Food Research 7 (6) : 197 - 204 (December 2023)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Extraction, foam-mat drying, and physicochemical analysis of Indonesian black glutinous rice (*Oryza sativa* L. var glutinosa) anthocyanins

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Article history:
Received: 5 February 2022
Received in revised form: 11 March 2022
Accepted: 5 September 2022
Available Online: 19 December 2023

Keywords:
Anthocyanins,
Foam-mat drying,
Indonesian black glutinous rice,
Maceration,
Physicochemical properties

DOI:
https://doi.org/10.26656/fr.2017.7(6).894

Abstract

Anthocyanins are water-soluble flavonoid that gives a purplish-blue colour to black glutinous rice. Anthocyanins can be degraded by high temperature (>65°C), oxygen, and light during storage. Foam-mat drying is expected to maintain anthocyanins from degradation and prolong their shelf life. This research aimed to obtain the optimum condition for anthocyanins extraction and foam-mat drying with the physicochemical evaluation of anthocyanins extract. The extraction process was done by the maceration method using food-grade solvents, water+citric acid and water, at four different times (6, 18, 24, and 48 hrs). Ethanol+citric acid were used as a control. The results showed that extraction using water+citric acid solvent for 48 hrs yielded higher total anthocyanins content (2.15±0.03 mg/g rice) than using water solvent (0.70±0.01 mg/g rice). Production of anthocyanins powder was carried out using the foam-mat drying method with the variation of maltodextrin (10 and 20%) and egg white (7.5, 10, and 20%) as the encapsulant and foaming agent. The highest anthocyanins content (0.45±0.06 mg/g powder) was obtained from water+citric acid extract mixed with 10% maltodextrin and 7.5% egg white. The solubility of its powder was acceptable (96.23±0.67%), and the water activity fulfilled the water activity standard of the powder drinks (0.33±0.00). In conclusion, the most optimum condition for anthocyanins extraction was using water+citric acid for 48 hrs and foam-mat drying using 10% maltodextrin and 7.5% egg white.

1. Introduction

Black glutinous rice (*Oryza sativa* Linn. Var. glutinosa) has good benefits for the body since it contains high amounts of phenolic compounds, especially anthocyanins. Black glutinous rice production in Indonesia can reach up to 550 tons per year. However, the consumption rate is generally low due to a slightly nutty flavour and high amylopectin content in black glutinous rice requiring soaking and long cooking time (Setiawati *et al*., 2013).

Anthocyanins of black glutinous rice have high antioxidant activity. Tananuwong and Tewaruth (2010) reported that anthocyanin extracted from black glutinous rice using acetone-water mixture was 352 µg/g flour with an antioxidant activity calculated in EC_{50} (g flour/g DPPH) was 59.3. In addition to antioxidant activity, anthocyanins also act as anti-carcinogenic, anti-inflammatory, antimutagen, and anti-hyperlipidemia (Pitija *et al*., 2013). Anthocyanins could be obtained using extraction (Ekaputra and Pramitasari, 2020). Anthocyanin extraction generally uses non-food grade solvents such as ethanol and methanol. Hence, the food-grade solvents (water and citric acid solution) were used in this study. The extractability of anthocyanins depends on the polarity and pH of the solvent, extraction time, and temperature. Therefore, it is necessary to find the optimum extraction conditions to obtain optimum extract results.

Anthocyanins degrade increasingly as water content and water activity increase due to the molecular water diffusion that increases the degradation reaction (Aguidelo-Lavarde *et al*., 2013; Lavelli and Kerr, 2019). Foam-mat drying is one method to decrease the water content and water activity. This method is processed in which liquid or semi-liquid food is whipped to a stable foam in the presence of a foaming agent and then subsequently dried. Its drying temperature is below the starting limit of degraded anthocyanins and uses a lower temperature than other conventional drying method (Abbasi and Azizpour, 2016). Besides, inhibition of the degradation rate was caused by maltodextrin as an encapsulation agent. It forms a barrier that protects

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

anthocyanins from oxidative degradation to increase the shelf life of anthocyanins (Idham *et al*., 2012). The purpose of this study was to obtain the optimum conditions of anthocyanin extraction and drying from black glutinous rice and the physicochemical properties evaluation of anthocyanin extracts.

