FOOD

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Evaluation of physicochemical properties of anthocyanin extracts and powders from purple sweet potato (*Ipomoea batatas* L.)

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Abstract

Purple sweet potato (*Ipomoea batatas* L.) is one of the food commodities that contain anthocyanin. This research aimed to evaluate the physicochemical properties of anthocyanin extracts and powders from purple sweet potato. Purple sweet potato anthocyanin was extracted using a water solvent with the addition of citric acid in different concentrations (0, 2, 4, and 6 g/100 mL). Ethanol solvent was used as a control. Foam mat drying was performed using variations of egg white composition (10 and 20 mg/100 mL). The result showed that extraction using a water solvent with 2 g/100 mL of citric acid was the most effective condition to obtain the highest total anthocyanin content ($p < 0.05$). However, its total phenolic, flavonoid, and antioxidant activity were lower compared to others. Total anthocyanin content of foam mat dried purple sweet potato powder made from the citric acid-water extract was significantly higher than the powder made from the citric acid-ethanol extract ($p < 0.05$). There was no effect in the total phenolic, flavonoid, viscosity, and yellowish-red color of the powder obtained from citric acid-water extract as the increase of egg white concentration. The use of 20 g/100 mL egg white in both powders produced from citric acid-water and ethanol extracts resulted in higher total anthocyanins and solubilities than powders using 10 g/100 mL egg white. The color of the powder obtained from citric acid-water extract had a lower brightness level and higher yellowish-red color intensity compared to the powder made from citric acid-ethanol extract.

1. Introduction

In recent years, the use of natural pigments is considering to substitute synthetic food colorants as the demand of consumers to natural, safer, and healthier food products (Martins *et al.*, 2016). Anthocyanin is a natural pigment that responsible for the red, purple, and blue colorants in vegetables, fruits, and tubers (Li *et al.*, 2012; Fang, 2015; Liu *et al.*, 2015). Anthocyanin is a water-soluble pigment that included in a group of flavonoid compounds. It is a glycoside of polyhydroxy and polymethoxy from 2-phenylbenzopyrylium (flavylium) derivates. It consists of two benzene aromatic rings combined with the heterocyclic ring contains an oxygen atom (Ma *et al.*, 2020). Besides the potential as the food colorant (Albuquerque *et al.*, 2020), anthocyanin has antioxidant activity from the hydrogen atom donation to radical compounds (Ma *et al.*, 2020), which contribute to health benefits (Arevström *et al.*, 2019; Guo *et al.*, 2020; Peng *et al.*, 2020).

Purple sweet potato (*Ipomoea batatas* L.) is one type of tuberous roots originated from South America, belongs to Convolvulaceae family, and usually grows in tropics and some warm temperate regions. The tuberous roots become fleshy and enlarged because of carbohydrates as food reserves (Levetin and McMahon, 2012). Other than that, purple sweet potato contains anthocyanin. Based on previous research, total anthocyanin content in purple sweet potatoes ranged between 51.5 – 174.7 mg/100 g (Steed and Truong, 2008). The use of anthocyanin as the natural food ingredient can be obtained through an extraction process (He *et al.*, 2015; Sinela *et al.*, 2017; Chen *et al.*, 2019). Maceration was used in this research to obtain the purple sweet potato anthocyanin. Maceration is a method of extraction with the soaking of the sample in a solvent to get certain compounds with the help of agitation (Mukherjee, 2019). This method is very simple, easy, and suitable for anthocyanin extraction (Azwanida, 2015; Puspawati *et al.*, 2018; Zhang *et al.*, 2018).

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The color stability of anthocyanin extract depends on the pH condition (Jiang *et al*., 2018). A previous study has reported that anthocyanin of purple sweet potato extract was stable and gave a red color at pH 1-3 due to the presence of the red flavylium cation. Meanwhile, pH 3-7 of the extract caused the hydration of the flavylium cation, which leads to a reduction of the red color intensity to pink, violet, and blue color. In this stage, the purple quinoidal anhydrase is dominant. At pH >8, formation the carbinol and chalcone was occurred due to the opening of the central pyran ring, allowing the production of green to yellow color (Pham *et al*., 2019)

The use of ethanol at low pH has been widely chosen to extract anthocyanin since it has been known to obtain the optimum of anthocyanin content. Cai *et al*. (2016) have reported the optimum number of purple sweet potato anthocyanin extracted using 80% ethanol acidified with 0.05% HCl was 2.08±7.24 mg/g. However, the use of ethanol is often doubtful due to the halal issue (Alzeer and Hadeed, 2016). Therefore, water or acidified water can be an alternative in anthocyanin extraction to obtained safer extract (Park *et al*., 2010; Xu *et al*., 2015).

