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Content and physicochemical properties of starches from different kinds of sweet potatoes grown in Dong Thap province

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ABSTRACT

Sweet potato (Ipomoea batatas L.) is an important agricultural plant grown in Dong Thap province to obtain tubers because of high starch yield. However, starch content and properties vary depending on genotype and growing conditions. The objective of this study was to determine content and physicochemical characteristics (chemical compositions, swelling power, viscosity and solubility) of starches obtained from two sweet potato samples (white and yellow sweet potatoes) from three locations in Chau Thanh district, Dong Thap province. On the dry matter basis, the starch content of sweet potatoes ranged from 49.8 to 66.8%, and the white sweet potato grown at Hoa Tan village had the highest starch content. On the wet matter basis, the starch content of sweet potatoes ranged from 16.1 to 20.4%, and the yellow sweet potato at Hoa Tan village had the highest starch content. The protein, fat, ash and total carbohydrate contents ranged from 0.15 to 0.25%, 0.07 to 0.14%, 0.15 to 0.22%, and 99.47 to 99.57%, respectively. The yellow sweet potato grown at Tan Phu village had highest starch swelling power at 90°C (15.42 g water/ g starch), while the yellow sweet potato from Hoa Tan village had highest solubility at 90°C (9.56%). In addition, starch suspension of the white sweet potato from Tan Phu village signified highest final viscosity and setback (626 and 390 BU, respectively), resulting in greatest resistance against retrogradation. The results of this study would provide useful information to select a high starch-content sweet potato practically grown in Dong Thap province for starch production.

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1 INTRODUCTION

Sweet potato (*Ipomoea batatas* L.), originated in Central America, but at present, is the seventh largest food crop generally cultivated all year round in various ecological habitats in many tropical and subtropical regions (Scott and Suarez, 1992). It is well known as a worldwide source of edible starch. Sweet potato supplies a considerable portion of the world's nourishment and is also an essential source for animal feed and industrial utilization.

Sweet potato which is well-known as a source of edible starch consists of around 6.9 to 30.7% of starch depending on the habitat in which they are grown (Liu *et al.*, 1985). Sweet potato starch is not only the most important ingredient in the human diet, but also a major industrial raw material for paper, adhesives, pharmaceutical, plastics, textile, prepared food, and cosmetic industries (Mweta *et al.*, 2008). Sweet potato starch granules are round, oval or polygonal in shape and vary greatly in size of 2-42 µm. They are also designated as A or C type of crystalline structure, and their amylose content ranges in 18.7-20% (Hoover, 2001; Hung and Morita, 2005). Kaur *et al.* (2002) concluded that the environmental factors had some significant impacts on starch properties. However, the difference in physicochemical characteristics of sweet potato starches might affect the final quality of food products because starch is a major component and directly contributes to the functional properties and quality of food products.

The starch granules existing in the sweet potato tubers are implanted in cellulosic fibers and linked together by pectin substrates (Rahman and Rakshit, 2004). Thus, sweet potato starches in industrial scale are usually isolated by ultrasound pretreatment (Nandan *et al.*, 2014), mechanical disintegration of the cell wall and then utilization of water to wash starch granules out (Joshi and Kulkarni, 1993), or enzyme-assisted extraction method. Recently, there are more and more projects applied enzymatic treatments to enhance the recovery of starch from roots and tubers (Gayal and Hadge, 2003; Sit *et al.*, 2011).

According to Loebenstein (2016), Vietnam was the second largest producer of sweet potato in all over the world in 2015 with an estimated production of 1.45 million tons which is based on statistic data of Vietnam Ministry of Agricultural and Rural Development. Dong Thap province was the second largest production of sweet potatoes in Mekong Delta with the area of 39,300 ha (Ly Nguyen Binh *et al.*, 2014). In Dong Thap, white, yellow, and purple sweet potatoes are grown extensively at Hoa Tan, Tan Phu, and Phu Long villages of Chau Thanh District. However, little information of the starch yield of sweet potatoes grown in Dong Thap and their physicochemical properties, which are useful information for starch production and application have been reported. Therefore, in this research, the extraction yield and starch characteristics obtained from white and yellow sweet potatoes grown at three locations in Dong Thap province (Hoa Tan, Tan Phu, and Phu Long villages) were investigated.

