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Characterization of some properties of starches isolated from *Xanthosoma sagittifolium* (*tannia*) and *Colocassia esculenta* (*taro*)

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Abstract

In this study, moisture, ash, amylose, phosphorous content, and the gelatinization profiles of starches isolated from *Colocasia esculenta* (*taro*), and *Xanthosoma sagitifolium* (*tannia*) storage organs were evaluated. The gelatinization profile and the changes in the heat flow or enthalpy during the gelatinization process were evaluated by DSC methodology. The phosphorous and amylose content were also analyzed by a colorimetric method. The results show that the amylose content of the starch isolated from *Xanthosoma sagittifolium* is higher than those shown by *Colocasia esculenta* and *Manihot esculenta* Crantz starches. The phosphorous content was higher in *Xanthosoma sagittifolium* than *Colocasia esculenta* or the commercial *Manihot esculenta* C. starches. The gelatinization profile range is wider in *Manihot esculenta C.* than the other two starches. Differences in these parameters may affect the functional properties of the products formulated with these starches. The most significant relationship between parameters was found between the amylose and gelatinization profile and enthalpic change and ash.

Keywords: Aroid's starches; Starch properties; Starches from *Xanthosoma sagittifolium* and *Colocassia esculenta*

1. Introduction

Most tropical plants produce underground storage organs classified as roots or modified stems or tubers, examples of plants that produce tubers as storage organs are *Xanthosoma sagittifolium* (tannia, yautia, ocumo criollo) and *Colocasia esculenta* (taro, ocumo chino). The tubers of this tropical plants belonging to the family *Araceae*, store a high starch concentration that ranges between 22 and 40% (Agbor Egbe & Rickard, 1990; Delpeuch, Favier, & Charbonniere, 1978; INN, 1999; Montaldo, 1992; Treche & Guion, 1980a,b), and for this reason, they are considered carbohydrate foods (Swinkels, 1985). They are not extensively commercialized at present, but are mostly grown in domestic gardens or 'conucos' in South America.

Improvements in agronomic techniques and utilization of modern genetic techniques may allow these tubers to be cultured and commercialized extensively. In addition, these tubers are widely consumed in tropical areas and may resolve starvation problems elsewhere.

However, they have a short shelf life because of their high moisture content. One of the best ways to preserve them may be by processing them to obtain flour and/or starches. Starches obtained from theses tubers have never been commercialized because their properties are unknown. Since the transformation into starch will decrease losses after the tubers have been harvested, value added processes such as wet milling may be useful in order to obtain starches from these tubers. It is, therefore, clear that a significant amount of work remains to be done on the functional characteristics of flours and native, as well as modified tropical starches if they are ever to become competitive with commercial starches such as corn, wheat, and potato (Satin, 1999). Before consideration is given to tubers as potential

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sources of starch to produce foods, it is necessary to characterize their chemical composition, physical, physicochemical, and functional properties.

Limitations for the use of this research are dependent upon agricultural developments of these crops. There are numerous factors that are related to these limitations such as: lack of interest in these cultures; especially crops of *Xanthosoma sagittifolium* and *Colocasia esculenta*, the climate and growing condition requirements of these crops, and unavailable information related to these crops.

The aim of this study is to characterize and compare the native starches isolated from *Xanthosoma sagittifolium* and *Colocasia esculenta*.

2. Material and methods

2.1. Material

2.1.1. Samples

Three batches of clean tubers of *Xanthosoma sagittifolium* and *Colocasia esculenta* were obtained from a local market. Commercial *Manihot esculenta* Crantz, starch obtained from Alfonzo Rivas C.A, Cagua, Venezuela was used as control.