The degradation of anthocyanin extract occurred during about two weeks of storage (Sinela *et al*., 2017; Achir *et al*., 2019; Chen *et al*., 2019). Anthocyanin degradation increased as increasing water content and water activity. Increased water will make increasing of molecular water diffusion and mobility in the anthocyanin molecules, thereby increasing the degradation reaction (Aguidelo-Lavarde *et al*., 2013; Lavelli and Kerr, 2019). Storage of foam mat dried anthocyanin powder has been reported to maintain color stability and the number of anthocyanin content (Tavares *et al*., 2020).

Foam mat drying is one type of drying process where the liquid is whipped into foams and then dried. This method is suitable for a heat-sensitive compound like anthocyanin. Another of its advantages because of simplicity, rapid drying, and cost-effectiveness (Hardy and Jideani, 2017). The foam mat drying process can retain the nutritional content and produce the porous form of the powder that has a good solubility when reconstituted (Iqbal *et al*., 2018). To get the excellent physicochemical properties of the powder, the foaming agent is a critical key to success in the foam mat drying. Abbasi and Azizpour (2016) have reported that the level of the foaming agent affected the physicochemical properties of foam dried sour cherry powder.

Many studies about anthocyanin extraction and foam mat drying have been reported, but they are still fragmented. There is no information about anthocyanin extraction of purple sweet potato using a halal solvent followed by foam mat drying to obtain the excellent physicochemical properties of the powder, especially in total anthocyanin content. Hence, it is essential to get anthocyanin extract from purple sweet potato in a suitable extraction condition, which is guaranteed to be safe and halal. The use of egg white as a foaming agent in the foam mat drying process needs to be optimized. Subsequently, this study aimed to evaluate the physicochemical properties of anthocyanin extracts and foam mat dried purple sweet potato powders.

2. Materials and methods

2.1 Materials and sample preparation

Commercial Japanese purple sweet potato (Dori) was purchased from the AEON supermarket, Banten, Indonesia. The purple sweet potato was peeled, washed, and mashed with the food processor. The sample was kept in the dark, airtight container in the refrigerator at 4°C for four days before analysis.

2.2 Chemicals and reagents

The commercial citric acid (Koepoe koepoe), carboxymethyl cellulose (CMC) (Koepoe koepoe), distilled water (Amidis), and liquid egg white were purchased from a local market in Banten, Indonesia. Maltodextrin DE 10-12 was purchased from Cipta Jaya Chemical, Indonesia. Other chemicals required in this study, including gallic acid, quercetin, ascorbic acid, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical (Sigma-Aldric), Follin-Ciocalteu (Chem-mix Pratama, Indonesia). Potassium chloride (KCl), sodium acetate (CH_3COONa), sodium carbonate (Na_2CO_3), potassium acetate (CH_3COOK), aluminum chloride ($AlCl_3$), and ethanol (analytical grade) were obtained from Atma Jaya Laboratory.

2.3 Anthocyanin extraction

Anthocyanin extraction was carried out using the re-maceration method at 25°C for 48 hrs using distilled water with the addition of citric acid in different concentrations (2, 4, 6, 8 g/100 mL). A control was performed by using 96% ethanol solvent. A total of 10 g/100 mL samples was macerated using an orbital shaker (GFL 3017, Germany) at 150 rpm for 48 hrs. Then the solution was centrifuged at 3220 x *g* for 15 mins to obtain the extract and precipitated the residue. The extract was filtered, and solvents were rotary evaporated (BUCHI R-300, Germany) at 45°C for ethanol and 55°C for water until the extract concentrated. The pH was measured using a pH meter (Mettler Toledo Five Easy F20) in each of the extracts. The extract then stored at 4°C refrigerator in the dark condition for further analysis (Ferarsa *et al*., 2018).

