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Physicochemical, antioxidant and sensory characteristics of chiffon cake prepared with black rice as replacement for wheat flour

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ABSTRACT

Black rice (BR) powders were used to substitute 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% (w/w) of wheat flour to manufacture chiffon cakes, assigned as BR10, BR20, BR30, BR40, BR50, BR60, BR70, BR80, BR90, and BR100, respectively. The specific gravity in cake batter, and crumb *a* value, hardness, cohesiveness, adhesiveness, gumminess and chewiness of baked cakes increased with increased black rice powder levels. However, the moisture in cake batter, and cake volume, crust color and crumb *L* and *b* values, springiness, and resilience of baked cakes showed a reverse trend. Total phenols, anthocyanins and scavenging ability of baked cake extracts increased with increased black rice powder levels. The hedonic sensory results of control and 10%–60% substituted cakes were comparable but 70%–100% substituted cakes showed lower sensory results. Altogether, black rice chiffon cake could be developed as a novel food with more bioactive components and effective antioxidant activity.

1. Introduction

Rice (*Oryza sativa* L.) is one of the important staple foods worldwide. Several studies reported that the rice bran of rice samples have antioxidant activity and many beneficial health effects on diabetes, cancer, and cardiovascular diseases, which are attributed to bioactive compounds, such as phenolic compounds, γ-oryzanols, tocopherols, tocotrienols, phytic acid, anthocyanins, and dietary fiber (Hou, Qin, & Ren, 2010; Iqbal, Bhanger, & Anwar, 2005; Jun, Song, Yang, Youn, & Kim, 2012; Jung, Ha, & Hwang, 2010; Min, McClung, & Chen, 2011; Norazalina, Norhaizan, Hairuszah, & Norashareena, 2010; Park, Cho, Kim, & Ha, 2007). Most of the rice crops grown and consumed throughout the world have the white pericarp, but some varieties produce grains with brown, red, purple or black pericarp (Jeng, Lai, Ho, Shih, & Sung, 2012). Cultivation and consumption of pigmented rice is popular in some Asian countries, and its demand has been increasing in recent years, especially black rice grown in Taiwan. Several studies showed that black rice extracts have many functional properties, such as high antioxidant activity, protect endothelial cells, prevent heart and cardiovascular diseases, and act as anticancer agents (Leardkamolkarn et al., 2011; Shao, Xu, Sun, Bao, & Beta, 2014a; Shao, Xu, Sun, Bao, & Beta, 2014b; Tanaka et al., 2011; Zhang et al., 2006).

The phytochemicals in pigmented rice, such as phenolics and anthocyanins, are related with reducing the risks of developing chronic diseases, such as diabetes, obesity, cancer, and cardiovascular disease (Okater & Liu, 2010). The phenolic acids are mainly present in the rice bran (Zhang, Zhang, Zhang, & Liu, 2010; Zhou, Robards, Helliwell, & Blanchard, 2004), and demonstrated positive effects on several human chronic diseases, such as obesity, diabetes, cardiovascular and cancer (Liu, 2007; Slavin, Jacobs, & Marquart, 1997). Ferulic acid is the most abundant bound phenolic acid in rice bran, it accounts for 50–65% of total bound phenolic acids (Irakli, Samanidou, Biliaderis, & Papadoyannis, 2012; Qiu, Liu, & Beta, 2010; Shao et al., 2014a). Futhermore, ferulic acid has therapeutic effects against diabetes, cardiovascular, inflammation, apoptosis, cancer, and neurodegenerative diseases (Srinivasan, Sudheer, & Menon, 2007). The colors of pigmented rice had been attributed to anthocyanins and proanthocyanins (Min et al., 2011), which have been reported to have many beneficial effects on human health, such as anti-inflammation, anti-obesity, antioxidants effects and inhibiting the growth of cancer cells (McGhie & Walton, 2007). The percentage contribution of free anthocyanins to the total ranged from 99.5 to 99.9% in black rice (Zhang et al., 2010). The cyanidin 3-glucoside (C3G) and peonidin 3-

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glucoside (P3G) were the main anthocyanins in black rice and C3G levels were significantly higher than P3G (Lee, 2010; Shao et al., 2014a, b).

Baked products, especially wheat flour processed products, are consumed all over the world. However, there is little information available regarding the effect of black rice on the physicochemical, antioxidant, and sensory quality characteristics of bakery products. Chiffon cake is a ready to eat and popular food appreciated by consumers all over the world, and it would be a good way to ingest more bioactive compounds. Thus, it would be beneficial to develop a novel formula for cake production with black rice. The purpose of this study was to manufacture chiffon cakes with 0–100% (w/w) replacement of wheat flour with black rice powder, to determine the physicochemical, antioxidant and sensory quality characteristics of black rice chiffon cakes.

2. Materials and methods

2.1. Materials

Black rice (*Oryza sativa* L.) was purchased from the local market in Taichung. It was ground in a mill (RT-30HS, Rong Tsong Precision Technology, Taichung, Taiwan), and screened through a 0.2 mm sieve. Its particle size distribution of powders was >0.149 mm (39.16%), 0.074–0.149 mm (27.86%), and <0.074 mm (32.98%). The black rice powders were sealed in a PET/Al/PE bag and then kept at 5 °C before use. Nonchlorinated and unheated wheat flour (7.8% protein) was purchased from Chia Fha Enterprise Co. (Taichung, Taiwan), and its particle size distribution of powders was >0.149 mm (0%), 0.074–0.149 mm (15.46%), and <0.074 mm (84.54%). Sucrose, sodium chloride, soybean oil, fresh eggs, nonfat dry milk powder, baking powder (Crescent Foods, Kent, WA, USA) and cream of tartar (Butakem, Butterworth RE of Transkei, