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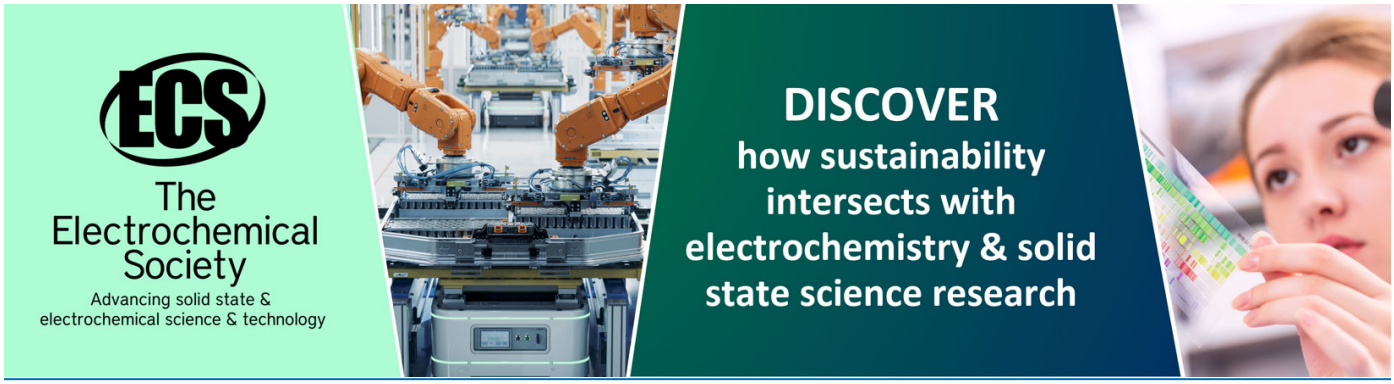

Carotenoids, phenolics and antioxidant properties of different sweet potatoes (*Ipomoea batatas*) varieties

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Abstract. Sweet potato (*Ipomoea batatas*) is one of the most important tuber crops for fresh consumption in Malaysia. However, it is not fully utilized with an approximately 30 % of the whole part sweet potato especially its skin is disposed upon consumption. Sweet potato contains abundant of valuable compounds such as carotenoids and phenolics with pharmaceutical values. This research was conducted to extract, quantify and determine the carotenoids, phenolics and antioxidant activity of skin and flesh from varieties of sweet potatoes. Extraction using acetone was carried out due to its ability to dissolve both polar and non-polar substances. Results exhibited that orange flesh sweet potato consisted of the highest total carotenoid content (187.88 ± 3.27 μg/g) while purple flesh comprised the highest total phenolic content (96.00 ± 1.3 mgGAE/g). Dark purple skin sweet potato was determined to exhibit the highest antioxidant activity (93.21 ± 1.33 %) when compared to others. Sweet potato particularly its skins could be utilised for value-added purposes such as food fortification, food additives, and animal feed enhancers instead of wasting them. Environmental problems due to food waste accumulation could be greatly reduced and data obtained could aid in future research.

1. Introduction

About 102 mil. tonnes of sweet potato produced worldwide, yearly. Approximately 53% of total sweet potato production was consumed as food following used as feed (40%) and 7% was disposed as waste [1]. Industrial processing of sweet potato skins generates substantial amount of waste annually. It is estimated about 30% of total raw material were disposed from the sweet potato canning industry, on which further utilised as fertilizer or animal feed [2]. In order to improve food usage efficiency, there are compounds that can be extracted from the sweet potatoes skin for other useful purposes. As such, there are high concentrations of carotenoids and phenolic compounds that can be further extracted and utilised. Thus, extraction of carotenoid and phenolic compounds can be performed from sweet potatoes to create beneficial products.

Observing the current trend on food consumption, consumers are looking beyond the basic nutrition provided by the food choice. They are aware of the beneficial compounds obtained in food consumed as it may contain valuable compounds such as phenolics and carotenoids that have good effects on human. Sweet potatoes have been demonstrated to exhibit multiple health benefits, closely related to their high contents in proteins, vitamins, carotenoids, polyphenols, minerals and other bioactive compounds with antioxidant properties [3]. The bioavailability of carotenoids and phenolic compounds are affected by various factors such as the release, stability, accessibility, mass

transfer and digestibility of many food compounds that influenced by food matrix [4]. Therefore, in order to analyse the bioavailability and potential beneficial effects of sweet potatoes, solvent extraction method using the same solvent will be applied to determine the contents of carotenoids and phenolic compounds.

The amount of carotenoid and phenolic contents in sweet potatoes varieties are compared, in order to investigate which type of sweet potato contains the highest concentration of carotenoids and phenolic compounds. This aids in future research when high concentration of carotenoids and phenolic are needed for analysis especially in food fortification purpose, and multivitamin supplement production. Furthermore, by identifying the sweet potatoes with highest carotenoid and phenolic contents, the potential sources of natural antioxidants are identified and people can make them as reference to plan daily diet for optimum nutrient intake [5].

In this study, different sweet potatoes varieties were selected as the samples for carotenoids and phenolic extraction, quantification of antioxidant is focused on their flesh and skin. The variation of sweet potatoes used in this study are orange flesh with orange skin sweet potato, purple flesh with dark purple skin sweet potato, and yellow flesh with reddish-purple skin sweet potato.

2. Material and method

2.1 Samples preparation

Sweet potato varieties (orange-flesh, purple-flesh and yellow-flesh) used in this study were purchased from local market in Jeli, Kelantan. The skin and flesh of the tubers were cleaned under tap water and were cut into thin slices and subsequently dried using Autumnz Food Dehydrator at 60 °C until achieved constant weight. Then, the dried samples were ground into powder form and kept for further uses.

2.2 Solvent extraction

2 g of sample powder (sweet potato flesh and skin) was weighed using analytical balance and transferred into a 50 mL Falcon's tube. 8 mL of acetone was added into each sample and were mixed thoroughly under vortex for 3 minutes. Subsequently, 2 mL of 20 % NaCl solution was added into the mixture. The samples were centrifuged at 5,000 rpm for 10 minutes at 25 °C. Then, the supernatant was kept for further analysis and the pallet was discarded. The solvent extraction was performed for all 3 types of sweet potatoes (both flesh and skin) in triplicate.

2.3 Analytical Method

2.3.1 Colour measurement

The 6 sample powders from 3 types of sweet potatoes were used to measure their colour difference using Konica Minolta Chroma Meter CR-400. Colour difference was defined as numerical comparison of samples' colour to the standard.

2.3.2 Total carotenoid content

The extracts from the 3 types of sweet potatoes were then measured spectrophotometrically at 450 nm. The total carotenoid content was calculated as below:

$$Total\ carotenoids\ content\ \left({}^{\mu g}/_{g}\right) = \frac{A_{450} \times V \times 10^4}{A_{1cm}^{1\%} \times W} \quad \text{(Eq 1)}$$

Where, A_{450} was the absorbance value at 450 nm, V was the volume of acetone and NaCl used, $A_{1cm}^{1\%}$ was the coefficient (2150) whereas W was the weight of sample powder used.

2.3.3 Total phenolic content

The phenolic compounds from the 3 types of sweet potatoes were then measured spectrophotometrically at 765 nm. In order to calculate the total phenolic content, standard gallic acid curve was constructed by using Folin-Ciocalteu reagent.

2.3.4 Antioxidant activity

Antioxidant activity was measured using DPPH (2,2-diphenyl-1-picrylhydrazyl) assay. 200 µL of sample solution was added into a test tube. After that, 1 mL of DPPH solution was added into the sample solution and mixed for 10 seconds. The solution was kept in dark for 30 minutes at room temperature [6] and the absorbance was measured at 517 nm using spectrophotometer. The antioxidant activity was calculated using the formula:

$$\text{DPPH radical scavenging activity } (\%) = [(A_c - A_t)/A_c] \times 100\% \quad \text{(Eq 2)}$$

Where, A_c was the absorbance value of DPPH radical in ethanol while A_t was the absorbance value of sample tested.

