



Rice extract: Antioxidant activities and formulations

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ABSTRACT

The objective of this study was to evaluate the potential use of the Thai black glutinous rice grain (RG) and black glutinous rice bran (RB) extract in cosmeceutical products. The ethanolic extracts were prepared. Anthocyanin, phenolic, and flavonoid contents in the extracts were determined, and antioxidant activities were evaluated using 2,2-Di(4-*tert*-octylphenyl)-1-picrylhydrazyl, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), and ferric reducing antioxidant power assays. The RB extract exhibited higher total phenolic (129.03 ± 2.44 μg of gallic acid equivalent/mg extract) and flavonoid (7.56 ± 0.40 μg of quercetin equivalent/mg extract) contents than the RG extract. In addition, the antioxidant activities of the RB extract were superior to the activities of the RG extract. Therefore, the RB extract was selected for loading into the water- and oil-based formulations. The stability testing consisted of centrifugation and six heating-cooling cycles. All formulations were stable without noticeable phase separation or aggregation after the stability testing. In addition, the pH values ranged between 5 and 5.5, which was proper for skin application. Our findings indicate that the RB extract is a source of phenolic compounds with antioxidants and suggest that this extract might be a promising active component in skincare products.

INTRODUCTION

Oryza sativa L., or rice, originated in Asia and is one of the human staple foods (Apak *et al.*, 2016; Ito and Lacerda, 2019). In Thailand, numerous varieties of rice can be classified according to color into two groups, white and colored rice. The colors of colored rice, e.g., red, purple, and black, come from pigments in the pericarp of the bran layer of the rice grain. Among red rice,

the Sangyod and Red Hom Mali varieties are popular with the domestic market demand in Thailand of approximately 10,000 tons/year for each type. Black nonglutinous rice, or Riceberry rice, has the highest domestic demand, which is approximately 20,000 tons/year. On the other hand, black glutinous rice, consumed as a dessert, has a small market of 5,000-6,000 tons/year, more or less (Orachos, 2020). Nowadays, the popularity of black rice, both glutinous and nonglutinous, is growing because of its health benefits. Black rice contains a high amount of nutrients, including carbohydrates, proteins, and lipids. There are approximately 75% of carbohydrates, mainly starch, and other polysaccharides, including simple sugars and insoluble dietary fibers. Black rice also has more essential amino acids than wheat and corn. The predominant lipids in black rice are triglycerides, principally oleic,

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linoleic, and palmitic acids. In addition, black rice has vitamin B-complex, vitamin A, vitamin E, potassium, iron, zinc, copper, magnesium, manganese, and phosphorus (Ito and Lacerda, 2019).

In addition to nutrients, black rice contains numerous phytochemicals that have beneficial health properties, including γ -oryzanol, tocopherols, tocotrienols, phytosterols, phytic acid, flavonoids, and phenolic compounds (Goufo and Trindade, 2014; Ito and Lacerda, 2019). Flavonoids and other phenolic compounds can be found ubiquitously in many plants and grains, including rice (Jung *et al.*, 2017). Black rice is a rich source of anthocyanins, the red to purple water-soluble flavonoids. Anthocyanin content is varied by the variety of rice, leading to the diversity of the color shade of black rice (Chen *et al.*, 2012; Ito and Lacerda, 2019; Orachos, 2020). Many anthocyanins that have been isolated from black rice include cyanidin-3,5-diglucoside, cyanidin-3-glucoside, cyanidin-3-rutinoside, peonidin-3-glucoside, malvidin, and petunidin-3-glucoside (Chen *et al.*, 2012; Shao *et al.*, 2018). Furthermore, black rice is also high in phenolic acids (Ito and Lacerda, 2019; Shao *et al.*, 2018). Flavonoids and phenolic compounds are known as excellent sources of antioxidants by acting as a radical scavenger and/or metal ion chelating agent (Tungmunnithum *et al.*, 2018), and the antioxidant capacity parallels the total phenolic and flavonoid contents (Tai *et al.*, 2021; Tungmunnithum *et al.*, 2018). In 2010, Sadabpod *et al.* (2018) evaluated the total polyphenol content and antioxidant activity of black nonglutinous rice (Hom Nil) and black glutinous rice and found that black glutinous rice exhibited more total polyphenol content and antioxidant activity than Hom Nil rice (Sadabpod *et al.*, 2018).

Oxidative stress is known as a cause of cell damage and eventually cell death. There are many strategies to prevent photoaging, and one of those is using external sources of antioxidants (De Jager *et al.*, 2017; Pillai *et al.*, 2005; Tungmunnithum *et al.*, 2018). The natural antioxidants from plants have been employed in cosmetics because the addition of a natural extract can improve consumer perception of cosmetic products (Kumar *et al.*, 2021). Natural ingredients are also perceived as more sustainable and more environmentally friendly (Fonseca-Santos *et al.*, 2015). Moreover, black rice bran extract had the highest antioxidant activities, followed by red and brown rice bran extracts (Ghasemzadeh *et al.*, 2018). To the best of our knowledge, there is no black rice extract in skin preparations currently on the market. Utilizing black rice in skin care not only allows adding the uniqueness of the raw material to the product but also allows the antioxidant effects of the product to be increased, thus increasing the economic value of black rice. Therefore, we aimed to investigate the potential of the black rice extract in cosmetic use. Our first objective was to evaluate the total anthocyanin, total flavonoid, and total phenolic contents (TPCs) and antioxidant activity of the Thai black glutinous rice grain (RG) and black glutinous rice bran (RB) extracts. The second objective was to formulate skincare products from the extract that exhibits the best antioxidant activity.

MATERIALS AND METHODS

Materials

Folin-Ciocalteu's phenol reagent, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), potassium persulfate ($K_2S_2O_8$), potassium chloride (KCl), sodium acetate (CH_3COONa), and acetone were purchased from Merck (Darmstadt, Germany). Quercetin and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic

acid (Trolox) were purchased from Sigma-Aldrich (WA). Aluminum chloride-6-hydrate ($AlCl_3 \cdot 6H_2O$), sodium acetate (CH_3COONa), and ferrous sulfate-7-hydrate ($FeSO_4 \cdot 7H_2O$) were purchased from KEMAUS (New South Wales, Australia). 2,2-Di(4-*tert*-octylphenyl)-1-picrylhydrazyl (DPPH), 2,4,6-Tris(2-pyridyl)-s-triazine (TPTZ), gallic acid, and *L*-ascorbic acid were purchased from TCI (Tokyo, Japan). All solvents were analytical grade. Hydrochloric and acetic acid were purchased from RCI Labscan (Bangkok, Thailand). Methanol and dimethyl sulfoxide (DMSO) were from Unitywell Co., Ltd. (Bangkok, Thailand), and CARLO ERBA Reagents (Val-de-Reuil, France). Sodium bicarbonate was purchased from Ajax Finechem (New South Wales, Australia), and ferric chloride-6-hydrate ($FeCl_3 \cdot 6H_2O$) was purchased from PanReac AppliChem (Barcelona, Spain). Polysorbate 80 and xanthan gum were obtained from P.C. Drug Center Co., Ltd. (Bangkok, Thailand). Potassium sorbate, sorbitol syrup, glyceryl monostearate, white petrolatum, PEG-40 hydrogenated castor oil, liquid paraffin, and stearyl alcohol were purchased from Chemipan (Bangkok, Thailand). Glycerin, triethanolamine, propylene glycol, and sorbitan monooleate were obtained from Chanjao Longevity Co., Ltd. (Bangkok, Thailand).

Extraction of rice extracts

RB from glutinous black rice was separated from RG by milling. RG (2 kg) was extracted with 75% of ethanol (2 l) on a shaker (N-Biotek, USA) for 24 hours (37°C and protected from light). The extractant was then filtrated. The marc, residues left after the first extraction, was repeatedly extracted. The filtrate from the repeated extraction was pooled and evaporated by a rotary evaporator (R100 Buchi, Switzerland) and was dried using a freeze-dryer (Labconco, USA) to obtain the RG crude extract. The RB crude extract was obtained by extracting 400 g of RB with 75% ethanol 400 ml using the aforementioned method used for RG extraction. Finally, the dried ethanolic crude extracts of RG and RB were weighed to calculate % the yield.

