Food Research 9 (4) : 178 - 190 (August 2025)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Blue-colored rice flour innovation: a study of the effect of rice type and butterfly pea flower concentration

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Article history:
Received: 24 November 2023
Received in revised form: 6 March 2024
Accepted: 3 February 2025
Available Online: 25 July 2025

Keywords:
Butterfly pea flower,
Pandan leaf,
Blue-colored rice flour,
Stability

DOI:
https://doi.org/10.26656/fr.2017.9(4).370

Abstract

Commercial rice flour is usually white and odorless. The innovation of making rice flour by adding natural ingredients such as butterfly pea, which contains a flavonoid component, and pandan leaves, which contain the aromatic compound 2-acetyl-1-pyrroline (ACPY), can be used as an alternative way to produce more attractive blue-colored rice flour (BCRF) with pandan fragrance. This study investigated the effects of rice type (white and brown rice) and levels of butterfly pea flowers (1, 3, 5, 7, and 9%) added on the physical and chemical characteristics of BCRF, and organoleptic characteristics of *kue* talam (talam cake). The result showed that these two variables significantly affected the properties of BCRF. The addition of 9% butterfly pea flower to both types of rice was determined as the best treatment using the Multiple Attribute Zeleny method. Compared to the control treatment (rice flour without butterfly pea flower and pandan leaves), BCRF has higher moisture, ash, and protein content. At the same time, the total carbohydrate content (by difference) was lower. A general preference for BCRF in the form of talam cake was acceptable (3.73-4.55 out of 6.00). The stability of BCRF to temperature, pH, and light was tested using the interpretation of color change value (ΔE). The stability test result showed that the BCRF was relatively stable when stored at low or room temperature, but the color change was quite visible at 100°C. The color of flour was strongly influenced by pH; the color changed from red (pH 1-4) to blue when pH was increased (7–10). The color was relatively stable when stored in a dark room but tended to fade with more exposure to light. BCRF has better color stability when stored at low to room temperature, away from direct light, and with a neutral pH.

1. Introduction

The appearance of a product gives a subjective impression and increases customer interest in the product (Huang *et al*., 2022). One of the parameters of appearance is color (Wadhera and Capaldi-Phillips, 2014). Color has a close connection with the level of acceptance and intensity of taste. Color contrast between components, combined with neat serving, can raise consumer expectations for food taste. Color also creates an identity for a product so consumers can identify it easier (Gebhardt *et al*., 2020). The food coloring market continues to grow at a rate of 4.6% per year, and food coloring that is derived from natural sources is becoming a global research interest. Carotenoids, anthocyanins, and betacyanins are the most widely used pigments (Prajapati and Jadeja, 2022)

The practice of coloring foods has become part of the local wisdom of Indonesian society, which has been passed down from generation to generation. This is shown by the abundance of Indonesian food in various colors, one of which is talam cake. Long ago, before the use of commercial or synthetic food coloring, people traditionally used natural materials such as plant parts, flowers, leaves, roots, tubers, seeds, stems, and fruit as natural dyes. For example, to prepare green rice cake, they prepare rice flour by soaking the rice grains in water for several hours, then pounding the rice together with fresh leaves. The interaction will be formed between the pigments and the components of leaves and the components of rice, and then the color from the leaves will be fixed to rice flour. According to Zeng *et al*. (2022), components such as polyphenolic flavonoids can interact with starch through hydrogen and van der Waals bonds. Natural dyes are being used again because of concerns about food safety and nutritional benefits (Mathiyalagan *et al*., 2019).

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

Rice is a cereal that is widely grown and cultivated in Indonesia, and many traditional Indonesian snacks are made from rice flour. Indonesia was the 4th largest rice producer in the world in 2021, with a total production of 54.4 million tons (FAOSTAT, 2023). The milled rice will produce brown rice, and the polishing treatment of brown rice will produce white rice. Brown rice has a higher content of ash (minerals), fat, protein, and antioxidant activity while having lower carbohydrates and a lower glycemic index than white rice (Abubakar *et al.*, 2018). The appearance, color, and aroma of brown rice are less attractive despite being nutritionally better. Brown rice, unlike white rice, is brown in color and has a high-fat content, making it more susceptible to rancidity during storage. Furthermore, because brown rice has a mild nutty flavor, it is less popular in society (Upadhyay and Karn, 2018). When referring to wheat flour, the terms "white flour" and "whole grain flour" are frequently used. White flour is made from the endosperm part only, while whole wheat flour includes the bran and germ parts. Whole wheat flour has more nutritional value, while white flour has a longer shelf life and is easier to use as an ingredient because it has less discoloration and better processing characteristics (Carter *et al.*, 2015)

The butterfly pea flower (*Clitoria ternatea*) is believed to originate from Asia. Sensient Technologies recently developed butterfly pea flower as a natural blue food colorant that is water soluble, heat- and light-stable for a variety of applications including sports drinks, carbonated drinks, tea, candy, ice cream, fruit juices, yogurt, and it has already received FDA approval (Sensient Technologies, 2022). The active ingredients in the butterfly pea flowers include flavonoids, flavonol glycosides, kaempferol glycosides, anthocyanins, quercetin glycosides, and myricetin glycosides (Anthika *et al.*, 2015). The total anthocyanin content in butterfly pea flowers is 6.93 mg/g which is greater than java plum (5.90 mg/g) and mulberry fruit (4.76 mg/g) (Siti Azima *et al.*, 2017). Anthocyanins are pigments from the phenol group that dissolve in water and give colors ranging from blue, purple, and red to fruit, vegetables, and flowers. Cyanidin-3-glucoside is the main anthocyanin pigment found in plants (Khoo *et al.*, 2017).

