Research Square

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Low amylose starch from discarded jicama tubers (Pachyrhizus erosus (L.) Urb.) and its techno-functional characterization

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Abstract

Purpose. The conversion of waste such as discarded jicama (DJ) to value added starch, offers possibility of local economic development and sustainability.

Methods. To evaluate the feasibility of reduced food waste, starch from discarded jicama (DJS) and commercial jicama (CJS) were obtained by a conventional method to compare whether the fact that the discarded product is used influences the yield and characteristics of the starch obtained.

Results. Significant differences in extraction yield were obtained, both starches presented a granule size between 1 and 12 μm, a type C diffraction pattern, amylose content around 14%, a gelatinization temperature of 61 °C to DJS and CJS; however, properties such as water solubility index (WSI), swelling power (SP), and pasting did present some differences, WSI and SP are higher for CJS causing a faster gelatinization process than in DJS.

Conclusion. There are differences in the characteristics of DJS and CJS, particularly it is suggested that DJ does have a significant impact on the internal structure of the starch granule, on the amylopectin fraction mainly.

Highlights

- Discarded jicama starch (DJS) and commercial jicama starch (CJS) were compared.
- Less amount of starch is obtained when using discarded jicama.
- The jicama starch obtained is clasified as low amylose starch.
- Amylopectin fraction differences from discarded jicama caused changes in the functional properties of the starch.

1. Introduction

Starch is a polysaccharide of great commercial importance, with a strong demand from various industrial sectors, driven by the diversity of end-use applications in both food and non-food products. The global market for starch and its derivatives is projected to reach USD 98 billion by 2028 with an approximate production of 168 million tons worldwide [1, 2]; wheat, corn, rice, potato and cassava are the main and leading crops for starch production [3]. There is a growing interest in finding new sources of starch to meet global demand, originated principally by the world population growth, limited water supply and to diversify the crops currently used. In this sense, the use of wastes, residues and by-products, has become a priority at global level, powering biorefinery concept in recent years, particularly second generation, which aims to use waste and byproducts from different crops as raw materials to obtaining products with a commercial importance, giving them added value [4], following the principles of circular bioeconomy, reducing contamination and food waste in considerable quantities.

Pachyrhizus erosus (L.) Urb. or Jicama, a plant that belongs to the *fabaceae* family, it is a species native to Mexico and Central America, which has been diversified in other parts of the world as Africa and Asia [5].

The chemical composition of jicama includes 16 to 22% dry matter, from which 1 to 1.6% corresponding to protein, 0.6 to 0.9% fat, 0.3 to 0.4% fiber, and 0.7 to 1% ash [6], the cell wall it is composed of polysaccharides like cellulose, lignin, hemicellulose and pectin. Starch is by far the principal carbohydrate as a reserve polysaccharide with an approximately 83% in dry matter content, making jicama a potential starch source [7].

Starch is defined as a semi-crystalline biopolymer and its present in granular form in the amyloplasts of vegetables cells. Chemically, starch is a mixture of 15 to 30% amylose which is an insoluble linear molecule and 70 to 85% of amylopectin, that is a branched water soluble molecule [8]. Generally, the starch granule of a tuber presents an oval, circular, elliptical and polygonal morphology, it appears as a type of B starch, with a gelatinization point of 50°C to 80°C [9, 10]; however, these characteristics can be change according to the starch source, to jicama starch, presents a type C diffraction pattern as exposed [11] some seed or root starches exhibit this type of diffraction pattern, according to Contreras-Jimenez, et al. [7] the size of jicama starch granule is relatively small, from 3 to 10 μm, and has a gelatinization temperature around 60°C, all these properties along with its rheology behavior are key to define the use and application. According to FAO [12] the jicama postharvest loss is calculated with a 25% per year, a part corresponds to jicama that does not meet the quality standards to be commercialized for being misshapen or with the wrong size, this jicama is known as discarded jicama which actually has not been exploited.

As mentioned above the need to find new starch alternatives with physicochemical and functional properties similar or superior to traditional starches is important, due to the accelerated increase in the demand for starch for food applications, but in a greater proportion today for non-food applications. Due to the lack of information and reports on the characteristics of starches obtained from discarded jicama, the aim of this research was to evaluate discarded jicama as an alternative source of starch as well as characterize physicochemical and rheological properties.

2 Materials And Methods

2.1 Materials

Discarded jicama (DJ) (*Pachyrhizus erosus*) and Commercial Jicama (CJ) batches obtained in 2020 harvest from Morelos State, Mexico (18°32'55.0"N 99°03'49.7"W), were used to obtain starch. Proximal analysis of both batches was carried out determining humidity, total solids, ash, fat, and protein content, according to the AOAC [13] methods, starch content was determine by total starch assay kit (Megazyme International, Ireland), and pectin content according to Filisetti-Cozzi and Carpita [14].

2.2 Jicama starch extraction

The jicama starch extraction procedure was carried out according to Contreras-Jimenez, et al. [7] methodology as follows, DJ and CJ were washed and peeled, the pulp was liquefied in a blender (BLSTBC4129-013 Oster, USA) with distilled water in 1:2 solid-liquid ratio, the mixture was drained (mesh #20, 0.850 mm as particle size), the solution obtained was refrigerated at 4°C to precipitate the starch, 24 h after the supernatant was removed and the precipitate was washed with distilled water, the dispersion was sifted (mesh #100, 0.150 mm as particle size). In each sieve, the residue was washed with distilled water until all starch was removed. The last suspension obtained was kept 24 h at 4°C to settle the starch, and then the water was decanted. The remaining of the suspension was centrifuged for 20 min at 1008 x *g* and kept 24 h at 4°C, the liquid phase was discarded, and the starch was dried at 40°C for 24 h in an oven (AR-130D, Arsa, Jalisco, Mexico). The starch dried was ground and sieved (mesh #60 0.360 mm as particle size). The starch yield was calculated according to the Eq. (1).

$$\text{Starch yield} = \frac{\text{starch (g)}}{\text{jicama sample (g)}^*} \text{ x } 100 \text{ (dry basis)}$$

1

*Jicama sample (g) was adjusted based on moisture content.