Determination of monomeric anthocyanin content

Monomeric anthocyanin was quantified using a pH differential method with a two-buffer system, which consisted of potassium chloride (KCl) buffer (pH 1.0, 0.025 M) and sodium acetate buffer (pH 4.5, 0.4 M), as described in Lee *et al.* (2005), and Yang *et al.* (2019). In brief, the rice extract was dissolved in 40% acetone, resulting in a 10% w/v sample solution. The dilution factor (DF) was determined by diluting the sample solution with a 0.025 M KCl buffer (pH 1.0) until the absorbance at 510 nm was in the range of 0.2–1.4 AU. Thereafter, the mixtures of sample solution and the buffers, KCl (pH 1) and acetate (pH 4.5), were prepared by adding the buffers with the same volume as obtained from DF to the sample and incubated for 15 minutes. The absorbance of the mixtures was measured by a UV-visible spectrophotometer (LabTech, USA) at 510 and 700 nm. The acetone was used as a blank. Anthocyanin content was calculated from the following equation and expressed as cyanidin-3-glucoside equivalent (CYE) in 100 g of dried powder extract (mg CYE/100 g dried powder extract):

$$\text{Monomeric anthocyanin (mg/l)} = A \times MW \times DF \times 1,000 / \epsilon \times 1, \quad (1)$$

where A (absorbance) = $(A_{510 \text{ nm}} - A_{700 \text{ nm}})_{\text{pH } 1.0} - (A_{510 \text{ nm}} - A_{700 \text{ nm}})_{\text{pH } 4.5}$, MW (molecular weight of CYE) = 449.2 g/mol, DF = dilution factor, ϵ = molar extinction coefficient of CYE (26,900

$l \times \text{mol}^{-1} \times \text{cm}^{-1}$), and l = pathlength in cm. The measurement of anthocyanin content was performed in triplicate.

Total phenolic contents (TPC) determination

The measurement method of TPC was carried out as described by [Vongsak *et al.* \(2020\)](#). Briefly, the gallic acid standard solution (0.52–33.33 $\mu\text{g}/\text{ml}$) and the sample stock solution (1 mg/ml) were diluted in DMSO. The sample or standard solution (20 μl) was added to a 96-well plate, to which 50 μl of 10% Folin-Ciocalteu's reagent in distilled water and 80 μl of a 7.5% (w/v) sodium bicarbonate solution in distilled water were then added. The mixtures were stored in the dark at room temperature for 30 minutes. The absorbance was measured by a microplate reader (FLUOstar Omega, BMG Labtech, Germany) at 765 nm. The standard curve for the concentration of gallic acid was constructed and used for the calculation of gallic acid in the extract. The experiment was performed in triplicate, and the results were reported as mean \pm standard deviation (SD) of mg gallic acid equivalent (GAE)/mg extract.

Total flavonoid contents (TFC) determination

The total flavonoid contents were determined as described by [Charinrat *et al.* \(2021\)](#). In brief, quercetin standard solution (1.95–125 $\mu\text{g}/\text{ml}$) and sample stock solutions of rice extracts (10 mg/ml) were diluted in DMSO. Eighty microliters of sample or quercetin standard solutions was mixed with 80 μl of a 2% (w/v) aluminum chloride solution in methanol in a 96-well plate. The mixtures were incubated for 10 minutes at room temperature. The absorbance was measured at 415 nm with the microplate reader. The results of TFC were calculated from the standard quercetin equation. The experiment was performed in triplicate and reported as mean \pm SD of mg quercetin equivalent (QE)/mg extract.