Flour is produced by milling the rice grain. Milling is generally done by dry, wet, or semi-dry methods. Dry milling does not require soaking the grains, but it creates flour with a large particle size that is difficult to mix with other ingredients during food processing (Wu et al., 2019). Wet milling usually requires soaking the grains for 6-12 hours to soften the texture and make grinding easier (Zhang *et al.*, 2021). The soaked grains are then ground without draining the water into a paste, dried at 40°C, ground again, and sieved. Wet milling yields fine flour (Zhang *et al.*, 2021), but it necessitates a large amount of water and a lengthy soaking process, which causes some nutritional components to dissolve (Wu *et al.*, 2019). In the semi-dry milling method, rice is soaked, dried to a moisture content of 15-17% and ground by machine (Cho *et al.*, 2019).

Semi-dry milling was used in this study to prepare rice flour. However, the soaking process of rice grains leads to a change in the starch structure, which swells as a result of water absorption and causes acidification in the presence of microbes. In addition, several processes of steeping, grinding and milling can cause lipid oxidation (Ahmed et al., 2016), which can lead to off-odors. Therefore, fragrant pandan leaves (*Pandanus amaryllifolius*) are added in the process of making rice flour to enhance the aroma of rice flour. The fragrant aroma of pandan leaves originates from the 2-acetyl-1-pyrroline (2AP) molecule (Saensuk *et al.*, 2016). Pandan leaves also contain bioactive components such as tannin, alkaloids, flavonoids, and polyphenols, which can act as anti-microbial (Aini and Mardiyaningsih, 2009).

This research aimed to innovate blue-colored rice flour (BCRF) adopting the traditional grinding method, with butterfly pea flowers used as a blue dye and pandan leaf as a fragrance. The color intensity of the rice flour is most likely influenced by the type of rice and the ratio of the addition of butterfly peas. Therefore, there are two factors in this study, the type of rice and the percentage of added butterfly peas. BCRF is then tested for physical, chemical, sensory and stability. Since the flour is an intermediate product, the sensory testing with the preference test is done after BCRF is applied to the talam cake. Kue Talam is one of Indonesia's traditional cakes made with rice flour and coconut milk as the main ingredients. It is usually a combination of two layers, a colored and sweet part and a white salty coconut milk part (Hartati *et al.*, 2021).

Anthocyanin is a naturally degradable pigment. The stability of anthocyanins is affected by several factors such as temperature, pH, light and structure (Khoo *et al.*, 2017). High-temperature processing and light exposure can degrade anthocyanin monomers, resulting in brown color formation (Jiang *et al.*, 2019). In addition, several enzymes can degrade anthocyanins, such as polyphenol oxidases, peroxidases and β-glucosidases (Verbeyst *et al.*, 2010). Therefore, the stability of colored flours in relation to temperature, pH and light is also observed.

2. Materials and methods

2.1 Materials

Blue-colored rice flour was made using medium-

https://doi.org/10.26656/fr.2017.9(4).370

grain white rice ("Lahap") and medium-grain brown rice (N790) purchased from a local retail store, fresh butterfly pea flowers, and fresh aromatic pandan leaves. The materials for making talam cake were commercial coconut milk (Sasa), sugar (Gulaku), salt (Kapal) and palm oil (Bimoli).

2.2 Procedure for blue-colored rice flour making

Rice grains were soaked in water in a ratio of 1:2 for 3 hr at room temperature, drained and air-dried for 1 hr, ground together with fresh butterfly pea flowers (1, 3, 5, 7, and 9%w/w rice grains) and fresh 1% pandan leaves (w/w rice grains) using a grinder. Then the flour was dried in a cabinet dryer for 5 hrs at 55°C, sieved through a 100-mesh screen, and packed in a plastic bag until used for analysis.

2.3 Analysis of properties of colored flour

Physical analysis was performed using CIELAB color analysis using a color reader (Minolta CR-14). The chemical analysis performed included pH measurement (AOAC Official Method 943.02), moisture content (AOAC Official Method 925.10), water activity with an aw meter (Decagon Pawkit), total anthocyanin analysis (Lee *et al*., 2005) and antioxidant activity analysis (Plank *et al*., 2012). Analysis of total anthocyanin was performed by a spectrophotometric method based on absorbance measurements of samples dissolved in a buffer solution at pH 1.0 and 4.5.

Approximately 20 g of flour was dissolved in 50 mL of distilled water, homogenized with an orbital shaker at 150 rpm for 5 hrs, and filtered with fine filter paper. Then 5 mL of the filtrate was diluted with 10 mL of buffer pH 4.5 (buffer pH 5 was prepared by dissolving 5.433 g of $CH_3COONa.3H_2O$ in 100 mL of distilled water, the pH was adjusted to 4.5 with HCl) and buffer pH 1.0 (buffer was prepared by mixing 0.186 g of KCl with 100 mL of distilled water, pH adjusted to 1.0 with HCl). The absorbance of the filtrate was measured at 700 nm and at the maximum wavelength. Total anthocyanin in the sample was expressed in %, and calculated using the following equation:

$$Anthocyanin\ content = \frac{A \times MW \times FP \times 10^3}{\varepsilon \times 1} \times 100\%$$

$$\%\ Anthocyanin\ in\ samples = \frac{x\left(\frac{mg}{L}\right)}{sample\ weight\ (mg)} \times 100\%$$

Where A = (maximum ʎ absorbance value - absorbance value at 700 nm) of dissolved sample in pH 1.0 buffer - (maximum ʎ absorbance value - absorbance value at 700 nm) of dissolved sample in pH 4.5 buffer, MW = molecular weight of cyanidin-3-glucoside = 449.2 g/mol and ε = molar absorptivity coefficient, 26.900 molar/mol.cm.