2 MATERIALS AND METHODS

2.1 Materials

White and yellow sweet potato samples (*Ipomoea batatas* L.) used in this research were grown at Hoa Tan, Tan Phu, and Phu Long villages (Chau Thanh, Dong Thap, Vietnam). The two sweet potato samples were practically distinguished based on the color of skin and flesh. The vines were planted in July, 2016 and harvested in October, 2016. All the tubers in this experiment was in the uniformity of shape and size and did not contain any contamination including insects, smelly and rotten parts. After collecting, sweet potatoes were washed carefully and stored at 8 to 10ºC for further experiments. The white sweet potato sample from Tan Phu, Phu Long, and Hoa Tan villages were coded as W-TP, W-PL, and W-HT, respectively and the yellow sweet potato sample from Tan Phu, Phu Long, and Hoa Tan villages were coded as Y-TP, Y-PL, and Y-HT, respectively.

Commercial cellulase from *Aspergillus aculeatus* named Viscozyme Cassava C used in starch isolation was bought from a local agent in Ho Chi Minh City, Vietnam. Other chemicals were also purchased from a chemical store in District 10, Ho Chi Minh City, Vietnam.

2.2 Methods

2.2.1 Isolation of sweet potato starch

Starches were isolated from sweet potatoes by enzyme-assisted extraction, as a modified method of Benesi *et al.* (2004). These tubers after washing with water were peeled and sliced. Sliced sweet potatoes (100 g) was mixed with 150 mL of water. The mixture was then ground in a blender, and its pH was controlled around 5.5 – 6 before 3 mL of enzyme cellulase (100 U/mL) was added. After being incubated in a shaken water bath (125 rpm, 40ºC) for 3 hours, the mixture was added with 100 mL of water and filtered through a sieve with a cut-off size of 0.250 mm. After that, the solid residue was mixed with water, and the mixture was sieved again three times. Following this, all the filtrates were filtered with 0.105 mm-sieve, and then centrifuged at 3,500 rpm for 10 min. After all, the final supernatant was removed, and the solid residue was dried in the oven at 40ºC for 24 hours to reach 10-11% moisture content and pulverized into fine powder. Finally, the recovered capacity of starch was determined.

2.2.2 Determination of chemical compositions of sweet potato starches

Moisture content of sweet potato starches was determined using Moisture Balance Analyzer. The AACC approved methods 46-10, 30-10, and 08-01 (AACC, 2000) were used to analyze protein, lipid, and ash contents of sweet potato starches, respectively. Total carbohydrate content was calculated from the subtraction of protein, lipid and ash contents.

2.2.3 Determination of swelling power of sweet potato starches

Swelling power (SP) of sweet potato starches was measured based on the method of Sasaki and Matsuki (1998) with a minor modification. The starch suspension prepared from 0.16 g of starch samples and 5 mL of distilled water was placed in the falcon with coated screw caps. The mixture was heated at 50, 60, 70, 80, or 90°C and shaken continuously at 200 rpm for 30 min. After cooling to room temperature, the sample was centrifuged at 3,000 g for 15 min. The weight of sediment was recorded after carefully removing the supernatant. SP of starch (g water/ g starch) was calculated by dividing the weight of sediment by the initial weight of starch sample in dry basis.

2.2.4 Determination of solubility of sweet potato starches

The procedure written by Leach *et al.* (1959) was slightly modified and then applied to analyze the solubility of sweet potato starches. Starch sample (0.5 g) was suspended in 30 mL of distilled water. The mixture was heated at different temperatures from 50°C to 90°C at 10°C intervals for 30 min in a shaking water bath. After cooling to room temperature, the sample was centrifuged at 1,500 g for 30 min. Supernatant was dried at 120°C for 4 hours and then weighed. Solubility of starch (%) was calculated by dividing the weight of remained solid after drying supernatant by the initial weight of starch sample in dry basis.

2.2.5 Determination of pasting properties of sweet potato starches

Pasting properties of sweet potato starches were measured using a micro visco-amylo-graph (Brabender® GmbH & Co. KG, Germany). The starch suspension (8%, w/v) was preheated to 30°C, heated up to 93°C at a constant rate of 7.5°C/min and then held at 93°C for 15 min. Then, the paste was cooled to 30°C at the same rate and then held at 30°C for 15 min. The pasting properties of the slurry were recorded as the visco-amylo-graph program described as pasting temperature, maximum viscosity, trough viscosity, final viscosity, breakdown and setback.

2.2.6 Statistical analysis

All tests were performed at least in duplicate. Analysis of variance (ANOVA) was performed using the Tukey's test with significance level at $p < 0.05$ using SPSS software (SPSS Inc., USA). Correlation coefficients were also done using SPSS program (SPSS Inc., USA).

