REVISTA BIO CIENCIAS
http://revistabiociencias.uan.edu.mx
https://doi.org/10.15741/revbio.10.e1427

ISSN 2007-3380

Original Article /Artículo Original

Physicochemical and proximal characterization of starch and flour of jicama (*Pachyrhizus erosus* L.)

Caracterización fisicoquímica y proximal de almidón y harina de jícama (*Pachyrhizus erosus* L.)

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Please cite this article as/Como citar este artículo: Ramírez-Balboa, G., Balois-Morales, R., León-Fernández, A. E., Bautista-Rosales, P.U., Jiménez-Zurita, J. O., Montalvo-González, E. (2023). Physicochemical and proximal characterization of starch and flour of jicama (*Pachyrhizus erosus* L.). *Revista Bio Ciencias*, 10 e1427. https://doi.org/10.15741/revbio.10.e1427

Article Info/Información del artículo
Received/Recibido: October 11th 2022.
Accepted/Aceptado: February 03th 2023.
Available on line/Publicado: February 23th 2023.

RESUMEN

Jicama (*Pachyrhizus erosus* L.) belongs to the legume family, the edible structural organ of this plant is the root and it is eaten fresh; the root contains vitamins, minerals, and starch, in addition to a low caloric content (40 cal). Starch is found in the form of intracellular granules, being of importance for food products. Flour is an option for food formulations since they contain fibers and nutrients, jicama root has chemical-physical properties (moisture, consistency, and stability) for use in food. This research aimed to characterize the physicochemistry and proximal analysis of jicama starch and flour from two locations in Tepic (Camichin) and Xalisco (Pantanal), Nayarit. Four treatments were designed (T1 = Pantanal Starch, T2 = Camichin Starch, T3 = Pantanal Flour, and T4 = Camichin Flour); pH, titratable acidity, apparent density, color, moisture, ashes, proteins, lipids, amylose, amylopectin, fiber, and total carbohydrates were evaluated. As a result, the T2 starches presented ash content (2.44 %), fiber (170 mg /100 g), and carbohydrates (1.50 g); T4 flour presented values of ash (3.55 %), protein (11.04 %), fiber (181 mg /100 g) and carbohydrates (1.70 g). Jicama starches can be substituted for commercial ones, and the use of flours for the preparation of food products.

PALABRAS CLAVE: Extraction, root, compounds, polysaccharides

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ISSN 2007-3380

RESUMEN

La jícama (*Pachyrhizus erosus* L.) pertenece a la familia de las leguminosas, el órgano estructural comestible de esta planta es la raíz y se consume en fresco; la raíz contiene vitaminas, minerales y almidón, además de un bajo contenido calórico (40 cal). El almidón se encuentra en forma de gránulos intracelulares, siendo de importancia para los productos alimenticios. La harina constituye una opción para formulaciones alimenticias, ya que contienen fibras y nutrientes, la raíz de jicama tiene propiedades químico-físicas (humedad, consistencia y estabilidad) para su uso en los alimentos. El objetivo de esta investigación fue caracterizar fisicoquímica y químico proximal el almidón y harina de jícama de dos localidades de Tepic (Camichin) y Xalisco (Pantanal), Nayarit. Se diseñaron cuatro tratamientos (T1 = Pantanal Almidón, T2 = Camichin Almidón, T3 = Pantanal Harina y T4 = Camichin Harina); se evaluó pH, acidez titulable, densidad aparente, color, humedad, cenizas, proteínas, lípidos, amilosa, amilopectina, fibra y carbohidratos totales. Como resultado se tiene que los almidones del T2 presentaron contenido de cenizas (2.44 %), fibra (170 mg /100 g) y carbohidratos (1.50 g); la harina del T4 presentó valores de cenizas (3.55 %), proteínas (11.04 %), fibra (181 mg / 100 g) y de carbohidratos (1.70 g). Los almidones de jícama pueden ser sustituidos por lo comerciales, y el uso de harinas para la elaboración de productos alimenticios.

PALABRAS CLAVE: Extracción, raíz, compuestos, polisacáridos.

Introduction

Jicama (*Pachyrhizus erosus* L.) belongs to the legume family and the Pachyrhizus genus; the edible structural organ of this plant is the root, it is cultivated at altitudes ranging from 900 to 2,750 masl and temperatures of 14 and 20 ºC (González-Lemus *et al*., 2017). At the national level, 219,003.90 t are produced, the entities with the highest production are: Nayarit (71,386.64 t), Guanajuato (50,034.24 t), Veracruz (32,039.80 t), and Morelos (26,875.21 t) according to the reported by the Servicio de Información Agrícola y Pesquera (SIAP, 2021).

Jicama is eaten fresh, has a low caloric content (40 cal), vitamin C, minerals (potassium, iron, calcium, and phosphorus), and carbohydrates such as starch (Jiménez *et al*., 2012; Nursandi *et al*., 2017); it also contains bioactive compounds (tannins, flavonoids, phenolic compounds such as gallic acid and quercetin) and inulin (Melgoza-Sevilla *et al*., 2017; Martínez-Bahena *et al*., 2020). Therefore, jicama is considered a potential source of starch.

Starch is a polymer whose molecular structure is based on the union of glucose molecules that are linked to each other by α-D-(1-4) and α-D-(1-6) bonds, which form its two main macromolecules: amylose, a linear polymer with a degree of polymerization of 100 to

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1000 glucose units and amylopectin, a branched polymer with a degree of polymerization of approximately 40,000 glucose units (Jiménez *et al*., 2012). Starch is unique among naturally occurring carbohydrates in the form of granules made up of amorphous and semi-crystalline regions. The physical arrangement of these granules is considered important in their functionality and thus in the behavior of food products with starch-rich formulations (Cruz *et al*., 2016; Shevkani *et al*., 2017; Velásquez-Barreto *et al*., 2018).

Due to the search for possible alternatives, agricultural production is becoming more diverse. This includes the production of new, low-cost foods with high nutritional value. Horticultural products like roots or tubers can be used to make alternative flours for the food industry, which can completely or partially replace the flours of common cereals like corn or wheat. These flours are a source of nutrients and ingredients that can be used to make food. This helps solve nutritional problems in some parts of the population (Moro *et al*., 2018; García-Pacheco *et al*., 2020).

On the other hand, root flours such as jicama promise to have chemical and physical properties and versatility to be used in the food industry, contributing significantly to the production of numerous foods by altering qualities such as moisture, consistency, appearance, and storage stability (Romero & Tuiran, 2017).

The physicochemical characteristics of food provide the necessary bases to understand the physical and chemical phenomena in food, the tools to control these phenomena and to create improved processes and foods (Romero & Tuiran, 2017); Likewise, the proximal analysis implies the characterization of the food, emphasizing the determination of the chemical associations that respond to certain analytical reactions, which therefore gives us a nutritional index and the number of certain compounds present (Julián-Loaeza, 2009).

Hence, the present investigation aimed to analyze the physicochemical and proximal characterization of jicama starch and flour, giving value to the jicama crop and having added value with the creation of new and innovative products.

Material and methods

Starch extraction

Jicama starch extraction was carried out based on the methodology of Flores-Gorosquera *et al*. (2004). This method comprised a wet grinding without a shell, the paste from the grinding was filtered through an organza mesh and washed (rinsed) with water until there were no apparent starch residues (white residues), the liquid part obtained was decanted for a period of 24 to 48 h, the supernatant part was removed and the white residue (starch) was resuspended in water; the solid phase obtained (starch) in the decantation was dehydrated in a drying oven (TERLAB®) at 40 °C for 24 h; once the water had been eliminated by drying, the starch was weighed for its quantification.

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Jicama flour

The residues obtained (after starch extraction), as a result of washing were dehydrated in a drying oven (TERLAB®) at 50°C for 48 h, and then ground until a fine powder similar to a flour, quantifying its performance.

The research was performed in the laboratories of the Food Technology Unit of the Autonomous University of Nayarit. The variables evaluated were carried out in starch and jicama flour separately.