3. Result and discussion

3.1 Colour measurement

It was observed that the colour of sweet potato varieties used in this study were different between flesh and skins. The skin of sweet potatoes is observed to be in orange, dark purple and reddish-purple in colour. However, the colour of the sweet potatoes' skins is different from the colour intensity of the flesh. Figure 1 shows the ground sweet potato varieties used in this study.

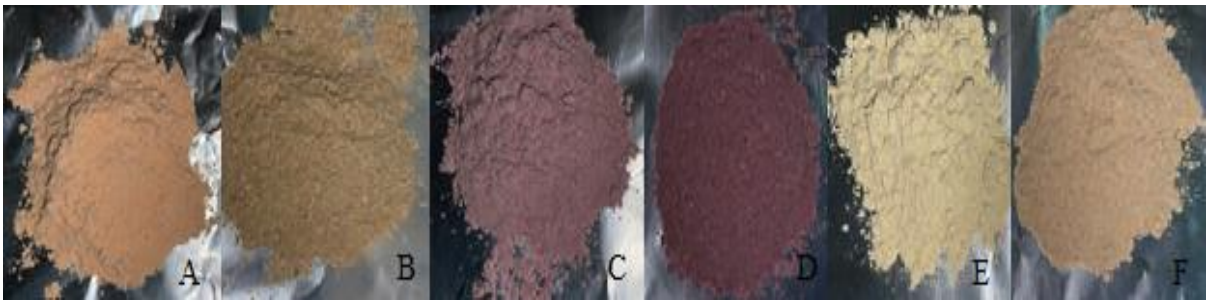

Figure 1. Colours of ground sweet potato used in this study.
A: orange flesh, B: orange skin, C: purple flesh, D: purple skin, E: yellow flesh, F: yellow skin.

The colour difference measurement between tuber skin and tuber flesh is shown in Table 1. In all samples tested, the colour of flesh is lighter than the colour of the skin. It was observed by the value of L* that represent the lightness of the samples (values; 0 for black, 100 for white). The higher the value of L* shows lighter colour of samples. As for a* values, it was observed that yellow flesh sweet potato have the least amount of redness compared to other varieties. The difference in colour of the sweet potato skins reflects to the different types of pigments present in their peels. Higher colour intensity of yellow sweet potato variety related directly to the amount of carotenoids presents such as β-carotene [7]. In addition, the purple pigmentation in sweet potato reflected to the presence of anthocyanin [8]. Anthocyanin is known as a naturally strong free-radical scavenger, contributed many pharmaceutical values including anti-oxidation, prevention and treatment of cardiovascular diseases [9].

Furthermore, the colour difference between flesh and skin was calculated and expressed by tristimulus values. These values are used to visually matching a colour under standardized

conditions against the three primary colours of red, green, and blue. The tristimulus values were L* (lightness, 0 for black, 100 for white), a* (-a* = greenness, +a* = redness) and b* (-b = blueness, +b = yellowness) [10].

Table 1. Colour difference in sample powder of skin and flesh sweet potatoes.

Sweet Potato	ΔL*	Δa*	Δb*	ΔE*
Orange	-11.51	-4.41	-8.61	15.04
Purple	-9.11	0.42	-2.41	9.43
Yellow	-13.74	2.61	-4.02	14.55

The orange skin sweet potato was then compared to its orange flesh and showed the tristimulus value at -11.51 L*, -4.41 a*, and -8.61 b*. These values indicated that the orange skin tuber was darker, less red and less yellow than the orange flesh tuber while the total colour difference (E*) in orange sweet potato was the highest, 15.04. The purple sweet potato displayed -9.11 L*, 0.42 a*, and -
2.41 b* of tristimulus value when compared its dark purple skin to its purple flesh. These values showed that the dark purple skin tuber was darker, more red and more blue than the purple flesh tuber while the E* in purple sweet potato was determined as 9.43. The reddish-purple skin tuber was compared to its yellow flesh, exhibited the tristimulus value at -13.73 L*, 2.61 a*, and -4.02 b*. The tristimulus values indicated that the reddish-purple skin tuber was darker, more red and more blue than its yellow flesh while the E* in yellow sweet potato was determined as 14.55.

