



Evaluation of Texture Profile, Color and Determination of FOS in Yacón Products (*Smallanthus sonchifolius*)

Valeria Del Castillo^{1,3,4*}, María Cristina Goldner^{1,2}, Margarita Armada^{1,3,4}

¹Instituto de Investigaciones para la Industria Química (INIQUI) Av. Bolivia. 5150. Salta. Argentina.

²Consejo Nacional de Investigaciones Científicas y Técnicas Av. Bolivia. 5150. Salta. Argentina.

³Facultad de Ingeniería. Universidad Nacional de Salta (UNSa) Av. Bolivia. 5150. Salta. Argentina.

⁴Consejo de Investigación. Universidad Nacional de Salta (CIUNSa) Av. Bolivia. 5150. Salta. Argentina.

ARTICLE INFO

Article history:

Received 29 February 2016

Accepted 01 June 2016

Available online, ISSN: 2148-127X

Keywords:

Yacón products

Texture profile

Color

FOS

Osmotic Dehydration

ABSTRACT

Textural characteristics, color and fructooligosaccharides (FOS) content, in yacón root products (syrup and dried snack subjected to different pretreatments with NaCl, blanching and ascorbic acid) were evaluated. Yacón from Salta Capital, with 8 months of growth were used. Texture profiles and Color were evaluated instrumentally and FOS content by HPLC. There were significant differences between the samples treated with NaCl and the ones treated by blanching and ascorbic acid for fracture strength, fracture number and hardness according to pretreatment used, and for hardness and tackiness by the drying time. Regarding to color: longer drying time reduces sample brightness. In processed products the FOS content is lower than in fresh yacón, but higher in sucrose, glucose and fructose.

* Corresponding Author:

E-mail: delcast@unsa.edu.ar

Introduction

Yacón (*Smallanthus sonchifolius*) is an indigenous plant species of the Andean region, understudied and underutilized, belonging to the Asteraceae family. It grows in many isolated villages in the Andes from Ecuador to northwestern Argentina (Salta and Jujuy provinces). The shelf life of fresh yacón does not exceed 15-20 days at normal conditions. Hence farmers in the region use simple techniques to give added value to their crops by producing food and sweets from its roots, such as pickles, juice, tea and dehydrated snacks (Maldonado et al., 2008), (Seminario et al., 2003).

It is a plant for health-conscious people, considered as a functional food due to its components such as dietary fiber with prebiotic function. These components are fructooligosaccharides (FOS) which are stored in large amounts in yacón roots (underground storage organs) (Vilhena et al., 2003; Guigoz et al., 2002). FOS are difficult to digest by enzymes in the human gastrointestinal tract, stimulating growth and activity of intestinal health promoting bacteria (Guigoz et al., 2002). Of the total carbohydrate content, 60 to 80% of the dry matters are FOS (Itaya et al., 2002).

The term "functional fiber" includes isolated non-digestible carbohydrates that have beneficial

physiological effects in humans, as well as fructans which are considered part of the functional fiber (Kip et al., 2005; National Academic Press, 2005).

Fructans are non-digestible carbohydrates derivatives of sucrose, formed by several units of fructose with a glucose residue. They can be produced by bacteria, algae, fungi and plants. In plants fructans are used as reserves of carbohydrates, found in different organs such as leaves, roots (including yacón), tubers, rhizomes and fruits (Madrigal and Sangronis, 2007).

The term fructan includes both oligosaccharides and polysaccharides (Banguela and Hernandez, 2006). Inulin-type fructans with degree of polymerization from 2 to 10 are known as fructooligosaccharides (FOS), whereas for those with a higher polymerization degree the term most often used is inulin.

Yacón fructans are identified as β (2-1) fructooligosaccharides with terminal fructose. The most abundant trisaccharide is 1-kestose, followed by nystose and 1- β -D fructofuranosilnystose (Lachman et al., 2004). The other carbohydrates are fructose (3-22% solids), sucrose (5-15%) and glucose (2 - 5% dry matter).