Starches of *Xanthosoma sagittifolium* and *Colocasia esculenta*, were obtained from three different batches of the tubers, following the method described by Pérez, Bahnasey, and Breene (1993), with some modification. The cleaned tubers were peeled, weighed, sliced and ground for 2 min at high speed in a waring blender with small volumes of distilled water. The homogenate was passed through an 80-mesh sieve. This grinding and screening operation was repeated four more times. The resulting slurry was passed consecutively through a 200- and 270-mesh sieve and centrifuged at 1500 rpm for 20 min. After removing the mucilaginous layer, the sediment was washed several times by suspension in distilled water and centrifuging until it appeared to be free of non-starch material. The sediment was then dried in an oven at 45 °C. The *Xanthosoma sagittifolium* and *Colocasia esculenta* dried starches were blended, passed through a 60-mesh sieve, and stored at room temperature in sealed plastic bags.

2.2. Methods

2.2.1. Chemical properties

Starches isolated from the three batches of each kind of tuber were analyzed for moisture, ash, crude protein ($N\times$ 6.25%) fatty material, crude fiber and total sugar contents as a percentage (w/w), following methods described in AOAC (2000), AACC (2000), and Whistler (1964). Phosphorous content, as a percentage (w/w), was determined following the photometric method as described by AOAC (2000). The amylose content was determined using the colorimetric method described by McGrance, Cornell, and Rix (1998). The standard curve was established using pure potato amylose: A0512 Sigma Type III.

Yield of the starch obtained from each batch was calculated using the equation = % yield = (wt of starch isolated/wt of edible portion of the tuber) $\times$ 100. Purity was calculated from the difference between 100 and percent of moisture, crude protein, fatty material and ash content following the equation: % purity = (100 − [% moisture + % crude protein + % fatty materials + % ash + % total sugars]).

2.2.2. Rheological properties

2.2.2.1. Brabender viscoamylograph analyses. Pasting properties were determined with the Brabender viscoamylograph (7% of concentration) by the method described in AACC (2000), and the breakdown, setback, and consistency indices were calculated from the corresponding plots. Values were expressed in Brabender Units (BU) following parameters as were described by Mazur, Schoch, and Kite (1957) and Merca and Juliano (1981).

2.2.2.2. Differential scanning calorimetry (DSC) analyses. DSC analyses were performed on a Perkin Elmer, Norwalk Differential Scanning Calorimeter Mod. DSC-4 following the procedure described by Pérez, Breene, and Bahnassey (1998a). A 200 mg (db) starch of known moisture content was weighed accurately; water was added and thoroughly mixed with the appropriate quantity of distilled water to give a starch:water ratio of 1:2. Measured portion of each sample was withdrawn and dispensed into weighed DSC sample pans. Each sample pan was hermetically sealed and stored for 1 h before testing. A sample pan was placed in the DSC sample cell and a sealed pan filled with 50 μl of water was placed in the reference cell. Temperature was raised from 25 to 160 °C at a rate of 15 °C/min and kept at this temperature for 2 min. The temperature was then decreased from 160 to 25 °C at the rate of 5 °C/min. Enthalpic data were collected during the cycle. The gelatinization profile analyzed by this method describes the change of enthalpy for the sample for the first, middle, and end points of the peak over the isotherm region. Thermal transition was defined in terms of T_o (onset) T_p (peak) and T_e (endpoint gelatinization temperature). Enthalpy value ($\Delta H/g$) was calculated from the endotherm plots (Biliaderis, 1983; Davis, 1998; Pérez et al., 1998a).

2.3. Microscopy

2.3.1. Scanning electron microscopy

Granular shape and size and distribution granular were studied by scanning electron microscopy (SEM). Starch was sprinkled onto double-sided adhesive tapes, attached to circular specimen stubs, coated with 200 A of pt/palladium using a Hitachi E 102 Ion Sputter, examined at 20.0 kV, and photographed in a Hitachi S 2400 scanning electron microscope. Starch granule diameter range was estimated

by measuring 20–30 randomly selected granules from triplicates microphotographs.