2.3 Amylose/amylopectin content

Amylose and Amylopectin content was determined using Megazyme Amylose/Amylopectin Assay Kit K-AMYL 12/16 (Megazyme International Ireland Limited, Wicklow, Ireland), based on the specific formation of amylopectin complexes with the concanavalin A, once the method was carried out, the absorbance was measured at 510 nm in a UV spectrophotometer (10S UV-Vis G10S UV-Vis, Genesys, Mexico).

2.4 Scanning electron microscopy (SEM)

The morphological characteristics of native starch granules were observed using a scanning electron microscope (JCM-6000, JEOL, Japan). Samples were coated with gold-palladium to improve their conductivity, and then fixed on double-sided carbon tapes and analyzed under the following at 15 A and 15 kV at different magnifications.

2.5 X-ray diffraction (XRD)

X-ray diffraction patterns were obtained in a diffractometer (D8 Advance Eco, Brucker, México City, México) in a range from 5° to 80° at 2 with an intensity of 25 mA and a voltage of 40 kV.

2.6 Thermal analysis

The thermal properties were determined through Differential Scanning Calorimetry (DSC) and Thermogravimetry (TGA). DSC was performed using a TA Q2000 differential scanning calorimeter (TA Instruments, DE, USA) as follows, 3 mg of the jicama starch samples with 9 µL of distilled water (1:3 w/v ratio) were placed into hermetic aluminum pans (Hermetic lids 900794.901, hermetic pans 900793.901, TA Instruments, DE, USA) sealed, and scanned over the range from 25°C to 150°C with a heating rate of

10°C/min [11]. The thermograms were analyzed using the TA Universal Analysis 2000 software 4.5A (TA Instruments, USA). Gelatinization onset (T_o), peak (T_p), conclusion (T_c) temperatures and melting enthalpies (ΔH) were measured.

TGA analysis was performed using a Thermal Analyzer (TGA Q500, TA Instruments, DE, USA). The jicama starch samples were heated from 25 to 600°C with a heating rate of 10°C/min in an inert atmosphere (N_2). Data collected were analyzed using Origin Pro Software 9.8.0.200 (MA, USA).

2.7 Fourier-transform infrared (FTIR) spectroscopy

The jicama starch samples were analyzed in a Fourier Transform IR Spectrometer (PerkinElmer Frontier, USA). The spectra were measured in a wavelength region of 4000 to 650 cm^{-1} with a resolution of 4 cm^{-1}. The collected data were analyzed on OriginPro Software 9.8.0.200 (MA, USA).

2.8 Water solubility index (WSI) and swelling power (SP)

WSI and SP were determined according to [15] with minor modifications. 0.2 g of jicama starch were placed into 50 mL centrifuge tube, 10 mL of distilled water were added and stirred. The suspensions were equilibrated at different temperatures (30, 40, 50, 60, 70, 80, and 90°C); then, these were centrifuge at 2800 x *g* for 20 min. The supernatant was placed into porcelain capsules and dried in an oven at 80°C; weight was recorded and registered as weight of soluble. The precipitate obtained was weighted and registered as gel weight, finally the WSI and SP were calculated using Eqs. 2 and 3.

$$\mathrm{WSI} = \frac{\text{weight of soluble (g)}}{\text{initial sample weight (g)}} * 100$$

2

$$\mathrm{SP} = \frac{\text{gel weight (g)}}{\text{initial sample weight (g)-weight of soluble (g)}}$$

3

2.9 Pasting properties

The determination of DJS and CJS pasting properties was performed using a Discovery Hybrid Rheometer 3 (TA Instruments, DE, USA) with a starch pasting cell accessory, according to Lemos, et al. [16] with minor modifications. 12% (w/v) suspensions were prepared. Each sample was heated from 30°C to 90°C (5°C/min), once the maximum temperature was reached, it was maintained for 5 min; afterwards, it was cooled down to 30°C (5°C/min) and kept it for 5 min. From pasting profile, gelatinization temperature (GT), peak viscosity (PV), hot paste viscosity (HPV), and cold paste viscosity (CPV) were determined from the data collected.

2.10 Statistical analysis

To obtain DJS and CJS, three extractions were made from each batch, and then each sample was measured at least in triplicate to reduce the experimental error in all determinations. Multiple comparison procedures were carried out using the Tukey methodology and was performed in the Minitab Software version 17.1 (Minitab Inc., PA, USA) with $p < 0.05$.

3 Results And Discussions

3.1 DJ and CJ composition and extraction yield of jicama starch

The composition of DJ batch was: 79.2%±0.41 moisture, 20.8%±0.4 total solids, 2.9%±0.2 ash, 0.8%±0.3 fat, 3.2%±0.4 protein, 61%±1.1 starch, and 5.4%±1.7 pectin, while for CJ batch was 90.1%±0.8 moisture, 9.9%±0.8 total solids, 3.1%±0.4 ash, 0.4%±0.2 fat, 8.7%±0.2 protein, 95%±2 starch, and 3.9%±0.5 pectin. The knowledge of the composition of both batches of jicama was fundamental, since it is the starting point for the evaluation of the possible differences that can cause damage or carelessness in the handling of the jicama that is discarded compared to the one that is destined for sale.