The aim of this work was to obtain dehydrated flakes of the yacón root and syrup and then to determine its texture, color and FOS content.

Materials and Methods

Yacón roots (8 months old crop) from Salta city were used. They were collected preventing physical or mechanical damages on the outside. For the preparation of the snacks, after washing the roots with tap water, they were cut (skin included) into slices 0.5 cm thick, and then were subjected to various pretreatments:

Sample 1: Blanching, by immersion of the slices in hot water at 70°C for 2 min. Sample 2: Osmotic dehydration (OD), by immersion in 20% NaCl solution at room temperature for 15 min under vacuum (-50cmHg). Sample 3: Immersion in 1% ascorbic acid solution, (yacón 50 g / 500 ml of solution) for 10 min at room temperature.

The yacón slices were then placed on perforated metal trays and dried with hot air at 60°C in an oven with forced convection air. Two different drying times were used: 3 h (t1) and 5 h (t2).

After cooled, the snacks were stored in closed plastic bags at room temperature.

To prepare the syrup, the roots were thoroughly washed with water and a 200 ppm sodium hypochlorite solution for 5 minutes, to reduce the microbial load. The peeling was performed with domestic potato peelers. A juicer was used for juice extraction, and for browning control 1.3 g ascorbic acid per kilogram of peeled roots was added to the juice.

The juice was filtered through a mesh (<100 microns pore size) to remove insoluble particles. Then citric acid and potassium sorbate were added to the juice to reach a final concentration of 0.08% and 0.04% respectively. Finally the juice was concentrated in a pot to about 70°Brix (Rivera Manrique, 2005).

The texture profile was performed using a texturometer (Farnel QTS) by penetration test. The snacks were analyzed for: fracture strength, number of fractures, gumminess, stiffness, hardness and adhesiveness.

The color was determined with the CIELAB system using a colorimeter (ColorTec-PCM, Accuracy microsensors Inc., Pittford, USA) equipped with a standard illuminant D65. Parameters lightness (L), redness-greenness (a) and yellowness-blueness (b) were measured.

FOS and sugars (sucrose, glucose and fructose) content was quantified by HPLC (high performance liquid chromatography) with a refractive index detector and RSO Rezex analytical column (Phenomenex rso-

oligosaccharide ag+ 4% 200x10mm), samples were injected automatically. Experimental conditions were, 30°C for column temperature and flow of 0.2 ml / min for the mobile phase (bidistilled water) (Bonfiglio, 2014). FOS extraction was performed in water suspension at a 1 g/10 ml yacón-to-solution ratio, at 90 ° C with a contact time of 40 minutes, allowing extraction of 100% of FOS in one step (Valdez Clinis, 2011).

Since the area of each peak of the chromatograms is proportional to the concentration of the corresponding compound in the sample, the relationship used for quantitative determinations was:

$$\text{Area} = \text{response factor (l/g)} \times \text{concentration (g/l)}$$

The response factor for each compound was obtained from the respective calibration curve.

The concentrations of each component in the samples were determined through the following calculation:

$$\text{Concentration (g/l)} = \text{Area/response factor (l/g)}$$

When samples were diluted, the dilution factor was considered to determine the concentration in the original sample.

Compound	Response factor (l/g)
Nystose	6.43 x 10 ⁵
Kestose	7.51 x 10 ⁵
Sucrose	8.76 x 10 ⁵
Glucose	8.99 x 10 ⁵
Fructose	7.92 x 10 ⁵

The snack developed in this work was compared with a commercial product used as a reference.

Statistical Analysis

Texture and color data was analyzed statistically with the software InfoStat (Di Rienzo et al., 2014) version 2012 p. Variance analysis ANOVA was performed to evaluate the effect of the pretreatment on the samples and Duncan test was used to compare the means. Student *t* test was used to compare the means between drying times (t1, t2). In all cases the significance level considered was 5%.

Results

As shown in Table 1, sample 2 (OD), presents the highest values for most of the parameters studied, except for adhesiveness. However, there were no statistically significant differences ($P < 0.05$) in samples for gumminess, stiffness and adhesiveness.