Antioxidant assays

The antioxidant of the whole grain and the RB extracts was determined by the DPPH radical scavenging assay, ABTS radical scavenging assay, and ferric reducing antioxidant power (FRAP).

DPPH radical scavenging activity assay

The antioxidant determination by the DPPH radical scavenging assay was modified from a previous study ([Jiangseubchatveera *et al.*, 2021](#)). The 0.5 mM DPPH reagent was prepared in methanol. The stock solutions of the rice extracts were prepared as a 5 mg/ml solution in DMSO and then diluted in DMSO to final concentrations in the range of 15–250 $\mu\text{g}/\text{ml}$. The 20 μl of sample solution was mixed with 150 μl of DPPH solution in a 96-well plate. The mixture was then incubated for 30 minutes in the dark at room temperature. The absorbance was measured at 520 nm using the microplate reader. The assay of each concentration of the sample was performed in triplicate, and the %scavenging activity of DPPH was calculated using the following equation:

$$\% \text{scavenging activity of DPPH} = \frac{(\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}})}{\text{Abs}_{\text{control}}} \times 100 \quad (2)$$

$\text{Abs}_{\text{control}}$ is the absorbance of the DPPH solution without sample and $\text{Abs}_{\text{sample}}$ is the absorbance of the sample or standard solutions. The %scavenging activity of DPPH was reported as $\text{IC}_{50} \pm \text{SD}$, and IC_{50} of the samples were compared with those of standards, Trolox, and *L*-ascorbic acid.

ABTS radical scavenging activity assay

The ABTS radical scavenging activity assay was modified from [Vongsak *et al.* \(2020\)](#), and [Jiangseubchatveera *et al.* \(2021\)](#). The blue-green ABTS cation free radical was prepared by mixing a 14 mM ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) aqueous solution and a 4.9 mM potassium persulfate aqueous solution at a 1:1 ratio. The blue-green ABTS cation free radical was then stored in the dark at room temperature for 16–20 hours before use. The sample stock solution was diluted in DMSO to the final concentrations in the range of 5–100 $\mu\text{g}/\text{ml}$. The prepared ABTS free radical solution was diluted with distilled water until the absorbance at 734 nm reached 700 ± 0.02 . The 100 μl of the sample solution was mixed with 100 μl of the diluted ABTS solution in a 96-well plate. The absorbance was measured, after 6 minutes incubation, at 734 nm using the microplate reader. The experiment was performed in triplicate. The %scavenging activity of ABTS was calculated using Equation (2).

Ferric reducing activity power (FRAP) assay

The FRAP assay was modified from [Vongsak *et al.* \(2015\)](#). The FRAP reagent was freshly prepared by mixing 10 mM TPTZ in the 1:1:10 ratio of the mixture of 40 mM hydrochloric acid, 20 mM $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, and 300 mM acetate buffer pH 3.6. The sample stock solution was diluted in DMSO to the final concentration of 2.5 mg/ml. Twenty μl of samples or standard solutions was mixed with 80 μl FRAP reagent in a 96-well plate and then incubated at 37°C for 8 minutes. FeSO_4 at the concentration of 40–720 μM was used as a reference standard. The assay was performed in triplicate. The absorbance was measured by the microplate reader at 593 nm. The linear standard curve between the absorbance and concentration of FeSO_4 was generated. The reducing power of samples, Trolox, and *L*-ascorbic acid standards was expressed as μmol of FeSO_4 equivalent/mg extract \pm SD.

Preparation of water-based formulation containing rice extract

Black rice extract lotion was prepared by the beaker method modified from [Jiangseubchatveera *et al.* \(2021\)](#). The extract (50 mg) was dissolved in a mixture of propylene glycol (2 ml) and polysorbate 80 (1 ml) and heated to 50°C until the mixture was completely homogenous. The aqueous solution of potassium sorbate (50 ml of 2 mg/ml) used as a preservative was mixed with humectants (4 ml of 70% sorbitol solution and 1 ml of glycerin). The aqueous mixture was then added to the solubilized extract and adjusted with water to 100 ml, resulting in a lotion.