3 RESULTS AND DISCUSSIONS

3.1 Extraction yield of sweet potato starches

Table 1 illustrates the results of the dry matter content of six cultivars of sweet potatoes and their starch-extraction yield. The dry matter content of sweet potatoes ranged from 26.6 to 35.1% and the extraction yield of sweet potato starches was in a range of 16.1 to 20.4% in term of wet basis or 49.8 to 66.8% in term of dry basis. Among six cultivars of sweet potato, Y-HT accounted for the highest percentages of dry matter content (35.1%) and extraction yield of starch in term of wet basis (20.4%), while the lowest dry matter content (26.6%) and extraction yield of starch in term of wet basis (16.1%) belonged to Y-TP and W-TP, respectively. Furthermore, W-HT had highest percentage of extraction yield in term of dry basis (66.8%). Therefore, there was no correlation between dry matter content and extraction yield of starch. Dry matter of Turkish sweet potatoes was in a range of 29.2 to 51.1% depending on genotypes, growing location and environment (Yildirim *et al.*, 2011).

Table 1: Dry matter content and starch extraction yield of sweet potatoes

Samples	Color		Dry matter content (%)	Extraction yield (%)	
	Skin	Flesh		Wet basis	Dry basis
W-TP	White	White	31.1 ± 0.1^{c}	16.1 ± 0.8^{a}	51.6 ± 2.6^{a}
W-PL	White	White	35.0 ± 0.1^{e}	20.1 ± 1.0^{b}	57.4 ± 2.9^{b}
W-HT	White	White	28.9 ± 1.4^{b}	19.3 ± 0.9^{b}	66.8 ± 3.3^{d}
Y-TP	Purple	White-yellow	26.6 ± 0.9^{a}	19.8 ± 0.9^{b}	64.7 ± 3.2^{bc}
Y-PL	Purple	White-yellow	32.5 ± 0.5^{d}	16.2 ± 0.8^{a}	49.8 ± 2.5^{a}
Y-HT	Purple	White-yellow	35.1 ± 0.3^{e}	20.4 ± 1.0^{b}	58.0 ± 2.9^{b}

Data followed by the same superscript letter in the same column are not significantly different (P < 0.05) according to the Tukey's HSD test.

3.2 Chemical compositions of sweet potato starches

Proximate compositions of six cultivars of sweet potato starches are shown in Table 2. There was no remarkable difference in moisture content of sweet potato starches which was less than 11%. The chemical compositions of different sweet potato starch consisted of 0.15 – 0.25% of protein, 0.07 – 0.14% of lipid, and 0.15 – 0.22% of ash. Among six cultivars of sweet potato starches, W-TP had highest protein content (0.25%), W-HT accounted for greatest percentage of lipid content (0.14%), and Y-HT contained highest ash content (0.15%); while the lowest amounts of protein, lipid and ash belonged to W-PL, Y-HT, and Y-HT, respectively. However, there was no noteworthy discrepancy in total carbohydrate content of sweet potato starches which was in a range of 99.47 to 99.57%. Starch isolated from sweet potato without using enzyme consisted of 1.1% of protein, 0.9% of lipid, 0.1% of ash, and 97.9% of total carbohydrate (Hung *et al.*, 2014). However, in this research, pectin – cellulosic matrix of cell wall was broken down by enzyme cellulase, which resulted in the release of the starch granules and then gave higher yield without affecting the starch properties (Moorthy and Balagopalan, 1999). This leaded to the higher amount of total carbohydrate (99.47-99.57%) compared to other extraction methods without using enzyme.

Table 2: Chemical compositions of sweet potato starches (%, db)

Samples	Moisture content	Protein content	Lipid content	Ash content	Carbohydrate content
W-TP	10.73 ± 0.53	0.25 ± 0.01^{d}	0.08 ± 0.01^{a}	0.17 ± 0.01^{b}	99.50 ± 0.11
W-PL	10.81 ± 0.09	0.15 ± 0.01^{a}	0.12 ± 0.02^{b}	0.20 ± 0.03^{bc}	99.53 ± 0.14
W-HT	10.40 ± 0.39	0.17 ± 0.01^{a}	0.14 ± 0.01^{b}	0.22 ± 0.01^{c}	99.47 ± 0.17
Y-TP	10.42 ± 0.32	0.22 ± 0.01^{bc}	0.09 ± 0.02^{a}	0.22 ± 0.01^{c}	99.47 ± 0.11
Y-PL	10.58 ± 0.12	0.23 ± 0.01^{cd}	0.09 ± 0.02^{a}	0.18 ± 0.02^{b}	99.50 ± 0.12
Y-HT	10.50 ± 0.21	0.21 ± 0.01^{b}	0.07 ± 0.03^{a}	0.15 ± 0.01^{a}	99.57 ± 0.14
	ns				ns

Data followed by the same superscript letter in the same column are not significantly different (P < 0.05) according to the Tukey's HSD test. ns: non-significant.