Starch yield for DJ was 5.4%±0.38 and CJ 8.3%±1.3, both on dry basis, according to the statistical analysis there is a significant difference in these results, showing that the extraction yield it is affected using DJ as starch source; however, this decrease in the extraction yield, considering that the JD is not used, still represents an advantage in terms of obtaining a value-added product from a byproduct that is considered as waste. In other hand, these values are in range with the values reported by Shi, et al. [17], who reported lower yield values of 1.09 and 2.20%, of two jicama samples from different cultivation areas. The differences in the extraction yields are influenced by many factors as the jicama characteristics, the extraction methods, washing procedures and the sieving process where the particle size resulting in a greater or lesser percentage of starch amount [18]. At the present research, some differences were found in the general composition of both batches of jicama (DJ and CJ), after having been subjected to the starch extraction process, it was a determining factor, so the use of DJ, being considered a subproduct, has two main advantages, on one hand, reducing the amount of jicama waste, thus contributing in a positive way to the environment, incorporating the circular bioeconomy principles and, an on the other hand, giving it added value by being able to obtain a product of industrial interest. In addition, it contributes to the generation of knowledge regarding this source of starch since although roots and tubers are currently considered a good alternative of starch non-cereal sources due to their content that ranges from 12 to 24% [19], only few options have been carried out on a large-scale, such as potato, cassava and sweet potato, but others such as taro, yam, and jicama have not yet been established [20].

3.2 Amylose/Amylopectin content

Amylose content for DJS and CJS was 14.1 and 14.5%, respectively, with no statistically significant differences; however, if compared DJS and CJS to other starch sources, the amylose content is relatively

low. According with Shao, et al. [21] based on amylose content, starches may be classified as waxy starch (0–5%), very low-amylose starch (5–12%), low amylose starch (12–20%) and high amylose starch (25–33%), thus DJS and CJS are classified as low amylose starch. Amylose content varies significatively in literature reports, from low content starches 10–20% [22] to high content starches 20–26% [23, 24], these variations could be explained to numerous factors as source type, water supply, climatic and soil conditions, cultivation techniques, length of cultivations days, to name a few. About the type of source, in general, the amylose content in cereal starches normally ranges between 20 and 40%, for legume starches it is between 20 and 30%, and for roots and tubers the vast majority are between 16 and 27%; however, some exceptions such as *arracacha xanthorriza* and *colocaisa esc*. are still below this range [25] or such is the case of the jicama starch obtained in the present research, which is around 14%. The amylose content in starches is fundamental, properties such as the gelatinization point, solubility index and swelling power depend on it [26]. Low content of amylose or the absence of it leads on easily gelatinization, resulting in clear and low structured pastes, this may represent an advantage as additive in food systems as thickening agents or emulsifiers, some applications could be the formation of noodles with desirable textures, sauces and soups [27], in contrast, high amylose content tends to promote strong retrogradation forming rigid crystalline structures with high organization [28].

3.3 SEM analysis

Starch granule size and morphology are key parameters on the functional properties and consequently in starch applications. The Fig. 1 shows the DJS (A) and CJS (B) SEM images, where the granule morphology can be observed, and it is clear that both samples have the similar characteristics, a polygonal and semi-spherical shape, in terms of size, it's found between 4 to 12 μm, this granule size agree with it reported by Amaya-Llano, et al. [29] and Stevenson, et al. [24] to jicama starch. Many factors are related with starch granule size and morphology variations such as biochemistry of amyloplast and the physiology of the plant [30], and as consequence of this variations, physicochemical and techno functional properties as swelling power, solubility index and water binding capacity are modified [31]. Actually is well known a direct relation between the low amylose content and small granule size as Singh and Kaur [32] demonstrates on a study of fractionation on large-, medium-, and small size starches form different potato cultivars.

3.4 XRD analysis

The XRD patterns of DJS and CJS are shown in Fig. 2, for both DJS and CJS diffraction peaks were found at 5.6°, 15°, 18°, and 24° 2θ. Generally, the starches are classified into type A-type and B-type according to the XRD patterns [33]. On one side, A-type starches are characterized by strong diffraction peaks at 15° and 23° 2θ and a doublet at 17° and 18° 2θ; while the B-type, are characterized by a strongest diffraction peak at 17° 2θ, some small ones at 15°, 22°, and 24° 2θ, and peculiarly a peak at around 5.6° 2θ. A-type starches are mainly from cereals, and B-type are more common in tubers [34].

The XRD patterns from DJS and CJS do not correspond to any of these, there is another group that is less common, which is known as C-type starches, in which their XRD patterns share characteristics of both A

and B types, which can in turn be classified into C_A, C_B, and C_C depending on the greatest similarity [35]; therefore, they are considered more complex. According to this, DJS and CJS correspond to C_B-type starches because the similarity to B-types predominate. In general, C-type starches have been obtained in legume seeds and some rhizomes. C_B-type starches have been found in other vegetable sources as chestnut [35], and common cattail [30]. According to He and Wei [30] the differences in crystallinity patterns can be due to the environmental conditions during growth and not only to the plant species from which the different starches are obtained. Knowing the type of crystallinity can contribute to a better understanding of the behavior of starches in different systems and under different conditions, thus allowing the visualization of possible applications.