Table 1 Texture Profile. ANOVA and Duncan test for samples by type of pretreatment and commercial products. Mean \pm E.D.

Variable	Sample 1	Sample 2	Sample 3	Commercial
Crushing Strength g	3.67 \pm 4.0a	618.67 \pm 508.3b	133.50 \pm 194.5a	0 \pm 0.00
Number of fractures	1.17 \pm 0.9a	9.67 \pm 9.6b	3.33 \pm 2.8ab	1 \pm 1.73
gumminess g	131.47 \pm 76.1a	256.27 \pm 175.1a	194.52 \pm 49.7a	178.47 \pm 33.9
stiffness g	9.17 \pm 26.9a	251.50 \pm 446.3a	21.43 \pm 29.9a	61.67 \pm 29.9
hardness g	241 \pm 156.5a	702.83 \pm 445.1b	327.17 \pm 139.1a	276.33 \pm 61.2
adhesiveness gs	-7.54 \pm 7.4a	-6.63 \pm 6.6a	-9.70 \pm 4.2a	-2.18 \pm 3.1

Different letters in rows correspond to significant differences ($P < 0.05$)

Table 2 Texture Profile. Student t test for samples by drying time

Variable	Time 1	Time 2
Crushing Strength g	146.6a	357.3a
Number of fractures	2.9a	6.6a
gumminess g	253.2b	135.0a
stiffness g	32.9a	155.1a
hardness g	280.4a	566.9b
adhesiveness gs	-8.9a	-6.9a

Different letters in rows correspond to significant differences ($P < 0.05$)

Table 3 Color.ANOVA and Duncan test for sample by type of pretreatment and commercial product. Mean \pm S.D.

Variable	Sample 1	Sample 2	Sample 3	Commercial
L	49.65 \pm 2.6 ^a	51.43 \pm 4.1 ^a	48.18 \pm 6.9 ^a	39.57 \pm 2.7
a	14.21 \pm 0.7 ^b	12.51 \pm 0.6 ^a	12.72 \pm 0.4 ^a	16.24 \pm 0.3
b	25.87 \pm 2.4 ^a	26.94 \pm 2.0 ^a	26.07 \pm 4.4 ^a	18.10 \pm 1.4

Different letters in rows correspond to significant differences ($P < 0.05$)

Table 4 Color.Student t test for samples by drying time. Mean \pm S.D.

Variable	Time 1	Time 2
L	53.58 \pm 1.8a	45.92 \pm 3.5b
a	12.87 \pm 0.8 ^a	13.42 \pm 1.1 ^a
b	25.08 \pm 3.1a	27.51 \pm 2.4 ^a

Different letters in rows correspond to significant differences ($P < 0.05$)

Table 5 Content of FOS and sugars in products of Yacón (g / 100g)

Muestra	Nystose	Kestose	Sucrose	Glucose	Fructose
Syrup	1.13	1.27	1.31	3.55	13.37
Snack*	1.05	1.4	0.84	1.08	4.41
Commercial	0.56	0.71	2.2	3.84	12.97

* Values correspond to sample 1

Regarding the influence of drying time on the texture profile, most of the parameters showed higher values for samples subjected to time 2 (T2), except for gumminess and stickiness (Table 2). There were no statistically significant differences ($P < 0.05$) between samples for fracture strength, number of fractures, stiffness and adhesiveness.

The commercial product (snack) had lower values of fracture strength and adhesiveness, and greater rigidity than the samples submitted to pretreatments. It also showed intermediate values for gumminess and hardness, with values between samples 1 and 3, and similar amount of fractures than sample 1 (Table 1).

With respect to color, the samples showed similar values for the parameter L (lightness) (Table 3).

For the parameter "a", differences ($P < 0.05$) between the sample 1 with respect to samples 2 and 3, were found, in the other hand, the sample 1 presented more red tone than the others.