2.4 Anthocyanin drying

Anthocyanin drying was performed with the foam mat drying method. A total of 100 mL concentrated extract of anthocyanin after evaporation was prepared, then 2 g/100 mL of 1% (w/v) CMC, 10 g/100 mL maltodextrin, and egg white with the variation in concentrations of 10 g and 20 g/100 mL were added. Afterwards, the mixture was stirred with mixer at high speed for 5 mins until all of the liquid becomes foam, then the foam was poured with 1 cm thickness. The foam was dried using oven dryer (Memmert UN 110, Germany) at $55^{\circ}C$ for overnight and sieved with 60 Mesh sieve shaker. Anthocyanin powder was stored at -$20^{\circ}C$ in tightly closed and airtight conditions for further analysis (Abbasi and Azizpour, 2016).

2.5 Chemical analyses

2.5.1 Total anthocyanin content

The total anthocyanin content was measured using the pH differential method, according to Giusti and Wrolstat (2005) and Belwal *et al.* (2016). Briefly, the sample was mixed with 0.025 mol/L KCl buffer pH 1.0 and 0.4 mol/L CH_3COONa buffer pH 4.5 with a ratio of 1:9 (1 mL and 9 mL) and 1:1 (1 mL and 1 mL) for anthocyanin extract and powder, respectively. The absorbance was measured at 520 (λ_{max} of anthocyanin) and 700 nm. It was using a UV-Vis spectrophotometer (Thermo Scientific, USA) with distilled water as a blank. Absorbance (A) was calculated by Equation (1):

$$A = [(A_{\lambda max} - A_{700\,nm})\,pH\,1.0] - [(A_{\lambda max} - A_{700\,nm})\,pH\,4.5] \tag{1}$$

The reading of anthocyanin absorbance at λ_{max} needs to subtracted with absorbance at $\lambda = 700$ nm to ensured that the absorbance (A) of anthocyanin was precision without the disturbance from other materials since there was no absorbance of anthocyanin that occurred at $\lambda = 700$ nm.

Total anthocyanin content was calculated by Equation (2) as mg cyanidin-3-glucoside (C3G) equivalent per g dried weight of purple sweet potato:

$$Total\ anthocyanin\ (mg/L) = \frac{A \times MW \times DF \times 1000}{\varepsilon \times L} \tag{2}$$

Where MW = molecular weight of C3G (449.2 g/mol), DF = dilution factor, 1000 = conversion factor from g to mg, ε = C3G molar absorptivity (26900 L/mol.cm), and L = cell path length (1 cm).

2.5.2 Total phenolic content

The total phenolic content was determined using the Folin-Ciocalteu method with a gallic acid standard curve at the concentration of 50, 75, 100, 125, and 150 mg/L in distilled water (Cindrić *et al.*, 2011; Belwal *et al.*, 2016). A total of 0.5 mL sample was dissolved in 4.5 mL of distilled water, then 0.5 mL of 10% (v/v) phenol Folin-Ciocalteu reagent was added and incubated for 5 mins. Afterward, 1.5 mL of 20% (w/v) Na_2CO_3 was added to form a blue complex and incubated again for 90 mins. The absorbance was measured at 765 nm with distilled water was used as a blank. Total phenolic content was calculated as mg gallic acid equivalent (GAE) per g dried weight of purple sweet potato.

2.5.3 Total flavonoid content

The total flavonoid content was analyzed using the $AlCl_3$ colorimetric method with a quercetin standard curve at the concentration level of 10, 20, 30, 40, and 50 mg/L in distilled water potato (Belwal *et al.*, 2016; Cai *et al.*, 2016). A total of 0.5 mL sample was dissolved in 1.5 mL of distilled water, then 0.5 mL of 10% (w/v) $AlCl_3$ was added. Afterward, 0.1 mL of CH_3COOK and 2.8 mL of distilled water were added and incubated for 30 mins. The absorbance was measured at 415 nm with distilled water as a blank. Total flavonoid content was calculated as mg quercetin equivalent (QE) per g dried weight of purple sweet.

