Exploring the functionality of starches from corms and cormels of *Xanthosoma sagittifolium*

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Abbreviations:

WBC: water binding capacity

OAC: oil absorption capacity

WHC: water holding capacity

SV: Swelling volume

SI: Solubility index

WAI: Water absorption index

WSI: water solubility index

Keywords: corms, cormels, functional properties, starch microstructure, *Xanthosoma sagittifolium*.

Authors declare that they do not have any conflict of interest in this submission.

23 **Abstract**

24 *Xanthosoma sagittifolium*, belonging to the araceas family, represents an attractive
25 alternative as a starch source. Nevertheless, as a rhizome plant two differentiated parts
26 could be distinguished named corms and cormels. The aim was to evaluate the
27 physicochemical properties of starch isolated from corms and cormels of *Xanthosoma*.
28 Granules morphology, composition, hydration properties, pasting/thermal behaviour, as
29 well as gelling performance were assessed. Scanning Electron Microscopy (SEM) revealed
30 different morphology, granules were organized as aggregates in starch isolated from
31 corms. Corms starch displayed lower hydration properties, lower apparent viscosity during
32 heating and cooling and higher gelatinization temperatures than cormels starch. Gels from
33 corms starch showed less syneresis than cormels starch, but no significant differences were
34 observed regarding their hardness. Therefore, the part of the araceas plant from which the
35 starch is extracted must be always defined, because significant differences in their
36 functionality are ascribed to their morphological origin.

37

1. Introduction

Xanthosoma sagittifolium (L.) Schott and *Colocasia esculenta* (L.) Schott are the most common edible species of Araceas, originally from northern south America and Asia countries, respectively (Eleazu *et al.*, 2018). Lately, the increasing knowledge about araceas' properties has prompted their worldwide distribution (Hoyos-Leyva *et al.*, 2017). Nutritional benefits related to starch high digestibility are behind that growing trend, making araceas recommended for infants (Owusu-Darko *et al.*, 2014) and elderly foods (Ubalua 2016), as well as functional foods (Graf *et al.*, 2018). Main component of these crops is starch organized in very small granules (Sit 2015) of irregular shapes (Aboubakar *et al.*, 2008, Agama *et al.*, 2011) although variations within araceas have been described. Starch from *Xanthosoma sagittifolium* (*Xanthosoma* spp.) tends to display spherical-polyglonal shapes (Graf *et al.*, 2018), whereas starch from *Colocasia esculenta* (*Colocasia* spp.) is irregular and polygonal in shape (Aboubakar *et al.*, 2008). In spite of the recent interest, scientific literature is very confusing, mainly in the case of *Xanthosoma* spp. either due to the variety of common names used for referring to those species or the lack of information regarding the physiological part used for the studies. In fact, common names for *Xanthosoma* spp. largely varied in the different countries, including *taro* in Cameroon, *yautía* in Dominican Republic, *malanga* in Cuba or *cocoyam* in Ghana and other South Africa regions (Hoyos-Leyva *et al.*, 2017, Graf *et al.*, 2018). Henceforth, the name of *malanga* is going to be used owing to its growing location.

Morphologically, *malanga* is characterized by subterranean stems, termed corms, which form secondary stems named cormels (Owusu-Darko *et al.*, 2014). Cormels are usually boiled, fried or pounded after boiling and used for human consumption, in opposition corms guarantee vegetative propagation (Owusu-Darko *et al.*, 2014). Although they are used differently, no specific study has been focused on assessing their physico-chemical

characteristics to explain their diverse applications, particularly concerning starch properties. Previous studies have been focused on comparing the starches isolated from different species, although without unraveling possible existing differences derived from their diverse morphological origin, namely among corms and cormels. In fact, Falade and Okafor (2013) confirmed differences between *Colocasia* spp. and *Xanthosoma* spp. starches isolated from corms, regarding physical, functional and pasting properties, which was also confirmed by Hoyos-Leyva *et al.*, (2017) when compared starches from those species grown in Mexico. Mepba *et al.*, (2009) concluded that cormels' starches from *Xanthosoma* spp. had higher apparent viscosity peak and enthalpy of gelatinization than starches from *Colocasia* spp. (Andrade 2017). Nevertheless, as far as the authors know, there are no studies of starch isolated from the corms and cormels of the same plant that allows to compare the properties of them. To extend the application of corms as starch source, the knowledge of the functional properties of starches from corms and cormels could help to predict their behavior in meals and thus to suggest the best end uses. As a result, the main objective of the present study was to characterize the structural and functional properties of starch isolated from corms and cormels of *Xanthosoma* spp.