Preparation of lipid-based formulation containing rice extract

In this study, emulsion and cream were referred to as lipid-based formulations. Rice extract-loaded lipid-based formulations were prepared by the beaker method ([Petchsomrit *et al.*, 2020](#)). To fabricate rice extract emulsions, rice extract (1%), sorbitan monooleate (6%), propylene glycol (10%), liquid paraffin (1%), and stearyl alcohol (1%) were mixed and used as the oil phase. Polysorbate 80 (6%), potassium sorbate (0.1 g), and water, to make 100 ml, were used in the water phase. Briefly, the oil and the water phase were heated to 75°C and 70°C, respectively. Then, the water phase was added to the oil phase while being constantly stirred. After that, the 2 ml of a 0.1% xanthan gum solution, which was used as a suspending agent, was mixed homogeneously. For the fabrication of

rice extract cream, glyceryl monostearate (2%), stearyl alcohol (7%), white petrolatum (3%), sorbitan monooleate (3%), propylene glycol (5%), and rice extract (0.5%) were mixed and used as the oil phase. The water phase was composed of potassium sorbate (0.1 g), PEG-40 hydrogenated castor oil (5%), and water (adjusted to 100 ml).

Characterization of the water-based and lipid-based formulations containing rice extract

Type of emulsion

The type of emulsion of each lipid-based formulation was determined using three tests as described below.

Water solution test

A gram of cream was dispersed in distilled water or mineral oil in a test tube and shaken (Orbital Shaker NB-101M, Bangkok High Lab, Thailand) for 30 minutes. The solubility of the solution was observed and determined as shown in Table 1.

Dye test

A dye test was used to identify the type of emulsion using microscopy to observe the droplets that were not visible to the naked eye. Under a phase-contrast inverted microscope (Olympus CKX41 Inverted Microscope, Japan), the emulsion and cream were stained with brilliant blue and covered with a coverslip. The o/w type presents as scattered colorless globules on a blue backdrop and vice versa for w/o preparations.

Conductivity test

Because water is a good electrical conductor, o/w emulsions conduct electricity while w/o emulsions do not. An electric conductivity meter (VIVOSUN TSD & EC Meter, CA) was used for the measurement.

Stability study

To evaluate the stability of the products, a centrifugation assay (Charoenjittichai *et al.*, 2016) and six cycles of an acceleration test were performed. The phase separation was observed after centrifugation (Centrifuge Legend X1R, Thermo Scientific, MA) at 3,500 rpm for 30 minutes at room temperature. For the heating-cooling cycle, samples were translocated between 4°C and 40°C and stored for 48 hours for six cycles. Physical appearances, color, phase separation, and pH values were determined after the preparation and at the end of these experiments. The pH values were determined using a pH meter (Mettler-Toledo, USA).

Statistical analysis

All results were expressed as the mean \pm SD. Differences between two related parameters were assessed by Student's *t*-test or one-way analysis of variance (GraphPad Prism 5.02, GraphPad Software Inc., USA). Differences were considered significant at $p < 0.05$.

Table 1. Interpretation of type of emulsion by water solution test.

Type of emulsion	Dissolve in oil	Dissolve in water
o/w	No	Yes
w/o	Yes	No

RESULTS AND DISCUSSION

Extraction yield and total anthocyanin, phenolic, and flavonoids contents

The % yields of the RG and RB crude extracts were 0.68% and 19.33%, respectively. Total anthocyanin content, TPC, and TFC in both the RB and RG extracts are shown in Table 2. The RG extract had a higher total anthocyanin content than the RB extract (Table 3). The TPC and TFC of the RB extract were significantly higher than those of the RG extract. In this study, the high amounts of phenolic compounds were not correlated with high quantities of anthocyanin, which is a group of flavonoid phenolic compounds, suggesting that anthocyanins were not the main flavonoids and phenolics in the extract. This agrees with Rafi *et al.* (2018), who reported that the amount of flavonoid and anthocyanin in an extract did not always correspond to the number of total phenolics in the extract.