The orange and yellow sweet potatoes were recognised as one of the best sources in natural bioavailable of β-carotene, the major precursor of vitamin A. The β-carotene not only gives vivid orange, yellow and red colours to vegetables and fruits, but it plays a crucial role as antioxidant that extremely good for eyes and skin [11].

3.2 Total carotenoids and phenolic contents

The three types of sweet potatoes with different skin and flesh colour indicate significant differences in total carotenoid content ($p < 0.05$). Table 2 shows that the highest total carotenoid content exhibited by the orange flesh sweet potato (187.88 ± 3.27 µg/g), followed by its skin (117 ± 0.63µg/g). Yellow sweet potato ranked third in total carotenoid content with its reddish-purple skin (39.86 ± 0.52 µg/g) and the yellow flesh (21.88 ± 0.46 µg/g). Purple sweet potato accumulated the least amount of total carotenoid content with 17.48 ± 0.21µg/g of the dark purple skin and 14.77 ± 0.12 µg/g of the purple flesh.

There was a significant relationship between the total carotenoid content and its colour intensity of sweet potato [12]. These results were compared and ascertained that orange sweet potato contains the highest amount of carotenoids as compared to yellow and purple sweet potato [13]. Total carotenoid content varies depending on the extraction and drying method, and environmental factors [14]. Climate temperature influences the total carotenoid content in vegetable and fruit; where elevated tropical climates accommodate the carotenoid biosynthesis, the vegetable and fruit grow in this type of climates normally contain higher carotenoid concentrations. In general, high colour intensity of vegetables and fruits are known to contain higher carotenoids content [11].

Total phenolic content for 6 sweet potato samples that analysed in this research ranged from 48.19 ± 1.29 to 96.00 ± 1.3 mgGAE/g. Based on the result showed in Table 2, only purple flesh tuber and its dark purple skin indicated significantly different amount of total phenolic content compared to orange and yellow sweet potato varieties ($p < 0.05$).

Results in this study is consistent with Rumbaoa *et al.* [15], who reported that that purple varieties of sweet potato contain significantly higher total phenolic content as compared to yellow

and orange varieties. The differences in total phenolic content among these varieties were related to their genotypes, that subsequently influence the accumulation of different quantities of phenolic compounds as well as the types of phenolics synthesised [16].

Table 2. Total carotenoid content in 2 g of sweet potatoes.

Sweet Potato	Sample	Total Carotenoid Content (μg/g)	Total Phenolic Content (mgGAE/g)
Orange	Flesh	187.88 ± 3.27^{a}	61.34 ± 0.40^{bc}
	Skin	117.00 ± 0.63^{b}	57.00 ± 1.53^{cd}
Purple	Flesh	14.77 ± 0.12^{e}	96.00 ± 1.3^{a}
	Skin	17.48 ± 0.21^{e}	66.70 ± 4.12^{b}
Yellow	Flesh	21.88 ± 0.46^{d}	52.80 ± 0.84^{de}
	Skin	39.86 ± 0.52^{c}	48.19 ± 1.29^{e}

[a-e]Means within column with different letter(s) indicate significant difference between treatments by Tukey test at $p \leq 0.05$. Each value is expressed as the mean ± standard deviation, (n = 6).

3.3 Antioxidant activity

Antioxidant activity of 3 sweet potatoes varieties was measured by DPPH (1,1-diphenyl-2-picrylhydrazyl) assay. The DPPH radical scavenging activity determined the ability of hydrogen-donating of antioxidants. The antioxidant activity was measured as the relative decrease in absorbance of DPPH as it reacted with the antioxidant contained in sweet potatoes.

