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Effects of slice thickness and drying temperature on total anthocyanin content and antioxidant capacity of steamed purple sweet potato powder

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Abstract
The purpose of this project is to investigate the optimal processing conditions to produce a steamed purple sweet potato powder with high amount of anthocyanin and antioxidant capacity. The purple sweet potato tubers were cut into slices with different thicknesses (1, 2, 3 and 4 cm). After steaming, the steamed slides were dried to reduce the moisture content of samples of less than 10%. The appropriate drying time and temperature were determined to get the highest anthocyanin content and antioxidant capacity. The highest anthocyanin composition was obtained (26.0 ± 0.6 mg anthocyanins/100g powder) under the optimal processing conditions using slice thickness of 3 cm and drying temperature of 55°C for 48 h. This condition was also suitable to get a high result on antioxidant activity (61.3 ± 2.3 %DPPH scavenging) of sample.

Keywords: Purple sweet potatoes, *Ipomoea batatas* (L.) Lam., anthocyanin, antioxidant activity

1. Introduction
Anthocyanins, one of the primary flavonoid group of phytochemicals, are considered as water-soluble pigments. They are responsible for colors ranging from blue to red in fruits and plants [1]. They may be visible in seedlings, roots, tubers, stems, bulbils, etc., and are also found in many gymnosperms, ferns and some bryophytes. Until 2009, nearly 650 anthocyanin have been recognized. Each consists of an aglycone (anthocyanidin) connected to one or more glycosyl moieties through O-linkages. The common anthocyanidins reported belong to six groups regarding to cyanidin, delphinidin, pelargonidin, malvidin, peonidin and petunidin. The anthocyanin sugars are composed of one or more units of glucose, galactose, rhamnose, arabinose, xylose or glucuronic acid. However, glucose is identified as the most common one [2]. Due to the ability of absorbing high energy quanta, the presence of anthocyanin in plants is proposed to serve a protective effect of photosynthetic apparatus and photolabile defense compounds [3]. Moreover, anthocyanins can reduce oxidative damages in leaves by directly scavenging free radicals and reactive oxygen species or moderate the light-driven reactions that generate reactive oxygen species [4]. Anthocyanins can also act as a protective mechanism against environmental stressors including cold temperatures, drought and especially ultraviolet light [5] [6].
Sweet potato (*Ipomoea batatas* L.) is one of the main tuberous roots in the world, especially tropical and subtropical regions. With the annual yield of more than 133 million metric tonnes, sweet potato now takes the fourth place among the most important food crops on a fresh-weight basis in developing countries after rice, wheat, and maize. There are many types of sweet potato classified by the different flesh colors, including white, yellow, orange and purple. Sweet potato particularly provides energy in the human diet in the form of carbohydrates. This kind of roots also plays an important role in biological function. Especially, purple sweet potatoes are considered to have the highest anthocyanin content. They have an intense purple color in the roots by the accumulation of anthocyanins that are mono-acylated or di-acylated forms of cyanidin and peonidin [7]. Rumbaboa et al. [8] reported that anthocyanin from purple sweet potato has better radical scavenging activity than that of red cabbage, grape skin, elderberry and purple corn. The stability of anthocyanin and phenolic contents are affected by many factors including species, environmental and agronomic factors [9]. Among them, polyphenol oxidase has a crucial in the degradation of anthocyanin and phenolic contents [10]. For that reason, purple sweet potatoes could be processed into powder to extend its storage ability and nutrition value. At present, there has been little discussion about the effects of processing conditions regarding slicing thickness and drying temperature on the loss of anthocyanin compounds of purple sweet potatoes. Thus, this study is to examine the effect of slicing thickness and drying temperature on the loss of anthocyanins and antioxidant activities to find out a suitable processing condition that preserve the highest level of anthocyanins and antioxidants.

2. Materials and Methods
2.1. Materials
Purple sweet potatoes were obtained from Vinh Long province, Vietnam. The chosen roots were uniform in size with diameter from 4 cm to 5 cm and only the middle of roots were used while the two heads and damaged parts were discarded.
DPPH reagent was purchased from Sigma – Aldrich Co. (St. Louis, MO, USA). Other chemicals such as hydrochloric acid, potassium chloride, sodium acetate, methanol, and

ethanol were purchased from local agents in Vietnam.