Furthermore, the amount of bran received from the milling process might be the reason why the anthocyanin content of the RB extract was less than the RG extract. The whole rice grain consists of four main components, including hull or husk, bran, germ or embryo, and endosperm. The hulling process separates the hull, the outermost part, from the rice grain to give brown rice. On the other hand, the milling process is a process that removes all the outer parts, not only the hull but also the bran and germ, from the rice grain. This process produces polish or white rice (Juliano and Tuano, 2019; Shafie and Norhaizan, 2017). However, the milling process did not remove all the bran layers from the black rice grain, but only a small amount of bran layer was removed. Therefore, most of the bran layer was still intact on the black rice grain, resulting in the level of anthocyanin of the black rice grain being higher than in the black RB (Ito and Lacerda, 2019).

Antioxidant properties

At least two methods are recommended for the determination of the antioxidant activity of plant extracts (Čiž *et al.*, 2010). The antioxidant activities of the rice extracts evaluated by the DPPH, ABTS, and FRAP assays are displayed in Table 3. The RB extract exhibited more potent activities than the RG extract in both antioxidant mechanisms, free radical scavenging (DPPH and ABTS assays) and reduction of the ferric-TPTZ complex to a ferrous complex (FRAP assay).

The results of the DPPH and ABTS assays revealed that the RB extract exhibited greater antioxidant capacity than the RG extract. The antioxidant activity of the RB extract was lower than the standard control (*L*-ascorbic acid and Trolox). The antioxidant of the rice extracts in the FRAP assay was determined by the

Table 2. Total anthocyanin contents, total phenolic contents, and total flavonoid contents from rice extracts.

Sample	RG	RB
Total anthocyanin contents ($\mu\text{g/g}$ dry weight)	18.67 \pm 1.50	13.62 \pm 1.00
Total phenolic contents (μg of GAE/mg extract)	50.96 \pm 2.11	129.03 \pm 2.44
Total flavonoid contents (μg of QE/mg extract)	1.65 \pm 0.46	7.56 \pm 0.40

formation of a blue Fe^{2+} -TPTZ complex. The assay showed that reduction of the ferric-TPTZ complex to a ferrous one occurred with the RB extract significantly better than with the RG extract ($p < 0.05$). The antioxidant capacities of the RB extract were greater than those of the RG extract. This might be because of the presence of other antioxidants in the RB extract. According to previous research, tocopherols, tocotrienols, and γ -oryzanol, which are antioxidants, were found in the RB extract in a higher amount than in the RG extract (Goufo and Trindade, 2014).

Antioxidant activity assays can be classified by the chemical reactions into three groups, including hydrogen atom transfer (HAT) and electron transfer- (ET-) based assays and mixed mode. The DPPH and ABTS methods have been classified as a mixed mode assay, having both HAT and ET reactions, whereas the FRAP assay is an ET-based method (Apak *et al.*, 2016; Gupta, 2015). Phenolic compounds exhibited antioxidant activity in all the assays; thus, the phenolic compounds in the RB/RG extract might have acted as an antioxidant by donating both hydrogen atoms and electrons to the radicals (Ito and Lacerda, 2019; Saikia *et al.*, 2012; Zhang *et al.*, 2015).

Selection of the extract to incorporate in skin preparation

From these results, the %yield, TPC, TFC, and antioxidant capacities were parameters used for selecting an appropriate extraction as a candidate. The RB extract was selected to incorporate in water- and oil-based formulations as the RB extract provided the highest % yield, contained a high amount

of phenolics and flavonoids, and exhibited potent antioxidant properties.

The characteristic of formulations containing RB extract

Type of emulsion

The type of emulsion in the lipid-based formulations was determined. The homogenous mixture occurred after mixing the emulsion or cream with water (Fig. 1). Bright-field microscope images from the dye test showed colorless oil droplets scattered on a blue backdrop (Fig. 2). Next, the conductivity test revealed that these formulations conducted electricity (128 ± 6.56 and 36 ± 3.61 $\mu\text{S}/\text{cm}$ for emulsion and cream, respectively). Therefore, we concluded that the formulated emulsion and cream in this study were o/w emulsions that are nongreasy and easily removable from the skin surface (Viyoch *et al.*, 2003).

