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Physicochemical properties and resistant starch contents of sweet potato starches from different varieties grown in Vietnam

[1] Luu Bui Bao Ngoc, [2] Phan Thanh Bao Trung, [3] Phan Ngoc Hoa, *[4] Pham Van Hung

[1, 3] Faculty of Chemical Engineering, University of Technology, Vietnam National University in HoChiMinh City, 268 Ly Thuong Kiet Street, District 10, HoChiMinh City, Vietnam

[2, 4] School of Biotechnology, International University, Vietnam National University in HoChiMinh City, Quarter 6, Linh trung Ward, Thu Duc District, HoChiMinh City, Vietnam

Abstract

Sweet potato (*Ipomoea batatas* L.), one of the seven most important food crops worldwide, varies in shape, size and color, depending on the cultivar and the environment. In this study, the physicochemical properties and digestibility of starches from white, yellow and purple sweet potato varieties grown at different location were investigated. Starches of white, yellow and purple sweet potato had 21.6, 22.9 and 19.0% amylose content, respectively. The white sweet potato starch had polygonal shape, while the yellow and purple sweet potato starches had the round and polygonal shapes. All of sweet potato starches exhibited the A-type crystal. The paste prepared from white sweet potato starch had significantly higher pasting temperature but lower peak and final viscosity and breakdown than did other sweet potato starches. Amounts of resistant starch in the native sweet potato starches ranged in 24.0 – 25.3%, in which the purple sweet potato starch had higher amount of resistant starch than did others. As a result, the physicochemical properties and digestibility of starches were different depending on their origin and growing location even though they had similar morphology and crystalline structure.

Keywords: Sweet potato; resistant starch; physicochemical characteristics; Pasting property

1. Introduction

Sweet potato (*Ipomoea batatas* L.) is one of the seven most important food crops worldwide. Sweet potatoes are cultivated throughout tropical and warm temperate regions with average annual global production of approximately 103 million tons. The sweet potato roots are tubers and vary in shape, size and color, depending on the cultivar and the environment in which they are produced [1]. The sweet potato roots contain high amount of carbohydrates (mainly starch) ranging between 25 and 30%, of which 98% is easily digested [1]. In addition, the sweet potato roots are rich in vitamins, minerals and dietary fibers. Sweet potato is widely used for consuming directly with simple cooking or for industrial production of starch, alcohol and their derivatives.

Starch, the most important reserve polysaccharide and the most abundant constituent of many plants, is also a main component of sweet potato roots. Physicochemical properties of sweet potato starches varied depending on the varieties and growing location. Hoover (2001) [2] reported that sweet potato starch had round, oval and polygonal shape with the size of 2 – 42 µm. However, sweet potato starches were found to have spherical shape with the size of 2 – 26 µm by Yadav *et al*. (2006) [3]. Sweet potato starches contained 18.7 - 20% of amylose and exhibited A or C type of crystalline structure [2, 4, 5]. Hoover (2001) [2] reported that gelatinization temperature of sweet potato starch was in a range of 64.6 – 84.6 ºC with transition enthalpy of 12.9 J/g, whereas Hung *et al*. (2005) [4] found that the gelatinization temperature of sweet potato starch was 57.4 – 74.5 ºC with the transition enthalpy of 12.3 J/g. Sweet potato starches had lower gelatinization temperature, final viscosity and paste clarity, but higher peak viscosity and swelling power as compared to potato and edible canna starches [4]. The difference in physicochemical characteristics of sweet potato starches with different varieties or between sweet potato starch and other root starches might affect the final quality of food products because the starch is a major component and directly contributes to the functional properties and quality of food products.

Sweet potato varieties can be classified based on skin and flesh color that range from white to yellow, orange, and deep purple. In Vietnam, purple sweet potato is grown mostly in Dong Thap province, while the yellow sweet potato is a special variety grown in Dak Nong province and white sweet potato is grown widely in other provinces. The different varieties and location might affect nutritional quality such as starch content and characteristics, protein, vitamin, mineral and phytochemicals. Therefore, the objective of this study is to determine the starch characteristics of three types of sweet potatos with different skin and pulp colors and growing locations including purple sweet potato grown in DongThap province, yellow sweet potato grown in DakNong province and white sweet potato grown in Vinh Long province.

