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Chemical compositions, bioactive compounds, and physicochemical properties of different purple sweet potato flours

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ABSTRACT

The difference in growing conditions, cultivating techniques or genotypes resulted in various quality of purple sweet potatoes. The objective of this study was to determine chemical compositions, bioactive compounds (total anthocyanin, phenolic and flavonoid contents) and physicochemical properties (swelling and water solubility indexes, and pasting properties) of flours prepared from purple sweet potatoes grown at five villages in Dong Thap and Vinh Long provinces. In term of dry basis, the chemical compositions of different purple sweet potato flours consisted of 1.08-3.09% of protein, 0.17-0.41% of lipid, 2.49-2.78% of ash, and 93.94-95.92% of total carbohydrate. Purple sweet potatoes grown at Phu Long village (Chau Thanh district, Dong Thap province) had the highest total anthocyanin content (6.8 mg cyanidin-3-glucoside/100 g flour), total phenolic content (202.2 mg FAE/100 g flour), total flavonoid content (85.6 mg RE/100 g flour) and water solubility index (13.6%) as compared to other purple sweet potato flours. Nevertheless, the paste of purple sweet potato from Hoa Tan village (Chau Thanh district, Dong Thap province) had the highest swelling index (7.5 g water/g flour) and manifested the greatest resistance against retrogradation, gel consistency and hot paste stability among other flours. The results of this study provided the useful information about the quality of purple sweet potatoes grown at different locations.

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1 INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is considered as one of the most important tubers in term of annual production in over the world (Sharma and Kaushal, 2016) and nutritional values. It contains a great amount of carbohydrate, dietary fiber, minerals, vitamins, and bioactive compounds like phenolic acids and anthocyanin. Sweet potatoes may be classified based on flesh color that ranges from white to yellow, orange, and deep purple (Onwueme, 1978). Purple sweet potatoes with two specified crops like winter-spring and summer-autumn have been extensively grown at Dong Thap, Vinh Long and Kien Giang provinces (Mekong Delta, Vietnam).

Phenolic compounds are one group of major antioxidants of fruits and vegetables, including sweet potato (Teow *et al.*, 2007). They play an important role in a therapeutic treatment and as the preventive potential of several chronic diseases including cardiovascular disease and possibly certain cancers (Scalbert *et al.*, 2005). Preceding researches proved that phenolic compounds found in sweet potato were helpful in restricting the growth of human colon, leukemia and stomach cancer cells (Kurata *et al.*, 2007), and alleviating diabetes in humans (Ludvik *et al.*, 2008).

Anthocyanin, one of the primary water-soluble pigments, is responsible for colors of fruits and plants ranging from blue to red (Gross, 1987). It could be found widely in some plant families, like *Vitaceae*, *Rosaceae*, *Solanaceae*, *Saxifragaceae*, *Cruciferae* and *Ericaceae* (Jackman and Smith, 1996). Grapes, red cabbages, blood oranges and fruit berries are considered as the best sources of anthocyanin, while black carrots, and purple sweet potatoes contain a minority (Mateus and de Freitas, 2008). Previous studies revealed that anthocyanin plays an important role in performing anti-inflammatory function, inhibiting the growth of microbes, protecting nerve system, and lowering the risk of carcinogenic and cardiovascular diseases (Oki *et al.*, 2002; Wallace, 2011).

In this research, chemical compositions, bioactive compounds (total flavonoid compounds, total anthocyanin content, and total phenolic compounds), and physicochemical properties (swelling index, water solubility index, and pasting properties) of five purple sweet potato flours (PSPF) (Hoa Tan, Tan Phu, Phu Long, Tan Thanh, and Thanh Dong) were investigated.

2 MATERIALS AND METHODS

2.1 Materials

A purple sweet potato (*Ipomoea batatas* L.), popularly grown at Hoa Tan, Tan Phu, and Phu Long villages (Chau Thanh district, Dong Thap province), and Tan Thanh and Thanh Dong villages (Binh Tan district, Vinh Long province), was used in this study. The vines were planted in July, 2017 and harvested in October, 2017. All tubers were in the uniformity of shape and size (200 – 300 g/tuber), and were examined for the absence of insect contamination like *Cylas formicarius*. PSPF prepared from tubers grown at Hoa Tan, Tan Phu, Phu Long, Tan Thanh and Thanh Dong villages were coded as HT, TP, PL, TT, and TD, respectively.

Ferulic acid, Rutin, and Folin-Ciocalteu reagent were purchased from Sigma Co. Ltd. Other chemicals were bought from chemical store in District 10, Ho Chi Minh City.

2.2 Methods

2.2.1 Flour preparation

Fresh tubers were carefully washed with water to remove all contaminants and drained at room temperature (28 ± 2°C). Then they were peeled, sliced into pieces (3 cm), and then dried in the convection oven at 55°C until moisture content of 10-11% (approximately 24 hours). Then, fine flour was obtained by grinding with analytical mill (A11 Basic, IKA, Germany).

2.2.2 Extraction method

Ethanol-assisted extraction, as a modified method of Tran Ngoc Tan and Pham Van Hung (2014), was applied to obtained extract from purple sweet potato flour. Flour (2.5 g) and 50 mL of 25% ethanol were mixed in a flask and then shaken in an incubator at 150 rpm for 2 hours. After centrifuging at 5,000 rpm for 15 min, the supernatant was collected and evaporated at 50°C to obtain residue. Then, it was reconstituted with distilled water to a final volume of 50 mL, and stored at 4°C until it was used.

2.2.3 Determination of chemical compositions of purple sweet potato flours

The AACC (American Association of Cereal Chemists) approved methods 46-10.01, 30-10.01, and 08-01.01 (AACC, 2000) were used to analyze protein, lipid, and ash contents of PSPF, respectively. Total carbohydrate content was calculated from the subtraction of protein, lipid and ash contents.

2.2.4 Determination of bioactive compounds of purple sweet potato flours

Total phenolic contents (TPC) in the extract of PSPF were measured using spectrophotometric methods as previously described by Liyana-Pathirana and Shahidi (2006) with minor modification. The mixture of 0.5 mL of extract and 0.5 mL of Folin-Ciocalteu reagent was added with 1 mL of saturated sodium carbonate solution, and followed by adjusting the volume to 10 mL distilled water. After mixing well, the whole mixture was stabilized at room temperature for 45 min in the dark, followed by centrifuging at 5,000 rpm for 10 min. After that, the absorbance of clear supernatants from samples or standard solution prepared from ferulic acid was recorded at 725 nm. TPC was calculated and expressed in micrograms of ferulic acid equivalent per 100 grams of sample in dry basis (mg FAE/ g flour, dry basic [db]).

Total flavonoid contents (TFC) in the extract of PSPF were evaluated by a slightly modified method of Al-Farsi and Lee (2008). The mixture of 0.5 mL of extract and 1.5 mL of ethanol 95% was mixed with 0.1 mL of aluminum chloride solution 10%, and followed by adding 0.1 mL of potassium acetate 1 M, and then 2.8 mL of distilled water. After stabilizing at room temperature for 30 min, the absorbance of samples or standard solution prepared from rutin was measured at 415 nm. TFC was calculated and expressed in micrograms of rutin equivalent per 100 grams of sample in dry basis (mg RE/ 100 g flour, db).

Anthocyanin content in the extract of PSPF was analyzed according to the method reported by Lee *et al.* (2005). Half of milliliter of each extract was prepared in two distinct test tubes, in which one was mixed with 2 mL of potassium chloride buffer (pH 1.0) and other was mixed with 2 mL of sodium acetate buffer (pH 4.5). After mixing and stabilizing at room temperature in the dark for 30 min, the absorbance of each mixture was taken at 520 nm and 700 nm. The amount of anthocyanin was expressed as mg cyanidin-3-glucoside equivalents per liters and calculated by the following formula:

$$Cyanidin - 3 - glucoside = (A\ x\ MW\ x\ DF\ x\ 1{,}000)/(\varepsilon L)$$

Where: $A = (A_{520nm} - A_{700nm})_{pH\ 1.0} - (A_{520nm} - A_{700nm})_{pH\ 4.5}$

MW is molecular weight of cyanidin-3-glucoside (449.2 g/mol)

DF is dilution factor

ε is molar extinction coefficient of cyanidin-3-glucoside (26,900 $L.mol^{-1}.cm^{-1}$)

L is the cell path length (cm)

2.2.5 Determination of physicochemical properties of purple sweet potato flours

Water solubility index (WSI) of PSPF was determined according the method of Kusumayanti *et al.* (2015) with a slight modification. The flour (0.5 g) was dispersed in 10 mL of distilled water, and mixed for 1 min. Then, the mixture was heated in a shaking water bath (200 rpm, 30 min, 90 ºC). Following this, the cooked paste was rapidly cooled to room temperature, and then centrifuged at 1,600 rpm for 10 min. The supernatant was collected, dried at 120 ºC for 4 hours, and then weighed. WSI was calculated as the mass of flours dissolved in the supernatant divided by the initial mass of sample and expressed in percentages.

Swelling index (SI) of PSPF was analyzed using the method of Abu *et al.* (2005). One gram of flour was dispersed in 20 mL water and vortexed for 1 min. The tube was heated in a shaking water bath (200 rpm, 30 min, 90ºC), then cooled under running tap water, and finally placed in ice water bath for 10 min to accelerate gel formation. After centrifuging (4500 rpm, 10 min, 20ºC), the falcon was placed at room temperature for 5 min. The supernatant was carefully removed and the weight of the residue was noted. SI was calculated as the ratio of final residue weight to initial sample weight.

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

2.2.6 Statistical analysis

All the experiments were performed at least in triplicate. Analysis of variance (ANOVA) was performed using the Tukey's test with significance level at $p < 0.05$ to compare the means of the results of chemical compositions, bioactive compounds and physicochemical characteristics of PSPF.

3 RESULTS AND DISCUSSIONS

3.1 Chemical compositions of purple sweet potato flours

Proximate compositions of five PSPF are shown in Table 1. The chemical compositions of different PSPF consisted of 1.08 – 3.09% of protein, 0.17 – 0.41% of lipid, 2.49 – 2.78% of ash, and 93.94 – 95.92% of total carbohydrate. Among five purple sweet potato flour samples, PL had the highest protein content (3.09%), TP accounted for the greatest percentage of lipid content (0.41%), while TT contained the highest ash and total carbohydrate contents (2.78 and 95.92%, respectively). These results were consistent with the data revealed by Woolfe (1992) found that chemical compositions of sweet potato consisted of 1.2 – 10.0% of protein, 1.0 – 2.5% of lipid, 0.6 – 4.5% of ash, and 83.0 – 97.2% of total carbohydrate. The results indicated that the chemical composition of purple sweet potato was affected by the growing locations.

Table 1: Chemical compositions of five purple sweet potato flours (%, db)

Flour samples	Protein	Ash	Crude fat	Carbohydrates
HT	2.20 ± 0.06[b]	2.61± 0.01[ab]	0.17 ± 0.01[a]	95.03 ± 0.06[bc]
TP	2.51 ± 0.51[bc]	2.49 ± 0.18[a]	0.41 ± 0.03[d]	94.60 ± 0.69[ab]
PL	3.09 ± 0.02[c]	2.66 ± 0.05[ab]	0.32 ± 0.01[c]	93.94 ± 0.06[a]
TT	1.08 ± 0.03[a]	2.78 ± 0.04[b]	0.22 ± 0.01[b]	95.92 ± 0.03[cd]
TD	1.31 ± 0.06[a]	2.76 ± 0.02[b]	0.20 ± 0.01[ab]	95.73 ± 0.08[d]

HT: Hoa Tan; TP: Tan Phu; PL: Phu Long; TT: Tan Thanh; TD: Thanh Dong.

Data followed by the same superscript letter in the same column are not significantly different (P <0.05).

3.2 Bioactive compounds of purple sweet potato flours

Table 2 demonstrates the amounts of total phenolic compounds in the extracts of five purple sweet potato flour samples. TPC of PSPF ranged from 173 to 202 mg FAE/100 g flour in dry basis. Among them, PL had the highest amount of total phenolic compounds (202 mg FAE/100 g flour, db), followed by TT with 191 mg FAE/100 g flour (db), while there was no remarkable difference observed among HT, TP, and TD. Previous studies revealed that the amounts of TPC in Taiwanese and Filipino purple sweet potatoes were 6.4 and 434.3-736.8 mg gallic acid equivalent per 100 g flour, respectively (Huang *et al.*, 2006; Rumbaoa *et al.*, 2009).

Table 2: Bioactive compounds (TPC, TFC, and AC) of purple sweet potato flours

Flour samples	TPC (mg FAE/100 g flour, db)	TFC (mg RE/100 g flour, db)	AC (mg cyanidin-3-glucoside/100 g flour, db)
HT	173 ± 10[a]	73.8 ± 1.5[b]	3.37 ± 0.07[a]
TP	185 ± 3[a]	77.3 ± 3.5[b]	5.20 ± 0.52[b]
PL	202 ± 1[c]	85.6 ± 3.2[c]	6.83 ± 0.14[c]
TT	191 ± 1[b]	78.5 ± 0.8[b]	3.11 ± 0.35[a]
TD	183 ± 0[a]	66.1 ± 1.0[a]	2.91 ± 0.20[a]

HT: Hoa Tan; TP: Tan Phu; PL: Phu Long; TT: Tan Thanh; TD: Thanh Dong.

TPC: total phenolic content; TFC, total flavonoid content; AC anthocyanin content.

Data followed by the same superscript letter in the same column are not significantly different (P <0.05).

The amounts of total flavonoid and anthocyanin compounds in the extracts of five purple sweet potato flour samples are also given in Table 2. TFC of these PSPF was in a range of 66.1 to 85.6 mg RE/100 g flour (db) and anthocyanin content of these PSPF was in a range of 2.91 to 6.83 mg of cyanidin-3-glucoside/100 g flour (db). Among them, PL had the highest amount of total flavonoid compounds (85.6 mg RE/100 g flour, db) and anthocyanin (6.83 mg of cyanidin-3-glucoside/100 g flour, db). The TFC of HT, TP, and TT flours were not significantly different, while the lowest TFC belonged to TD (66.1 mg RE/100 g flour, db). The AC of TP was 5.20 mg of cyanidin-3-glucoside/100 g flour (db), significantly higher than HT, TT, and TD flours. These data corresponded with the result reported by Huang *et al.* (2006) who concluded that the amounts of total flavonoid compounds and anthocyanin in Taiwanese purple sweet potato were 34.8 mg gallic acid equivalent per 100 g flour and in a range of 0.5 to 9.0 mg cyanidin-3-glucoside per 100 g flour, respectively. Other studies revealed that anthocyanin content in purple sweet potato flour was around 6.2 mg peonidin-3-glucoside per 100 g flour (Ji *et al.*, 2015). Thus, the amounts of bioactive compounds were found to be significantly different depending on the growing locations.

