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Starch Properties of Chinese Yam, *Dioscorea opposita* Thunb.

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ABSTRACT The starch properties of two chinese yams were evaluated in this study. Amylose content ranged 13.5% to 19.3%. The swelling power of starches varied 10.98% to 11.43%. Water binding capacity in chinese yam starches ranged 93.46% to 107.21%, high WBC was observed in Ma 1. The onset temperature (T*o*) of two chinese yam starches ranged 62.9 to 75.0℃, peak temperature (T*p*) ranged 76.2 to 84.7℃. The PHI(peak height index) was about 4-fold higher in Anwon cultivar than in Ma 1 cultivar. SEM revealed that starches has a presence of large oval or spherical to small irregular-shape granules. Starch granule size ranged 15.23 to 15.52 µm, showing a typical C-type X-ray pattern.

Keywords : Chinese yam, *Dioscorea opposita* Thunb., starch, DSC, RVA

Chinese yam has been utilized in many pharmaceutical preparations. In addition, chinese yam has both cultural and social significant in Andong region, Gyeongsangbuk-do. Farmers in Korea maintain several yam land-races, which are mostly distinct from nagaimo cultivar widely cultivated in Aomori, Hyogo and Hokkaido Prefecture, Japan. Yam (*Dioscorea* spp.) is a tuber crop traditionally used as antidiabetic and antidipticum medication (Ubdie and Akubue 1986), and for foods with healthy benefits, examples are the acetylated β-(1,4)-mannan-rich mucilage (Tomoda *et al.*, 1981), and low α-amylase digestability (~70%) of yam starches with over 26% amylose (Gallant *et al.*, 1982). Yam (*Dioscorea opposita* Thunb.) is a major starchy food source and also used for medicinal purpose in Korea. Starch was most abundant carbohydrate in *Dioscorea opposita* tubers ranged of 20 to 60%. Starches in chinese yam has begun to use as food and pharmaceutical industries. Structural and physicochemical properties of starches are mainly studied for varieties of tropical and subtropical chinese yam (Tamiru *et al.*, 2008; Wang *et al.*, 2008; Wickramasinghe *et al.*, 2009). Extensive research has been conducted on the structure and functional properties of the commercial starches obtained from tropical yams due to their ready availability and their extensive utilization in food and non-food applications. However, the starch from medicinal plants has not been paid enough attention by starch researchers. There is very little information on starch separated from chinese yams. The objective of the present study is to investigate the difference in starch properties of two chinese yam cultivars grown in Korea.

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MATERIALS AND METHODS

Plant Materials

Two chinese yam (*D. opposita* Thunb. cvs Anwon, Ma 1) cultivars were obtained from Institute for Bioresources Research, Andong, Gyeongsangbuk-do Province, Korea. These two yams were morphologically characterized with tuber types. The Ma 1 has a medium size in tuber length ranged 30 to 40 cm long and 5 to 8 cm thickness with cylindrical type, and shows an irregular tuber. The Anwon cultivar has a short in tuber type ranged 8 to 12 cm long and 12 to 15 cm thickness with round type. The Sliced (5 mm thickness) tubers were immediately frozen in liquid nitrogen and stored at -80℃. When all the required materials for starch analysis had been prepared, the samples were lyophilized for 48 h. The lyophilized tubers were ground and sieved with a 100 mesh sifter. After sieving, powders were extracted with 100 and 85% MeOH. Starches extracted with SDS (Sodium dodecyl sulfate) five times. Finally the starches were washed three times with 85% MeOH and distilled water, respectively.

Swelling power and water binding capacity

Swelling power was evaluated with some modifications (Konik-Rose *et al.*, 2001). Starch (50 mg, based on dry basis) was weighted in to a pre-weighted 2.0 ml micro-centrifuge tube, and deionized water (5 ml) was added. The samples were vortexed for 10 s, and allowed to hydrate at room temperature for 10 min. The sample was heated on a heating block set at 85℃ for 30 min with gentle inversion of the tube every 5 min. The sample was cooled in an ice bath for 5 min and then centrifuged at 10,000×g for 10 min.

The supernatant was transferred into another pre-weighted micro-centrifuge tube using a disposable pipette. The tube with the starch paste residue was wiped dry with a paper towel and then weighted. The tube with the supernatant was dried in a convection oven set at 40℃ to constant weight. swelling power was calculated as the ratio of paste weight to starch sample.

Water binding capacity (WBC) of starches was determined using the method (Yamazaki, 1953), as modified by the report (Medcalf and Gilles, 1965). A suspension of 5g starch (dry weight) in 75 ml distilled water was agitated for 1 h and centrifuged at 3,000×*g* for 10 min. The free water was removed from wet starch, drained for 10 min and wet starch was weighed.

Blue value and amylose content

The amylose content was determined by the blue value determination as described by Noda *et al.* (1992). A 2% starch suspension was prepared by dissolving starch in dimethyl sulfoxide (DMSO) at 70℃ for 3 h, and diluting the mixture to a 0.1% starch suspension using deionized water. The absorbance at 680 nm was recorded for a mixture (5 ml) containing 0.2 mg of starch, 0.4 mg of iodine, and 4 mg of potassium iodide (KI) at 30 min after color development. The apparent amylose content was calculated using the blue values of the samples.