2. Materials and methods

2.1 Materials

Black glutinous rice (*Oryza sativa* L. var. glutinosa) and citric acid (Koepoe Koepoe) were purchased from the local market. Reagents used were ethanol and methanol (PT. Smart Lab, Indonesia), potassium chloride, sodium acetate, 1,1-diphenyl-2-picrylhydrazyl (DPPH), gallic acid, quercetin, ascorbic acid (Sigma Aldrich, Germany), and maltodextrin DE 10 (Qinhuangdao Lihua Starch, China). All chemical reagents are analytical grade.

2.2 Preparation of black glutinous rice

The black glutinous rice without other impurities was crushed using a blender (Miyako BL-152 GF, Indonesia) until it became powder. The powder was then sieved using an 80-mesh sieve to obtain a powder at an appropriate and uniform size. Furthermore, the powder was stored in a dry place, tightly closed and protected from sunlight with a temperature of 4°C.

2.3 Anthocyanins extraction

The extraction method was adapted from Sam *et al.* (2008) with modification. The black glutinous rice powder was extracted with water and water-citric acid mixture (4% w/v). Ethanol-citric acid mixture (25% w/v) was used as a control. Citric acid was used to decrease pH up to pH 2. Sample: solvent ratio for maceration was 1:10 (w/v). The extraction was done three times to obtain a total extraction time of 6, 18, 24, 48 hrs. At room temperature, all extractions were done in an orbital shaker (GFL 3017, Germany) at 100 rpm. The supernatant and pellet were separated by centrifugation at 700×*g* for 20 mins at room temperature. The supernatant was combined from the first to the third extraction and filtered using Whatman No. 1 filter paper. The control ethanol solvent was evaporated using a rotary evaporator (BUCHI R-300, Germany) at 50°C.

2.4 Determination of total anthocyanin content

Total anthocyanins content was determined by the pH differential method (Giusti and Wrolstad, 2005). This assay was carried out for anthocyanin extract before and after drying. The crude extract was diluted with pH 1 potassium chloride buffer and pH 4.5 sodium acetate buffer. The absorption of the sample was measured at a wavelength of 513 nm using a UV-Vis spectrophotometer (Thermo Scientific, USA). Measurement of the wavelength at 700 nm was also used to eliminate the effect of haze or sediment in the sample. The following equation calculated the concentration of anthocyanins content:

$$\text{Total anthocyanins content (mg/L)} = [A_{diff} \times MW \times DF \times 1000] \,]/\, \varepsilon \quad (1)$$

$$A_{diff} = (A_{520} - A_{700})_{pH\ 1.0} - (A_{520} - A_{700})_{pH\ 4.5} \quad (2)$$

Where MW represents the molecular weight of cyanidin3-glucoside (449.2), DF is the dilution factor, ε is molar absorptivity of cyanidin-3-glucoside (256,9000 L/mol cm).

2.5 DPPH radical scavenging activity assay

The antioxidant activity was determined according to Pedro *et al.* (2015), with slight modification. Measurements were made on anthocyanin extract before and after drying. A total of 2 mL of crude extract was mixed with 1.5 mL 0.2 mM DPPH solution and stored at room temperature for 30 mins. Absorbance measurement was carried out at a wavelength of 517 nm. 200 mg/L of ascorbic acid was used as a standard. The ability of the extract to scavenge the DPPH was calculated using equation (3):

$$\text{Scavenging ability (\%)} = [(\text{A control} - \text{A sample}) / \text{A control}] \times 100 \quad (3)$$

Where A control is the absorbance of the blank DPPH in the form of a mixture of DPPH solution, A sample is the absorbance of the mixture of sample and DPPH solution.

2.6 Determination of total phenolic content

Total phenolic content was determined according to Pedro *et al.* (2015) with modification. The total phenolic content was calculated using the Folin-Ciocalteu method before and after drying. A total of 0.2 mL crude extract was mixed with 1 mL of Folin-Ciocalteu reagent 0.01% (v/v) and incubated for 5 mins in a water bath shaker at 50°C and 1×*g*. After that, 0.8 mL of 7.5% sodium carbonate solution was added then its absorbance was measured at a wavelength of 765 nm. It was performed using the calculation from standard curves made from gallic acid for total phenolic content.