2.5.4 Antioxidant activity

Antioxidant activity was analyzed using the DPPH method, according to Marinova and Batchvarov (2011). Sample absorbance was measured by adding a 150 µL sample with 1350 µL of 96% ethanol and 1.5 mL of 0.06 mmol/L DPPH solution. Control absorbance was measured by adding 1.5 mL of 96% ethanol with 1.5 mL of 0.06 mmol/L DPPH solution. Afterward, all of the solutions were incubated for 30 mins. The absorbance was measured at 517 nm, with 96% ethanol was used as a blank. The calculation of antioxidant activity calculated by Equation (3)

$$Antioxidant\ activity\ (\%) = \left[\frac{(A_{control} - A_{sample})}{A_{control}}\right] \times 100\% \tag{3}$$

2.6 Physical analyses

2.6.1 Water content

The water content of the anthocyanin powder was measured, according to Yaméogo *et al.* (2011). A total of 1 g anthocyanin powder was put into a weighed petri dish (initial weight), then dried in the oven dryer at $105^{\circ}C$ for 2 hrs. Afterward, the petri dish was moved into desiccator for 1 hr and finally weighed. The water content was calculated by Equation (4):

$$Water\ content\ (\%) = \frac{Initial\ weight - final\ weight}{sample\ weight} \times 100\% \tag{4}$$

2.6.2 Water activity

A total of 5 g anthocyanin powder was put into a small petri dish. The water activity was determined using water activity (A_w) meter (AQUALAB® 4TE, USA) at 25°C (Zhu and Sun, 2019).

2.6.3 Solubility

The solubility of the powder was carried out, as described by Jivan *et al*. (2014). A total of 5 g anthocyanin powder was dissolved in 100 mL water and shaken at 2500 rpm for 1 min on a vortex. The solution was centrifuged at 1811 x *g* for 5 mins, and then the supernatant was put into a weighed petri dish and dried in the oven dryer at 105°C overnight. The petri dish was weighed, then the solubility was calculated by Equation (5):

$$\text{Solubility (\%)} = \frac{\text{Weight of solid in supernatant}}{\text{Sample weight}} \times 100\% \qquad (5)$$

2.6.4 Viscosity

The viscosity of powder was measured, according to Ekpong *et al*. (2016). A total of 5 g anthocyanin powder was dissolved in 100 mL water (5% w/v). The dial reading number was measured using a viscometer (Brookfield LVT 230, USA). Viscosity was calculated by Equation (6):

Viscosity (mPa.s) = Dial reading number x factor (spindle number 61 at 30 rpm)   (6)

2.6.5 Color

A total of 5 g anthocyanin powder was put into a small petri dish. The brightness level (L*), red (a*), yellow (b*) color intensity, hue (h*), and chroma (C*) of the powder were measured using Portable Colorimeter (NH301, China) at 25°C. The values were standardized with a white plate (Steed and Truong, 2008; Ekpong *et al*., 2016).

2.7 Statistical analysis

All analyses were done in duplicate. One-way analysis of variance (ANOVA) was performed on the statistical data analysis using IBM SPSS Statistics 24. Further statistical analysis of significant differences was performed by Duncan Test at $p < 0.05$.

3. Results and discussion

3.1 Chemical properties of anthocyanin extract

Ethanol has been known to effectively extracted the total anthocyanin content as its lysis ability on the vacuole membrane and enhance osmosis efficiency. A previous study has revealed that the total anthocyanin content in the purple sweet potato, which extracted using citric acid-ethanol solvent (0.83 mg/g), was higher than the citric acid-water solvent (0.17 mg/g) (Chen *et al*., 2019). Interestingly, total anthocyanin and flavonoid contents extracted with citric acid-water in this study were higher significantly ($p < 0.05$) than citric acid-ethanol, as shown in Table 1. This finding gives useful information about the cost-effectiveness of the optimum extraction condition since water is cheaper than ethanol. Agrees with Halee *et al*. (2018), water has been able to extract higher anthocyanin content compared to ethanol in black rice bran. It might be due to the lower viscosity of water rather than ethanol (0.89 cps and 1.07 cps, respectively) that increased the efficiency of extraction as it could be more dispersed into the sample and dissolved anthocyanin and flavonoid contents (Alam *et al*., 2018).