2. Material and methods

2.1. Starch isolation

Corms and cormels from *Xanthosoma* ssp. MX-2007 cultivars were harvested at 9-13 months of maturity by the National Institute of Tropical Food Research Farms (INIVIT) in Cuba. Starch isolation was obtained from washed and peeled rhizomes, which were cut into slices of 1 cm and immersed in a solution of sodium metabisulfite (20 mg/kg) during 30 min. Resulting pieces were dehydrated with a forced convection tray dryer (Keller, Ihne & Tesch KG No. 3709, Lampertheim, Germany) at 45 °C for 24 h. The powder obtained

after grinding in a Fitzpatrick mill (Fitzmill model, Waterloo, ON, Canada) was mixed with distilled water (1:10) and filtered through cotton filter cloth. Sediments were washed several times with distilled water till they were free of starch. Starchy solutions were pooled and centrifuge for 10 min at 3,000 g. The starch obtained was freeze-dried, passed through a 60-mesh sieve, and kept at 4 °C for further analyses.

2.2. Scanning electron microscopy (SEM)

Samples were coated with gold using a vacuum evaporator (JEE 400, JEOL, Tokyo, Japan). Observation was done using a scanning electron microscope (SEM) (S-4800, Hitachi, Ibaraki, Japan) at an accelerating voltage of 10 kV. The image analysis to assess size was carried out using the methodology described by Benavent-Gil and Rosell (2017).

2.3. Composition

A standard procedure (AOAC.968.06-1969) was applied to measure protein content. For amylose content, a commercial assay kit (Megazyme International Ireland Ltd., Bray, Co. Wicklow, Ireland) was used, which is based on the concanavalin A method (Gibson *et al.*, 1997).

2.4. CIE $L^* a^* b^*$ color determination

Color were analyzed by using a Minolta colorimeter (Chromameter CR-400/410. Konica Minolta. Japan). Prior standardization with a white calibration plate ($L^* = 96.9$; $a^* = -0.04$; $b^* = 1.84$) was done. The color was recorded using CIE- $L^* a^* b^*$ uniform color space (CIE-Lab), recording lightness (L^*), hue on a green (-) to red (+) axis (a^*), and hue on a blue (-) to yellow (+) axis (b^*).

2.5. Starch hydration properties

The water binding capacity (WBC) was determined according to the micromethod described by Cornejo and Rosell (2015). The water holding capacity (WHC) and oil absorption capacity (OAC) quantified the amount of either water or oil retained by the

sample without being subjected to any stress. Those were determined by mixing 0.100 ± 0.001 g of starch with distilled water (1 mL) or vegetal oil (1 mL), respectively. After 24 h at room temperature, the supernatant was carefully removed with a pipette. Swelling volume (SV) was carried out according to the method reported by Cornejo and Rosell (2015), as the volume occupied by swollen granules after 24 h at room temperature. Solubility index (SI) of starch powder was measured according to the method described by Dura *et al.*, (2014), assessing the weight of dry solids recovered after evaporating the supernatant at 50 °C till constant weight. Equations used for calculating above described parameters were:

$$WBC \text{ (g/g)} = \frac{\text{Weight of sediment after centrifugation} - \text{Sample weight}}{\text{Sample weight}} \quad \text{Eq. 1}$$

$$OAC \text{ (g/g)} = \frac{\text{Weight of sediment after draining oil}}{\text{Sample weight}} \quad \text{Eq. 2}$$

$$WHC \text{ (g/g)} = \frac{\text{Weight of sediment after draining supernatant} - \text{Sample weight}}{\text{Sample weight}} \quad \text{Eq. 3}$$

$$SV \text{ (ml/g)} = \frac{\text{Total volume of swollen sample}}{\text{Sample weight}} \quad \text{Eq. 4}$$

$$SI \text{ (g/g)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Sample weight}} \quad \text{Eq. 5}$$

Hydration properties were also evaluated on starchy gels following the method described by Cornejo and Rosell (2015). Water absorption index (WAI) and water solubility index (WSI) were assessed using the following equations:

$$WAI \text{ (g/g)} = \frac{\text{Weight of sediment}}{\text{Sample weight}} \quad \text{Eq. 6}$$

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$$WSI \text{ (g/g)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Sample weight}} \quad \text{Eq. 7}$$