Antioxidant activity test was performed by trolox method using DPPH reagent. The principle is to find the concentration of the sample when the absorbance value matches the absorbance value of the Trolox standard. A 2.5 g sample was dissolved in 10 mL methanol, homogenized with an orbital shaker at 150 rpm for 5 hrs, and filtered with fine filter paper to obtain the filtrate. Then, 1 mL of filtrate was added with 2 mL of DPPH solution, vortexed, and allowed to stand for 30 mins before measuring the absorbance at the maximum wavelength. Trolox standard curves were prepared by preparing a solution of trolox in ethanol at a series of concentrations of 0-10 µg/mL. 2 mL of DPPH solution for each concentration was added to 1 mL of Trolox solution, vortexed and allowed to stand for 30 mins. Absorbance was measured at the maximum wavelength. The sample concentration was expressed in mg TE/g and calculated using the following equation:

$$TEAC = \frac{V\ of\ sample\ reacted\ with\ DPPH \times Trolox\ concentration \times Dilution\ Factor}{Sample\ weight\ (initial)}$$

Sensory analysis of colored flour was performed using the hedonic method/preferability test applied to the Talam cake product. There were 40 panelists ranging from 16 to 60 years old. 10 samples were provided. The scores used were on a 6-point scale (1 = very dislike, 2 = dislike, 3 = somewhat dislike, = somewhat like, 5 = like, 6 = very like). The parameters tested were color, aroma, taste, texture, and overall liking. The formulation for Talam cake was rice flour: commercial coconut milk: sugar = 1: .5:1 and the amount of salt was 1.15% of the weight of the flour. Talam cake was made by heating a mixture of coconut milk, sugar, and salt to a boil. The coconut milk mixture was then added to the colored flour and stirred until the batter was smooth. A total of 900 mL of batter was poured into a 16 cm × 16 cm square mold that was greased with a small amount of cooking oil. The talam cake batter was steamed at 90°C for 30 minutes, cooled, removed from the mold, and cut into squares.

The best treatment was selected using the Zeleny method (Zeleny, 1982). Proximate characteristics of the best-colored flour were analyzed and were compared with a control rice flour (without butterfly pea flower added). Proximate analysis performed were moisture content (AOAC Official Method 925.10), protein content (AOAC Official Method 920.87), fat content (AOAC Official Method 2003.05), and carbohydrates (by different). The best-treated sample was also tested for temperature, pH, and light stability (Karma, 2020). The stability of blue-colored rice flour was determined by measuring the lightness (L*), redness (a*) and yellowness (b*) of the initial flour and the treated sample. Color change value (ΑE) was calculated from

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the L*, a*, b* values. ΔE is a parameter for measuring between two color coordinate points based on the CIELAB system (Mokrzycki and Tatol, 2011), given by the formula:

$$\Delta E_{Lab} = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2}$$

Different perceptions of color change were indicated by ΔE values. ΔE values greater than 1.0 indicates that the color change was not visible to the naked eye. Color changes visible under close inspection are indicated by ΔE values of 1-2. A color change visible at a glance was indicated by an ΔE value of 2-10. An ΔE value of 11-49 indicates that the color has almost significantly changed. Meanwhile, an ΔE value of 100 indicates that the color has significantly changed (Karma, 2020).

2.4 Data analysis

This study used a nested design. The type of rice (white rice and brown rice) was a major factor in this study, and the percentage of butterfly pea flowers (1, 3, 5, 7, and 9%) was a minor factor. Data were analyzed with 95% confidence using analysis of variance (ANOVA) and a post hoc test of Duncan's Multiple Range Test (DMRT). The Multiple Attribute Zeleny method was used to determine the best treatment for each type of rice. The best sample's proximate value was compared to the control using a paired t-test. The difference in color (ΔE) was used to determine the stability of pandan-scented blue flour for temperature, pH, and light.

3. Results and discussion

3.1 Blue-colored rice flour characteristics

3.1.1 Color

The CIELAB method is one of the most common color models used in colorimetric systems. According to (Bora *et al*., 2015), the CIELAB method has three values: L*, a*, and b*. Lightness (L*) indicates the product's lightness level, which ranges from 1-100. The higher the (L*) value, the brighter the color of the product. a* denotes the product's degree of redness. Positive a* corresponds to a reddish color, whereas negative a* corresponds to a greenish color. b* denotes the product's yellowness. Positive b* corresponds to a yellowish color, while negative b* corresponds to a blueish color.

The amount of butterfly pea flowers used had a significant impact on the color of BCRF. Increasing the concentration of butterfly pea flower decreased the lightness (L*) and yellowness (b*) values while increasing the redness (a*) (Table 1). The pigment of butterfly pea flowers and pandan leaves influenced the intensity of BCRF color. Butterfly pea flowers have anthocyanin pigment, which gives them a purplish-blue color (Suarna and Wijaya, 2021). While pandan leaves contain chlorophyll pigments that give them a green color (Song *et al*., 2021). The color intensity provided by pandan leaves was insufficient. As a result, the colored flour would have a bluish appearance. The L*, a*, and b* values obtained must be converted to RGB using the #HEX code in order to obtain the color spectrum of the BCRF.

The final color of BCRF was also affected by the type of rice used. Brown rice, according to Upadhyay and Karn (2018), is whole-grain rice that has had the inedible outer hull removed. White rice, on the other hand, is a refined grain because it has been stripped of its bran and germ. White rice appears white, whereas brown rice appears brownish. As a result, the lightness (L*) value of colored flour made from white rice is higher than that of colored flour made from brown rice. Figure 1 depicts the interpretation of the color spectrum produced.

Table 1. Physical characteristics of BCRF.