Stability study

This study showed that the extract could be incorporated into both water- and oil-based formulations. After the stability test, the color of the rice extract in all types of preparations did not change (Fig. 3). The color of the product depended on the quantity of the rice extract and excipient color. Phase separation did not occur after the centrifugation test and six-cycle acceleration test. Additionally, the lotion was not aggregate. The pH values of the lotion, emulsion, and cream ranged between 5 and 5.5 (Table 4), which was the range that was suitable for skin application.

Table 3. The antioxidant activities of rice extracts.

Sample	DPPH assay	ABTS assay	FRAP assay
	$\text{IC}_{50} \pm \text{SD}$ ($\mu\text{g}/\text{ml}$)	$\text{IC}_{50} \pm \text{SD}$ ($\mu\text{g}/\text{ml}$)	(μmol of FeSO_4 equivalent/ mg extract)
RG	73.25 ± 0.85	42.71 ± 1.04	8.73 ± 0.14
RB	32.17 ± 3.77	36.18 ± 1.19	10.25 ± 0.58
Ascorbic acid	6.75 ± 0.46	9.34 ± 0.70	105.77 ± 2.58
Trolox	2.62 ± 0.13	9.62 ± 1.91	54.78 ± 1.97

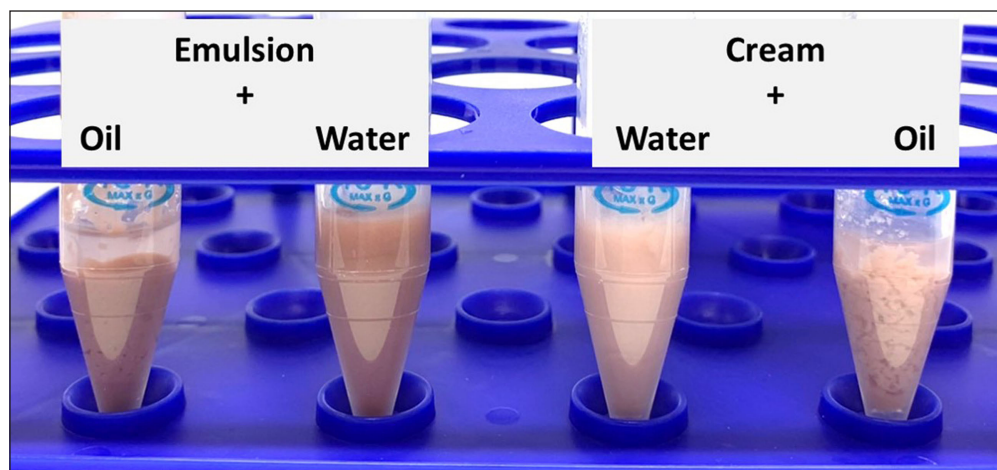


Figure 1. Type of emulsion by water solution test.