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141 *2.6. Assessment of gelatinization parameters of starches*

142 The gelatinization characteristics of starches were determined using a differential scanning
 143 calorimetry (DSC) from Perkin–Elmer (DSC 7, Perkin–Elmer Instruments, Norwalk, CT).
 144 Starch and water (1:3) were mixed and placed into stainless steel capsules that were then
 145 hermetically sealed. After that, samples were equilibrated at room temperature for one hour
 146 before analysis. Samples were scanned from 30 to 120 °C at a heating rate of 10 °C/min
 147 under nitrogen atmosphere, using an empty stainless steel capsule as reference. Onset
 148 temperature, peak temperature, conclusion temperature and enthalpy of gelatinization were
 149 recorded.

150 *2.7. Determination of pasting properties of starches*

151 The pasting properties of starches were measured using the standard method (AACC.61-
 152 02.01 2012) with a Rapid Visco Analyzer (RVA-4500, Perten Instruments, Hägersten,
 153 Sweden). Starch (2 g based on 14% moisture content) was added to 20mL of water. Slurries
 154 underwent a controlled heating and cooling cycle, from 50 to 95 °C in 282 s, holding at 95
 155 °C for 150 s and then cooling to 50 °C. The initial speed for mixing was 960 min⁻¹ for 10 s,
 156 followed by 160 min⁻¹ paddle speed that was maintained for the rest of assay. Pasting
 157 parameters such as onset temperature, peak viscosity, trough, breakdown (peak viscosity-
 158 trough), final viscosity, setback (cold paste viscosity-trough) were recorded using
 159 Thermocline software for Windows (Perten Instruments, Hägersten, Sweden).

160 *2.8. Gel hardness*

To evaluate the hardness of the gels, a TA.XT-Plus Texture Analyses (Stable Micro Systems Ltd., Godalming, UK) equipped with a 5 kg load cell and a 2-mm aluminum cylindrical probe was used. Briefly, the paste obtained from RVA was transferred into disposable sample cups with a diameter of 60 mm and height of 15 mm. These were allowed to cool down to room temperature and then stored at 4 °C for 24 h. Gel penetration up to 50% was performed in the texturometer at a speed of 1×10^{-3} m/s. Three replicates were made for each sample.

2.9. Syneresis

Syneresis was evaluated by a spinning test (Ribotta *et al.*, 2007) by using a Eppendorf 5415 R centrifuge, (Eppendorf, Germany). Starch gels were stored up 7 days (168 hours) at 4 °C. For syneresis measurements, gels were kept at 25 °C for 2 h and centrifuged at 5175 g for 10 min at 25 °C. After centrifugation the free water was separated, weighed, and calculated the percentage of water released from gels. Measurements were the mean of three repetitions for each duplicated gel.

2.10. Statistical analysis

The data reported in the tables are average values of two batches of samples and expressed as a mean $\pm$ standard deviation. They were subjected to analysis of variance. Multifactorial analysis were carried out with Fisher's least significant differences test with a significance level of 0.05. To indicate correlations and their significance, Pearson correlation coefficient (r) and P -value were determined by using Statgraphics Centurion XVII software (Bitstream, Cambridge, N).

3. Results

3.1. Granular morphology of corms and cormels starches

Figure 1 shows selected SEM micrographs of starch granules isolated from corms and cormels of *Xanthosoma sagittifolium* (L.) Schott that were observed at three different magnifications 2,000x (A, B), 5,000x (C, D) and 10,000x (E, F). Although no clear evidence has been previously reported regarding differences in the granule size distribution of the corms and cormels from the same plant (Zhu 2016), noticeable differences were observed on the granule size and shape of isolated starches. Granules from corms comprised two different populations, the large A-type granules exhibited truncated shapes and several grooves on the surface, while the small B-type granules had principally polygonal shape. Their average area was $24.56 \mu\text{m}^2$ and $7.18 \mu\text{m}^2$ for A-type and B-type granules, respectively (Figure 1 A, C, E). Two different populations have been previously reported for tuber starches like potato starch (Benavent-Gil and Rosell 2017). At lower magnifications, SEM micrographs also revealed that corms starch granules appeared to be grouped as aggregates, likely due to the smallest fraction. In fact, it has been described that small granules size starches have the ability to form aggregates (Gonzalez-Soto *et al.*, 2011), which are induced by the residual protein remaining in the starch powder (Beirão-da-Costa *et al.*, 2011). Conversely, starch granules isolated from cormels were composed of many truncated granules with an average area of $44.36 \mu\text{m}^2$, presenting comparable shapes to the corms A-type granules with larger size (Figure 1 B, D, F). Those morphological characteristics along with size distribution have been previously reported for cocoyam starches (Lawal 2004), suggesting that cormels were the source used.