3.5 Thermal properties

Thermal properties of DJS and CJS were determined by DSC and TGA, and their thermal parameters are given in Table 1. DJS and CJS presented similar characteristics since they did not show statistically significant differences to T_o, T_p, T_c, and ΔH. Contreras-Jimenez, et al. [7] determined to jicama starch T_o=53.8°C, T_p=59.6°C, T_c=72.3°C values, which agrees with the values founded at the present work. Thermal parameters usually change even if the starches are from the same vegetal source, since they can be affected by different factors such as granule size distribution, amylose content, amylopectin branch chain, crystalline structure among others [36]. Low enthalpy values observed in this research can be highlighted in contrast with high vales reported by Stevenson, et al. [24] (ΔH = 14.8–15.4 J/g), this could be attributed to differences in the crystallinity characteristics, since they report A-type profile while in this work C_B-type were founded for DJS and CJS. Conversely, similar low values of enthalpy agrees to that reported by Shi, et al. [17] (ΔH = 2.9–3.1 J/g) for a B-type crystallinity profile. Based on what they report, and the observed in the present study, we can attribute this behavior to the type of crystallinity since low enthalpy values have been related to B-type starches [37] because the amylopectin clusters are less dense than A-type ones [38]. According to XDR patterns, DJS and CJS are C_B-type starches, so low enthalpies would be expected, as obtained; in addition to the fact that the size of the granule is also relatively small facilitates heat transport phenomena.

Table 1
Thermal properties of discarded jicama starch (DJS) and commercial jicama starch (CJS).

Parameter	DJS	CJS
T_0 (°C)	$56.55^a \pm 2.60$	$56.80^a \pm 4.02$
T_p(°C)	$61^a \pm 2.85$	$61^a \pm 3.35$
T_c(°C)	$68.09^a \pm 2.27$	$66.16^a \pm 0.71$
ΔH (J/g)	$1.88^a \pm 0.79$	$1.70^a \pm 0.50$
Moisture Weight loss (%)	$10.51^a \pm 0.56$	$10.80^a \pm 0.37$
Moisture Weight loss (mg)	$1.32^b \pm 0.35$	$2.70^a \pm 0.23$
Temperature (°C)	$311.09^a \pm 1.60$	$313.19^a \pm 2.18$
Mass loss in starch (%)	$80.83^a \pm 1.95$	$78.36^a \pm 0.90$
Mass loss in starch (mg)	$10.14^b \pm 2.51$	$19.79^a \pm 2.40$
Ash Formation (%)	$8.36^b \pm 0.93$	$10.61^a \pm 0.48$
Ash Formation (mg)	$1.07^b \pm 0.36$	$2.67^a \pm 0.30$

Average of three replicates ± SD. Different letter in the same row is significantli different (Tukey, $p < 0.05$). T_0 = initial temperature, T_p=peak of temperature, T_c=end temperature, and ΔH = enthalpy.

Respect to TGA analysis, the phenomena of degradation and thermal stability were evaluated. Figure 3 shows the TGA and DTGA curves for DJS and CJS samples. For TGA, three characteristic zones stand out. The first one below 100°C, which is attributed to dehydration of the sample [39], with a weight loss of 10.5 and 10.8% to DJS and CJS, respectively. Subsequently, between 250 and 350°C, the amylose and amylopectin degradation occur is observed with a weight loss of 80.8 and 78.4% to DJS and CJS, where their corresponding chains are broken [40]. Finally, around 600°C it can identify the third zone that has generally been attributed to the carbonization of residues that may be in the sample, with a weight loss of 8.4 and 10.6% to DJS and CJS, in fact this phenomenon has been reported from 400°C [41]. On the other hand, according to the DTGA results, the highest peak observed at 311.09°C ± 1.60 for DJS and at 313.19°C ± 2.18 for CJS indicates the decomposition temperature, which is very similar for both jicama starch samples. In addition to this, the width of this peak can be related to the speed of said decomposition, since it has been observed that narrow peaks, in a low temperature range ($\Delta T \approx 50°C$) correspond to rapid degradation processes, while wider peaks correspond to slower degradation processes. According to this, although the degradation temperature for both starch samples is very similar, the peak for DJS is wider than that CJS, thus suggesting that the decomposition process in DJS is slightly slower.

3.6 Water solubility index (WSI), swelling power (SP), and pasting properties

The WSI and SP of the DJS and CJS at different temperature are presented in Table 2. As can be observed in obtained data, both WSI and SP shows an increase as temperature increase as well. Before 60°C, no significant differences were observed; after that, the increase was drastic, behavior that is agree to that reported by Shi, et al. [17] for two jicama (*Pachyrhizus erosus*) starches from two different places (Fujian Province and Guangxi Province in China). Although the trend for DJS and CJS is the same, the magnitude of WSI and SP values is higher for CJS. Generally, the differences of WSI and SP for starches are attributed to various factors such as botanical source, amylose content, granule size or the type of crystalline structure [33, 37]; however, for DJS and CJS, no differences were found in these parameters. Thereby, the differences in this case are due to other factors. It's known that SP also can be influenced by less compact structure in the granule [42] and the bond strength between molecules and by the molecular structure of amylopectin [43]. Once the granules swell, solubilization consequently occurs, thus WSI and SP are closely related. According to what was observed in the present work, the differences between DJS and CJS can be attributed not to differences in the amylose/amylopectin content, otherwise to possible differences in the distribution of the amylopectin chains and in the size and extension of the chains [44, 45], which suggests that the fact that discarded jicama is used to obtain starch does have a significant impact on the internal structure of the granule, on the amylopectin fraction mainly. It may be due to the tuber suffered some type of degradation during the time that the discarded jicama remains in the crops before being harvested or even to the storage conditions can be attributed, since it is not a consumer product, the conditions are not usually the more suitable. More robust studies will be needed to fully elucidate this assumption.

Table 2
Water soluble index (WSI) and swelling power (SP) to discarded jicama starch (DJS) and commercial jicama starch (CJS).

Temperature (°C)	WSI (%)		SP (g/g)	
	DJS	CJS	DJS	CJS
30	$0.18^{a} \pm 0.32$	$0.07^{a} \pm 0.10$	$2.40^{a} \pm 0.16$	$2.29^{a} \pm 0.08$
40	$0^{a} \pm 0$	$0.17^{a} \pm 0.14$	$2.44^{a} \pm 0.17$	$2.28^{a} \pm 0.11$
50	$0^{a} \pm 0$	$0.21^{a} \pm 0.17$	$2.89^{a} \pm 0.66$	$2.46^{a} \pm 0.15$
60	$2.51^{a} \pm 0.32$	$6.10^{b} \pm 1.19$	$8.65^{a} \pm 0.32$	$12.67^{b} \pm 0.55$
70	$6.27^{a} \pm 3.59$	$9.29^{a} \pm 1.39$	$22.24^{a} \pm 0.29$	$14.64^{b} \pm 0.39$
80	$6.25^{a} \pm 0.22$	$12.29^{b} \pm 0.62$	$13.04^{a} \pm 0.79$	$20.49^{b} \pm 0.64$
90	$9.03^{a} \pm 0.18$	$25.14^{b} \pm 2.79$	$17.98^{a} \pm 0.91$	$25.77^{b} \pm 0.34$

Average of three replicates ± SD. Different letter in the same row for WSI and SP respectively are significantly different (Tukey, $p < 0.05$).

The viscosity profiles shown in the Fig. 4, where there are differences in the gelatinization process between the DJS and CJS samples, highlighting that for CJS it is faster, CJS presented higher WSI and SP, which in a certain way favors the gelatinization process, since it allows a faster hydration of the granules and therefore gelatinization occurs in the same direction. On the other hand, the cold paste viscosity (CPV) and retrogradation point are lower than for DJS. According to [43] these parameters can be affected by the granule characteristics (size and rigidity), chemical composition (amylose and amylopectin proportion), and SP. The pasting characteristics of DJS and CJS are shown in Table 3. All parameters evaluated as gelatinization temperature (GT), peak viscosity (PV), hot paste viscosity (HPV), cold paste viscosity (CPV), rupture (PV-HPV), and retrogradation (CPV-HPV) presented significant differences.

Table 3
Pasting properties of discarded jicama starch (DJS) and commercial jicama (CJS).

Parameter	DJS	CJS
Gelatinization temperature (GT) (°C)	$62.05^{a} \pm 1.69$	$57.08^{b} \pm 0.02$
Peak viscosity (PV) (Pa·s)	$3.04^{b} \pm 0.03$	$3.98^{a} \pm 0.16$
Hot paste viscosity (HPV) (Pa·s)	$1.22^{a} \pm 0.01$	$0.83^{b} \pm 0.01$
Cold paste viscosity (CPV) (Pa·s)	$2.87^{a} \pm 0.02$	$2.09^{b} \pm 0.06$
Rupture (PV-HPV) (Pa·s)	$1.82^{b} \pm 0.03$	$3.12^{a} \pm 0.17$
Retrogradation (CPV-HPV) (Pa·s)	$1.65^{a} \pm 0.02$	$1.25^{b} \pm 0.04$

Average of three replicates ± SD. Different letter in the same row is significantly different (Tukey, $p < 0.05$).

3.7 FTIR Analysis

The FTIR spectra obtained for CJS and DJS are shown in Fig. 5. Both starch samples presented similar patterns, which are characteristic for polysaccharides [46]. The highest intensity bands were found between 900 to 1800 cm^{-1}, which are characteristic of starches, in general are attributed to the presence of C – O, C – C, and C – O–H bending vibrations [47]. On the other hand, the peak observed around 1650 cm^{-1} is associated with a certain water content that can be absorbed in the amylose fraction of starch [47]. In accordance with the, it is evident that there are no significant differences in the FTIR spectra between DJS and CJS.

Most of the parameters evaluated did not show significant differences, except for the WSI and SP, as well as moisture loss and ash formation in the TGA. It has been reported that the presence of minerals in starches can cause some phenomena in the viscosity profiles, since a higher viscosity value has been observed at the end of the viscosity profile at a lower mineral content, in contrast to those have presented a lower mineral content [7], this agree with was observed for DJS and CJS, the latter being the one that presented the highest ash formation, represent different type of metallic substances (Table 1), showing a lower viscosity at the end of the profile. This behavior can be attributed to the starch-water suspension does not have a kinematic viscosity [48]. Based on what was observed, although structurally the starches from DJ and CJ do not present very marked differences, through this analysis it was possible to observe that the fact of using DJ does significantly affect the pasting properties, which would have to be further study to exploit these differences in possible applications.

4 Conclusions

The use of discarded jicama as an alternative source of starch has been effective since in terms of yield using the same extraction method, no significant differences were observed; on the other hand, a large

part of the morphological and compositional characteristics remain very similar between both starches (DJS and CJS). However, in the functional properties there were some differences, particularly for the WSI, SP, and pasting, since these properties are so important to determine future applications, it has been decisive for the present study to be able to identify them, essential to determine if it can be used as a gelling agent, thickener, emulsifier, etc. This work has laid the foundations for later studies, since by demonstrating that discarded jicama can be a non-conventional source of starch; In addition, without putting at risk or reducing the availability of products that are suitable for human consumption, positively impacting the reduction of agricultural waste through second-generation biorefinery. It is now necessary to focus on optimizing the extraction process and exploring starch modification alternatives to diversify its possible applications.