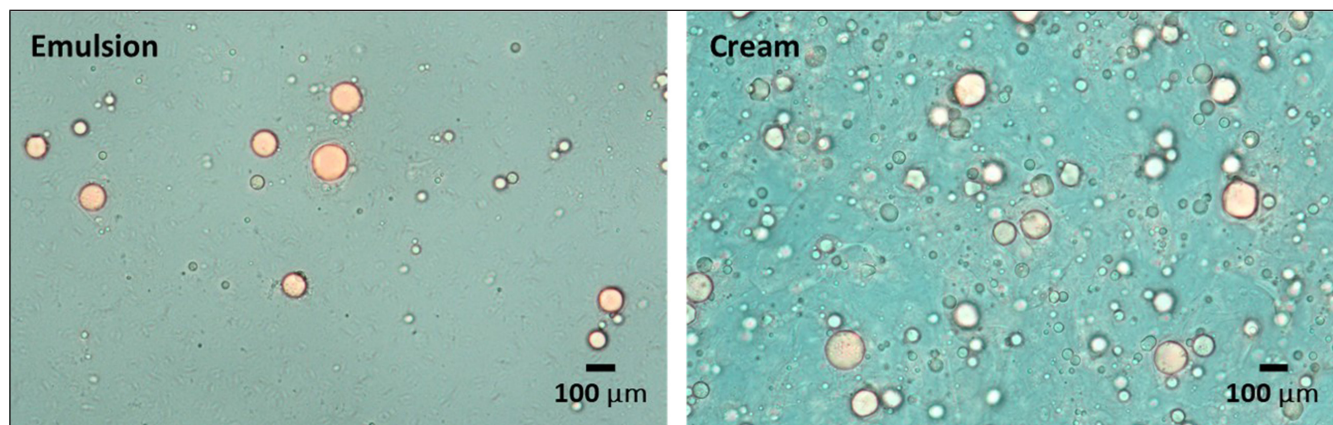


Figure 2. Light microscope images (40×) from the dye test.

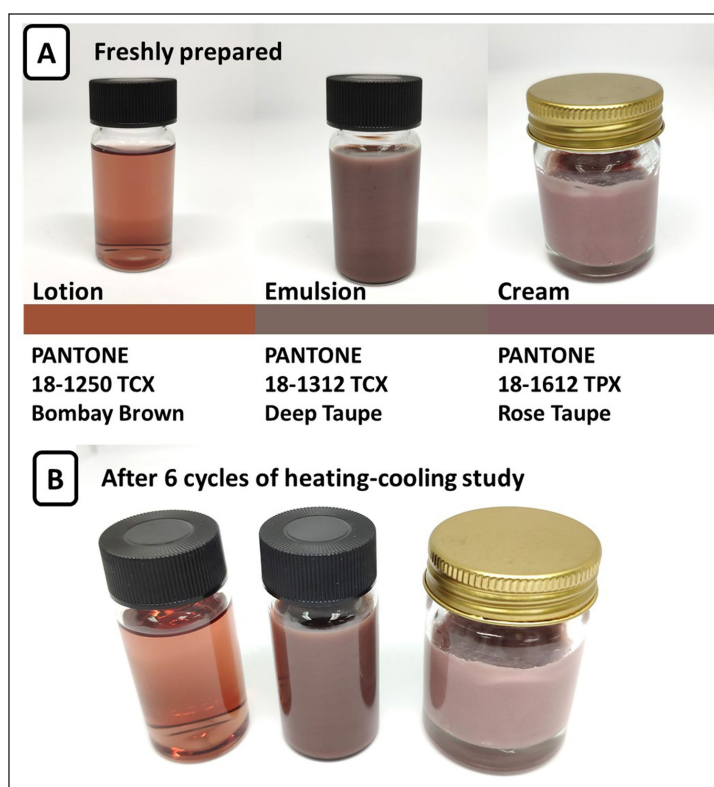


Figure 3. The appearance of water- and oil-based formulations. (A) Freshly prepared and (B) After six cycles of heating-cooling study.

Table 4. The pH values of all formulations before and after six cycles of the heating-cooling cycle.

Formulation	Lotion	Emulsion	Cream
Before	5.27 ± 0.06	5.23 ± 0.15	5.27 ± 0.15
After	5.37 ± 0.25	5.30 ± 0.30	5.10 ± 0.10

CONCLUSION

This research revealed that the RB extract could be a potential source of natural antioxidants. The RB extract provided higher TPC, TFC, and antioxidant capacities than the rice grain extract. After the incorporation of the RB extract into the water- and oil-based formulations, the rice-extract-loaded formulations were stable and yielded good physical appearances. We concluded

that the RB extract has an excellent antioxidant capacity and is compatible with water- and lipid-based formulations. Moreover, the RB extract might be used as an active component in cosmeceutical products.

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CONFLICT OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

DATA AVAILABILITY

All data generated and analyzed are included within this research article.

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