Physicochemicals

pH (Ocaña-Palacios, 2019)

A starch solution was prepared (5 g of starch in 50 mL of distilled water) and the reading was performed directly with a potentiometer (HANNA HI2211).

Titratable acidity (Ocaña-Palacios, 2019)

A starch solution (5 g in 15 mL of distilled water), was prepared, and titrated volumetrically with NaOH (0.1 N) and phenolphthalein as indicators. The following formula was used for the calculations and interpretation of the results.

$$\text{Titratable acidity (\%)} = \frac{\text{Volume (mL)NaOH} * 0.1\text{N} * \text{factor} * 100}{\text{Weight of the sample}}$$

Bulk density (Gujska & Khan, 1990)

The weight of a test tube with a volume of 10 mL was recorded, the sample was added on a dry basis (starch and/or flour) up to its maximum total capacity, without compacting, the weight of the test tube was recorded again. The following formula was utilized for the calculations and interpretation of the results.

$$\text{Da} = \frac{\text{Weight of the sample (g)}}{\text{Volume of the test tube (mL)}}$$

Color (Ocaña-Palacios, 2019)

Color measurement was performed with a previously calibrated manual colorimeter (KONICA MINOLTA, LC100, USA); placing starch in Petri dishes, five measurements were taken in different areas of the Petri dishes, recording the averages. The parameters evaluated were Luminosity (L*), Chromaticity (C*), and Hue (°H).

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Proximal analysis

Moisture (AOAC, 2005)

1 g of sample was placed in previously weighed porcelain crucibles, in a drying oven at 100 °C for 24 h, in triplicate. The moisture percentage was determined using the following equation.

$$Moisture\ (\%) = \frac{(Cm - Cms)}{\mathrm{m}} X\ 100$$

Where:

Cm: capsule mass with the wet sample (g)

Cms: capsule mass with dry sample (g)

m= mass of the weight (g)

Ashes (AOAC, 2005)

1 g of sample was placed in porcelain crucibles at constant weight, calcining them in a muffle (FELISA FE-340) at 500 °C for 12 h, and then allowed to cool at room temperature. The ash determination content was determined using the following equation.

$$Ashes\ (\%) = \frac{(Cc - C)}{\mathrm{m}} X\ 100$$

Where:

Cc = crucible mass with ashes (g)

C = dry crucible mass (g)

m = sample mass (g)

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Protein (AOAC, 2005)

The Kjeldahl method was used to determine protein. Total nitrogen percentage was calculated by converting total nitrogen to protein content. A triplicate was carried out.

$$N = \frac{(V - Vo)(NHCl)(meq)}{\mathrm{Mm}}$$

Where:

N = total nitrogen (g nitrogen/ g sample)

V = volume of HCI spent on sample titration (mL)

VO = volume of HCI spent on the blank titration (mL)

NHCl = normality of HCl (milliequivalents/mL)

meq = nitrogen equivalent weight (g/ milliequivalents) = 0.014

Mm= mass of the sample (g)

Lipids (AOAC, 2005)

4 g of sample were placed in cellulose cartridges, in a fat extractor (TECNAL Extractor SOXHLET TE-1881/6). Petroleum ether was used as a solvent in a constant-weight flask, boiling for eight hours. The calculation was determined by the difference in weight in the flasks.

Amylose and amylopectin (Morrison & Laignelet, 1983)

The determination of amylose and amylopectin was performed with the colorimetric method of iodine solution. Amylopectin content was calculated by difference to 100 % amylose content by colorimetry.

Total dietary fiber (Mañas & Saura-Calixto, 1995)

For the quantification of total dietary fiber, 250 mg of sample were weighed and a triple enzymatic hydrolysis was performed.

Thermostable α-amylase (A-3306, Sigma) for 35 min, 100 °C, pH 6

Bacillus licheniformis protease type VIII (P-5380, Sigma) with shaking 35 min, 60 °C, pH 7.5

amyloglucosidase (A-9913, Sigma®) with shaking 35 min, 60 °C, pH 4.5

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Subsequently, the samples were centrifuged (3000 rpm - 15 min at 4 °C), recovering the supernatants in 100 mL volumetric flasks, the remaining residues (solids) were recovered with distilled water (shaking and centrifuging) adding them to the recovery from the enzymatic treatment. Then, dialysis was carried out for 48 h, using cellulose membranes with a cut-off point for a molecular weight between 12,000 and 14,000 Da. Later, the content was diluted to a volume of 100 mL, this fraction corresponds to the soluble fiber (SF). 17 mL of the SF solution were taken by adding 1 mL of concentrated H_2SO_4 to hydrolyze the polysaccharides that form SF, taking it to a water bath at 100 °C for 90 min.

The hydrolysis was allowed to cool to room temperature, and the soluble and insoluble fiber was determined, these were quantified in a spectrophotometer (Power wave Biotek, Germany) at 530 nm using 3,5-dinitrosalicylic (DNS) as reagent, by separated. For quantification and concentration, a standard glucose curve was used (200 mg of analytical grade glucose with 85 % ethanol, volumetric to 100 mL), the results were expressed in g/100 g of dry basis (db).

Total carbohydrates (Dubois, 1956)

All sugars, including polysaccharides, are dehydrated with concentrated H_2SO_4, forming monosaccharides, which in turn condense with phenols present in the reaction mixture to give yellowish-orange compounds whose intensity is measured spectrophotometrically.

37.5 mg of sample (starch and flour) were weighed separately in 50 mL Falcon tubes, adding 1.5 mL of 85 % ethanol to each tube, placed in a water bath at 50 °C for a period of 2 h, and then centrifuged at 3000 rpm for 15 min. 1 mL of the supernatant was recovered, adding 0.5 mL of 5 % phenol and 2.5 mL of concentrated H_2SO_4. Then, it was placed in a water bath for 30 min at 30 °C, observing changes in color ranging from white to yellow, the final tone will depend on the sugar content. Absorbances at 490 nm were read in a spectrophotometer (Power Wave Biotek, Germany) using a blank as a control (85 % ethanol). A 400 µg/mL glucose calibration curve was prepared (40 mg of calibrated analytical grade glucose to 100 mL with 85 % ethanol). The results were expressed in g/100g db.

Experimental design

A completely randomized design with four treatments was used, taking into account the jicama harvest locations and the evaluated products; T1:PA (Pantanal starch), T2: CA (Camichin starch), T3:PH (Pantanal flour) and T4:CH (Camichin flour). The results were analyzed with a one-way ANOVA and a comparison of means with the Tukey test with a significance level ($p \geq 0.05$) using the statistical language R.

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Results and Discussion

Physicochemical

The physicochemical characterization of jicama starch presented pH values of 6.08 and 5.10 for treatments 1 (PA) and 2 (CA), presenting statistical difference ($p \geq 0.05$); the titratable acidity of the starch was 3.50 % (T1) and 3.96 % (T2), showing no statistical difference between them; the apparent density of jicama starch was 1.14 and 1.15 g/cm^3 for treatments 1 and 2 respectively, showing no statistical difference (Table 1).

Table 1. Physicochemical analysis of jicama starch.

Physicochemical	T1 = PA	T2 = CA	CV	DMS
pH	6.08 ± 0.07^a	5.10 ± 0.02^b	3.92	0.80
Acidity (%)	3.50 ± 0.20^b	3.96 ± 0.05^a	3.92	0.34
Bulk density (g/cm^3)	1.14 ± 0.00^a	1.15 ± 0.00^a	3.92	1.20

T1 = PA (Pantanal starch), T2 = CA (Camichin starch). The same letters per row do not differ statistically (Tukey, $p \geq 0.05$).

The high concentration of polysaccharides and the relationship with the content of organic acids present (oxalic acid) determine the acidity of the jicama root (Rodríguez-Miranda *et al*., 2011; Madrigal-Ambriz *et al*., 2018). Therefore, based on the pH values (table 1), it is possible that the starch extracted from jicama is acid, its low apparent density is directly related to the shape and size of its granulometry, a favorable characteristic for storage and compaction of the starch (Madrigal-Ambriz *et al*., 2018).

The physicochemical characterization of jicama flour presented pH values of 4.46 (T3) and 4.54 (T4), not presenting statistical difference; while the titratable acidity of the flour was 3.76 (T3) and 2.66 (T4) ($p \geq 0.05$); an apparent density of 1.13 g/cm^3 (T3) and 1.15 g/cm^3 (T4), both variables presented a statistical difference ($p \geq 0.05$) (Table 2).

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Table 2. Physicochemical of jicama flour.

Physicochemicals	T3=PH	T4=CH	CV	DMS
pH	4.46 ± 0.01[a]	4.54 ± 0.06[a]	3.92	0.80
Acidity (%)	3.76 ± 0.15[a]	2.66 ± 0.15[b]	3.92	0.92
Bulk density (g/cm^3)	1.13 ± 0.00[b]	1.17 ± 0.00[a]	3.92	0.02

T3 = PH (Pantanal starch), T4 = CH (Camichin starch). The same letters per row do not differ statistically (Tukey, $p \geq 0.05$).

According to the results of the pH, jicama flour is acid with a low bulk density; Rodríguez-Miranda *et al*., (2011) reported that the pH concentration is related to a possible reduction of the chemical and enzymatic activity, these interact with the titratable acids of the product; the fiber present in the flour influences its granulometry, due to its size and shape, since it can alter the density of the polymeric matrix. This density favors flour storage due to a compaction or agglomeration of its particles (Rodríguez, 2013; Lalaleo, 2017; Techeira *et al*., 2014; Contreras-Jiménez *et al*., 2019).

Color

Color is one of the most important parameters in the acceptance of food products by consumers (Alonso-Miravalles *et al*., 2020); jicama starch and flour presented similar colors, white was the predominant color with yellow tones, with high values in the °Hue and luminosity parameters (Table 3 and 4); this coloration is due to the pigments synthesized and stored in the plastids of the cells during the development of the root. Hence, in the extraction and processing of the products preserve the original coloration of the jicama and consequently, the luminosity and color tone behave in the same manner (Villar-Lozano, 2021).

Table 3. Color of jicama starch (L, C, °H).

Parameters	T1 = PA	T2 = CA	CV	DMS
*L	91.77 ± 2.87[a]	92.19 ± 0.95[a]	3.92	1.15
*C	1.82 ± 0.30[a]	2.29 ± 0.07[a]	3.92	1.00
°H	91.67 ± 1.51[a]	96.22 ± 0.57[a]	3.92	5.60

PA = Pantanal Starch), CA = Camichin Starch, *L = Lightness, *C = Chromaticity, °H = Hue Angle. The same letters per row do not differ statistically (Tukey, $p \geq 0.05$).

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Table 4. Jicama flour color (L, C, °H).

Parameters	T3=PH	T4=CH	CV	DMS
*L	90.45 ± 3.96[a]	92.82 ± 6.09[a]	3.92	3.28
*C	1.52 ± 0.45[a]	1.50 ± 0.39[a]	3.92	0.15
°H	92.14 ± 0.80[a]	88.16 ± 0.17[a]	3.92	4.20

PH = Pantanal flour, CH = Camichin flour, *L = Lightness, *C = Chromaticity, °H = Hue Angle). Same letters per row do not differ statistically (Tukey, $p \geq 0.05$).

Proximal analysis

The physicochemical variables of lipids and amylose presented significant statistical differences ($p \geq 0.05$) between the treatments; while the variables of moisture, ashes, proteins, fiber, total carbohydrates, and amylopectin did not present statistical differences (Table 5).

Table 5. Proximal analysis of jicama starch.

Proximal análisis	T1:PA	T2:CA	CV	DMS
Moisture (%)	5.00 ± 0.00[a]	6.66 ± 2.88[a]	3.92	1.80
Ashes (%)	2.42 ± 0.28[a]	2.44 ± 0.04[a]	3.92	0.10
Lipids (%)	0.16 ± 0.00[b]	0.23 ± 0.01[a]	3.92	0.03
Protein (%)	0.61 ± 0.28[a]	0.53 ± 0.66[a]	3.92	0.47
Fiber (mg/100g)	157 ± 11.74[a]	170 ± 7.98[a]	3.92	22.75
Total carbohydrates (g/100g)	1.40 ± 0.59[a]	1.50 ± 0.83[a]	3.92	0.35
Amylose (%)	34.37 ± 0.00[a]	33.49 ± 0.00[b]	3.92	0.94
Amylopectin (%)	65.64 ± 0.00[a]	66.51 ± 0.00[a]	3.92	1.00

T1 = PA (Pantanal starch), T2 = CA (Camichin starch). The same letters per row do not differ statistically (Tukey, $p \geq 0.05$).

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Regarding the proximal characterization of jicama flour, the ash and amylose variables presented a significant statistical difference ($p \geq 0.05$), but not in moisture, lipids, proteins, fiber, and total carbohydrates (Table 6).

Table 6. Proximal analysis of jicama flour

Proximal análisis	T3:PH	T4:CH	CV	DMS
Moisture (%)	6.66 ± 2.88[a]	5.00 ± 0.00[a]	3.92	1.80
Ashes (%)	3.12 ± 0.16[b]	3.55 ± 0.35[a]	3.92	0.30
Lipids (%)	1.58 ± 0.00[a]	1.10 ± 0.00[b]	3.92	0.20
Protein (%)	8.82 ± 0.63[a]	11.04 ± 1.61[a]	3.92	2.77
Fiber (mg/100g)	148 ± 23.16[a]	181 ± 4.43[a]	3.92	37.80
Total carbohydrates (g/100g)	1.30 ± 0.86[a]	1.70 ± 0.13[a]	3.92	2.00
Amylose (%)	2.96 ± 0.00[b]	2.23 ± 0.00[a]	3.92	0.20

PH = Pantanal flour, CH = Camichin flour. The same letters per row do not differ statistically (Tukey, $p \geq 0.05$).

The results of the proximal characterization of jicama starch and flour present low moisture percentages, these can be attributed to the presence of free sugars such as glucose, since their hydrophilic groups interact and establish hydrogen bonds reacting with the water content present (Bernabé & Cancho, 2017). On the other hand, a low moisture content is related to the quality of the product, since it can be stored at room temperature without being prone to the proliferation of microorganisms and plays a vital role in handling, processing, and storage (Lalaleo, 2017; Barbosa *et al*., 2005). Water restriction favors the highest concentration of carbohydrates; the increase in these is attributed to different climatic conditions during the development of jicama, as well as the harvest period, which is directly reflected in the quality of the roots (León-Pacheco *et al*., 2018).

Rojas (2012) points out that the food industry prefers roots with a high starch content, but with a low sugar content, because the presence of these is related to the degree of non-enzymatic darkening developed in frying and, as a consequence, can cause rejection of the product by the consumer. Just like carbohydrates, fiber also has the same behavior in the food industry; Hasbún *et al*., (2009), mention that the fiber content is correlated with the texture (hardness) of the product, high fiber contents favor greater hardness in the fried product, which makes them unacceptable, in products such as starch and flour, those with low fiber content.

The content of mineral salts is related to the ash content, which largely depends on the type of soil and the amount of water acquired in the development, that is, they will only contain those chemical elements that are provided as part of their soil nutrition (fertilization, pesticides, etc.), or by irrigation (rain, river, well, etc.) (Badui, 2006); in each case, the concentration and type of mineral will be different and this will be reflected at the time it is harvested; minerals

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such as calcium, phosphorus, iron and copper are the minerals present in jicama (Rodiles-López *et al*., 2019).

Amylose products are commercially preferred due to the formation of gels; they have better mechanical properties, are less soluble, and show greater resistance to chemical or enzymatic degradation. Industrially, the amylose/amylopectin range can be genetically, physically, and chemically manipulated to modify its own characteristics, such as viscosity, gelatinization, texture, solubility, gel stability, and retrogradation, to give it stable industrial properties (Vargas & Hernández, 2012; Jiménez-Villalba *et al*., 2019).