2.3.2. Optic microscopy (polarized light)

Granular shape and Maltese cross were evaluated by optical microscopy using polarized light filter. Starch was sprinkled in a glass slide, 1–2 drops of distilled water were added and mixed with starch, 2–3 drops of Lugol solution were added and the sample was held for 5 min. After the holding time, the slide was covered with a slip cover glass, and it was held for 2 more minutes, examined, and photographed in a Nikon Optiphot-2 microscope.

2.4. Statistical analysis

Analysis of variance (ANOVA) at the significant level of 5% ($\alpha \leq 0.05$) was performed to obtained results, using the Statgraphics Program (Statically Graphics Educational, version 6.0 1992. Manugistics, Inc. and Statistical Graphics Corp., USA). When statistical differences were found, the Duncan's Multiple Range Test was applied ($\alpha \leq 0.05$) in order to classify samples.

3. Results and discussion

3.1. Yield purity and chemical composition

Table 1 shows chemical composition of starches obtained from each tuber. The moisture contents of these starches are among the moisture range generally accepted for dry products in order to obtain a desirable shelf life and other conventional starches (Brown, 1995; INN, 1999; Sriroth, Piyachomkwan, Wanlapatit, & Oastes, 2000; Swinkels, 1985; Thomas & Atwell, 1999). Also, no statistically significant differences ($p \leq 0.05$) were found among them.

Table 1
Chemical composition, yield and purity (w/w; dry basis) of starches isolated from tubers of *Colocasia esculenta*, *Xanthosoma sagittifolium* and *Manihot esculenta* C.

Parameters	*Xanthosoma sagittifolium*	*Colocasia esculenta*	*Manihot esculenta* C. (commercial)
% Moisture	13.43 ± 0.01a	14.01 ± 0.05a	13.63 ± 0.12a
% Crude protein	0.56 ± 0.05a	0.53 ± 0.04a	ND ± 0.00
% Fatty material	0.1 ± 0.01b	0.27 ± 0.01a	0.04 ± 0.01c
% Ash	0.20 ± 0.04b	0.31 ± 0.01a	0.12 ± 0.02c
% Crude fiber	ND	ND	0.28 ± 0.01
% Total sugars	0.08 ± 0.00a	0.04 ± 0.00b	0.02 ± 0.04c
Phosphorous (mg/100 g)	0.07 ± 0.001a	0.01 ± 0.01c	0.05 ± 0.01b
% Amylose	35.34 ± 0.65a	30.62 ± 0.16b	16.89 ± 0.09c
% Yield	10–12	10–12	10–12
% Purity	99.06b	98.85c	99.54a

ND, non-detected by the method used. Data are the average of three-repetition ± standard error. Same letter indicate that there are no significant differences ($\alpha \leq 0.05\%$).

Usually the recovered starch contains minor to trace amounts of protein. Together with trace quantities of the other component such as trace amounts of fatty acid glycerides, usually less than 0.1%, most other starches also contain about 0.5–0.6% of free fatty acids, which appear to be complexes with the molecular compounds of the granular native starch (Whistler, 1964). As shown in Table 1, crude protein and fatty material (as ether extractable lipids) present in *Manihot esculenta* Crantz. Commercial are similar to those reported in literature (González & Pérez, 2003; Pérez, 1996, 1998a,b; Thomas & Atwell, 1999). Fatty material contents of *Colocasia esculenta*, *Xanthososma sagittifolium* and *Manihot esculenta* Crantz starches showed statistically significant differences ($p \leq 0.05$) among them. Crude protein contents of the two starches are higher than that shown by *Manihot esculenta* Crantz starch, also there was no statistically significant differences ($p \leq 0.05$) found among *Colocasia esculenta* and *Xanthososma sagittifolium* crude protein content.

As shown in Table 1, the ash content of the tropical tuber starches fall in the range found in the literature for commercial starches (Pérez, 1996; Sriroth et al., 2000; Swinkels, 1985) and statistically significant differences ($p \leq 0.05$) were found among the three kinds of starches evaluated. Due to the isolation methods for obtaining starches, their minor chemical and mineral content is dependent not only on botanical source, but also on the extraction methods.