2.7 Determination of total flavonoid content

The measurement of flavonoid content was carried out by the colorimetric aluminium chloride method for anthocyanins extract before and after drying. The 0.1 g of anthocyanin samples were dissolved in 1 mL of distilled water. Added the 0.5 mL of the solution with

https://doi.org/10.26656/fr.2017.7(6).894

1.5 mL ethanol, 0.1 mL of aluminium chloride 10% (w/v), 0.1 mL CH_3COOK 1M, and 2.8 mL distilled water then left for 40 mins at room temperature. Absorbance was measured with a wavelength of 415 nm. Quercetin standard curves are used in calculations (Azizah *et al.*, 2014).

2.8 Foam-mat drying

With slight modifications, the method was obtained from Abbasi and Azizpour (2016) and Sritongtae *et al.* (2017). For the hydration of the gum, 1 g carboxymethyl cellulose (CMC) was dissolved in 100 mL of hot distilled water until the hydration process was completed and then kept in the refrigerator (4°C). The making of anthocyanin extract powder from the crude extract was carried out using foam-mat drying. The crude extract was added with maltodextrin (10 and 20 g/100 g), egg white (7.5, 10, 20 g/100 g), and CMC 1 g/100 g solution, then mixed for 4 mins until formed a stable foam. The foam was spread on the aluminium tray and then dried in an oven (Memmert UN 110, Germany) at 50°C overnight. Then the drying powder was sieved with a 60-mesh sieve and stored at -20°C for further analysis.

2.9 Solubility

Solubility was measured as Vongsumran *et al.* (2014) described with some modifications. Five grams of anthocyanin powder were dissolved in 50 mL of distilled water and then transferred to the centrifugation tube. The tubes were centrifuged at 9000×*g* for 10 mins. The pellet was poured into the Petri dish. The weight of the dry solid was found by heating it overnight in an oven at 105°C. Solubility was calculated by equation (4):

$$\text{Solubility} = 1\text{-}(M2\text{-}M1 \,/\, \text{dry weight sample}) \times 100 \quad (4)$$

Where M1 is the weight of an empty Petri dish and M2 is the weight of the Petri dish after drying.

2.10 Viscosity

Viscosity measurement was carried out using a viscometer (Brookfield LVT 230, USA) with a spindle number of 61 and a speed number of 20. The viscosity results were obtained from the factor number times the values obtained from the viscometer. The factor number was determined by spindle number and speed (Ekpong *et al.*, 2016)

2.11 Water activity

Water activity measurement was carried out using the Aw Meter (AquaLab 4TE, USA). Anthocyanin powder was placed in a container until it reached the specified limit and then put into the tool (Ferrari *et al.,* 2013).

2.12 Moisture content

Moisture content was determined according to Andriani *et al.* (2015). Anthocyanin powder was spread on a Petri dish and then dried in an oven at 105°C. The extract is weighed repeatedly over a while until the weight becomes constant. Moisture content was then calculated using the following equation (5):

$$\text{Moisture content (\%)} = (\text{initial sample weight} - \text{final sample weight})/\text{initial sample weight} \times 100 \quad (5)$$

2.13 Colour measurement

The colour of the anthocyanin extract was measured using a colorimeter (NH301, China) that was calibrated using white calibration tiles. The results were obtained in several parameters, L*, a*, and b*. L* indicates brightness from 100-0 (white-black), a* represents the colour trait between green (-a*) and red (+a*), while b* represents the colour trait between blue (-b*) and yellow (+b*) (Franco *et al.* 2016).

2.14 Statistical analysis

Statistical analysis was performed using IBM SPSS 22 software. Analysis of variance (ANOVA) of the experimental data and Duncan Test was performed to determine significant differences from the mean at a 95% significance level.