The percentage of lipids in jicama starch (T1 = 0.16, T2 = 0.23) is lower compared to commercial starches such as corn (0.35) and sweet potato (0.31), it is usually similar to cassava starch (0.20). and greater than potato (0.05) (table 7). The amylose content in jicama starch was T1 (34.37) and T2 (33.49), these are higher than commercial starches such as corn (28.3), potato (21.0), sweet potato (19.6), as well as cassava (17.0) (Table 7). The determination of the amylose content is really important since it allows determining the most suitable processing conditions and evaluating the quality of different food products; the amylose fraction imparts definitive characteristics to the starch and, therefore, its concentration is considered an important quality criterion (Techeira *et al*., 2014; Arzapalo-Quinto *et al*., 2015).

Table 7. Proximal analysis of commercial starches

Flours	Moisture (%)	Ashes (%)	Protein (%)	Lipids (%)	Fiber (%)	Amylose (%)	Amylopectin (%)
Corn	9.9	0.06	0.10	0.35	0.62	28.3	71.7
Potato	19	0.40	0.06	0.05	--	21.0	79.0
Sweet potato	9.83	0.26	0.22	0.31	0.28	19.6	80.4
Yucca	9.48	0.29	0.06	0.20	1.01	17.0	83.0

Hernández-Medina *et al*., (2008)

Jicama flour has physical characteristics similar to commercial flours, but with different proximal chemical values; jicama flour contains a high amount of ash T3 (3.12 %) and T4 (3.55 %) compared to corn flour (1.21 %) wheat (1.69 %), oats (1.59 %), cassava (1.15 %) and carrot (0.87 %), these differences are attributed to the content of mineral salts present in horticultural products and is reflected in flours (Table 8).

This is also reflected in the lipid content since jicama flour has a lower content (T3 = 1.58; T4 = 1.10) compared to corn (3.95 %), wheat (2.93 %), and oat (7.50 %) but less than the flours of cassava (0.25 %) and carrot (0.09) (Table 8).

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Table 8. Proximal chemical of commercial flours

Flours	Moisture (%)	Ashes (%)	Protein (%)	Lipids (%)	Fiber (%)	Carbohydrates (%)
Corn	11.65	1.21	8.47	3.95	1.23	73.49
Wheat	10.39	1.69	12.43	2.93	3.16	70.22
Oats	7.33	1.59	11.43	7.50	1.78	70.37
Yucca	63.92	1.15	0.55	0.25	1.04	33.40
Carrot	89.89	0.87	0.55	0.09	1.21	8.38

Coral *et al*., (2015)

Jicama flour is considered a unique by-product in the food industry. These differences in the proximal chemical characterization are due to the fact that jicama flour is free of starch; this carbohydrate has the ability to adhere, therefore, certain macromolecules such as proteins, fiber, and lipids adhere to starch and carry on during its extraction, reflecting on the total quantification of the parameters.

Conclusions

The physicochemical and proximal chemical analysis of jicama starch and flour grown in Pantanal and Camichin, Nayarit, Mexico show low moisture and lipid content, promoting shelf life without oxidation, flavor, and unfavorable odor. In this regard, the starch and flour of the jicama root can be used in healthy foods, since they contain fiber and protein.

Author contributions

Conceptualization (RBG, BMR, LFAE, BRPU). Methodology (RBG). Software (RBG, LFAE). Validation (RBG, LFAE). Results analysis (RBG, BMR, LFAE, BRPU, JZJO, MGE). Data curation (GRB, BMR, LFAE, BRPU, JZJO, MGE). Writing-original draft (GRB, BMR, LFAE). Writing, review and edition (GRB, BMR, LFAE, BRPU, JZJO, MGE). Project administration (BMR). Funding acquisition (BMR).

All authors have read and accepted the published version of the manuscript.

Funding

This research did not receive external funding.

Revista Bio ciencias
ISSN 2007-3380

Acknowledgment

The authors thank the National Council for Science and Technology of Mexico (CONACyT) for the scholarship granted to Ramírez Balboa Gabriel (Number 784778).

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