2.2. Sample preparation

The clean purple sweet potatoes were peeled off and sliced into different thickness (1 cm, 2 cm, 3 cm and 4 cm). After being steamed, they were cooled down in room temperature, then dried at 45 ºC until the moisture content was lower than 10%. The dry samples were grinded into powder and stored in sealed plastic bags. Based on the amount of anthocyanin, the suitable cutting size was chosen. Then, the steps were kept with the cutting size chosen from the previous experiments but the drying temperature changes into 55ºC, 65ºC and 75ºC, respectively. Total anthocyanin determination were conducted to choose the suitable drying temperature.

2.3. Extraction of anthocyanin

The dried sweet potato powder (2.5 g) was added with 50 ml of 25% ethanol to a flask. The container was kept in shaking incubator at room temperature with the speed of 150 rpm in 2 h. After centrifugation at 8000 rpm for 10 min, the supernatant was kept and stored at 4ºC for further analysis.

2.4. Determination of total anthocyanin content

Anthocyanin contents were measured based on pH differential method reported by Lee et al. [11]. A volume of 2 ml of potassium chloride (pH 1.0) and sodium acetate (pH 4.5) buffers were respectively added to a test tube containing 0.5 ml extract. After storing in the dark at room temperature in 30 min, the absorbance of each dilution was measured at 520 nm and 700 nm with a water blank using spectrophotometer (Genesys 10S UV- Vis, USA). The concentration of anthocyanin was calculated based on the following equation:

Anthocyanin pigment (cyaniding-3-glucoside equivalents, mg/L) = (A x MW x DF x V x 100)/(ε x L x w)
Where:
A = (A520nm – A700nm)pH 1.0 – (A520nm – A700nm)pH 4.5
MW is the molecular weight of cyaniding-3-glucoside (449.2 g/mol)
DF is dilution factor
V is the total volume of extract (mL)
w is the weight of the sample used in the extraction (g)
L is the cell width (1cm)
ε is the molar extinction coefficient of cyanidin-3-glucoside (26900 L x mol-1 x cm-1).
100 is the conversion factor for obtaining mg/100 g of sample

2.5. Determination of DPPH scavenging activity

The DPPH radical scavenging activity was determined by slightly modifying a method of Sasaki and Ohba [12]. A volume of 3.9 ml DPPH solution (0.15mM) was added to 0.1 ml of extract. After being shaken and store in dark room in 30 min, the absorbance was measured at 515 nm with methanol blank. The control was a mixture of 3.9 ml of DPPH and 0.1 ml methanol. The scavenging of DPPH was calculated by the following equation:

%DPPH scavenging = [($A_{control} - A_{sample}$)/ $A_{control}$] x 100
Where:
$A_{control}$ is the absorbance of the control (DPPH + Methanol)
A_{sample} is the absorbance of the sample (DPPH + extract)

2.6. Data analysis

All data was expressed as means ± standard deviation (SD). The results were statistically analyzed using the analysis of variance (ANOVA) and the Turkey test. Significance level was considered at $p < 0.05$.

3. Results and Discussion

3.1. Effects of thickness of sweet potato slices on drying time and anthocyanin content

Purple sweet potatoes were cut in slices of four different thicknesses (1, 2, 3 and 4cm in length). After being steamed, they were dried until the moisture content reached the level under 10%, at a temperature of 45°C. Table 2 shows the drying time of purple sweet potato slices with four thicknesses at 45ºC. Different slice thicknesses resulted in different drying times. These results expressed that thickness of the slices had great influence in drying time. The thicker those slices were, the much time they consumed to get dried and reduce the moisture content to the level less than 10%.

Table 1. Drying time of purple sweet potato powder with different slice thicknesses

Thickness (cm)	Drying time (h)
1	48
2	54
3	66
4	72

The total anthocyanin contents (mg/100g of dried flour) of four dried samples with the slice thickness of 1cm, 2cm, 3cm and 4cm are described in Figure 1. The anthocyanin contents of four samples were measured after being dried at 45ºC. The results showed that the thickness of slices had some impacts on the amount of anthocyanin compositions.