The highest of total anthocyanin content was obtained by extraction using water with 2 g/100 mL of citric acid. The addition of 2 g/100 mL citric acid produced a pH value of 2.01. Based on Lu *et al*. (2010), the optimum of total anthocyanin content has been obtained from extraction using acidified water at pH <3, since it made anthocyanin a stable flavylium cation form. However, the use of a higher concentration of acid caused partial hydrolysis of anthocyanin, which

Table 1. Chemical properties of anthocyanin extracts

Solvent	Citric acid (g/100 mL)	pH	Total anthocyanin content (mg/g)	Total phenolic content (mg GAE/g)	Total flavonoid content (mg QE/g)	Antioxidant activity (%)
Water	0	4.72	1.78±0.35[e]	13.24±0.01[d]	9.62±0.11[c]	64.54±2.16[a]
	2	2.01	5.23±0.07[a]	12.81±0.01[f]	7.65±0.29[f]	57.72±4.93[b]
	4	1.82	4.61±0.23[b]	13.13±0.03[d]	8.98±0.26[d]	29.32±0.78[e]
	6	1.71	4.58±0.19[b]	12.99±0.06[e]	9.60±0.40[c]	4.77±0.29[g]
Ethanol	0	7.86	3.67±0.04[c]	14.99±0.10[a]	29.62±0.15[a]	63.18±0.24[a]
	2	3.21	3.87±0.06[c]	12.94±0.08[e]	6.34±0.11[g]	48.63±0.97[c]
	4	2.94	3.56±0.32[c]	13.37±0.00[c]	8.21±0.02[e]	38.64±0.39[d]
	6	2.77	2.41±0.07[d]	14.04±0.01[b]	12.75±0.00[b]	12.73±2.01[f]

Values were expressed as mean±S.D. Different superscripts in the same column indicate significantly different at $p < 0.05$

decreased in anthocyanin content (Abou-Arab *et al*., 2011).

The total phenolic content in the citric acid-ethanol extract was significantly higher ($p < 0.05$) than in citric acid-water. This finding is a contradiction with the anthocyanin and flavonoid content, which was higher in citric acid-water than citric acid-ethanol extract since anthocyanin and flavonoid included in the group of phenolic compound. It might be due to the purple sweet potato used in this study likely contain other phenolic components that extracted more effectively using ethanol, as have been revealed in previous studies (Jung, 2011; Musilová *et al*., 2017; Meng *et al*., 2019).

Although the increase in citric acid concentration increases the number of total phenolic and flavonoid contents, still the extract without the addition of citric acid in both types of solvent produced higher total phenolic and flavonoid contents compared to those added with acid citric. This finding agrees with research by Halee *et al*. (2018). The phenolic component of purple sweet potato consists of two forms, which are free and bound. Free-form phenolics can be extracted well using acidified organic solvents. Meanwhile, the bound-form phenolics can be extracted using acid or base hydrolysis. Thus it can be extracted well without the addition of acid (Gao *et al*., 2017; Meng *et al*., 2019).

The antioxidant activity of the extracts showed an upward trend as the increase in total anthocyanin content. Anthocyanin has antioxidant activity due to the facilitation of electron donor capacity or donation of the hydrogen atom (Ma *et al*., 2020). According to Sun *et al*. (2018), purple sweet potato has peonidin and cyanidin-based anthocyanins, which have high antioxidant activity compared to other types of anthocyanins. A high value of antioxidant activity was obtained in a sample containing lower anthocyanin but had the highest of the total phenolic and flavonoid contents as well. This finding is due to the role of phenolic and flavonoid, which also contributes to increasing antioxidant activity (Dovene *et al*., 2019).

3.2 Chemical properties of anthocyanin powder

Anthocyanin powder was obtained using a foam mat drying process from anthocyanin extracted with the addition of 2 mg/100 mL citric acid as the optimum extraction condition due to the total anthocyanin content. According to Table 2, total anthocyanin content in the powder made from water extract was significantly higher ($p < 0.05$) than ethanol extract. This value is in line with the total anthocyanin content in the extract before the drying process. The use of 20 g/100 mL egg white as a foaming agent has significantly reduced the total anthocyanin content than the use of 10 g/100 mL egg white in both extracts. It might be due to the dilution effect of anthocyanin as the increase in the number of egg white (Abbasi and Azizpour, 2016). The total anthocyanin, phenolic, and flavonoid contents in all powders decreased compared to extract. It occurred due to degradation of the phenolics compound during heating (Abbasi and Azizpour, 2016) and the effect of dilution of the components due to the addition of other materials in making foam such as egg whites, CMC, and maltodextrin.