Rice type	Butterfly Pea flower (%)	Average physical characteristics of BCRF			
		color (L*)	color (a*)	color (b*)	Aw
White rice	1	84.6±0.64^a	-13.1±0.15^e	11.7±0.30^a	0.46±0.003^e
	3	81.8±0.49^b	-8.9±0.32^d	-2.5±0.23^b	0.52±0.006^d
	5	76.6±0.19^c	-2.6±0.18^a	-8.7±0.30^c	0.53±0.006^c
	7	70.2±1.01^d	-3.0±0.09^c	-15.7±0.20^d	0.56±0.003^b
	9	61.8±2.35^e	-2.7±0.06^b	-20.3±0.35^e	0.61±0.015^a
Brown rice	1	72.4±0.71^a	-9.1±0.10^e	13.0±0.22^a	0.53±0.003^e
	3	70.5±0.45^b	-6.0±0.07^d	4.2±0.22^b	0.56±0.012^d
	5	67.0±0.28^c	-4.8±0.03^c	0.8±0.09^c	0.59±0.012^c
	7	54.6±0.63^d	-3.6±0.12^b	-10.3±0.15^d	0.62±0.012^b
	9	44.3±0.29^e	-2.3±0.07^a	-12.1±0.12^e	0.68±0.015^a

Values are presented as mean±SE of triplicate. Values with different superscripts in the same column are statistically significantly different (α = 0.05).

https://doi.org/10.26656/fr.2017.9(4).370

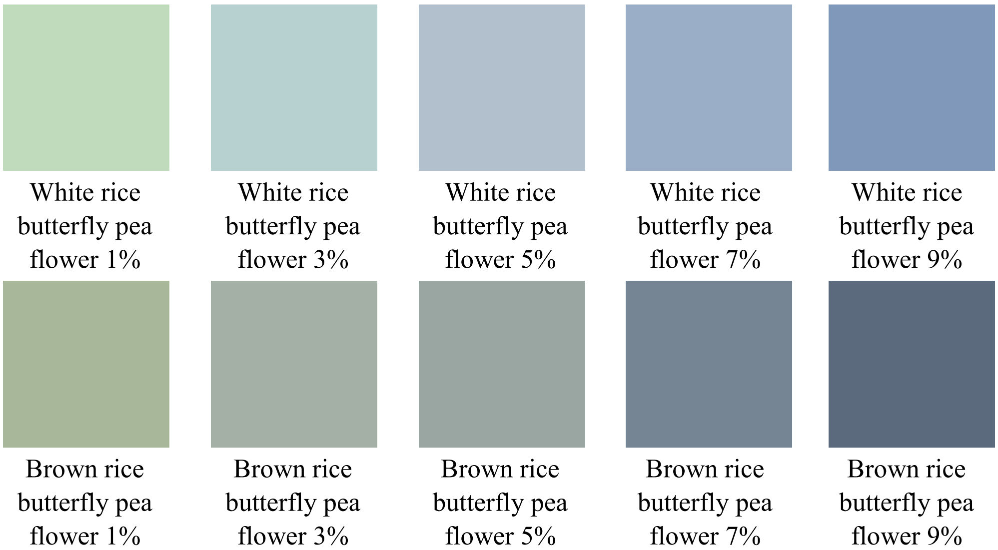

Figure 1. BCRF color spectrum interpretation.

3.1.2 Water activity and moisture content

Water activity (A_w) refers to the availability of free water that can be used by microorganisms. The A_w value is between 0 and 1. The higher the A_w value, the more free water is available, increasing the possibility of microbial growth (Quek et al., 2007). A_w analysis is useful for ensuring the microbial safety and stability of the flour. Fungi and mold thrive at A_w 0.7 and higher. Lower Aw corresponds to lower product rancidity (Carter *et al*., 2015).

BCRF made from white rice has less water activity and moisture content than those made from brown rice. Because brown rice still has a pericarp layer that is high in fiber, pigment, protein, vitamin, and mineral content, it can absorb more water than white rice. The addition of fresh butterfly pea flowers also increases the Aw and moisture content of BCRF (Table 1). According to (Rashid *et al*., 2011), the flower is the part of the plant with the highest moisture content (79.5%). However, the BCRF of this study with A_w ranging from 0.4 to 0.6 was still considered a stable ingredient, because food material is considered stable if its A_w is less than 0.6 (Quek *et al*., 2007).

Flour, as a food ingredient, must maintain a good and consistent quality during storage until it is used. Microbial decay, agglomerate, faded color, and rancidity are all signs of poor-quality flour (Carter *et al*., 2015). Rice flour is a hygroscopic material (easily absorbs water). The moisture content of BCRF made from white rice ranged from 7-10%, while BCRF made from brown rice ranged from 9-11%. If the products are stored correctly and in good environmental conditions, the moisture content of both BCRF remains within acceptable limits. According to the Codex Alimentarius Commission (1995) in the codex standard for rice (Codex Standard 198-1995), the maximum moisture content of rice required for storage is 15%.

3.1.3 pH

BCRF made from white rice has a higher pH than BCRF made from brown rice (Table 2). Brown rice contains phenolic compounds such as gallic acid, protocatechuic acid, p-hydroxybenzoic acid, vanillic acid, syringic acid, chlorogenic acid, caffeic acid, p-coumaric acid, sinapic acid, ferulic acid, cinnamic acid, and ellagic acid, which can lower the pH level (Ravichanthiran *et al*., 2018). The pH of BCRF ranged between 6.3 and 7.8. (neutral). The pH of BCRF tends to rise as the percentage of butterfly pea flowers added increases (Table 2). Anthocyanin nature is unstable, and it constantly adjusts its pH level depending on its surroundings (Charurungsipong *et al*., 2020). The blueish color and higher pH of butterfly pea flowers are due to anthocyanin. Butterfly pea flowers contain "ternatins" (delphinidin, bright, blue-colored anthocyanins). The blue anthocyanin extract is more stable at neutral pH (Netravati *et al*., 2022).

3.1.4 Anthocyanin

BCRF was made primarily of rice grain, butterfly pea flower (1-9%), and pandan leaves (1%). Butterfly pea flower was the main source of anthocyanin among these three ingredients. However, because butterfly pea flower was only added in small amounts (1-9%), the anthocyanin content of BCRF was low (less than 1%). The anthocyanin content of the flour increases as the amount of butterfly pea flower added increases because butterfly pea flower contains anthocyanin at a concentration of 5.40±0.23 nmol/mg (Anthika *et al*., 2015). Plant anthocyanins are commonly found as cyanidin, delphinidin, pelargonidin, peonidin, malvidin, and petunidin (Khoo *et al*., 2017).