3.3 Physicochemical properties of purple sweet potato flours

Swelling index (SI) of five purple sweet potato flour samples is illustrated in Figure 1. Among these flour samples, HT had the highest swelling index (7.5 g water/g flour), while the lowest statistics belonged to TD (5.3 g water/g flour). SI of TT, PL and TP was in the line between that of TD and HT. These differences in these SI were mainly due to the presence of lipid (Leach *et al.*, 1959) or amylose content and its properties like amylose-lipid complexation or total leached amylose in addition to phosphate content (Zuluaga *et al.*, 2007).

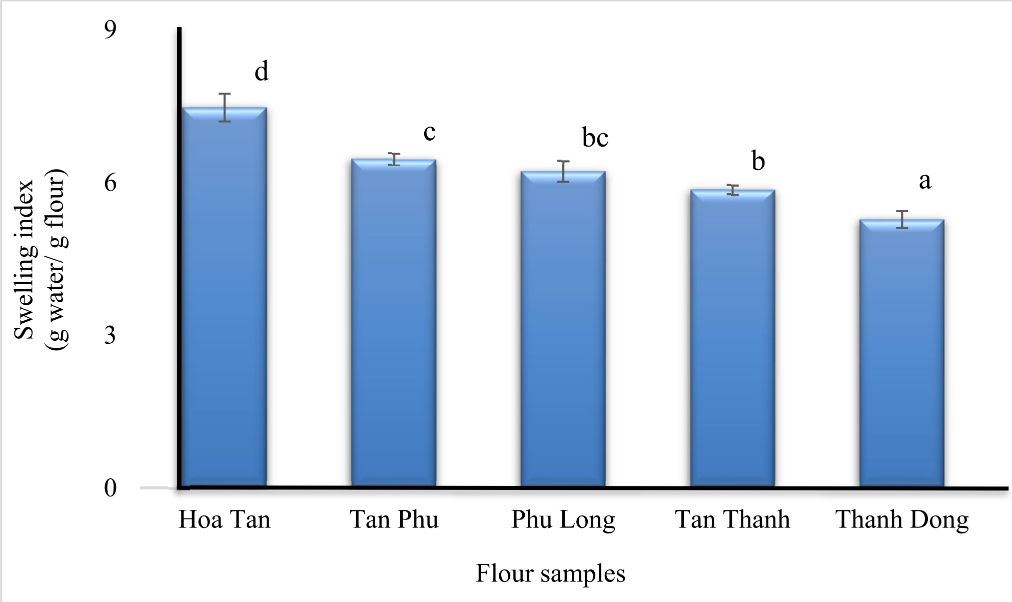

Fig. 1: Swelling index of purple sweet potato flours (g water/ g flour)

Bars followed by the same superscript letter are not significantly different (P <0.05).