3.2. Phosphorous content in starches (obtained from each tuber)

Phosphorous content is an important parameter used to define the functional properties of starches. The phosphorous content of potato starch (0.06–0.1%) is due to the presence of phosphate ester groups (Whistler & BeMiller, 1997). As shown in Table 1, *Xanthosoma sagittifolium* starch has higher phosphorous content than those shown for *Colocasia esculenta* and *Manihot esculenta* Crantz starches. Statistically significant differences ($p \leq 0.05$) were found among them.

3.3. The amylose content in starches (obtained from each tropical tuber)

The amylose content in starches has an important effect on their functional properties. Therefore, it is quite important that the amylose content be quantified for food processing and quality. However, literature has pointed out a controversy related to amylose determination (Martínez & Prodolliet, 1996). As shown in Table 1, amylose content of *Xanthosoma sagittifolium* and *Colocasia esculenta* starches, as determined by the colorimetric method was higher than that shown by *Manihot esculenta* Crantz starch.

The amylose content of the *Manihot esculenta* Crantz starch was similar to those shown in the literature (Swinkels, 1985; Thomas & Atwell, 1999; Whistler & BeMiller, 1997), and it has approximately half the amylose content of the *Xanthosoma sagittifolium* and *Colocasia esculenta* starches, therefore statistically significant differences ($p \leq 0.05$) were found among them.

Purity as can be seen from Table 1 is quite high for three starches ranging from 98.85 to 99.54%, despite that relative high crude protein content shown by the two starches studied as compared with *Manihot esculenta* Crantz starch. As reported in the Food Composition Table A from Brown (1995), tapioca pearl dry (equivalent to *Manihot esculenta* Crantz starch) shows less than 0.6% crude protein and fat content, and 1.3% of dietary fiber. Except for dietary fiber content, these results agree with those of our study.

3.4. Enthalpic changes (ΔH) in cal/g and gelatinization profiles of starches (obtained from each tuber)

Table 2 shows the gelatinization profile in °C, and enthalpic change (ΔH is expressed in cal/g) of starches isolated from aroids of *Xanthosoma sagittifolium* and *Colocasia esculenta*, measured using the DSC technique.

The starches show a similar ΔH that ranges between 3312 and 3999 cal/g. Starch isolated from *Colocasia esculenta* shows higher ΔH than those isolated from *Xanthosoma sagittifolium* and *Manihot esculenta* Crantz.

The gelatinization profiles of starches are shown in Table 2. The initial, middle, and end gelatinization temperatures of each starch are higher than that of *Manihot esculenta* C. starch. *Manihot esculenta* Crantz starch was used as a control ($\alpha \leq 0.05\%$). *Colocasia esculenta* starch has a narrow gelatinization range than the *Xanthosoma sagittifolium* starch.

Table 3 shows rheological properties of the starches measured by the amylograph Brabender. As can be seen in Table 3, the gelatinization temperature of the three starches is lower than those reported using DSC (Table 2). Initial gelatinization temperature (IGT) measured through the amylographic curve is related to viscosity development, which depends on more than one factor in the system as concentration, temperature, shear rate, and intrinsic granular

Table 2
Gelatinization temperature (°C) and enthalpic changes (ΔH expressed in cal/g) measured by the DSC technique for starches isolated from tubers of *Xanthosoma sagittifolium*, *Colocasia esculenta*, and *Manihot esculenta* C.

Tubers	ΔH[a]	Gelatinization and pasting temperatures (°C)		
		Initial	Middle	End
Xanthosoma sagittifolium	3470a	78.0a	82.6a	93.8a
Colocasia esculenta	3999b	77.2a	83.2a	89.7b
Manihot esculenta C. (commercial)	3312a	65.2b	72.0b	85.2c

Data are the average of three repetition ± standard error, however, repetition of each thermogram (same sample) were identical to each other. Same letter indicates that there are no significant differences ($\alpha \leq 0.05\%$).