3. Results and discussion

3.1 Determined the optimum condition of black glutinous rice crude extract

The chemical properties of anthocyanin extract obtained from different extraction conditions are shown in Table 1. The statistical analysis showed that the total anthocyanin for water+citric acid did not significantly differ after 18 hrs of maceration time. Total anthocyanin for water solvent decreased after 24 hrs maceration, while in control (ethanol+citric acid) did not provide a significant difference. The highest number of anthocyanins content in the water solvent was lower than the control ethanol+citric acid, while the water+citric acid solvent did not differ significantly from the control.

Anthocyanins are bioactive compounds that are stable under acidic conditions. In acidic conditions, cation flavylium forms, which causes the red colour and stable condition. Under the condition of neutral pH, cation flavylium will change to quinoidal form, which is an unstable component (Lee *et al.,* 2005). Water solvent has a neutral pH, causing unstable anthocyanin conditions, making anthocyanin decrease after 24 hrs of maceration. In contrast to water+citric acid and ethanol+citric acid, which have a low pH (pH = 2), anthocyanins are stable. The colour of the anthocyanin

https://doi.org/10.26656/fr.2017.7(6).894

Table 1. Total anthocyanins content, antioxidant activity, total phenolic content, total flavonoid content of black glutinous rice crude extracts obtained from different extraction times and solvent.

Solvent	Time (hrs)	Total anthocyanins (mg/g rice)	Antioxidant activity (%)	Total Phenolic (mg GAE/g rice)	Total Flavonoid (mg QE/g rice)
Water	6	0.46±0.03^{ab}	58.38±7.21^{def}	0.73±0.04^{bcd}	0.10±0.04^{ab}
	18	0.62±0.05^{bc}	60.25±2.42^{ef}	0.63±0.07^{abc}	0.11±0.07^{ab}
	24	0.70±0.01^{c}	53.75±0.86^{bcdef}	0.47±0.04^{a}	0.10±0.07^{ab}
	48	0.39±0.07^{a}	38.99±2.58^{a}	0.52±0.04^{ab}	0.10±0.05^{ab}
Water+citric acid	6	1.71±0.15^{d}	45.48±0.31^{abc}	0.93±0.00^{de}	0.21±0.02^{abc}
	18	2.05±0.05^{ef}	55.61±3.22^{cdef}	0.92±0.04^{de}	0.09±0.03^{ab}
	24	2.10±0.01^{ef}	57.99±3.67^{def}	0.99±0.28^{e}	0.05±0.05^{a}
	48	2.15±0.02^{f}	50.33±7.07^{abcde}	0.97±0.02^{de}	0.16±0.13^{ab}
Ethanol+citric acid (control)	6	1.71±0.09^{d}	43.04±8.85^{ab}	0.98±0.17^{e}	0.28±0.04^{bc}
	18	1.94±0.03^{e}	47.14±5.76^{abcd}	0.82±0.01^{cde}	0.13±0.00^{ab}
	24	2.03±0.17^{ef}	55.90±2.90^{cdef}	0.94±0.01^{de}	0.29±0.11^{bc}
	48	2.22±0.03^{f}	65.28±5.62^{f}	0.98±0.02^{e}	0.41±0.17^{c}

Values are presented as mean±standard deviation. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

extract was redder than the extract from the water solvent. The acidic condition also can help the denaturation process of plant cells, making anthocyanins easier to dissolve. Thus, the total anthocyanins obtained from solvents with acidic conditions were higher than the solvent with neutral pH (Basito, 2011).

Anthocyanins have antioxidant activity due to hydroxyl groups that could provide their hydrogen atom for reactive species. Antioxidant activity in water solvent decreased after 24 hrs of maceration, while in water+citric acid did not differ significantly. The results are positively correlated with total anthocyanins content. Therefore, the antioxidant activity in this study could be sure that the majority comes from anthocyanins content. The antioxidant activity in water+citric acid and water did not significantly differ ($p>0.05$) from control ethanol+citric acid. However, the antioxidant activity from water and water+citric acid was lower compared to the antioxidant activity from standard ascorbic acid (82.16%).