2. Materials and Methods

2.1 Materials

Three kinds of fresh tubers named *Ipomoea batatas*, purple sweet potato grown in Dong Thap, yellow sweet potato grown in DakNong province and white sweet potato grown in Vinh Long province of Vietnam, were used in this study and their starches were isolated. The roots were harvested after planting approximately 3 to 4 months, depending on each cultivar, soil and growing conditions.

Alpha-amylase from *A. oryzae* (~ 30 U/mg) and amyloglucosidase from *A. niger* (≥ 300 U/ml) used in this study were purchased from Sigma-Aldrich Co. (St. Louis, MO, US). Other chemicals were purchased from Merck Co. (Darmstadt, Germany).

2.2 Starch isolation

The starch isolation was isolated according to the method of Lawal [6] with minor modification. The fresh sweet potato roots were washed, peeled, sliced and ground with small volumes of distilled water using a Waring blender (7015N, Waring® Commercial, USA). Then the homogenate was passed through a sieve of 0.232 mm in aperture size. The residue was mixed with water and repeatedly filtrated for three times. Then the starch filtrates was filtered again through the sieves (0.232 and 0.105 mm in aperture size) and centrifuged at 1500 ×*g* for 20 min. The starch sediment was washed thoroughly in distilled water for three times and dried in an oven at 40 ºC for 24 h to 10-11% moisture.

After isolation, the starches were analyzed for their chemical composition to evaluate their purity. Amylose content of starch was determined according to the method previously descried by Hung *et al*. [7]. Protein content was determined using a Kjeldahl digestion system (KI 26, Gerhardt, Germany) based on the standard AACC Approved Method 46-10 [8]. Lipid contents were determined by extraction with hexane for 6 h using a Soxhlet apparatus (EV6, Gerhardt, Germany) and ash content was determined by burning in a muffle furnace at 550 ºC for 3 h [8]. Total starch was calculated as follows: total starch (%, db) = 100% - protein content (%, db) – lipid content (%, db) – ash (%, db).

2.3 Scanning electron microscope

Images of native sweet potato starch granules were observed using a Scanning electron microscopy (Hitachi model S-800, Tokyo, Japan) according to the procedure of Hung *et al.* [7]. The starches were coated with Pt/Pd and photographs were taken using a SEM apparatus at an accelerating potential of 10 kV.

2.4 Determination of crystalline structure of starch

X-ray diffraction analysis was performed using an - X ray diffractometer (Rigaku Co., Ltd, Rint-2000 type, Tokyo, Japan) operated at 40 kV and 80 mA. Diffractograms were obtained from 2º 2θ to 35º 2θ with a scanning speed of 8º/min and scanning step of 0.02º [7].

2.5 Determination of pasting property of starch

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

2.6 Determination of starch fractions (RDS, SDS, RS)

Rapid digestible starch (%RDS), slowly digestible starch (%SDS) and resistant starch (%RS) of the native sweet potato starches were measured based on the method of Englyst *et al*. [9] with a moderate modification as follows. Starch (0.3 g, db) was mixed with 20 ml of sodium acetate buffer (pH 6.0) and then boiled for 30 min in a water bath. The sample was equilibrated at 37 ºC for 15 min and then an enzyme solution (5 ml) of α-amylase (1,400 U/ml) and amyloglucosidase (13 AGU/ml) was added. The starch solution was incubated with shaking at 37 ºC for 120 min. The total glucose concentrations of the 20 min-digested and 120 min-digested hydrolysates (G_{20} and G_{120}, respectively) were determined using the phenol-sulfuric acid method. The remained residue was intensively hydrolyzed with 7M KOH and then with amyloglucosidase (50 AGU/ml). The final hydrolysate was then determined for total glucose concentration (TG). The values obtained for G_{20}, G_{120} and TG were used to calculate for RDS, SDS and RS as follows.

$RDS = G_{20} \times 0.9$

$SDS = (G_{120} - G_{20}) \times 0.9$

$RS = (TG - G_{120}) \times 0.9$

2.9 Statistical analysis

All tests were performed at least in duplicate. Analysis of variance (ANOVA) was performed using Duncan's multiple-range test to compare treatment means at $P < 0.05$ using SPSS software (SPSS Inc., USA).

3. Results and Discussion

3.1 Amylose contents and blue values of different sweet potato starches

Amylose contents and blue values of three sweet potato starches are given in Table 1. Starches of white sweet potato, yellow sweet potato and purple sweet potato had 21.6, 22.9 and 19.0% amylose content, respectively. The blue values of starches were also different among three kinds of sweet potato. Hoover (2001) [2] reported that the sweet potato starch had 19.1% amylose, similar to the purple sweet potato starch in this study. Hung *et al*. [5] also reported that the sweet potato starch had 18.7% amylose content. Thus, the sweet potato starches from different sources had different amylose contents, in which the starches from white sweet potato and yellow sweet potato had higher amylose content than did the purple sweet potato in this study and the samples reported by Hoover (2001) [2] and Hung *et al*. [5]. The difference in amylose content of the sweet potato starches might affect the physicochemical properties of starches and technological quality of starch-based foods.

Table 1: Amylose content and blue value (%, w/w, db) of different sweet potato starches[1,2]

Compositions (%, db)	WSP	YSP	PSP
Amylose content (%)	21.6 ± 0.2	22.9 ± 1.6	19.0 ± 0.7
Blue value	0.416 ± 0.001	0.428 ± 0.014	0.393 ± 0.006

[1] WSPS, White sweet potato starch; YSPS, Yellow sweet potato starch; PSPS, Purple sweet potato starch.

[2] All data are the means of duplicate experiments ± standard deviations.

3.2 Morphology of different sweet potato starches
Appearances of different sweet potato starches are observed in Fig. 1. All native starch granules had smooth surface and no evidence of cracks because of the low level of starch damage during isolation. The isolated starches had no contaminant as the total amount of protein, lipid and ash was less than 1% (data not shown). The white sweet potato starch had polygonal shape, while the yellow and purple sweet potato starches had the round and polygonal shapes. The size of starch granules of all sweet potato starches were less than 50 µm. The results found in this study are consistent with those reported previously that sweet potato starch had round, oval and polygonal shape with the size of 2 – 42 µm [2].

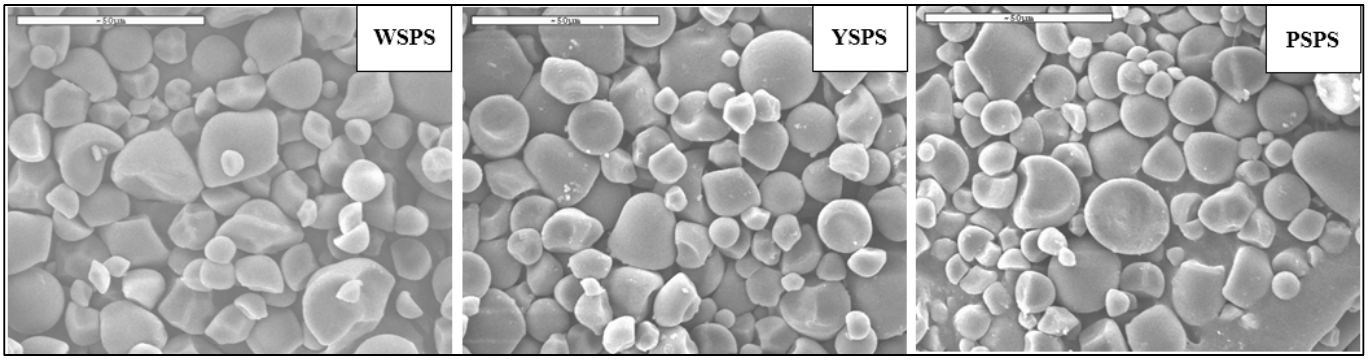

Fig 1: Scanning electron microscopy (SEM) of different sweet potato starches. WSPS, White sweet potato starch; YSPS, Yellow sweet potato starch; PSPS, Purple sweet potato starch.