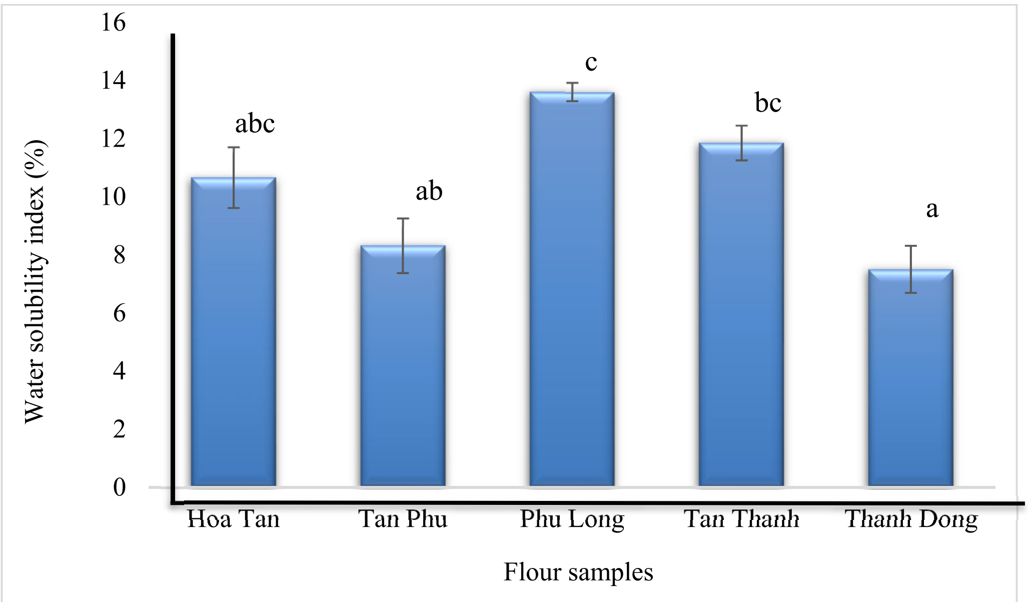

Fig. 2: Water solubility index (%) of purple sweet potato flours

Bars followed by the same superscript letter are not significantly different (P <0.05).

WSI of five purple sweet potato flour samples is presented in Figure 2. PL was found to have the highest percentage of WSI (13.6%) followed by TT (11.9%), while there no substantial discrepancy noted among HT, TP, and TD. The suitable explanation for WSI of these PSPF was mainly due to the difference in their amylose content and amylose-lipid complexation (Zuluaga *et al.*, 2007). Other research reported that higher hydrophilic constituents like polysaccharides and development in the amylose leaching and solubility of starch were also responsible for WSI (Chandra *et al.*, 2015).

Table 3: Pasting properties of purple sweet potato flours

Flour samples	Pasting temperature (ºC)	Maximum viscosity (BU)	Final viscosity (BU)	Trough viscosity (BU)	Breakdown (BU)	Setback (BU)
HT	32.8 ± 1.4^{a}	1025 ± 9^{c}	940 ± 19^{a}	393 ± 31^{c}	632 ± 22^{b}	547 ± 50^{b}
TP	32.4 ± 0.8^{a}	740 ± 74^{b}	680 ± 75^{b}	360 ± 1^{bc}	381 ± 74^{a}	321 ± 76^{a}
PL	32.4 ± 0.8^{a}	676 ± 90^{b}	613 ± 6^{b}	265 ± 57^{b}	411 ± 33^{a}	349 ± 63^{ab}
TT	38.2 ± 0.1^{b}	453 ± 1^{a}	540 ± 53^{b}	116 ± 7^{a}	337 ± 8^{a}	424 ± 46^{ab}
TD	37.9 ± 0.6^{b}	458 ± 19^{a}	632 ± 42^{b}	140 ± 9^{a}	318 ± 10^{a}	493 ± 33^{ab}

HT: Hoa Tan; TP: Tan Phu; PL: Phu Long; TT: Tan Thanh; TD: Thanh Dong.

Data followed by the same superscript letter in the same column are not significantly different (P <0.05).

Table 3 provides the results of pasting properties of five purple sweet potato flour samples expressed as pasting temperature, maximum viscosity, final viscosity, trough viscosity, breakdown, and setback. The pasting profiles of these PSPF were considerably different. Among these flours, TT had the highest pasting temperature, while other pasting parameters including maximum viscosity, final viscosity, trough viscosity, breakdown, and setback of HT were the highest. Pasting temperature is vigorously associated to water absorption capacity of starch, in which 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, the paste of purple sweet potato from Hoa Tan village manifested the greater resistance against retrogradation, gel consistency and hot paste stability among other flours.

4 CONCLUSIONS

In this project, the bioactive compounds and physicochemical properties of purple sweet potatoes grown at different locations in Dong Thap and Vinh Long provinces were investigated. The results indicated that chemical compositions, bioactive compounds and physicochemical properties of these flours were significantly different. It is noticeable that purple sweet potatoes grown at Phu Long village (Chau Thanh district, Dong Thap province) had the highest amount of bioactive compounds and satisfied chemical compositions and physicochemical properties. Further study should be done to know the effects of soil composition and climate conditions on the quality of the purple sweet potatoes.

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