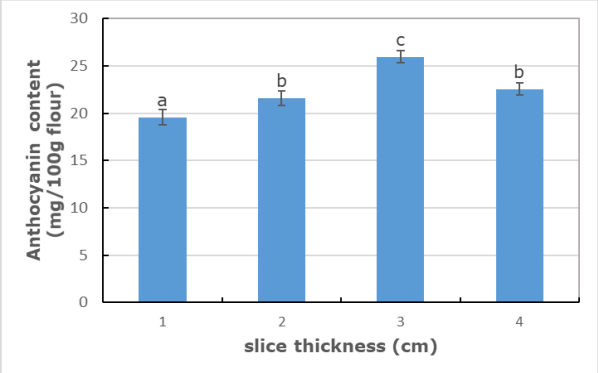

Fig 1. Anthocyanin content in purple sweet potato powder with different slice thicknesses

The total anthocyanin content obtained purple sweet potato flour was ranged from 19.55 ± 0.81 mg to 25.96 ± 0.65 (mg/100 g of dried powder). The thinnest slice of sample (1 cm) resulted in the lowest amount of total anthocyanin while the 3-cm-thickness slice showed the highest level of total anthocyanin than the others. The results found in 2-cm and 4-cm-thickness slices were 21.58 ± 0.75 mg and 22.56 ± 064 mg, respectively, that were not significantly different. When steaming, an amount of anthocyanin was lost due to

the evaporation and condensation. The steam went up and met the purple sweet potatoes to cook, it also carried the anthocyanin pigment out. So that, the thinner slices the purple sweet potatoes were, the easier anthocyanin lost. The slices with thickness of 1 cm and 2 cm lost higher amounts of anthocyanin pigment. This can observed from the fading of purple color after steaming when compared to the 3-cm and 4-cm-thickness slices. However, the 4-cm-thickness slice required 72 h for drying at 45 ºC, which was longer time than the others (Table 1). As the time increased, the degradation rate of anthocyanin increased, this made the anthocyanin content in 4-cm-thickness slice decreased [13].

The antioxidant capacities of sweet potato powder with different slice thicknesses are shown in Table 2. DPPH scavenging (%) was used to describe the activity of those compounds.

Table 2. Antioxidant activity (%DPPH scavenging) of purple sweet potato powder with different slice thicknesses

Thickness (cm)	%DPPH scavenging
1	55.7 ± 2.1^{a}
2	57.6 ± 1.7^{a}
3	61.3 ± 2.3^{a}
4	60.5 ± 2.1^{a}

Values in the same column with different letters are significantly different ($P < 0.05$).

Although the change in slice thickness led to the differences in anthocyanin compounds in a range of 55.67% to 61.31%, the antioxidant activity of all samples was not significantly different. The 3-cm-thickness slices gave the highest antioxidant activity (61.3 ± 2.3%), while the thinnest slices (1-cm-thickness) presented the lowest number of %DPPH (55.7 ± 2.1%). %DPPH scavenging of 2-cm and 4-cm-thickness slices were 57.6 ± 1.7% and 60.5 ± 2.1%, respectively.

The obtained results indicate that there was a linkage between anthocyanin content and antioxidant capacity of purple sweet potatoes. The more of anthocyanin compositions, the higher the % DPPH scavenging activity. With the concentration of anthocyanin between 19.55 mg to 25.96 mg, Jiao et al. [14] reported that the highest antioxidant activity in this range was 75.8% while Li and Xiao [15] shown the number up to 82.05%.

Thus, based on the highest level of anthocyanins and antioxidant activity, 3-cm-thickness slices was considered to be the appropriate thickness for steaming.

3.2. Effects of drying temperature on drying time and anthocyanin content

Purple sweet potato slices with the thickness of 3 cm were dried in oven with the temperature of 45 ºC, 55 ºC, 65 ºC and 75 ºC until the moisture content lowered than 10%. The time consumed for drying sample are described in Table 3. The higher the temperature, the less time needed for the slices to get dried.

