para las cenizas, el método 935.29 para las proteínas, el método 923.03 para los hidratos de carbono, el método 923.03 para la energía química, el método 923.03 para la caloría. Los resultados de cada determinación se expresaron basados en el promedio de tres replicados para cada muestra.

The proximal composition of the yacón jams

The proximal composition of the yacón jams was determined by the Instituto Adolfo Lutz (Adolfo Lutz Institute) (17). The results of each determination were expressed based on the average of three replicates for each sample.

The following analyses were performed: moisture content, by the gravimetric method (method 935.29); protein, by the micro-Kjeldahl method (method 991.20); lipids, by direct extraction in Soxhlet (Method 963.15); and ashes, by incineration (method 923.03).

The levels of total dietary fiber and fructooligosaccharides (FOS) were determined based on the results obtained by Vasconcelos et al. (14), who studied the proximal composition of yacón of same origin used in this work. The quantity of total dietary fiber was obtained by the sum of insoluble and soluble fibers, FOS and inulin.

The carbohydrate fraction was determined to be the remaining portion of the sample after discounting the levels of moisture, protein, lipids, ashes and total dietary fiber (15).

The caloric value of yacón jams was calculated by using the following equation:

\[ 	ext{Caloric value} = 4 \text{ kcal/g for proteins and carbohydrates, and 9 kcal/g for lipids} \]

Physical-chemical analyses of the yacón jams

The determination of pH of the yacón jams was made according to the 017/IV method described by the Instituto Adolfo Lutz (Adolfo Lutz Institute) (17) through direct reading with a digital pH meter (Tekna T-1000, model T-1000) using a 10 g from each experimental unit.

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Total soluble solid content (TSS) was measured directly in a bench-top ABBE refractometer at 20 °C, with results given in °Brix according to the analytical standards of the Adolfo Lutz Institute (17).

The roots of yacón were weighed before and after of husked, to calculate the average yield of the jams. The jams also were weighed and it was calculated the percentage of yield in relation to the weight of the roots with husk.

Microbiological analysis of yacón jams

Following the standards established by the Resolution Number 12 of the CNNPA 1978 ANVISA (18) for jams, the microbiological analysis of total coliforms, thermotolerant coliforms (45 °C) and salmonella were performed, and counting of fungi and yeasts. The analyses were conducted as recommended by the Normative Instruction Number 62, of August 26, 2003, of the Ministry of Agriculture, Cattle Raising and Supply (19). Portions of 25 g of the product aseptically weig- hed were homogenized with 225 mL of 0.1% peptone water in Stomacher® (Seward, UK). Appropriate decimal dilutions were prepared and aliquots of these dilutions were transferred to specific medium for each group of microorganism. Each dilution was plated in duplicate.
Proteins, lipids and ashes are present in small amounts in the yacon jams. This had already been expected, because the yacon pulp has low content of these components (3).

The caloric value of the yacon jams was ranged from 116.4 to 140.0 kcal/100g or 23.3 to 28.0 kcal/portion. Higher caloric values were found for fruit jams in the Table Brazilian of the Food Composition (29) (238 kcal/100g) and Table of Chemical Composition of Foods of the UNIFESP (30) (278 kcal/100g), demonstrating that the addition of yacon can reduce the caloric value of yacon jams.

The yacon jams reduced caloric value in more than 40%, compared to the caloric value of the jams already mentioned, and can be considered as light or “reduced calorie” products (27). The high sweetening ability of the sugars present in yacon, mainly fructose (31), contributed to the preparation of a jam with low addition of sucrose and therefore, with low content of calories.

The average content of soluble solids was 27.6 °Brix, which is below the value recommended by law, at least 62 °Brix for the common jam (18), due to reduced sugar composition, being considered light.

The final products presented average pH of 3.8. The control of pH in the jams affect microbial control (32) and gel formation. In jams, usually occurs gelatinization at pH up to 3.4. However, syneresis occurs at pH below 3.1 (11). The formulations were prepared at pH 3.8, which provided adequate gelatinization. The pH value is also important to prevent the degradation of FOS, since they can undergo hydrolysis at values below 3.5 and thus increase the heating period during the processing of jam and reduce the content of this prebiotic component (30).