Total phenolic content in the crude extract was in the range of 0.47-0.99 mg GAE/g rice, which was within the range of total phenolic in rice, 0.54-3.13 mg GAE/g rice according to Fardet *et al.* (2008). Only two extraction conditions are below that range, which is from water solvent 24 and 48 hrs of maceration. This can be due to neutral pH from water causing instability for phenolic conditions (Basito, 2011). The total flavonoid content in this study ranged between 0.05-0.41 mg QE/g rice. Antioxidant activity was caused by the ability of phenolics to donate hydrogen atoms to hydroxyl groups through electron transfer for radical species. The process converts phenolics into a stable phenoxyl radical. Likewise, the antioxidant activity from flavonoids also happened because of the ability to donate hydrogen atoms to free radical species (Adawiah *et al.,* 2016; Adawiah *et al.,* 2016). The phenolic content in black glutinous rice was ferulic acid, syringic acid, protocatechuic acid, gallic acid, caffeic acid, vanilla acid, 3,5-xylenol, cresol, p-coumaric acid, guaiacol, p-hydroxybenzoic acid (Vichapong *et al.,* 2010). The flavonoid compounds found in rice were quercetin-3-O-glucoside, quercetin-3-O-routineoside, apigenin-5/8-pentoxide-8/6-C-hexoside, isorhamnetin-3-O-glucoside (Peirera-Caro *et al*., 2013).

3.2 Determined the optimum foam-mat drying conditions of anthocyanin extract

The optimum extraction condition of each solvent (24 hrs for water, 48 hrs for water+citric acid, and ethanol+citric acid) was continued for the drying process of anthocyanin extracts. Based on Table 2, egg white and maltodextrin could cause the dilution effects of anthocyanins. Thereby the total anthocyanin content is decreased. Compared with control ethanol+citric acid, the total anthocyanins content from water+citric acid was lower. Probably because foam stability could not be ascertained during the heating process, causing a longer heating time that decreased the total anthocyanin content. Anthocyanins content from the water solvent was lower than both water+ citric acid and control ethanol+citric acid. It could be influenced by anthocyanin conditions which were already unstable due to neutral pH (Ahmed *et al.,* 2009).

The antioxidant activity from water+ citric acid and water solvent was lower than control ethanol+ citric acid. The results are positively correlated with the total anthocyanins content of the powder. However, some

https://doi.org/10.26656/fr.2017.7(6).894

Table 2. Total anthocyanins content, antioxidant activity, total phenolic content, total flavonoid content of anthocyanin powders.

Solvent	Maltodextrin (g/100 g)	Egg white (g/100 g)	Total Anthocyanins (mg/g powder)	Antioxidant activity (%)	Total phenolic (mg GAE/g powder)	Total flavonoid (mg QE/g powder)
Water (24 hrs)	10	7.5	0.20±0.00^{a}	54.56±1.82^{abc}	0.10±0.00^{b}	0.01±0.00^{a}
		10	0.25±0.01^{ab}	55.58±1.27^{bc}	0.11±0.01^{c}	0.01±0.00^{ab}
	20	7.5	0.30±0.02^{bc}	53.08±1.36^{ab}	0.07±0.01^{a}	0.01±0.00^{a}
		10	0.30±0.01^{bc}	54.69±4.36^{abc}	0.10±0.00^{b}	0.01±0.01^{abc}
Water+citric acid (48 hrs)	10	7.5	0.45±0.06^{d}	66.30±0.63^{e}	0.13±0.00^{d}	0.02±0.00^{abc}
		10	0.37±0.02^{cd}	50.58±2.00^{a}	0.14±0.01^{e}	0.02±0.00^{bcd}
	20	7.5	0.42±0.01^{d}	57.89±0.00^{cd}	0.11±0.00^{c}	0.01±0.00^{abc}
		10	0.40±0.01^{d}	53.65±0.45^{abc}	0.12±0.00^{cd}	0.02±0.00^{bcd}
Ethanol+citric acid (48 hrs) (control)	10	7.5	0.70±0.03^{e}	67.91±1.01^{e}	0.11±0.00^{c}	0.03±0.01^{cde}
		10	0.65±0.08^{e}	66.88±2.00^{e}	0.15±0.01^{e}	0.04±0.01^{def}
	20	7.5	0.67±0.05^{e}	61.23±2.72^{d}	0.16±0.00^{f}	0.04±0.01^{ef}
		10	0.69±0.07^{e}	66.30±1.00^{e}	0.15±0.00^{e}	0.05±0.00^{f}

Values are presented as mean±standard deviation. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

values of antioxidant activity from water+citric acid did not have a positive correlation between total anthocyanins and activity antioxidants. Possibly, other phytochemicals may play a role in the antioxidant activity (Ahmed *et al.,* 2009).