[a] Enthalpy change.

Table 3
Gelatinization profile of *Colocasia esculenta*, *Xanthosoma sagittifolium* and *Manihot esculenta* C. starches measured using Brabender viscoamylograph, and expressed as Brabender Units (BU) ($n = 3$)

Parameters	*Colocasia esculenta*	*Xanthosoma sagittifolium*	*Manihot esculenta* C.
Initial gelatinization temperature (°C)	85.5a	84.5a	60.8b
Peak viscosity (BU) (*P*)	390a	300a	900b
Viscosity at 95 °C (BU)	250a	300ba	380b
Viscosity at 95 °C; 30 min (BU) (*H*)	380a	360a	240b
Viscosity at 50 °C (*C*)	420ba	490c	400a
Viscosity at 50 °C; 30 min (UB)	520b	600a	420c
Breakdown ($P-H$)	10b	−60c	660a
Setback ($C-P$)	30b	190a	−500c
Consistency ($C-H$)	40b	10c	160a

Data are the average of three repetition ± standard error, however, repetitions of each Amylogram (same sample) were identical to each other. Same letter indicates that there are not significant differences ($\alpha \leq 0.05\%$).

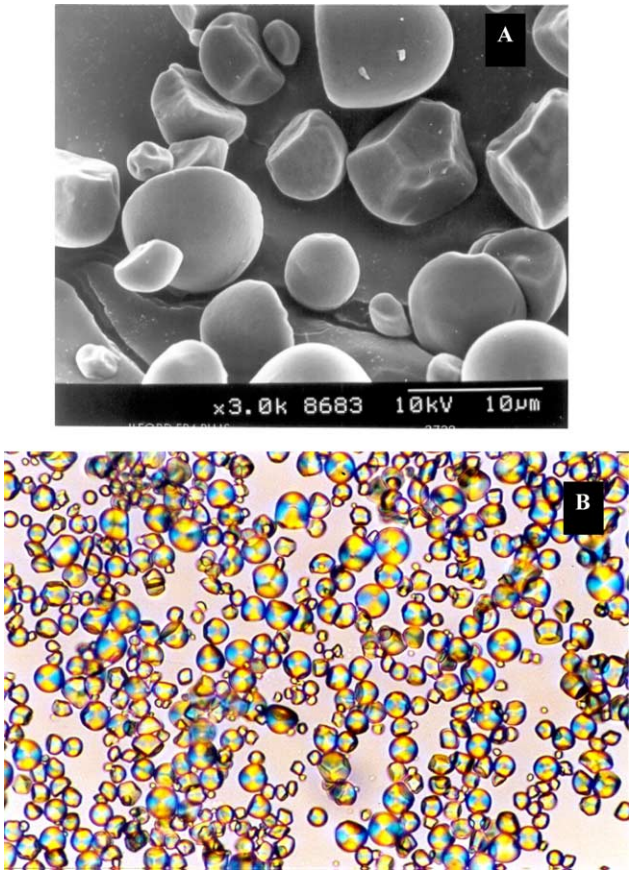

Fig. 1. Microphotography of *Xanthosoma sagittifolium* starch viewed by SEM (A) and optical microscope using light polarized (B) (10×10).