Table 3. Drying time of purple sweet potato powder with different drying temperatures

Drying temperature (ºC)	Drying time (h)
45	66
55	48
65	24
75	12

Effects of drying temperature on the total anthocyanin content of purple sweet potatoes are shown in Figure 2. In which, the amount of anthocyanin was described as mg per 100g of dry powder sample.

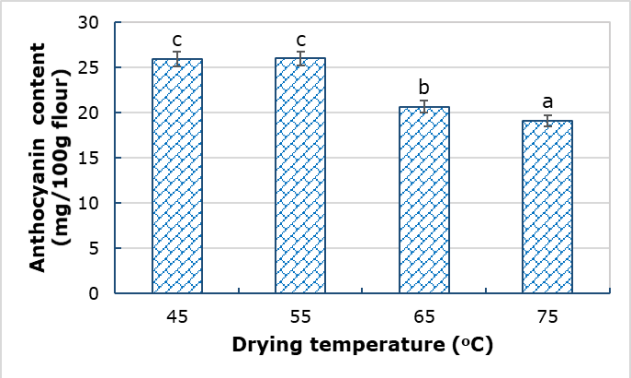

Fig 2. Anthocyanin content in purple sweet potato powder with different drying temperatures.

At different drying temperatures, the total anthocyanin content varied from 19.1 ± 0.5 mg to 26.0 ± 0.6 mg per 100 g of purple sweet potato powder. It was noticed that the result taken at 45ºC and 55ºC was similar (25.9 ± 0.6 mg and 26.0 ± 0.6 mg, respectively). That means the temperature did not significant effects on the anthocyanin compounds. With the increase in temperature from 55 ºC to 75 ºC, the anthocyanins considerably decreased ($p<0.05$). The anthocyanin content of the powder dried at 65 ºC was 20.6 ± 0.4 mg and that dried at 75ºC was 19.1 ± 0.5 mg which was much lower than those dried at 45 ºC and 55 ºC.

The degradation of anthocyanin is partially due to the loss of glycosyl moieties through the hydrolysis of glycosidic linkage. Moreover, anthocyanin compositions could be enzymatically degraded by enzyme polyphenol oxidase (PPO) that might lead to the loss of color and could even turn into brown. This enzyme could be inactivated at mild temperature, so this was the reason that the anthocyanin levels at 45ºC - 55ºC were much higher than those at 65ºC - 75ºC [16] [17].

The antioxidant capacities of purple sweet potatoes dried at different temperatures are shown in Table 4. % DPPH scavenging was used to describe the activity.

Table 4. Antioxidant activity (%DPPH scavenging) of purple sweet potato powder with different drying temperatures

Drying temperature (ºC)	%DPPH scavenging
45	61.6 ± 2.1^{b}
55	63.9 ± 2.4^{b}
65	62.2 ± 2.5^{b}
75	53.4 ± 0.8^{a}

Values in the same column with different letters are significantly different ($P < 0.05$).

The antioxidant activity of purple sweet potatoes fluctuated from 53.4 ± 0.8% to 63.9 ± 2.4%. The highest antioxidant capacity was found in the sample dried at 55 ºC and the lowest was at 75 ºC. While there was no significant effect of temperature from 45 ºC to 65 ºC on DPPH scavenging of the samples but it was shown a considerably fall of %DPPH scavenging at 75 ºC because of a higher temperature.

The results obtained showed that anthocyanin contents at 45 ºC and 55 ºC were the highest. Although this range of mild

temperature did not affect the antioxidant capacity of purple sweet potato powder, Drying at 55 ºC was chosen because of the shorter drying time (48 h) than dried at 45 ºC (66 h).

4. Conclusion

In this study, the most appropriate technical specifications for processing of purple sweet potato powder were determined. Generally, the slice thickness of purple sweet potatoes affected the anthocyanin level but did not affect the antioxidant capacity. The thermal processing took significant influence in both attributes. However, drying at mild temperature in suitable time can diminish the degradation of anthocyanin compounds.

5. Acknowledgment

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