The antioxidant activity of the sweet potato varieties is shown in Figure 2. Antioxidant activity for the 3 type sweet potatoes were analysed in the research ranged from 85.01 ± 1.60 % to 93.21 ± 1.33 %. Statistical analysis indicated that the orange flesh tuber and its orange skin were not significantly different ($p > 0.05$) from each other. Among the sweet potato varieties, the results indicated that purple sweet potatoes tend to be correlated with high total antioxidant activity. The dark purple skin sweet potato had the highest radical scavenging activity at 93.21 ± 1.33 %, while the yellow flesh sweet potato had the lowest at 85.01 ± 1.60 % as shown in Figure 2. The antioxidant activity of orange skin tuber ranked second with 90.89 ± 0.18 %, followed by purple flesh tuber, reddish-purple skin tuber, orange flesh tuber and yellow flesh tuber with 90.65 ± 0.16 %, 88.22 ± 0.17 %, 87.13 ± 0.54 % and 85.01 ± 1.60 %, respectively.

Previous study reported that between yellow, orange and purple varieties of sweet potato, the latter had the highest radical scavenging activity due to the presence of significantly higher total phenolic content as compared to the other 2 varieties. This finding leads to the conclusion that total phenolic content could serve as a beneficial indicator of antioxidant activities in sweet potatoes [17]. The available information on this antioxidant content of sweet potatoes varieties would also be helpful in increasing the awareness of the consumers in the selection of nutritious tubers based on the level of phytochemicals compounds present in sweet potatoes.

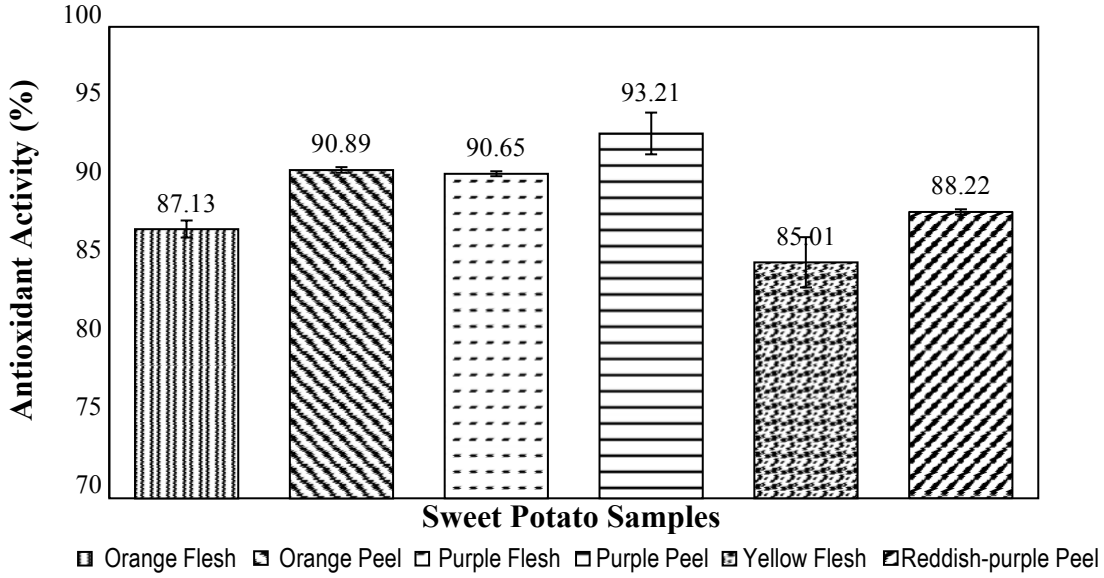

Figure 2. Antioxidant activity from variation sweet potatoes.

4. Conclusions

In a nutshell, composition analysis of total carotenoid content, total phenolic content and antioxidant activity were determined from 3 variation sweet potatoes (orange, purple and yellow) extracted using solvent extraction method. The colour difference measurement was conducted and total colour difference between skin and flesh of orange sweet potato was the highest. The orange and yellow sweet potato variation had higher total carotenoid content compared to purple variation while purple sweet potato variation had the highest total phenolic content and antioxidant activities. The 3 variation sweet potatoes extracted indicating high antioxidant activities, however, their skins consisting higher antioxidant activity compared to their flesh. Thus, the skins of sweet potatoes could be utilised for value-added purposes such as food fortification, food additives, and animal feed enhancers. Environmental problems due to food waste accumulation could be greatly reduced and data obtained could aid in future research.

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