3.3 Crystalline structure of different sweet potato starches
Crystalline structure of three sweet potato starches presented by X-ray diffraction patterns is shown in Fig. 2. The native sweet potato starches exhibited the A-type crystal with the major peaks at around d-spacings 5.8 Å (line 3b), 5.2 and 4.8 Å (line 4a, 4b) and 3.8 Å (line 6a). The A-type structure classified by Zobel (1988) [10] is a typical crystalline structure of sweet potato starch as reported by previous study [2, 4, 5]. The type of crystalline polymorph was found to be mainly affected by the chain length of amylopectin [2]. The starch contained amylopectin with chain length < 19.7 or with chain length ≥ 21.6 had A-type or B-type crystals, respectively, while starch contained amylopectin with chain length between 20.3 and 21.3 exhibited A, B or C-type crystal [11].

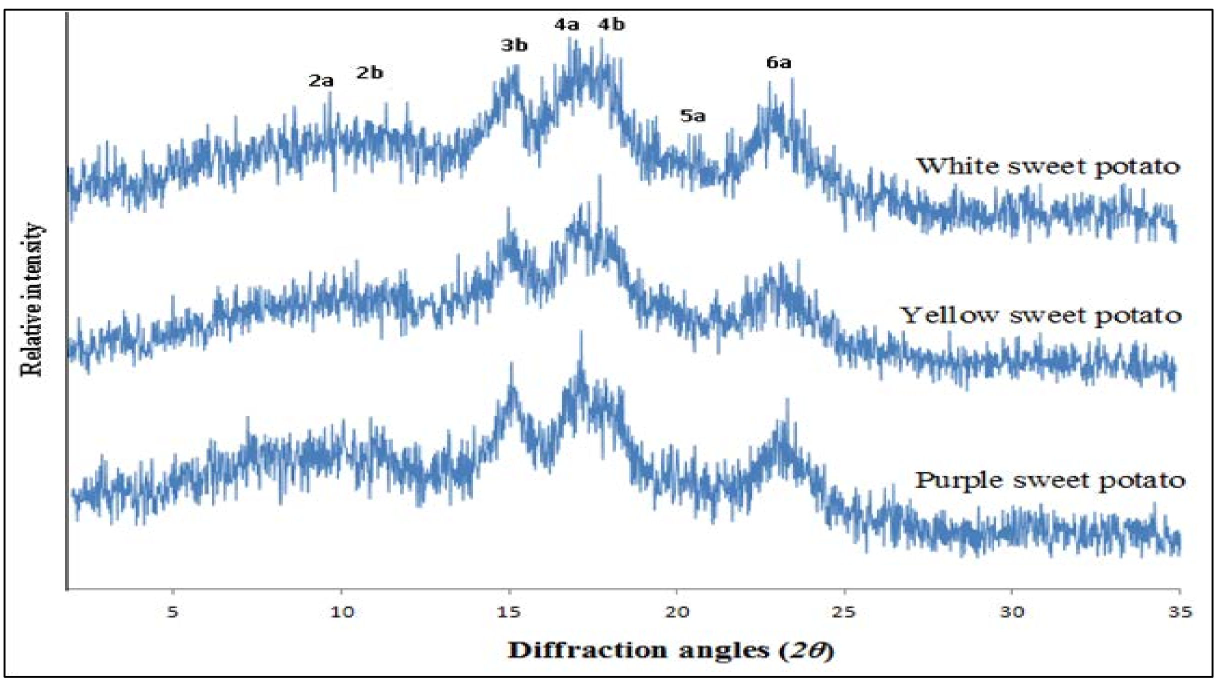

Fig 2: X-ray diffraction pattern of different sweet potato starches. WSPS, White sweet potato starch; YSPS, Yellow sweet potato starch; PSPS, Purple sweet potato starch.