3.2. Color parameters of starches

Visibly, the color of corms and cormels starches was light, which was further confirmed by their higher L^* value ranging from 98.2 (corms) to 97.7 (cormels). Overall, the L^* (lightness) values were higher than those reported, likely due to the discoloration of the starch granules after extraction (Moorthy 2002). Regarding a^* , both samples exhibited

negative (green hue) values, varying significantly from -0.11 (corms) to -0.03 (cormels). Conversely, the b^* scale displayed positive values (yellow hue) for both samples, differing significantly from 1.1 (corms) to 1.9 (cormels). Difference in the color characteristics could be ascribed to inherent pigments, since yellow intensity is dependent on the beta carotene pigment (Falade and Okafor 2015). According Aboubakar *et al.*, (2008) botanical origin of the plant and composition of the flour determine the pigments content. Results suggest that malanga composition is dependent on the part of the plant, allowing to isolate starches with diverse quality.

3.3. Composition of isolated starches

Amylose starch content was determined in starches isolated from both parts, corms and comels. The statistical analysis indicated significant differences in amylose contents among the starches studied. Corms starch displayed an amylose content of 19.06%, while cormels starch showed a value of 27.65%. Reported results about the amylose content of starches from corms ranged from 15.04 to 33.77, (Lawal 2004, Falade and Okafor 2013). Mepba *et al.*, (2009) found 23% amylose in starch from cormels. Present results supported that amylose content was also greatly dependent on the part of the plant from which the starch was extracted. The content of protein in the starch samples from corms was 1.10%, confirming the presence of protein acting as gluing material, which would explain the aggregates formation. In the case of starch from cormels, the amount of protein was even higher (2.72%), but likely owing to larger size of the granules, protein content was not enough to induce extensive aggregation.

3.4. Starch and starch gel hydration properties

The hydration properties of corms and cormels starch granules and starch gels are summarized in Table 1. Statistical differences among starch samples were observed in all parameters studied. Unexpectedly, despite their smaller size, corms starch granules led to

substantially lower WBC, OAC and WHC compared to cormels starch. A correlation analysis indicated a positive significant relationship between granule size and WBC ($r = 0.994$; $P < 0.01$), OAC ($r = 0.999$, $P < 0.05$), and also with WHC ($r = 0.974$, $P < 0.05$). Conversely, some researchers have reported that an increase in granule size results in reduced absorptive capacities, de la Hera *et al.*, (2013) owing to the reduction in the surface area. Presumably, the formation of aggregates in the case of starch from corms could have affected these capacities (Gani *et al.*, 2013). Granules aggregation reduces the surface area that might be in contact with water molecules, inducing lower intake of water. On the other hand, it has been described that amylose content promotes a reduction in these capacities. However, the amylose content showed a positive correlation with WBC ($r = 0.959$, $P < 0.05$), OAC ($r = 0.956$, $P < 0.05$) and WHC ($r = 0.995$, $P < 0.01$). Therefore, it seems that differences observed in the amylose content were not large enough to compensate the modifications derived from the agglomerates structure, which was responsible for the hydration properties.

Starch sample isolated from corms also had lower value of SV. Again, granule size ($r = 0.979$, $P < 0.05$) as well as amylose content ($r = 0.989$, $P < 0.05$) significantly influenced this parameter. Correlations also indicated that SI was affected by granule size ($r = -0.997$, $P < 0.01$), which agrees with previous results (Lin *et al.*, 2015).

The water uptake during thermal treatment was measured by determining the WAI and WSI (Table 1). Both parameters were significantly dependent on the starch source. Corms starch showed higher WAI values than those obtained by cormels sample. In line with other report (Kadan *et al.*, 2008), no correlation was obtained between granule size and WAI. Nevertheless, a negative correlation between amylose content and WAI ($r = -0.9726$; $P < 0.05$) was found. Cornejo and Rosell (2015) suggested that in flours with high WBC, water become less available to hydrate the amorphous region of the starch, during the

hydration and gelatinization of the flour, leading to WAI decrease. WSI showed significant lower value in corms starch than in cormels starch. A positive relationship between granule size and WSI ($r = 0.9734$; $P < 0.05$) and between amylose content and WSI ($r = 0.9926$; $P < 0.01$) were observed, likely due to the amylose leached out during heating (de la Hera *et al.*, 2013).