Rapid Visco Analyser (RVA) and Differential Scanning Calorimetry (DSC)

The pasting properties of the starches (3 g, 14% moisture basis) in water (25 ml) were determined using the Rapid Visco Analyzer (RVA, Newport Scientific Pty. Ltd., Narrabeen, Australia). DSC was performed on a Differential Scanning Calorimeter (DSC-SP, Rheometric Scientific, New Castle, DE, USA) and the instrument was calibrated with indium. Starch samples and distilled water (1:3, w/w) were sealed in aluminum pans, held overnight, and heated from 30 to 120℃ with 10℃/min heating speed. An empty aluminum pan was used as reference. Starch granules were sputter coated with gold and examined with scanning electron microscope (Model JSM-56000LV, JEOL) at 10 or 20 kV. DSC of starches was measured as described by the method (Fujita *et al.*, 2003).

RESULTS AND DISCUSSION

The blue value, apparent amylose, swelling poser, water-binding capacity and mean diameter of two different chinese yam starches were showed in Table 1. The blue value of Ma 1 was higher than that of Anwon. Amylose content ranged between 13.5% and 19.3%. The amylose content was higher in Ma 1 than in Anwon. This result inferred from the fact that higher amylose content of starch may due to the presence of large-size granules.

Table 1. Characteristics of starches separated from two *Dioscorea opposita* cultivars

Cultivars	Blue value (680 nm)	Amylose (mg g^{-1})	Swelling power (%)	WBC (%)	Mean diameter (μm)
Ma 1	0.28	19.3a	10.98a	107.2a	15.52a
Anwon	0.35	13.5b	11.43a	93.4b	15.23b

Data are means of four determinations. Different letters within each column indicate significant differences (p<0.05).

It is known that the amylose content is responsible for some factors affecting swelling powder, solubility and gel forming property of starch. These differences might be explained by the different growing conditions, the methods used for lipid extraction and amylose determination (Mali *et al*., 2003).

The swelling power of two different cultivars varied from 10.98% to 11.43%. Starch swelling occurs concomitantly with loss of birefringence and precedes solubilisation. Higher swelling power in Anwon starches was observed, whereas Ma 1 starch had the lower value. Swelling power has been reported be influenced by strongly bonded micellar network (Gujska *et al*., 1994) and amyloectin molecular structure (Tester *et al*., 1993). The low swelling power of starches may be attributed to the presence of a large number of chrystallines formed by the association between long amylopectin chains (Tester and Karkalas, 1996). In addition, starch with large granules swells rapidly when heated in water, and amylose is considered to be a resistant factor for high swelling (Tester and Morrison, 1990). Crystallite formation increases granular stability thereby reducing extent of granular swelling. Water binding capacity (WBC) of two chinese yam starches ranged between 93.46% to 107.21%, high WBC was observed in Ma 1. The differences in WBC of starches may be attributed to the variation in their granule structure (Singh and Singh, 2001).

DSC data of starches separated from different chinese yams are summarized in Table 2. The transition temperatures (T*o*, T*p*, and T*c*), range (T*c*-T*o*), enthalpy of gelatinization (ΔH_{gel}), and peak height indices (PHI) of starches were different significantly. DSC parameters showed that the onset temperature (T*o*) of two samples ranged from 62.9 to 75.0℃, peak temperature (T*p*) ranged 76.2 to 84.7℃, and their gelatinization enthalpy varied from 4.3 to 11.7 J/g, respectively. A high gelatinization temperature was obtained for Anwon (75.0℃) compared to Ma 1 (62.9℃). Difference in gelatinization temperature may be attributed to the differences in amylose content, size, shape and distribution of starch granules, and to the internal arrangement of starch fractions within the granules. Transition temperatures are influenced by the molecular architecture of the crystalline region, which correspond to the amylose and amylopectin ration (Noda *et al*., 1998). In change of the enthalpy of the gelatinization (ΔH_{gel}), high ΔH_{gel} of starches suggested that the double helices (formed by the outer branches of adjacent amylopectin chains) that unravel and melt during gelatinization are strongly associated within the native granule. The ΔH_{gel} enthalpy reflects the overall measure of crystallinity (quality and quantity of crystallites) of amylopectin and is an indicator of the loss of molecular order within the granules (Tester and Morrison, 1990). The PHI was about 4-fold higher in Anwon than in Ma 1, this indicates that the higher PHI value of starch may be attributed to presence of large-size granules (Aggarwal *et al*., 2004).

The pasting properties of two chinese yam starches were exhibited in Table 3. The highest peak, highest breakdown, very high final viscosity and very low setback were observed in Anwon. In contrast, the lowest peak viscosity, breakdown and final viscosity were also observed in Ma 1. Parades-Lopez (1994) reported that low peak viscosity is due to short chain length and to irreversible damage treated with alkaline media.

Scanning electron photographs (SEM) of starch granules in two chinese yams are presented in Fig. 1. SEM of starches showed the presence of large oval or spherical to small irregular-shape granules. The granule surface of starches appeared to be smooth with no evidence of any

Table 2. Thermal properties of *Dioscorea opposita* starches determined by Differential Scanning Calorimetry

Cultivars	Gelatinization parameters					
	T*o*	T*p*	T*c*	ΔH_{gel} (J/g)	PHI	R
Ma 1	62.9b	76.2b	80.7b	4.3b	32.3b	17.8a
Anwon	75.0a	84.7a	92.6a	11.7a	120.6a	17.6a

T*o*, onset temperature; T*p*, peak temperature; T*c*, conclusion temperature; R, gelatinization range (T*c*-T*o*); ΔH, enthalpy of gelatinization (based on starch dry weight); PHI, peak height index ΔH gel/(T*p*-T*o*). Data are means of four determinations. Different letters within each column indicate significant differences ($p<0.05$).

Table 3. Pasting properties of *Dioscorea opposita* flours determined by Rapid Visco Analyser

Cultivars	Pasting temp. (℃)	Viscosity (RVU)				
		Peak (P)	Holding strength (H)	Final (C)	Breakdown (P-H)	Setback (C-H)
Ma 1	68.5b	1,284b	1,419b	1,493b	38a	74b
Anwon	77.4a	1,495a	1,471a	1,777a	24b	306a

Data are means of four determinations, different letters within each column indicate significant differences ($p<0.05$).

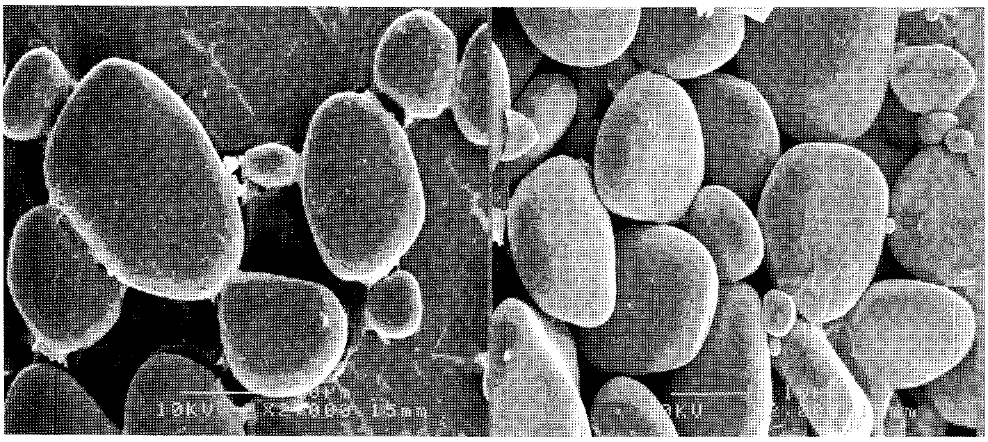

Fig. 1. Scanning electron micrographs of *Dioscorea opposita* Thunb. cvs. Ma 1 and Anwon starch granules (2000×). Left, Ma 1; right, Anwon.

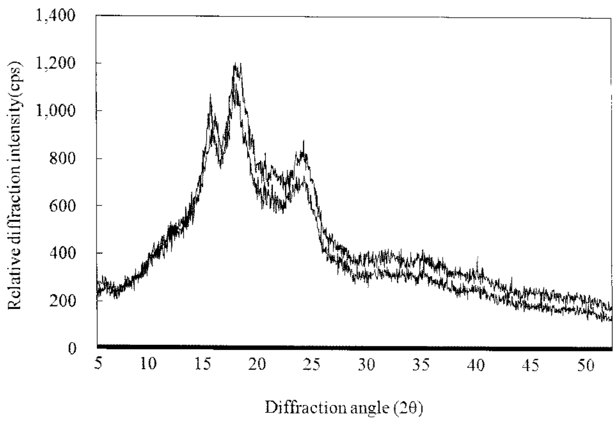

Fig. 2. X-ray diffraction spectra of *Dioscorea opposita* Thunb. cv. Ma 1 and Anwon. Higher peak is Ma #1; lower peak is Anwon.

fissures. These starch granule in mean diameter ranged 15.23-15.52 μm, respectively. The variation in size and shape off starch granules may be due to the biological origin (Svegmark and Hermansson, 1993). The morphology of starch granules depends on the biochemistry of the chloroplast or amyloplast, as well as physiology of the plant (Badenhuizen, 1969). X-ray diffraction spectra showed in Fig. 2. These starches showed a C-type X-ray pattern, with reflections at 2θ about range of 6.2°, 16.9°, 18.7° and 23.9°. Of all the diffraction peaks, the peaks at round values of 6.2° and 18.7° were characteristic of the B-type pattern, while only one peak at 23.9° appeared which were indicative of the A-type pattern. This result had similarity with those of other *Dioscorea* cultivar starches which also displayed the typical C-type X-ray pattern.

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