Regarding color changes related to the drying time, no differences were found for the parameters "a" and "b". However there are differences for the "L" parameter, the brightness of the samples was lower at higher drying time (Table 4).

On the other hand, the commercial product was less bright and yellow and more red (Table 3) than the samples object of this study.

Nystose content in the syrup and snack (Table 5) were within the range reported by Bonfiglio (2014) for fresh roots (from 0.82 to 2.61 g /100), while the commercial product (snack) showed lower content of this FOS.

Regarding kestose, the three products were in the range reported by Bonfiglio (0.5 to 1.74 g / 100 g), the commercial product presented again, the least content of this FOS (Table 5).

Discussion

In OD, products lose weight and shrinks, and changes are generated in the optical and mechanical properties, depending on the process conditions and characteristics of each food to dehydrate (Bianchi et. al. 2011). This could explain the difference in the hardness of sample 2 (Table 1).

The results of this study are similar to those of Bianchi et al. (2011) who reported an increase in hardness sliced pears dehydrated with sucrose solutions at 60°Brix.

Dehydration produced changes in the microstructure of the tissues of fruits and vegetables and such changes may cause an unacceptable product to the consumers. These changes are related to the loss of water from the inner parts causing stiffness, deterioration and alteration of cell walls. (Maltini et. al., 2003).

Muñiz Becerá et al. (2011) reported increased hardness in dried papaya (OD using sucrose at 70°Brix)

from 82.09% on fresh fruit, due to crystallization of sugar in the syrup that was used as osmotic solution.

The process used to obtain the commercial product is unknown. However, according to the values resulting from the textural evaluation, it is likely that it was not subjected to any pretreatment before drying (Table 1).

Regarding drying times, most textural parameters showed higher values for samples subjected to time 2 (T2), except for gumminess and stickiness (Table 2). This may be because the samples stayed longer in the oven and became harder, rigid, frangible, and less rubbery and sticky. Thus, better conditions of packaging, transport and storage are decisive in order to maintain product quality.

Heiler et al (2013) treated apple snacks at temperatures of 57.1°C and 60°C for 5 hours to thicknesses of 1.4 and 1.0 mm respectively. The textural parameters reported, increased with increasing temperature, except for elasticity.

With respect to color, sample 1 showed 1 more tone of red than the other samples. It may be that during blanching the pigment of the yacón shell diffused into the liquid medium causing staining of the pulp (Table 3).

Bianchi et al (2011) reported no significant change in the overall color of osmotically dehydrated pears, regarding fruit undehydrated.

Color retention in dehydrated pears was due to low denaturing work conditions (moderate temperatures of 30°C) and the protective effect of solute (sucrose) who limiting oxidation reactions to avoid contact of the fruit with oxygen and inactivates the enzymes responsible for enzymatic browning (Bianchi et. al. 2011)

Heiler, et al. (2013) treated apples prior dehydration with citric acid and sodium bisulfite as an antioxidant that prevents enzymatic browning and retains pigments that give natural color to fruits.

Regarding the content of FOS, all samples in this study had lower contents than those reported by Bonfiglio (2014) for fresh roots. However, for sugar the contents were higher, especially fructose. This may be due to degradation of FOS during processing (Table 5).

On the other hand, fresh yacón contains free sugars (fructose, glucose and sucrose) in the following proportion, 5 to 15% sucrose, 5 to 15% fructose and less than 5% glucose (Manrique et al. 2005).

Vilhena et al. (2003) reported that the change in sugar content depends on the age of the crop. After 7 months a significant increase of reducing sugars occurs, with the highest amount after 9 months after planting. After harvest, a rapid process of change in the chemical composition of sugars starts, polymerized sugars tend to be degraded forming simple sugars such as fructose, glucose and sucrose (Graefe et al., 2004).

Chirinos Gallardo (1999), in assessing the physical and chemical characteristics and oligofructans present in yacón roots, found different concentration of oligofructans, fructose, sucrose and glucose, depending on the degree of ripeness, too.