3.3 Swelling power of sweet potato starches

Results for swelling power of six cultivars of sweet potato starches at different temperatures ranging from 50 to 90ºC are shown in Figure 1. Swelling power of sweet potato starches considerably increased when heating temperature was between 70 and 80ºC. Therefore, the data indicated that swelling power of sweet potato starches was not significantly different when heating temperature was lower than or equal to 70ºC. Generally, swelling power was highest in Y-TP (15.42 g water/ g starch) at 90ºC among six kinds of sweet potato starches, while the lowest SP belonged to Y-PL (11.52 g water/ g starch) at the same temperature. These outcomes were agreeable with the research by Gunaratne and Hoover (2002) showing that swelling power of starch had an uninterrupted escalation between the temperatures of 55 to 95ºC. These differences in these swelling powers were mainly due to amylose content and its properties like amylose lipid complexation or total leached amylose in addition to phosphate content (Zuluaga *et al.*, 2007).

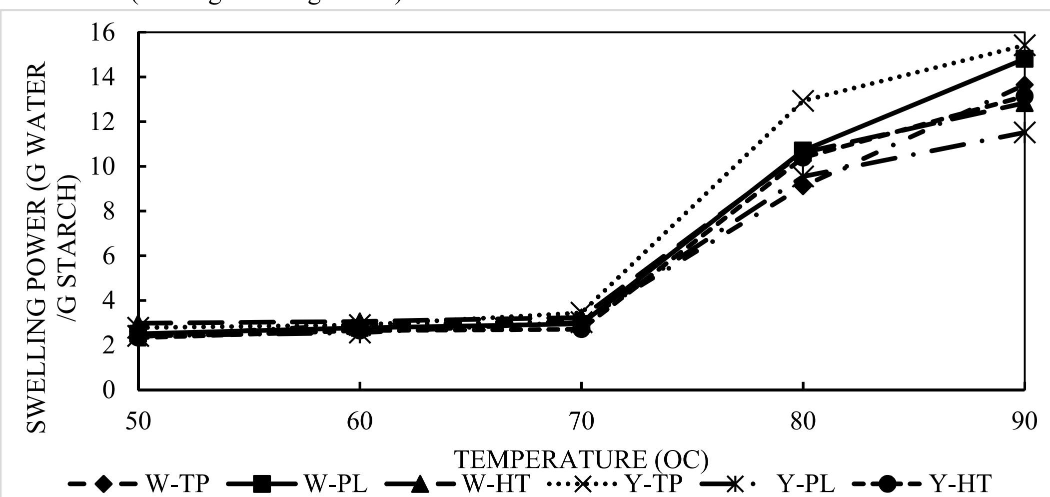

Fig. 1: Swelling power of sweet potato starches (g water/ g starch)

3.4 Solubility of sweet potato starches

Solubility of six cultivars of sweet potato starches are presented in Figure 2. The design witnessed in the solubilized attributes of six types of sweet potato starches was nearly the same as recognized from their swelling power. Their solubility considerably enhanced when heating temperature was higher than 70ºC. Generally, the level of solubilization was highest in Y-HT (9.56%) at 90ºC among six cultivars of sweet potato starches, followed by that of Y-TP, W-HT and then Y-PL, while the lowest amount of amylose leaching belonged to W-TP and W-PL (around 6.37%). These data corresponded with the research by Gunaratne and Hoover (2002) figuring out that solubility of starch elevated with a growth in temperature. These differences in solubility of sweet potato starches were mainly due to their amylose content and amylose-lipid complexation (Zuluaga *et al.*, 2007).