Statements And Declarations

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

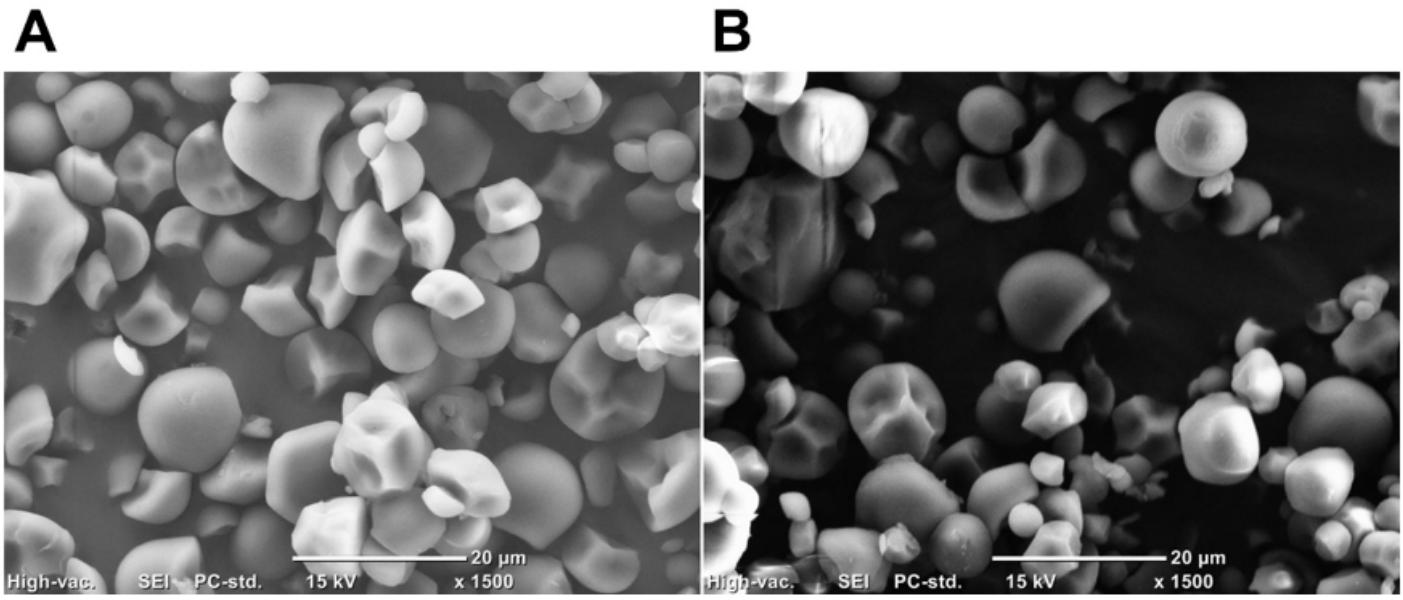


Figure 1

SEM images (1500x) of (A) discarded jicama starch (DJS) and (B) commercial jicama starch (CJS)

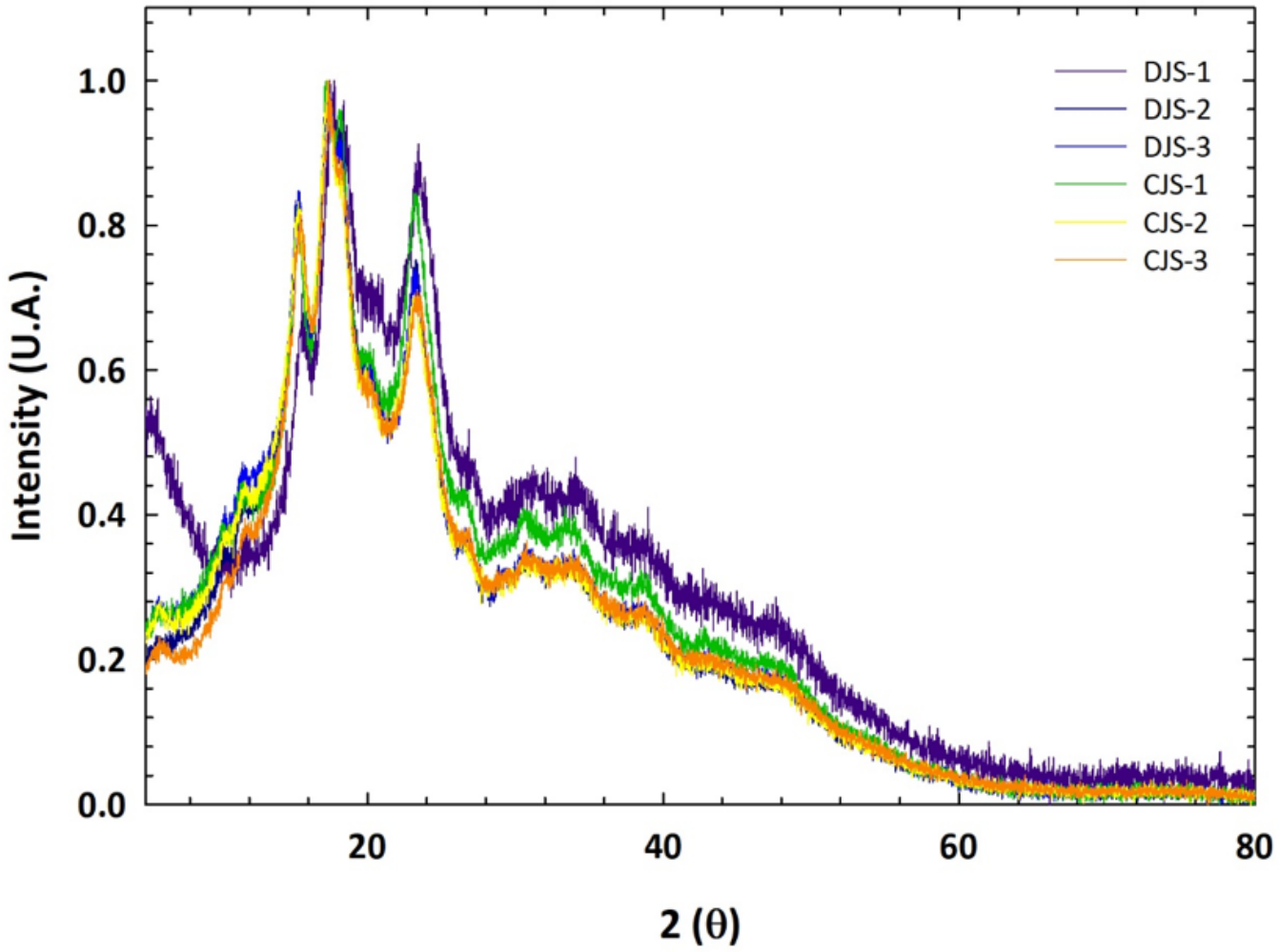


Figure 2

XRD patterns of discarded jicama starch (DJS) and commercial jicama starch (CJS)