3.4 Pasting properties of different sweet potato starches
Although the sweet potato starches had similar shape and size, pasting properties of these sweet potato starches were significantly different as shown in Table 2. The paste prepared from white sweet potato starch had significantly higher pasting temperature but lower peak and final viscosity and breakdown than did other sweet potato starches. This means the paste of the white sweet potato starch exhibited a greater gel consistency and hot paste stability as compared with the others. However, the lower final viscosity and setback of this starch paste indicated

that this starch paste had high resistance against retrogradation. The paste of the yellow sweet potato starch had lowest pasting temperature and highest peak and final viscosities and breakdown as compared to other sweet potato starches. These results showed that the paste of yellow sweet potato starch had a weak resistance against retrogradation caused by high amylose content in starches. These results are consistent with the findings by Hung *et al*. [4].

Table 2. Pasting properties of different sweet potato starches [1, 2]

Sample	Pasting temperature (ºC)	Peak viscosity (cP)	Trough viscosity (cP)	Final viscosity (cP)	Breakdown (cP)	Setback (cP)
WSPS	78.7c	661a	289b	647a	372a	358a
YSPS	71.4a	823c	294b	742c	529c	448c
PSPS	77.6b	701b	277a	708b	424b	431b

[1]WSPS, White sweet potato starch; YSPS, Yellow sweet potato starch; PSPS, Purple sweet potato starch.

3.5 Starch fractions (RDS, SDS, RS) of different sweet potato starches

Amounts of rapid digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) of native sweet potato starches are given in Table 3. Amounts of RDS of sweet potato starches ranged in 73.7 – 75.3%, in which WSPS had the highest amount of RDS. Sweet potato starches had low amounts of SDS (0.7 – 1.0%), while they contained high amounts of RS (24.0 – 25.3%). The difference in amounts of SDS and RS was due to the different amylose contents and amylopectin fine structure in starch granules. Zhu *et al*. [12] also reported that the SDS content of rice starch decreased as amylose content increased and RS content of the waxy rice starch was higher than that of the low-amylose rice starch. In this study, the purple sweet potato starch contained lower amylose content exhibited the highest amount of RS as compared to other sweet potato starches. The amounts of RDS and SDS of the sweet potato starches found in this study were lower than those reported by Hung *et al*. [5], while the amount of RS was higher. The different obtained results were due to the different varieties and growing location of sweet potatos used in these studies. In addition, the overestimated results were also obtained in these studies.

Table 3. RDS, SDS and RS contents (%, w/w, db) of different sweet potato starches[1,2,3]

Sample	RDS	SDS	RS
WSPS	75.3 ± 0.5a	0.7 ± 0.1a	24.0 ± 0.6a
YSPS	74.9 ± 2.0a	0.9 ± 0.1a	24.1 ± 1.9a
PSPS	73.7 ± 1.1a	1.0 ± 0.4a	25.3 ± 0.7a

[1]WSPS, White sweet potato starch; YSPS, Yellow sweet potato starch; PSPS, Purple sweet potato starch.
[2]RDS, rapid digestible starch; SDS. Slowly digestible starch; RS, resistant starch
[3]Data followed by the same letter in the same column are not significantly different ($P \leq 0.05$).

4. Conclusion

Physicochemical properties of starches isolated from different kinds of sweet potato varieties (white, yellow and purple sweet potatos) were investigated in this study. The morphology and crystalline structure of starches from different sweet potato varieties were not significantly different. However, they had different amylose content, pasting properties and resistant starch content. As a result, each sweet variety had its own physicochemical characteristics, which affect the end-use quality of starch-based foods. Therefore, the information of sweet potato starch characteristics in this study is useful for further food processing.

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The authors have declared no conflict of interest.

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