Increasing the egg white caused increased antioxidant activity in both samples. It might be due to changing bioactivity of protein in the egg white during drying, which produced antioxidant activity (Wang *et al*., 2018). Antioxidant activity was affected by total phenolic and flavonoid contents as well. Buljat *et al*. (2019) have stated that some polyphenols and antioxidants that extracted using ethanol were able to bind the proteins and form the stable complexes, which affected their physiological properties, including antioxidant activity.

3.3 Yield and physical properties of anthocyanin powders

An increase in egg white concentration increased the yield of the powders, as seen in Table 3. This finding is in line with Haryanto (2016), which reported that an increase in egg white concentration could increase the yield of mangosteen peel powder because of an increase in total solid of egg white. The yield of the powder from ethanol extract was lower than the water extract. Ethanol could decrease surface tension that formed the unstable transient foam. The drying of unstable foam resulted in reducing the total solids of powder (Hardy and Jideani, 2017).

Table 2. Chemical properties of anthocyanin powders

Solvent	Egg white (g/100 mL)	Total anthocyanin content (mg/g)	Total phenolic content (mg GAE/g)	Total flavonoid content (mg QE/g)	Antioxidant activity (%)
Water and 2 g/100 mL citric acid	10	0.17±0.00[a]	6.65±0.15[b]	0.78±0.02[b]	53.12±0.12[c]
	20	0.16±0.00[b]	6.51±0.10[b]	0.74±0.02[b]	59.76±0.23[b]
Ethanol and 2 g/100 mL citric acid	10	0.07±0.00[c]	6.53±0.00[b]	1.31±0.03[a]	88.94±1.90[a]
	20	0.04±0.00[d]	7.27±0.02[a]	1.30±0.02[a]	90.35±2.19[a]

Values were expressed as mean±S.D. Different superscripts in the same column indicate significantly different at $p < 0.05$

Table 3. Yield and physical properties of anthocyanin powders

Solvent	Egg white (g/100 mL)	Yield (%)	Water content (%)	Water activity	Solubility (%)	Viscosity (mPa.s)
Water and 2 g/100 mL citric acid	10	8.74±2.41[ab]	5.47±0.13[a]	0.27±0.00[b]	80.26±2.17[a]	6.40±0.57[a]
	20	11.86±1.15[a]	3.08±0.40[b]	0.30±0.00[a]	75.92±0.69[b]	6.00±0.00[a]
Ethanol and 2 g/100 mL citric acid	10	5.52±0.61[c]	3.51±0.07[b]	0.24±0.01[c]	82.26±0.03[a]	6.60±0.57[a]
	20	7.92±0.11[b]	2.38±0.02[c]	0.27±0.00[b]	78.98±0.53[ab]	6.00±0.00[a]

Values were expressed as mean±S.D. Different superscripts in the same column indicate significantly different at $p < 0.05$

The water content of powders can be seen in Table 3. The higher the egg white concentration was used, the lower the water content was obtained. An increase in egg white could increase the surface area of the foam. Thus, water evaporation occurred faster passed the foam layers during the foam mat drying process resulted in the lower water content (Abbasi and Azizpour, 2016; Hardy and Jideani, 2017).

Water activity determined the food product shelf life since the higher water activity can support the microorganism's growth and biochemical reactions (Nawi *et al*., 2015). Based on the analysis (Table 3), the water activity of the powders was low, which means it was microbiologically stable because of the values less than 0.60. The increase in egg white concentration increased the water activity value. It caused by amphiphilic albumin in egg white tends to re-absorb water after going through a drying process (Hardy and Jideani, 2017).