Cancino Chavez (2003) performed OD of yacón with different concentrations of sucrose solutions (between 40 and 60°Brix) and determined the content of

fructooligosaccharides (FOS) reported the following results (in %): FOS 63.46, glucose 1.955; fructose 3.105; sucrose 7.076.

Manrique et al (2005) when processing yacón syrup two different cultivars (AMM5163 and Hualqui) reported a big difference in the concentration of FOS in syrup: 50% and 10% AMM5163 Hualqui. This example illustrates the enormous variation that can be obtained from the chemical composition of the syrup.

Pinto Maguiña and Rosales Cornejo (2007) compared two technological methods to obtain yacón syrup at pilot plant level, both at atmospheric pressure boiling as in a vacuum concentrator. In the analysis Fructooligosaccharides (FOS) are obtained as results between 34.55 and 41.77 g /100 g, respectively.

Conclusions

The texture of yacón snacks does not vary regardless the pretreatment used before hot air drying, but samples subject to osmotic dehydration had the highest values for all parameters evaluated.

With longer drying time the parameters hardness, rigidity and fracturability increase, while gumminess and adhesiveness decrease.

There were no significant differences in the color depending on the type of pretreatment used with regarding the drying times. But, samples that stayed longer in the oven were less bright.

Compared to fresh roots, in all samples FOS content was lower and sugar content higher.

Acknowledgements

The authors wish to thank Ing. Patricia Ortín for donating yacón plants used in this work, Lic. Gisella Bonfiglio, Lic. Patricia Jiménez and Dra. Mirta Daz for their help.

References

- Araya H, Lutz M. 2003. Alimentos funcionales y saludables. Rev. Chil. de Nut. 30: 1.
- Banguela A, Hernández L. 2006. Fructans: from natural sources to transgenic plants. Biot. Apli. 23: 202 – 210.
- Bastos Pereira RA. 2009. Extração e utilização de frutanos de yacón na funcionalização de alimentos. Fac. Cs. Agr. Univ. Est. Paulista Júlio de Mesquita Filho.
- Bianchi M, Guarnaschelli A, Milisenda P. 2011. Dehidrocongelación de frutas: Estudio de los parámetros de calidad. INVENIO 14: 117-132
- Bonfiglio GV. 2014. Extracción de Fructooligosacáridos de Raíces de Yacón. (*Smallanthus Sonchifolius*).Fac. Cs. de la Salud. Univ. Nac. de Salta.
- Cancino Chávez K. 2003. Influencia del zumo concentrado en la deshidratación osmótica del yacón (*Smallanthus sonchifolius* Poepp. & Endl.). Univ. Nac. Agraria La Molina. Lima. Perú
- Chirinos Gallardo SR. 1999. Obtención y caracterización de los oligofructanos a partir de la raíz de yacón (*Smallanthus sonchifolius*). Univ. Nac. Agraria La Molina. Lima. Perú.
- Di Renzo JA, Casanoves F, Balzarini MG, Gonzalez L, Tablada M, Robledo CW. InfoStat, FCA, Univ. Nac. de Córdoba, Argentina [Software]. Download available from: <http://www.infostat.com.ar> . Accessed 04/11/2015