Although rice is not a source of anthocyanins, it

https://doi.org/10.26656/fr.2017.9(4).370

Table 2. Chemical characteristics of BCRF.

Rice type	Butterfly Pea flower (%)	Average chemical characteristics of BCRF			
		pH	Moisture content (%)	Anthocyanin content (%)	Antioxidant activity (µg TE/g)
White rice	1	6.97±0.09^{e}	7.94±0.14^{e}	0.04±0.003^{e}	0.23±0.01^{e}
	3	7.17±0.09^{d}	8.05±0.28^{d}	0.06±0.002^{d}	4.41±0.11^{d}
	5	7.23±0.09^{c}	8.77±0.13^{c}	0.07±0.006^{c}	6.20±0.07^{c}
	7	7.53±0.03^{b}	9.10±0.20^{b}	0.27±0.009^{b}	10.90±0.04^{b}
	9	7.67±0.07^{a}	10.29±0.15^{a}	0.58±0.008^{a}	15.97±0.49^{a}
Brown rice	1	6.43±0.07^{d}	9.06±0.19^{e}	0.17±0.004^{e}	0.65±0.02^{e}
	3	6.37±0.03^{e}	9.28±0.34^{d}	0.39±0.006^{d}	8.25±0.13^{d}
	5	6.63±0.07^{c}	10.36±0.36^{c}	0.47±0.012^{c}	13.99±0.78^{c}
	7	6.73±0.09^{b}	10.46±0.26^{b}	0.47±0.010^{b}	22.56±0.68^{b}
	9	7.13±0.09^{a}	11.92±0.31^{a}	0.55±0.012^{a}	32.42±0.48^{a}

Values are presented as mean±SE of triplicate. Values with different superscripts in the same column are statistically significantly different (α = 0.05).

turns out that the type of rice influences the anthocyanin content of BCRF. The average anthocyanin content of BCRF derived from white rice was lower than that of BCRF derived from brown rice. Anthocyanins are found in a variety of parts of the rice plant, including the leaves, husks, pericarp, and other tissue parts (Xia *et al*., 2021). White rice is refined rice that has had the pericarp polished and many components removed, including, if any, anthocyanin components. Depending on their chemical structure, anthocyanin pigments produce a variety of colors (Thuy *et al*., 2021). Because brown rice has a brown color, the BCRF was slightly darker than that made from white rice.

3.1.5 Antioxidant activity

The antioxidant activity of BCRF made from brown rice was higher than BCRF made from white rice, due to the presence of various phytochemical components with high antioxidant activity in brown rice, such as phenolic compounds, tocopherol, and ɣ-oryzanol (Feng *et al*., 2021). While, because of the hulling process, white rice was considered to contain fewer nutrients. Table 2 also showed that the larger the amount of butterfly pea flower added, the higher the antioxidant activity of the BCRF. This was because butterfly pea flowers contain bioactive components that function as antioxidants. According to Anthika *et al*. (2015), the butterfly pea flowers contain flavonoid (20.07±0.55 nmol/mg), flavonol glycosides (14.66±0.33 nmol/mg), kaempferol glycosides (12.71±0.46 nmol/mg), anthocyanin (5.40±0.23 nmol/mg), quercetin glycosides (1.92±0.12 nmol.mg) and myricetin glycoside (0.04±0.01 nmol/mg). Antioxidant activity in butterfly pea flowers has been linked to a variety of health advantages, including the prevention of cancer, aging, cardiovascular issues, and other degenerative disorders (Mehmood *et al.*, 2019).

3.1.6 Organoleptic

The concentration of butterfly flower and rice type produced differences in the level of liking of the talam cake in the color, taste, and texture parameters, but not in the aroma parameter (Table 3). The intensity of anthocyanin pigments given by butterfly flowers accounts for the color variation in the talam cake. The more butterfly flowers are added, the more intense the blue color becomes (Anthika *et al.*, 2015). Brown rice produces a less liked brown color, hence the average degree of liking for the color of the talam cake made from brown rice-BCRF was lower than the talam cake prepared from white rice-BCRF.

The number of butterfly pea flowers and the type of rice influenced panelists' preferences for the flavor parameter of talam cake. Butterfly flowers, however, have a bland flavor. The perception of flavor produced by the difference in sample color causes the difference in taste of talam cake. Color and taste, according to Spence (2019), are interrelated factors. The sense of sight works faster than the sense of taste, so panelists can perceive the taste of different talam cakes.

The moisture content of the fresh butterfly flower causes the texture variance in the talam cake. The more butterfly flowers added, the higher the moisture content of BCRF, and thus the softer the texture of the talam cake. The texture of talam cake from brown rice-BCRF was less preferable than that from white rice-BCRF. Cooked brown rice has a (33%) harder texture and 5% less springiness than cooked white rice (Huang *et al*., 2021). Meanwhile, kue talam is a traditional wet snack with a chewy texture that is not too soft or too hard (Hakiki, 2019).

There was no difference in the panelists' level of

https://doi.org/10.26656/fr.2017.9(4).370

Table 3. Sensory characteristics of BCRF in the form of talam cake.

Rice type	Butterfly pea flower percentage (%)	Average organoleptic score of talam cake				
		Color	Aroma	Taste	Texture	Overall liking
White rice	1	3.78	4.05	4.00	3.25	3.73
	3	4.23	4.13	4.03	3.45	3.98
	5	4.15	3.90	3.83	3.65	3.80
	7	5.08	4.33	4.58	4.17	4.50
	9	4.98	4.15	4.70	4.00	4.55
Brown rice	1	2.45	3.63	3.30	3.25	3.30
	3	2.88	3.75	3.10	3.15	3.10
	5	2.95	4.05	3.33	3.53	3.33
	7	3.35	3.70	3.35	3.13	3.35
	9	3.68	4.00	3.73	3.55	3.73

Note: 1.00 (dislike) to 7.00 (very like)

liking for the aroma. Talam cake was made by adding 1% pandan leaves as a fixed ingredient in the production of BCRF. Pandan leaves have a fragrant because they contain 2-acetyl-1-pyroline (2AP) molecules, and also other volatile compounds such as dipropyl ether, ethyl acetate, and hexanal that contribute to the aroma (Wakte *et al*., 2010). Because all samples were prepared with the same amount of pandan leaves, the average level of panelists' preference for the aroma parameter of talam cakes did not differ considerably.