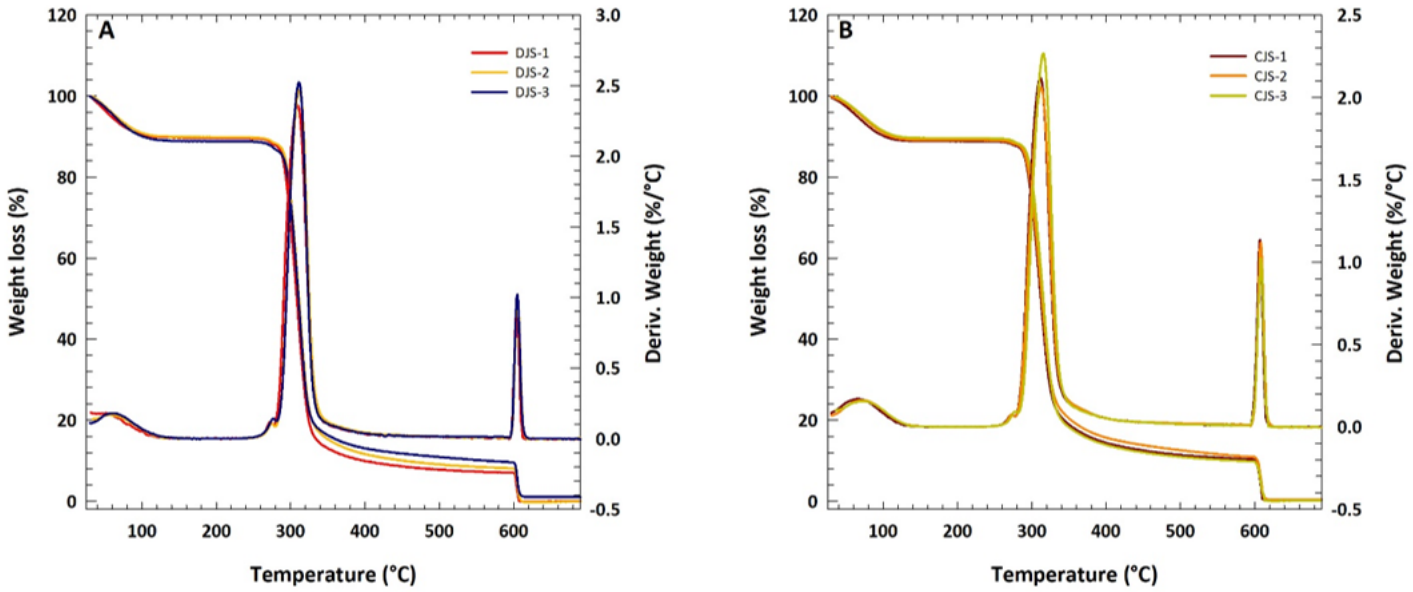


Figure 3

TGA and DTGA curves corresponding to the decomposition process (A) discarded jicama starch (DJS) and commercial jicama starch (CJS).