The total phenolic content from water+citric acid and water decreased with the addition of maltodextrin (Table 2). The addition of maltodextrin increases dissolved solids in the sample to reduce the total phenolic content. Meanwhile, the total flavonoid content of the powder (Table 2) showed no significant difference in the addition of maltodextrin and egg white concentrations (Ahmed *et al.,* 2009).

The solubility of the powder is shown in Table 3. Solubility values did not show any significant difference. Therefore, the addition of maltodextrin and egg white concentrations did not significantly affect the solubility results ($p>0.05$). The solubility of the sample also was not significantly different from the standard of commercial drinks. The solubility values of the sample are quite high. Solubility could be caused by maltodextrin and CMC. Both have a role in maintaining the stability of the foam structure when heating. More bubbles from the foam during the heating process will increase the porosity and solubility of the powder, which leads to relatively high solubility in the sample. Besides, maltodextrin and CMC have several hydroxyl groups that can absorb water quickly and increase solubility (Ekaputra and Pramitasari, 2020; Abbasi and Azizpour, 2016).

The viscosity range could reach from 0.6-5,000,000 mPa s at a temperature range of -40°C-150°C (Manning and Hoover, 2003). Viscosity for water solvent obtained in the range of 5.50±0.7-10.50±0.71mPa s, for water+ citric acid solvent was 2.00±0.71-3.25±0.35 mPa s, and for ethanol+citric acid solvent was 1.00±0.00-3.00±0.00 mPa s. The viscosity for control of commercial drinks was 2.50±1.00 mPa s. This value did not significantly differ from the samples. The addition of CMC increases the viscosity due to its function as a thickening agent (Ekpong *et al.,* 2016). CMC was added to all treatments with the same amount. There was no significant difference between ethanol+citric acid and water+ citric acid solvents, but the extract from water solvent had a higher viscosity than from ethanol+citric acid solvent. However, the viscosities were still in the range of the standard (Manning and Hoover, 2003).

The water activity of the powders was less than the standard, which is 0.6. Microorganisms cannot grow at water activity less than 0.6, making it could extend the shelf life of the sample (Franco *et al.,* 2015). Moisture content could be affected by egg white and CMC. Egg white acts as a foaming agent and the foam was stabilized with the addition of CMC. The foaming agent and stabilizer make the drying process more accessible and faster, causing a decrease in water content value (Kadam and Balasubramanian, 2011). Based on Table 3, the addition of maltodextrin and egg white concentrations did not provide a significant difference in moisture content. However, there were significant differences when compared to standard commercial powder drinks. It might happen by differences in the drying method, where the temperature used for drying in this study was lower than the other conventional drying. Higher drying temperatures for commercial drinks were causing a decrease in moisture content (Mishra *et al.,* 2013).

https://doi.org/10.26656/fr.2017.7(6).894

Table 3. Solubility, viscosity, water activity, moisture content of anthocyanin powders.