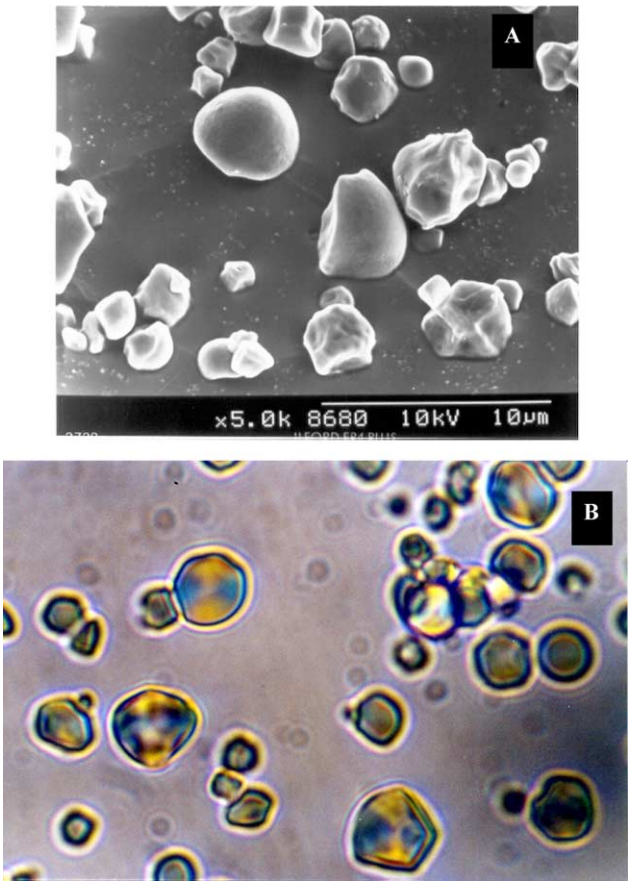

Fig. 2. Microphotography of *Colocasia esculenta* starch viewed by SEM (A) and optical microscope using light polarized (B) (20×10).

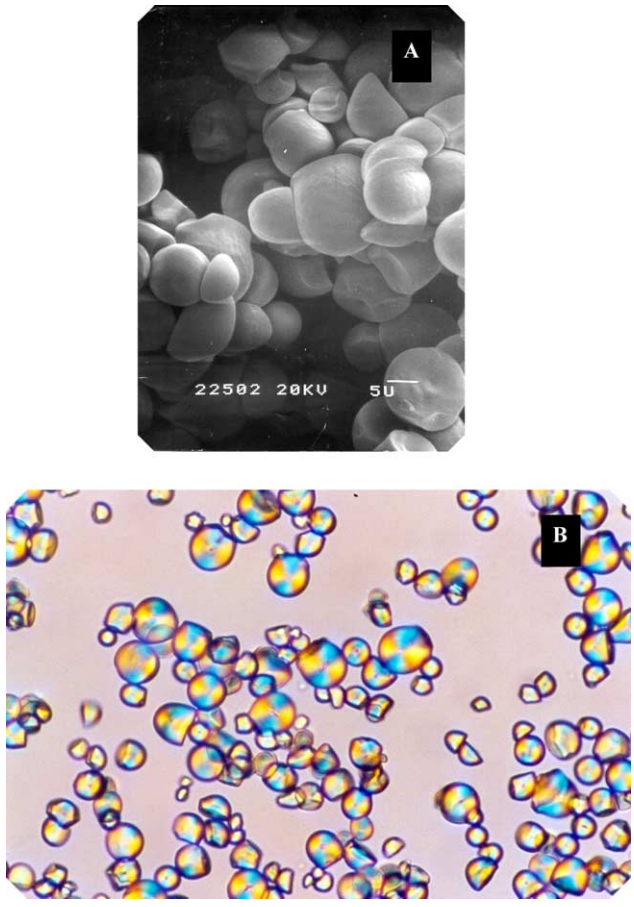

Fig. 3. Microphotography of *Manihot esculenta* Crantz starch viewed by SEM (A) and optical microscope using light polarized (B) (10×10).

factors, while ITG measured by DSC is related to an enthalpic change. The enthalpic change is only dependant on temperature.

The aroid starch amylographic curves show the lower temperature peak than is shown by *Manihot esculenta* Crantz starch, but the overall viscosity is similar ($\alpha \leq 0.05\%$) among the three starches. However, *Xanthosoma sagittifolium* starch shows slightly higher overall viscosity than the other two starches. Moreover, breakdown and consistency are lower in *Xanthosoma sagittifolium* starch than in the other two. *Xanthosoma sagittifolium* starch also has a higher tendency for retrogradation because it shows a high setback value. As conclusion compared to *Manihot esculenta* Crantz starch, the starches isolated from *Xanthosoma sagittifolium* and *Colocasia esculenta* show high gelatinization and pasting temperatures and low, but stable paste consistency.