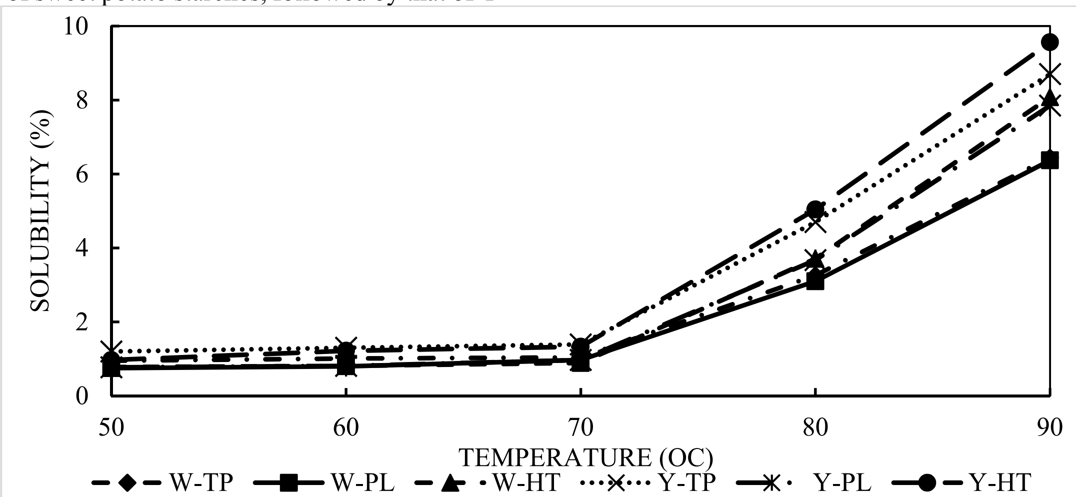

Fig. 2: Solubility of sweet potato starches (%)

3.5 Pasting properties of sweet potato starches

Pasting properties of six cultivars of sweet potato starches expressed as pasting temperature, maximum viscosity, final viscosity, trough viscosity, breakdown, and setback are demonstrated in Table 3. Generally, white sweet potato starches had higher pasting temperature as compared to yellow ones, and that of these starches ranged from 76.8 to 78.8ºC. Among six cultivars of sweet potato starches, the maximum viscosity and breakdown of Y-HT (609 and 357 BU, respectively) were the highest, while W-TP had highest final viscosity and setback (626 and 390 BU, respectively). Maximum viscosity and breakdown reverberate the sensitivity of swollen granules to disperse approaching shear; and final viscosity and setback demonstrate the inclination and manner of retrogradation of the starch gel (Afoakwa *et al.*, 2010). Thus, among six cultivars of sweet potato starches, the paste of yellow sweet potato starch from Hoa Tan village manifested the highest gel consistency and hot paste stability, while the starch suspension of white sweet potato from Tan Phu village signified greatest resistance against retrogradation. The differences in these viscosity parameters were mainly due to their various amylose and protein contents (Hung *et al.*, 2007; Singh *et al.*, 2008).

Table 3: Pasting properties of sweet potato starch1,2

Samples	PT	MV	TV	FV	BD	SB
W-TP	78.3 ± 0.1^{c}	588 ± 4^{bc}	236 ± 1^{b}	626 ± 1^{d}	352 ± 4^{b}	390 ± 1^{e}
W-PL	78.6 ± 0.2^{cd}	582 ± 11^{b}	255 ± 5^{c}	569 ± 4^{a}	327 ± 7^{a}	314 ± 4^{a}
W-HT	78.8 ± 0.1^{d}	590 ± 4^{bc}	254 ± 2^{c}	607 ± 4^{c}	336 ± 5^{ab}	353 ± 3^{c}
Y-TP	76.8 ± 0.1^{a}	549 ± 9^{a}	220 ± 3^{a}	593 ± 7^{b}	329 ± 6^{a}	373 ± 4^{d}
Y-PL	77.2 ± 0.2^{b}	579 ± 11^{b}	225 ± 2^{a}	560 ± 6^{a}	354 ± 12^{b}	334 ± 7^{b}
Y-HT	77.3 ± 0.1^{b}	609 ± 7^{c}	218 ± 1^{a}	558 ± 4^{a}	391 ± 6^{c}	339 ± 5^{b}

[1]*PT, pasting temperature (ºC); MV, maximum viscosity (BU); FV, final viscosity (BU); TV, trough viscosity (BU); BD, breakdown (BU); SB, setback (BU).*

[2]*Data followed by the same superscript letter in the same column are not significantly different (P <0.05) according to the Tukey's HSD test.*

4 CONCLUSIONS

In this project, white and yellow sweet potatoes grown at different locations in Dong Thap province had different dry matter content, extraction yield, chemical compositions, swelling power, solubility, and pasting properties of starch. The white sweet potato from Phu Long village and the yellow sweet potato starch from Hoa Tan village had the highest dry matter content and extraction yield. These sweet potatoes could be used for starch extraction with high efficiency. However, yellow sweet potato from Hoa Tan village should be examined more in the future.

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