3.5. Thermal properties

The values for the thermal parameters of the isolated starches were determined by DSC to detect possible changes in physical states of the starch structures. The transition temperatures (T_o , T_p) significantly ($P < 0.05$) differed among samples. Corms starch exhibited higher T_o and T_p than cormels starch. No statistically significant differences were observed in T_c . Wang and Copeland (2012), indicated that DSC thermal transition represents water absorption and swelling of starch granules. Considering the described impact of granule size and amylose content on the hydration properties, those might have relevant influence in T_o and T_p parameters. In fact, T_o was negatively correlated with granule size ($r = -0.988$, $P < 0.05$), amylose content ($r = -0.979$, $P < 0.05$) and WBC ($r = -0.997$, $P < 0.05$). Moreover, amylose content showed also significant relationship with T_p ($r = -0.999$, $P < 0.01$). These correlations suggest that the lower WBC of corms starch caused a delay in the onset of swelling behavior, which leads to higher T_o . On the other hand, Liu *et al.*, (2015) indicated that smaller starch granule tend to absorb water faster, which reinforces the hypothesis that the formation of aggregates in corms starch plays a crucial role on the functional properties of this starch.

Similar enthalpy was recorded for both starches, suggesting similar structural order in both starches (Ribotta *et al.*, 2007).

3.6. Pasting properties

The overall shape of the RVA pasting curves of both starches displayed typical behavior when starchy suspensions were subjected to a heating and cooling cycle (Figure 2). As expected, clear dissimilarities were observed taking into account the great microstructure divergences earlier mentioned. Regarding starch source, starch from corms showed a delayed pasting formation, suggesting retarded gelatinization. Cormels sample reached higher viscosity after heating and it was also observed along the cooling stage. Parameters recorded from the pasting curves are summarized in Table 2. The statistical analysis revealed significant differences in all their pasting parameters. The onset temperature, where viscosity begins to increase, was significantly ($P < 0.05$) higher in corms starch. Therefore, higher temperature would be required for its gelatinization, likely due to its lower water absorption ($r = -0.979$, $P < 0.05$). Corms starch exhibited the lowest pasting viscosities. The peak, trough, breakdown, final and setback viscosities of corms sample were lower than those recorded for the cormels sample. The pasting viscosities of corms starches were similar to the results of Falade and Okafor (2013). Again, different behavior on pasting performance, might be attributed to different granule size and amylose content. In fact, positive significant correlations between granule size and pasting parameters were found (not shown), except for the breakdown. Similarly, amylose content had relevant influence in pasting properties as demonstrated its positive correlation with all the pasting parameters. Similar correlations have been previously described in the literature for other type of starches (Schirmer *et al.*, 2013).

3.7. Texture profile analysis (TPA) and syneresis during storage

The hardness of corms and cormels gels was measured after storage at 4 °C for 24 h. Results obtained did not reveal significant differences. The behavior of those gels over a period of up to 168 h at 4 °C was assessed evaluating their syneresis or water released from the polymer network after cooling. It was virtually zero during the first days of storage, and only after 120 h at 4 °C could be detected (Table 1). The gels obtained from cormels

starch exhibited lower syneresis values than the corms starch after 120 h, holding the water molecules in its structure, which has been related to its tendency to retrograde (Tetchi *et al.*, 2007).

Nevertheless, inverse behavior was observed after longer storage, when syneresis of gels from cormels exhibited significantly higher values. As expected, storage time promoted a significant increase of the syneresis in both samples, which agrees with previous results obtained by Tetchi *et al.*, (2007) when evaluated the physicochemical characteristics of starches from diverse araceas, although authors did not specify if they were isolated from corms or cormels.

4. Conclusions

Corms and cormels from *Xanthosoma sagittifolium* contained morphologically different starch granules. Starch isolated from corms exhibited smaller granules with an aggregate disposition which, besides the lower amylose content, might be responsible of their hydration properties (lower WBC, OAC WHC, SV and higher SI), lower apparent viscosity during heating and cooling, higher To and Tp, as well as lower syneresis after 7-days storage. In fact, correlation analysis confirmed that granule size and amylose content play a determinant role in the functional behavior of starch granules. Differences noticed between starches isolated from corms and cormels of *Xanthosoma sagittifolium* stressed the importance of identifying the starch source within the botanical parts of araceas to allow understanding and comparing research studies.