Solvent	Maltodextrin (g/100 g)	Egg white (g/100 g)	Solubility (%)	Viscosity (mPa s)	Water activity	Moisture content (%)
Water (24 hrs)	10	7.5	99.01±0.52^{a}	7.00±1.41^{b}	0.33±0.00^{f}	7.95±0.83^{bc}
		10	98.80±0.72^{a}	5.50±0.71^{b}	0.23±0.00^{a}	6.77±0.49^{bc}
	20	7.5	99.26±0.51^{a}	10.50±0.71^{c}	0.30±0.00^{d}	7.39±0.99^{bc}
		10	99.02±0.53^{a}	7.50±2.12^{b}	0.23±0.00^{a}	7.23±0.72^{bc}
Water+citric acid (48 hrs)	10	7.5	96.23±0.67^{a}	3.25±0.35^{a}	0.33±0.00^{f}	7.62±0.14^{c}
		10	98.15±2.21^{a}	3.50±0.00^{a}	0.31±0.00^{e}	7.39±1.77^{bc}
	20	7.5	96.68±2.67^{a}	2.00±0.71^{a}	0.34±0.00^{f}	7.78±0.85^{bc}
		10	98.35±1.77^{a}	3.00±000^{a}	0.30±0.00^{d}	7.12±1.02^{bc}
Ethanol+citric acid (48 hrs) (control)	10	7.5	98.27±0.23^{a}	1.50±0.00^{a}	0.27±0.00^{c}	7.42±0.57^{bc}
		10	98.30±0.52^{a}	2.50±0.00^{a}	0.25±0.00^{b}	6.52±0.37^{b}
	20	7.5	96.22±3.57^{a}	1.00±0.00^{a}	0.25±0.02^{b}	7.63±0.38^{bc}
		10	94.86±5.62^{a}	3.00±0.00^{a}	0.26±0.00^{bc}	7.95±0.16^{bc}
Commercial powder drink (standard)			99.65%±0.03^{a}	2.50±1.00^{a}	0.29±0.02^{d}	0.53±0.02^{a}

Values are presented as mean±standard deviation. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

Table 4. Colour measurement (L*, a*, and b*) of anthocyanins powders.

Solvent	Maltodextrin (g/100 g)	Egg white (g/100 g)	L*	a*	b*
Water (24 hrs)	10	7.5	28.51±0.01^{f}	1.45±0.01^{a}	-0.82±0.01^{d}
		10	28.44±0.25^{c}	1.79±0.12^{b}	0.19±0.11^{g}
	20	7.5	27.41±0.04^{d}	1.90±0.06^{b}	-0.08±0.01^{f}
		10	26.08±0.08^{c}	2.26±0.18^{c}	0.36±0.13^{h}
Water+citric acid (48 hrs)	10	7.5	27.04±0.01^{d}	3.56±0.04^{g}	-0.92±0.03^{cd}
		10	27.57±0.20^{e}	3.51±0.09^{g}	-1.17±0.04^{a}
	20	7.5	28.33±0.01^{f}	2.99±0.03^{ef}	-1.11±0.01^{a}
		10	27.39±0.14^{d}	3.11±0.00^{f}	-0.83±0.06^{d}
Ethanol+citric acid (48 hrs) (control)	10	7.5	26.29±0.01^{c}	3.03±0.02^{f}	-1.02±0.14^{bc}
		10	24.85±0.00^{a}	2.74±0.07^{d}	-0.59±0.00^{e}
	20	7.5	25.30±0.11^{b}	2.95±0.01^{ef}	-0.60±0.00^{e}
		10	25.06±0.01^{a}	2.85±0.03^{d}	-6.25±0.00^{e}

Values are presented as mean±standard deviation. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

Several factors could influence L* values, i.e., concentration and type of pigment. The L* values for powder from water and water+citric acid solvents were higher than control ethanol+citric acid (Table 4). It might be due to more elevated anthocyanins content in the ethanol+citric acid solvent, making the colour of the sample more concentrated and less bright, resulting in the lower L*. The addition of maltodextrin and egg white reduced the value of a* because these ingredients were causing a decrease in anthocyanin content, making the intensity of the red colour decrease. The majority of b* values increased with increasing maltodextrin concentration, making the blue colour anthocyanin decrease (Yuliawaty and Susanto, 2015).

4. Conclusion

The optimum condition of black glutinous rice anthocyanin extraction based on total anthocyanin content in the crude extract was using water+citric acid solvent for 48 hrs. The highest anthocyanin content (0.45±0.06 mg/g powder) was obtained from water+citric acid extract mixed with 10% maltodextrin and 7.5% egg white. The solubility of its powder was acceptable (96.23±0.67%), and the water activity fulfilled the water activity standard of the powder drinks (0.33±0.00). The black glutinous rice anthocyanins powder had the potential to be a functional food ingredient based on its physicochemical properties.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors are thankful to the Faculty of Biotechnology, Atma Jaya Catholic University of

https://doi.org/10.26656/fr.2017.7(6).894

Indonesia, for providing facilities and financial support for this research work.

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