3.2 Zeleny method of best treatment determination

The determination of the best treatment of BCRF by differences in the type of rice and percentage of butterfly pea flower was conducted with multiple attribute Zeleny method (Zeleny, 1982). Determination of the best BCRF was carried out on 14 predetermined test parameters with equal importance of weight. The best BCRF was obtained by adding 9% butterfly pea flowers both on white or brown rice (Table 4). The result was supported by the calculation on L1, L2, and L max of multiple attribute Zeleny method.

3.3 Proximate comparison of blue-colored rice flour with control rice flour

The proximate content of BCRF made from either white or brown rice with the addition of 9% butterfly pea flowers was significantly different from control rice flour (rice flour made from the same rice type without butterfly pea flowers) in all parameters (Table 5). In general, the moisture, ash, protein and fat content of BCRF were higher while carbohydrate by difference was lower than the control rice flour. The difference was caused by the content of butterfly pea flowers which have high moisture content (92.4%), total ash (0.45% db), protein (0.32% db), fat (2.5% db), and carbohydrate (2.23% db) (Neda *et al*., 2013).

3.4 *Stability of blue-colored rice flour*

The stability of the BCRF against temperature, pH and light was measured using the ΔE value (Table 6). The results of the stability test of BCRF against temperature are presented in Figure 2. The ΔE value at 4°C was at 4-8 (can be seen at a glance by the eye), the

Table 4. Characteristics of the best BCRF.

	BCRF made from white rice + butterfly pea flower 9%	BCRF made from brown rice + butterfly pea flower 9%
Brightness value (L*)	61.8±2.35	44.3±0.29
Redness value (a*)	-2.7±0.06	-2.3±0.07
Yellowness value (b*)	-20.3±0.35	-12.1±0.12
Water activity (aw)	0.61±0.015	0.68±0.015
Acidity (pH)	7.67± 0.07	7.13±0.09
Water content (%)	10.29±0.13	11.92±0.31
Anthocyanin content (%)	0.58±0.008	0.55±0.01
Antioxidant activity (µg TE/g)	15.97±0.49	32.42±0.48
Hedonic score		
Color parameter	4.98	3.68
Aroma parameter	4.15	4.00
Flavor parameter	4.70	3.73
Texture parameter	4.00	3.55
Overall	4.55	3.83

Values are presented as mean±SE of triplicate.

https://doi.org/10.26656/fr.2017.9(4).370

Table 5. Comparison of proximate analysis results between control rice flour and the best BCRF made from white rice and brown rice.

	Control (%)	BCRF made from white rice (%)	Control (%)	BCRF made from brown rice (%)
Water content	9.44±0.17	10.44±0.01*	9.71±0.09	10.99±0.23*
Ash content	0.48±0.01	0.69±0.03*	1.26±0.04	1.44±0.002*
Protein content	6.22±0.06	6.50±0.03*	6.44±0.05	6.66±0.04*
Fat content	1.34±0.01	1.53±0.01*	2.59±0.01	2.82±0.06
Carbohydrate content (by different)	82.52±0.14	80.84±0.07*	81.25±0.19	79.38±0.17*

Values are presented as mean±SE of triplicate. Values with different superscripts in the same column are statistically significantly different (α = 0.05) between the control rice flour and the colored rice flour with best treatment.

Table 6. ΔE value of the best BCRF.

Treatment	ΔE Value	
	BCRF made from white rice + butterfly pea plower 9%	BCRF made from brown rice +butterfly pea flower 9%
4°C	8.44±0.40	4.67±0.10
Room	1.65±0.43	1.86±0.30
100°C	16.31±0.88	17.97±0.09
pH 1	39.66±0.75	59.02±0.78
pH 4	12.89±0.35	25.22±3.65
pH 7	12.86±1.27	15.60±3.68
pH 9	11.68±0.45	18.94±2.61
Dark room	2.33±0.46	1.66±0.52
Light Box	7.75±1.91	3.46±0.66

Values are presented as mean±SE of triplicate. Values with different superscripts in the same column are statistically significantly different (α = 0.05). ΔE value ≤1 = invisible to the eye, 1-2 = can be seen through close observation (precision observation), 2-10 = can be seen at a glance by the eye, 11-49 = almost completely different color, and 100 = different color (Karma, 2020).

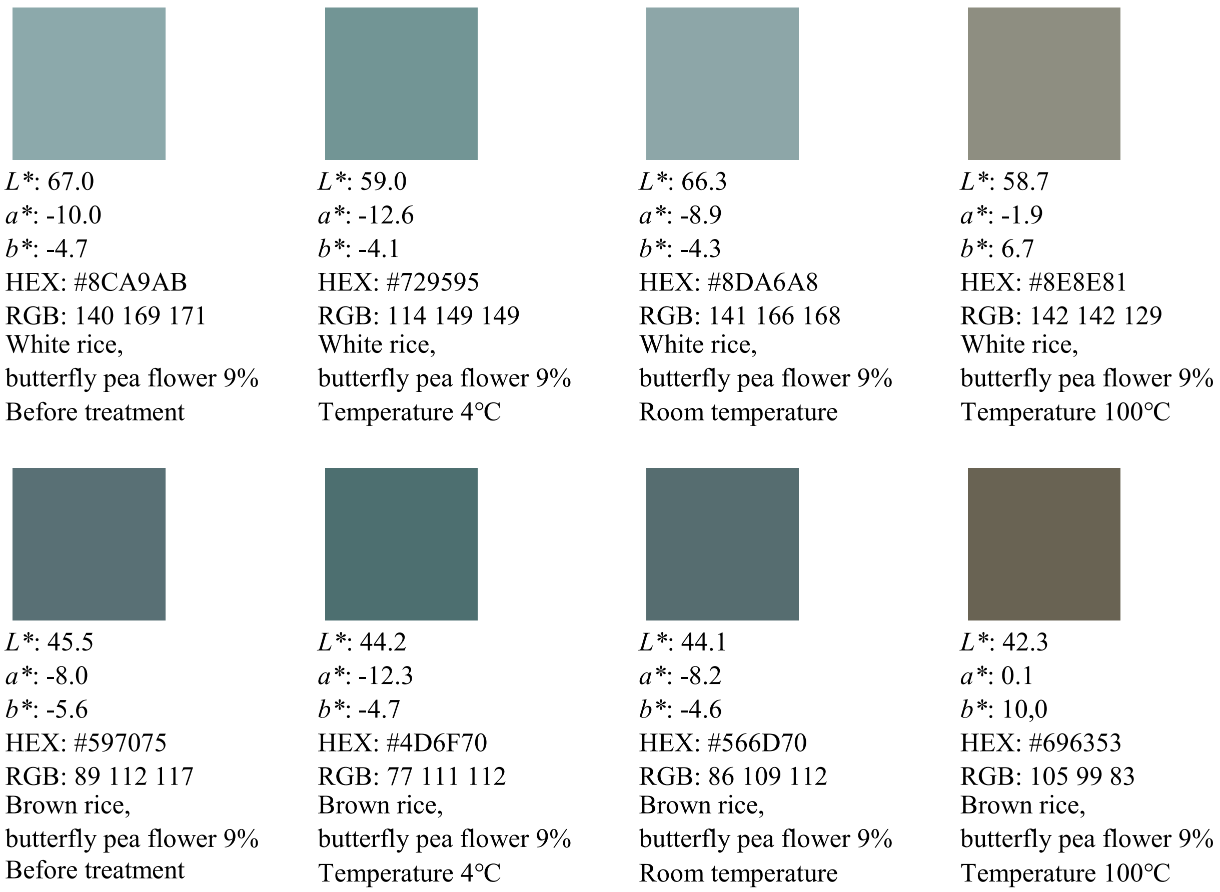

Figure 2. Interpretation of color spectrum changes of BCRF in temperature stability tests.

https://doi.org/10.26656/fr.2017.9(4).370

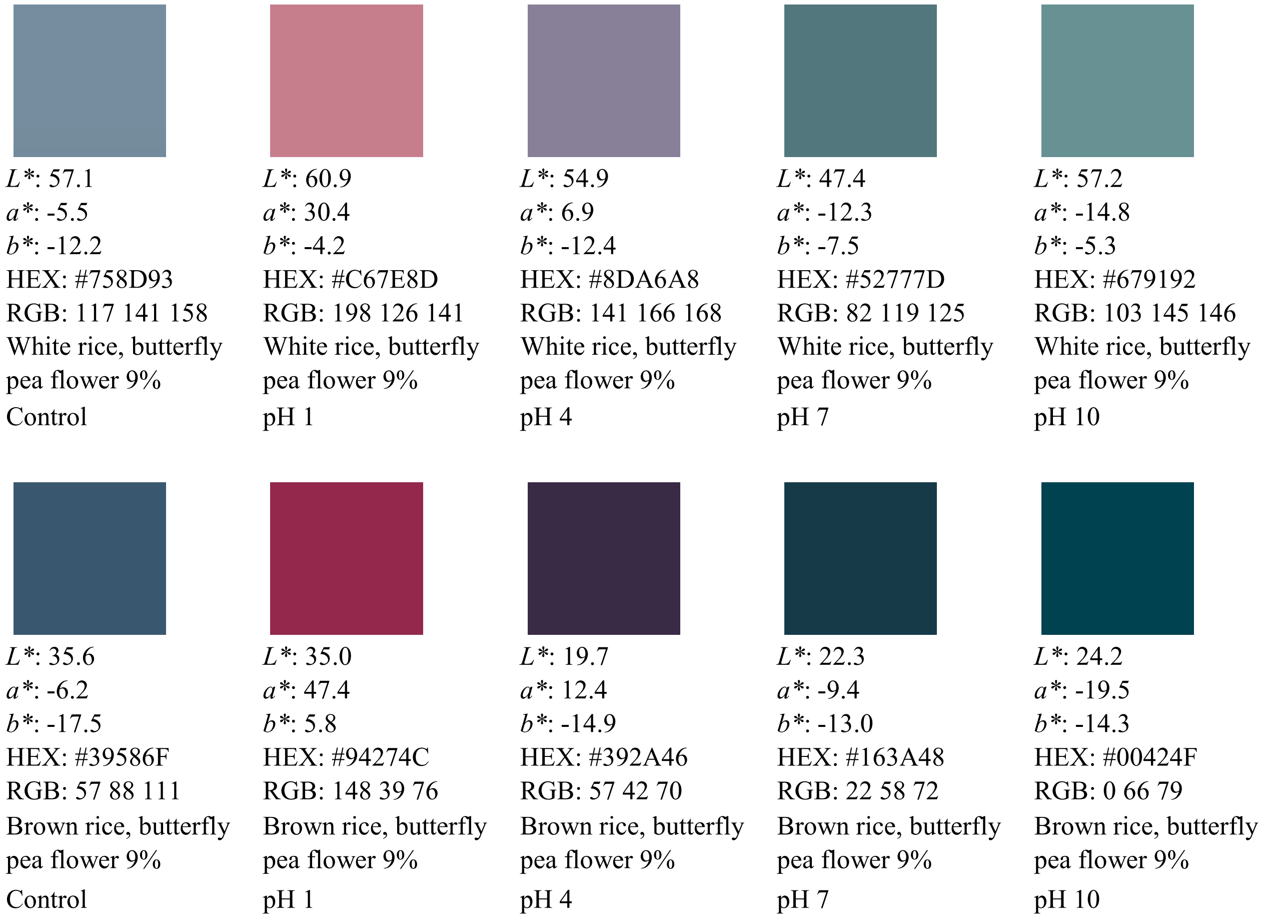

Figure 2. Interpretation of color spectrum changes of BCRF in temperature stability tests.