The average yield of the jams was 65%, with correction factor of 1.24, suggesting that yacon is a viable alternative for the preparation of jams.

**Microbiological analysis of yacon jams**

All yacon jams developed were of according with recommended requirements to ensure the safety of the products ready for consumption (table 3).

**Sensory analysis of yacon jams**

The samples of jam were evaluated by 100 consumers from 13 to 60 years of age, 59% male and 56% of consumers were regular consumers of jam.

The jams of yacon, yacon with cinnamon, yacon with nutmeg and yacon with ginger were accepted by most consumers, and were ranked with the hedonic terms “I extremely liked” and “I slightly liked” by 83, 87, 82 and 83% of the consumers, respectively (table 4).

The average acceptance rating of the tested yacon jams was 6.80. This value is similar to the ratings for quince “japanese” jam (33) and pepper with acerola jam (34).

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**TABLE 1**

Proportion of the ingredients used in the elaboration of yacon jams.

<table>
<thead>
<tr>
<th>Ingredients (%)</th>
<th>Jam</th>
<th>Yacon</th>
<th>Yacon with cinnamon</th>
<th>Yacon with nutmeg</th>
<th>Yacon with ginger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yacon pulp</td>
<td></td>
<td>85.1</td>
<td>84.4</td>
<td>85.0</td>
<td>84.8</td>
</tr>
<tr>
<td>Sugar</td>
<td></td>
<td>13.6</td>
<td>13.5</td>
<td>13.6</td>
<td>13.6</td>
</tr>
<tr>
<td>Pectin</td>
<td></td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Sodium bisulfite</td>
<td></td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Citric acid</td>
<td></td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Condiment</td>
<td></td>
<td>0.0</td>
<td>0.8</td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**TABLE 2**

Average values of the proximal composition and caloric value of yacon jams.

<table>
<thead>
<tr>
<th>Components g/100g-1</th>
<th>Yacon</th>
<th>Yacon with cinnamon</th>
<th>Yacon with nutmeg</th>
<th>Yacon with ginger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>62.0</td>
<td>66.5</td>
<td>68.1</td>
<td>66.1</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>34.7</td>
<td>30.4</td>
<td>28.7</td>
<td>30.6</td>
</tr>
<tr>
<td>*Total dietary fiber</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>*FOS</td>
<td>1.0</td>
<td>0.9</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Protein</td>
<td>0.4</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>*Lipids</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Ashes</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Caloric value**</td>
<td>140.0</td>
<td>122.8</td>
<td>116.4</td>
<td>124.0</td>
</tr>
</tbody>
</table>

*Calculated according to the concentration in the yacon pulp (Vasconcelos et al., 2010).

**Energetic value (kcal/100 g) calculated based on the results for carbohydrates, proteins and lipids.
The Internal Preference Mapping analysis (Figure 1) was performed with the data obtained in the acceptance test of the four formulations. The first Principal Component (PC) explained 42.68 \% and the second, 33.70 \%, totaling 76.38 \% of the variance among the samples, regarding their acceptance.

The spatial separation of the samples of yacon jams suggested the existence of four distinct groups, according to their acceptance (figure 1). In figure 1, each point represented the correlations among the data from consumer acceptance and the first two principal components.

The consumers near to the center of the graph were not correlated with any of the two main components and contributed little to the discrimination of samples, i.e., these consumers demonstrated similar acceptance of the yacon jams. This group was formed by a small number of consumers. On the other hand, consumers correlated with at least one of the components considered some difference in the acceptance of the samples. For most consumers, there was a positive correlation with the first principal component, indicating that they assigned higher grades for samples of yacon jams without any condiment and that with cinnamon.

The yacon jam with ginger was the least accepted. It was in the second quadrant, where there was a smaller group of consumers correlated with this sample (Figure 1). However, its acceptance still presented high scores.