Acknowledgments

Authors acknowledge the financial support of the Spanish Ministry of Economy and Competitiveness (Project AGL2014-52928-C2-1-R), the European Regional Development Fund (FEDER) and Generalitat Valenciana (Project Prometeo 2017/189). Tropical Food Research Institute from Cuba provided the rhizomes.

Conflict of interest

The authors have declared no conflict of interest.

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432 **FIGURE CAPTIONS**

433 **Figure 1.** Scanning electron micrograph of corms (A, C and E) and cormels (B, D and F)
434 starch samples. Magnifications 2000x (A, B), 5000x (C, D) and 10000x (E, F).

435 **Figure 2.** Apparent viscosity profiles corms (—) and cormels (---) starches obtained with a
436 rapid viscosity analyzer (RVA). Thick solid line indicated the temperature settings during
437 the heating-cooling cycle.

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Table 1. Color and hydration properties of starch granules and gels isolated from corms and cormels

Starch Properties	Corms	Cormels	<i>P</i> -value
<i>Color</i>			
<i>L</i> *	98.2 ± 1.39	97.7 ± 0.10	0.5418
<i>a</i> *	-0.11 ± 0.03a	-0.03 ± 0.02b	0.0189
<i>b</i> *	1.10 ± 0.14a	1.90 ± 0.16b	0.0042
<i>Hydration</i>			
WBC (g/g)	1.02 ± 0.02a	1.30 ± 0.05b	0.0203
OAC (g/g)	0.96 ± 0.00a	1.39 ± 0.08b	0.0162
WHC (g/g)	0.62 ± 0.01a	0.96 ± 0.00b	0.0008
SV (mL/g)	2.00 ± 0.01a	3.00 ± 0.00b	0.0001
SI (g/g)	3.00 ± 0.11b	1.98 ± 0.20a	0.0241
<i>Gels</i>			
<i>Hydration</i>			
WAI (g/g)	8.80 ± 0.30b	6.47 ± 0.38a	0.0211
WSI (g/g)	1.40 ± 0.00a	7.30 ± 0.14b	0.0003
<i>Gels Syneresis</i>			
120 h (%)	6.00 ± 1.00b	2.67 ± 0.58a	0.0075
168 h (%)	12.33 ± 1.53a	20.67 ± 0.58b	0.0009

Values with different letters in the same row are significantly different ($P < 0.05$) (n = 3).

WBC: Water binding capacity; OAC: Oil absorption capacity; WHC: Water holding capacity; SV: Swelling volume; SI: Solubility index; WAI: Water absorption index; WSI: Water solubility index.

Table 2. Properties of starches isolated from corms and cormels measured with the RVA for assessing pasting behavior, DSC for thermal properties and texturometer for gel hardness.

Properties	Corms	Cormels	<i>P</i> -value
<i>Pasting</i>			
T _o (°C)	84.80 ± 0.00b	81.50 ± 0.00a	0.0000
PV (×10 ³ Pa•s)	2762 ± 24a	3410 ± 34b	0.0020
Trough (×10 ³ Pa•s)	1709 ± 19a	2236 ± 57b	0.0067
Breakdown (×10 ³ Pa•s)	1053 ± 43a	1174 ± 23b	0.0480
FV (×10 ³ Pa•s)	3191 ± 4a	3961 ± 54b	0.0025
Setback (×10 ³ Pa•s)	1482 ± 16a	1725 ± 2b	0.0019
<i>Thermal</i>			
To (°C)	74.17 ± 0.25b	71.65 ± 0.28a	0.0109
Tp (°C)	79.45 ± 0.35b	76.28 ± 0.35a	0.0122
Tc (°C)	86.69 ± 0.48	85.51 ± 0.04	0.0748
Gelatinisation enthalpy (J/g)	18.82 ± 1.37	16.80 ± 0.19	0.1759
<i>Textural</i>			
Gel hardness (N)	0.207 ± 0.1	0.197 ± 1.5	0.1705

Means in the same row with different letters are significantly different ($P < 0.05$) ($n = 3$).

T_o: Onset; PV: Peak viscosity; FV: Final viscosity; To: Onset temperature; Tp: Peak temperature; Tc: Conclusion temperature

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458 Figure 2.

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