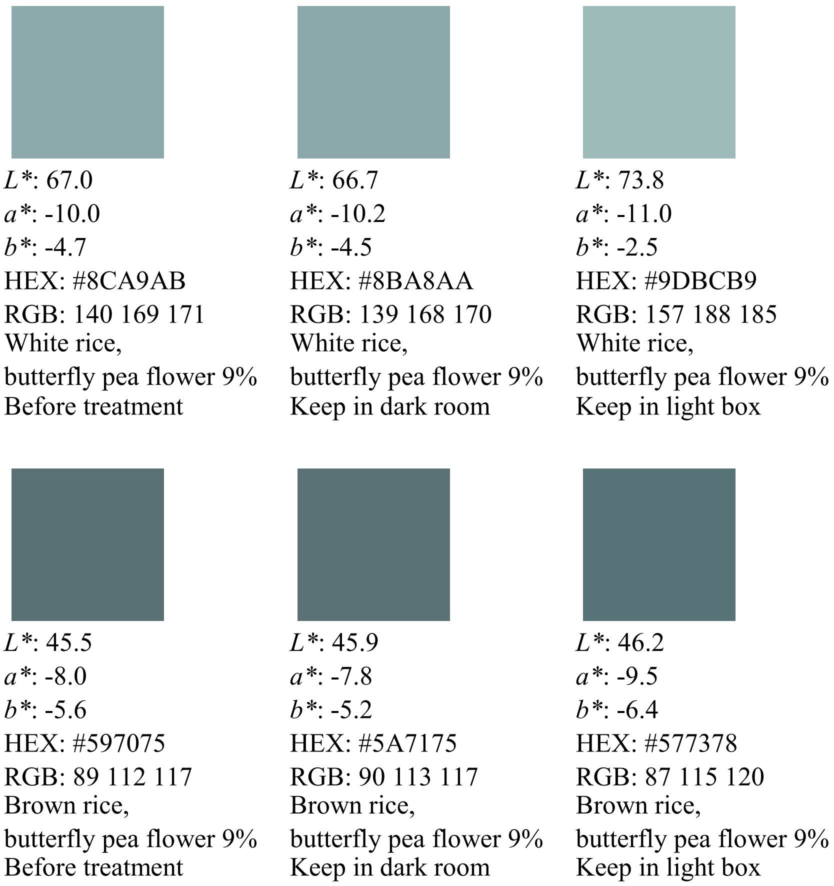

Figure 4. Interpretation of color spectrum changes of BCRF in light stability tests.

https://doi.org/10.26656/fr.2017.9(4).370

room temperature was 1.6-1.8 (can be seen through observation with accuracy), and 100°C was 16-17 (the color was almost completely different). Exposure to high temperatures produces the most serious color changes. Anthocyanins will be degraded at 60-75°C (Jiménez and Bassama, 2020). Meanwhile, low temperatures can maintain the stability and slow down the degradation rate of anthocyanins (Jiang *et al*., 2019).

The results of the BCRF stability test against pH are presented in Figure 3. The ΔE value of colored flour in all pH treatments ranged from 11-49, indicating that there was a significant color change. However, the least change (meaning the BCRF color was relatively more stable) was observed at pH 4, 7 and 10. While the highest change was observed at pH 1. The nature of anthocyanins is strongly influenced by the pH of the environment. According to Wahyuningsih *et al*. (2016), anthocyanins change color to red at low pH (acidic conditions), purple at pH 7 (neutral conditions), blue at high pH (alkaline conditions), until they become colorless.

The results of the stability test against light are presented in Figure 4. The ΔE value in the dark room and light box was relatively low, meaning that the color was relatively more stable against light exposure, although color changes still occur. According to Laleh *et al.* (2006), light exposure can reduce the number of anthocyanins in the material. This has an impact on decreasing the color intensity of anthocyanin pigments and decreasing antioxidant activity in the material.

4. Conclusion

The physical, chemical, and organoleptic properties of BCRF were significantly affected by the type of rice and concentration of butterfly pea flowers (α = 0.05). The addition of 9% butterfly pea flower can provide better BCRF characteristics than the other concentrations (1-7%) tested in this study. BCRF made from white rice and 9% butterfly pea flower had (L*) value of 61.8±2.35; (a*) value of -2.7±0.06, (b*) value of -20.3±0.35; water activity 0.607±0.015; pH 7.667±0.067; moisture content 10.286±0.153%; anthocyanin content 0.578±0.008%; and antioxidant activity 15.967±0.489 µg TE/g. BCRF made from brown rice and 9% butterfly pea flower had (L*) value of 44.3 0.29, (a*) value of -2.3±0.07, (b*) value of -12.1±0.35, water activity 0.68±0.02, pH 7.13±0.09, moisture content 11.92±0.31%, anthocyanin content 0.55±0.01%, and antioxidant activity 32.42±0.48 µg TE/g. The proximate composition of BCRF differed significantly (α = 0.05) from that of control rice flour, displaying higher moisture, protein, ash, and fat levels and lower carbohydrates. Anthocyanin stability can be reduced by high temperatures and light exposure, while pH can produce substantial color changes. Further research is required to improve the stability of BCRF.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors would like to thank the Department of Food Science and Biotechnology and Faculty of Agricultural Technology at Universitas Brawijaya for supporting this publication.

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