### TABLE 3

<table>
<thead>
<tr>
<th>Jam</th>
<th>*Total coliforms MPN/g</th>
<th>*Coliforms at 45 °C NMP/g</th>
<th>*Counting of fungi and yeasts CFU/g</th>
<th>*Salmonella</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yacon</td>
<td>&lt; 3</td>
<td>&lt; 3</td>
<td>&lt; 10²</td>
<td>Absent in 25 g</td>
</tr>
<tr>
<td>Yacon with cinnamon</td>
<td>&lt; 3</td>
<td>&lt; 3</td>
<td>&lt; 10²</td>
<td>Absent in 25 g</td>
</tr>
<tr>
<td>Yacon with nutmeg</td>
<td>&lt; 3</td>
<td>&lt; 3</td>
<td>&lt; 10²</td>
<td>Absent in 25 g</td>
</tr>
<tr>
<td>Yacon with ginger</td>
<td>&lt; 3</td>
<td>&lt; 3</td>
<td>&lt; 10²</td>
<td>Absent in 25 g</td>
</tr>
</tbody>
</table>

MPN: Most Probable Number; CFU: Colony-forming unit.
*average of three replications.

### TABLE 4

<table>
<thead>
<tr>
<th>Hedonic Terms</th>
<th>Scores</th>
<th>Yacon</th>
<th>Yacon with cinnamon</th>
<th>Yacon with nutmeg</th>
<th>Yacon with ginger</th>
</tr>
</thead>
<tbody>
<tr>
<td>I extremely liked</td>
<td>9</td>
<td>4</td>
<td>14</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>I very much liked</td>
<td>8</td>
<td>35</td>
<td>38</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>I moderately liked</td>
<td>7</td>
<td>30</td>
<td>23</td>
<td>32</td>
<td>25</td>
</tr>
<tr>
<td>I slightly liked</td>
<td>6</td>
<td>14</td>
<td>12</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>Indifferent</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>I slightly disliked</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>I moderately disliked</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>I very much disliked</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I extremely disliked</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td>6.81</td>
<td>7.12</td>
<td>6.66</td>
<td>6.62</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

The yacon jams presented reduced caloric value and can be considered light products, without the addition of dietary sweeteners, tough. Besides, the components of the jams, including dietary fiber, mainly fructooligosaccharides, are considered prebiotic.

All the yacon jams developed were well accepted, mainly natural yacon and yacon with cinnamon. They are a viable yacon-based product, aimed at expanding the consumption of yacon and obtaining its benefits.

These characteristics suggest that yacon jams, with or without condiments, can be an excellent alternative to replace traditional jams, due to their lower levels of simple sugars, reduced caloric value, addition of functional components and sensory characteristics which are pleasant for consumers.

RESUMEN

Este estudio tuvo como objetivo evaluar las características físico-químicas, microbiológicas y sensoriales de cuatro formulaciones de mermeladas de yacón. Las características analizadas fueron: composición química, contenido de sólidos solubles, pH, presencia microbiológica de coliformes totales, coliformes y salmonella a 45 °C, y la presencia de hongos y levaduras. Los atascos de yacón mostraron alto contenido de humedad (> 62\%), así como altas concentraciones de hidratos de carbono (> 28\%) y fibra dietética total (2,5\%), principal-
mente fructooligosacáridos (> 0,9%). El valor energético promedio fue de 124,6 kcal/100g. El pH promedio fue de 3,8 y los sólidos solubles mide 27,6 ° Brix. Todas las mermeladas de yacón cumplieron con los requisitos microbiológicos estándar y recibió altos puntajes de aceptación, en especial la mermelada de yacón y mermelada de yacón con canela. Productos de mermelada de yacón pueden ofrecer una excelente alternativa a los atascos más comunes debido a sus concentraciones más bajas de azúcar simple, un valor más bajo de calorías, el aumento de la presencia de fibras dietéticas y las características sensoriales deseadas.

Palabras clave: yacón, mermelada, fibra alimentaria, los fructooligosacáridos, la seguridad microbiológica, análisis sensorial.

REFERENCES

FIGURE 1
Correlations among the data of the acceptance of each consumer and the two first principal components and dispersion of the samples of yacon jam related to acceptance.
Desarrollo de jalea de yacón de reducido valor calórico: caracterización físico-química, microbiológica y sensorial