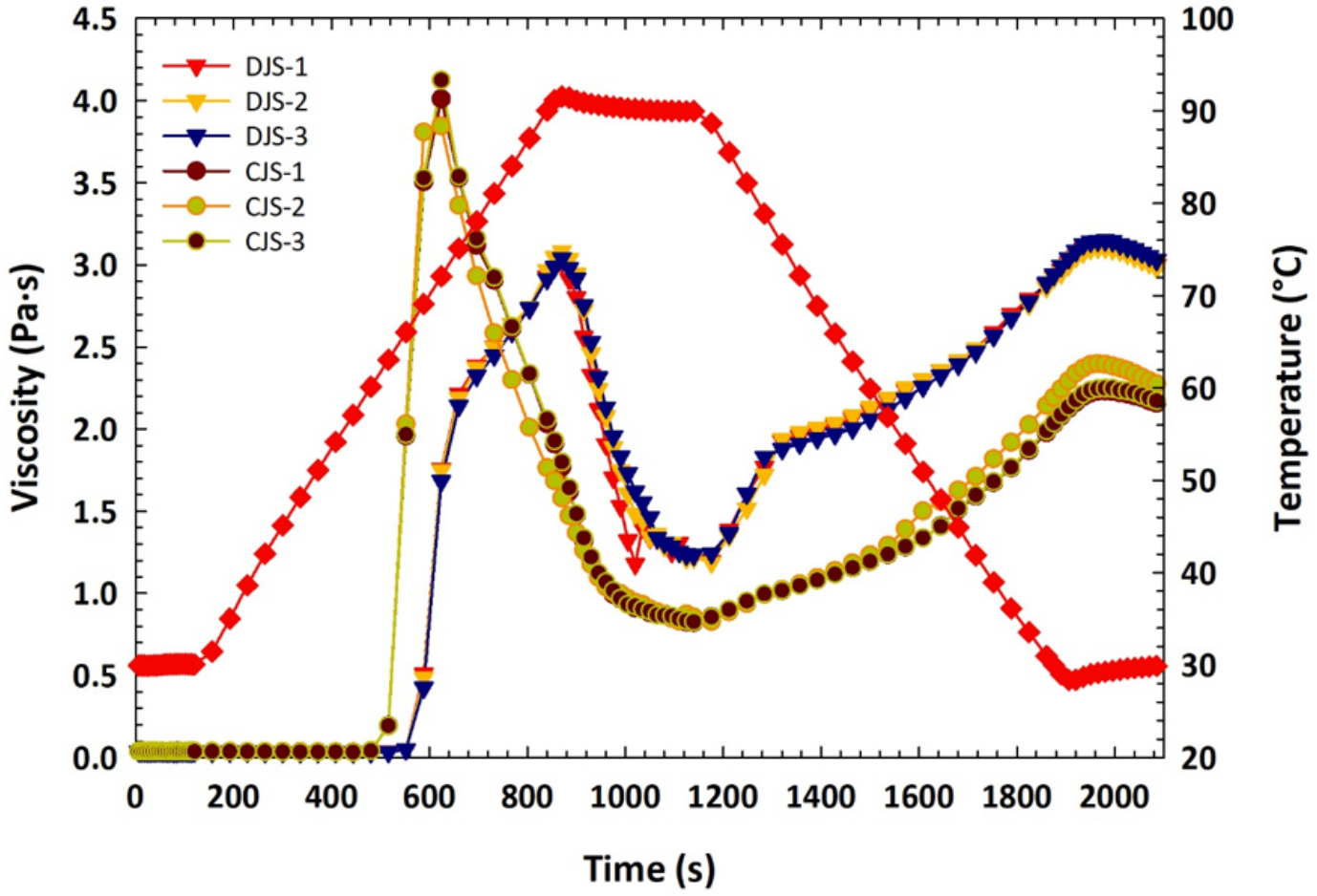


Figure 4

Viscosity profiles of discarded jicama starch (DJS) and commercial jicama starch (CJS).

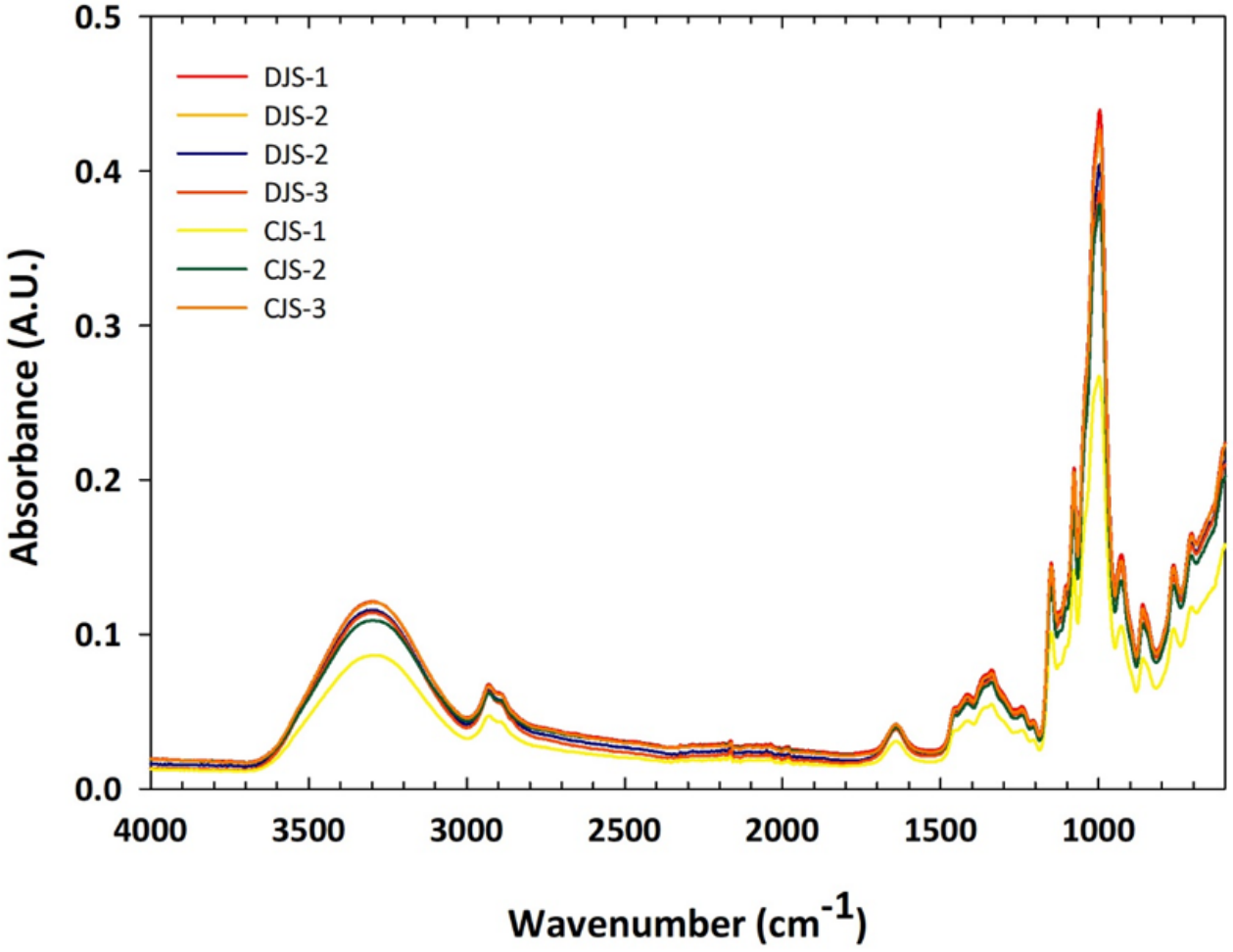


Figure 5

FTIR spectra for discarded jicama starch (DJS) and commercial jicama starch (CJS).