- Graefe S, Hermann M, Manrique I, Golombek S, Buerkert A. 2004. Effects of post – harvest treatments on the carbohydrate composition of yacón roots in the Peruvian Andes. *Field Crops Research* 86: 157 – 165.
- Guigoz Y. 2002. Effects of oligosaccharides on the fecal flora and non-specific immune system in elderly people. *Nutrition of Research*. 22: 13 – 25.
- Heiler A, Bazán Cruz E, Cabrera Sánchez J, Huaccha K, Rojas S. 2013 Optimization of humidity and texture in apple snacks evaluating thickness and drying temperature. *Agroind Sci* 2: 91-100.
- Ibáñez MS. 2008. El Yacón: una especie nativa de los Andes con propiedades beneficiosas premisorias. INTA – Estación Experimental Agropecuaria Balcarce – Facultad de Ciencias Agrarias. Buenos Aires
- Itaya NM, De Carvalho MA, Figueiredo Ribeiro RDL. 2002. Fructosyltransferase and hydrolase activities in rhizophores and tuberous roots upon growth of *Polymnia sonchifolius*. *Physio. Plant*. 116: 451 – 459.
- Kip P, Meyer D, Jellema R. 2005. Inulin improve sensoric and textural properties of low fat yogurts. *Dairy Journal*. 16: 1098 – 1103.
- Lachman J, Havrland B, Fernández EC, Dudjak J. 2004. Saccharides of yacón (*Smallanthus sonchifolius*) tubers and rhizomes and factors affecting their content. *Plant Soil Environ*. 50: 383 – 390.
- Madrigal L, Sangronis E. 2007. La inulina y derivados como ingredientes claves en alimentos funcionales. *Arch. Lat.Nut*. 57: 387 – 395.
- Maldonado S, Luna Pizarro P, Martínez V, Villatarco M, Singh J. 2008. Producción y Comercialización de Yacón (*Smallanthus sonchifolius*) en Comunidades Rurales del Noroeste Argentino. *Agroal*. 26: 119-125.
- Maltini E, Torreggiani D, Venir E, Bertolo G. 2003. Water activity and the preservation of plant foods. *Food Chemistry* 82: 79–86.
- Manrique I, Parraga A, Hermann M. 2005. Jarabe de yacón: Principios y Procesamiento Conservación y uso de la biodiversidad de raíces y tubérculos andinos: Una década de investigación para el desarrollo (1993-2003). Centro Internacional de la Papa (CIP). Lima, Perú.
- Muñiz Becerá S, García Pereira A, Calderín García A, Hernández Gómez A. 2011. Evaluación de la calidad de la fruta bomba (Carica papaya L.) variedad Maradol roja deshidratada utilizando el método de deshidratación osmótica (DO). *Rev Cie Téc Agr*. 20: 52-56.
- National Academies Press. 2005. Dietary, Functional and Total Fiber. Dietary Reference Intakes. Cáp 7. Washington DC. 339 – 421.
- Pedreschi R, Campos D, Noratto G, Chirinos R, Cisneros Zeballos L. 2003. Andean Yacón Root (*Smallanthus sonchifolius*) Fructooligosaccharides as a potential novel source of prebiotics. *Journal of Agr. and Food Chem*. 51: 5278 – 5284.
- Pinto Maguiña LG, Rosales Cornejo Y. 2007. Mejoramiento de técnicas de conservación y procesamiento de producto y subproductos de yacón. Univ. Nac. Mayor de San Marcos. Lima. Perú. Available from: http://cybertesis.unmsm.edu.pe/sdx/sisbib/envoi?dest=file:d:/cybertesis/tesis/production/sisbib/2007/pinto_ml/xml/./pdf/pinto_ml.pdf&type=application/pdf Accessed 30/10/2015
- Rivera D, Manrique I. 2005. Zumo de Yacón. Centro Internacional de la Papa (CIP) Lima, Perú. Available from: www.cipotato.org/artc/ciprops/fichazumoyacon.pdf. Accessed 30/10/2015
- Seminario J, Valderrama M, Manrique I. 2003. El yacón. Fundamentos para el aprovechamiento de un recurso promisorio. Centro Internacional de la Papa. Lima. Perú.
- Valdez Clinis GA. 2011. Diseño de una barra dietética funcional prebiótica con yacón deshidratado. Univ. Nac. de Salta.
- Vilhena SMC, Camara FLA, Piza IMY, Lima GPP. 2003. Contenido de fructanos en raíces tuberosas de yacón (*Polymnia sonchifolia*). *Ciencia y Tecnología Alimentaria*. 4: 35 – 40
- Yaginuma SR. 2007. Extração e purificação parcial de inulina a partir de yacón (*Smallanthus sonchifolius*) por adsorção em resinas de troca iônica. Univ.Fed. de Santa Catarina. Brasil.