3.5. Starch granule shape and size

Photomicrographs taken from scanning electron and optical light polarized microscopes of *Xanthosoma sagittifolium, Colocasia esculenta* and *Manihot esculenta* Crantz starches are presented in Figs. 1–3. *Xanthosoma sagittifolium* starch shows small rounded and large truncated ellipsoidal-shaped granules with a granular diameter that ranges from 2 to 12.5 µm (Fig. 1A). The distribution of granular size was as follows: 8% of granular size from 11.3 to 12.5 µm; 28% from 7.5 to 11.3 µm; and 64% with a granular size of lower than 7.5 µm as shown in Table 4. Lauzon, Shiraishi, Yaazaki, Suiyama, and Kawabata (1995) have reported a size of 12.5–14.2 µm for *Xanthosoma sagittifolium* starch isolated from red and white varieties, respectively. *Colocasia esculenta* shows small rounded, medium ellipsoidal-truncated, and large polyhedrical shaped starch granules that ranged from 0.5 to 5.0 µm (Fig. 2A). The distribution of granular size was as follows: 12% of granular size from 4.0 to 5.0 µm; 30% from 4.0 to 2.3 µm; and 58% with a granular size of lower than 2.3 µm (Table 4). Lii and Chang (1991) found large polyhedrical starches ranging from 0.9 to 2.0 µm in size. *Manihot esculenta* Crantz starch shows small rounded, and large egg-truncated size from 6.0 to 17.0 µm (Fig. 3A) The distribution of granular size was as follows: 12% of granular size from 11.4 to 17.0 µm; 33% from 9.0 to 11.4 µm; and 55% with a granular size of lower than 9.0 µm (Table 4). The three starches have Maltese cross as shown in Figs. 1B, 2B and 3B. Under polarized light, one can also observe

Table 4
Overall size, shape and granular distribution ($n=30$) measured using SEM in starch granules isolated from *Colocasia esculenta*, *Xanthosoma sagittifolium* and *Manihot esculenta* Crantz

Starch type	Overall size (μm)	Granular distribution		Shape
		%	Size (μm)	
Xanthsosma sagittifolium	2.0–12.5	8	11.3–12.5	Small rounded
		28	7.5–11.3	Large ellipsoidal-truncated
		64	2.0–7.5	
Colocasia esculenta	0.5–5.0	12	4.0–5.0	Small rounded
		30	2.3–4.0	Medium ellipsoidal-truncated
		58	0.5–2.3	Large polyedrical
Manihot esculenta C.	6.0–17	12	11.4–17.0	Small rounded
		33	9.0–11.4	Large egg-truncated
		55	6.0–9.0	

round and ellipsoidal-shaped granules of *Xanthosoma sagittifolium* (Fig. 1B) and the polyhedrical and round shapes of *Colocasia esculenta* starch (Fig. 2B).

4. Conclusion

It can be concluded that the moisture content of these starches are similar to the moisture content generally accepted for safe storage. *Manihot esculenta* Crantz amylose content was similar to those shown in the literature, and it has approximately half the content of the other two starches. *Xanthosoma sagittifolium* starch has a higher phosphorous content than those shown for *Colocasia esculenta*, and *Manihot esculenta* Crantz starches. The morphometric characteristics of each starch are quite different in size and shape. *Manihot esculenta* Crantz starch has an egg-truncated and round granules sized comparatively to that reported in the literature. *Xanthosoma sagittifolium* starch showed small rounded and large truncated ellipsoidal-shaped granules with a granular diameter that ranges from 2 to 10 μm. *Colocasia esculenta* showed small rounded, ellipsoidal-truncated, and large polyhedrical shaped starch granules that ranged from 0.5 to 5 μm in diameter. Each one of these characteristics has to be considered at the moment of the starch use.

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