Based on the solubility analysis (Table 3), the powders yielded good solubility. The addition of maltodextrin and CMC might cause it. The number of hydroxyl groups in both materials contributes to the solubility of anthocyanin powder because it can absorb water easily. Also, CMC could form and maintain the porosity or absorption properties of the powder after drying, which is easily dissolved by water (Abbasi and Azizpour, 2016; Ekpong *et al*., 2016). In this study, maltodextrin was used as a carrier agent to prevents the formation of the aggregates. Meanwhile, CMC was used as a foam stabilizer. According to the result in Table 3, the higher the egg white concentration used, the lower the powder solubility was obtained. It might be due to the protein denaturation during the drying process resulting in the formation of insoluble residue and decreased solubility level (Hardy and Jideani, 2017).

According to the viscosity analysis (Table 3), variations of egg white concentration did not affect the viscosity in all samples. Ekpong *et al*. (2016) have reported that various viscosity caused by the addition of maltodextrin. In addition, the use of CMC might have been related to the change of viscosity rather than maltodextrin, as CMC was a thickening agent. In this study, the concentration of maltodextrin and CMC were the same in all treatment. Thus the viscosities were the same in all samples.

Color properties are shown in Table 4. The brightness level of anthocyanin powders made from water extract was lower than ethanol extract. Contrary to that, the red and yellow color intensities of anthocyanin powders made from water extract were higher than ethanol extract. As the pH of anthocyanin extract from water extract (2.01) was lower than ethanol extract (3.21), the color of the powder from water extract becomes redder and darker since anthocyanin gives a red color in flavylium cation form at pH 1-3. At pH > 3, the hydration of the flavylium cation was occurred, allowing the reduction of the red color intensity (Pham *et al*., 2019).

The concentration of the egg white did not affect the red and yellow color intensity in all powders. Meanwhile, the use of 20 g/100 mL egg white significantly increased the brightness level in the powder made from water extract but did not affect the powder obtained from ethanol extract. These results are in line with Tan and Sulaiman (2020) for Hibiscus sabdariffa L. The white color of egg white and presenting of the air in the porous powder lead to the increase in brightness level.

Hue was used to defining the color. The hue values of powders were in the range of 14.32-20.05°, indicating that the colors of powders were a red color, as an angle

Table 4. Color properties of anthocyanin powders

Solvent	Egg white (g/100 mL)	Brightness	Red	Yellow	Hue (°)	Chroma
Water and 2 g/100 mL citric acid	10	23.21±1.62[c]	23.16±1.03[a]	8.47±0.99[a]	20.05±1.33[b]	24.67±1.31[b]
	20	28.19±0.87[b]	22.52±0.78[a]	7.88±0.25[a]	19.28±0.06[b]	23.86±0.81[b]
Ethanol and 2 g/100 mL citric acid	10	33.47±0.45[a]	16.93±0.18[b]	4.39±0.08[b]	14.53±0.13[a]	17.49±0.20[a]
	20	32.48±1.70[a]	17.36±0.98[b]	4.42±0.08[b]	14.32±1.01[a]	17.92±0.93[a]

Values were expressed as mean±S.D. Different superscripts in the same column indicate significantly different at $p < 0.05$

of 0 or 360° represents red hue. Chroma was used to determine the degree of the hue. The red color intensity was increased as the increase in chroma value (Pathare *et al*., 2013).

4. Conclusion

Extraction using a water solvent with 2 g/100 mL of citric acid was the most effective condition to obtain the highest total anthocyanin content. However, its total phenolic, flavonoid, and antioxidant activity were lower compared to others. Total anthocyanin content of foam mat dried purple sweet potato powder made from the citric acid-water extract was significantly higher than the powder made from the citric acid-ethanol extract. There was no effect in the total phenolic, flavonoid, viscosity, and yellowish-red color of the powder obtained from citric acid-water extract as the increase of egg white concentration. The use of 20 g/100 mL egg white in both powders produced from citric acid-water and ethanol extracts resulted in higher total anthocyanins and solubilities than powders using 10 g/100 mL egg white. The color of the powder obtained from citric acid-water extract had a lower brightness level and higher yellowish-red color intensity compared to the powder made from citric acid-ethanol extract. Based on the total anthocyanin content and its physical properties, the foam mat dried purple sweet potato anthocyanin powder produced by using 20 mg/100 mL of egg white from water extract added by 2 g/100 mL of citric acid can be applied as a functional ingredient that contains antioxidant activity in the food product development.

Conflict of interest

The authors declare no conflict of interest.

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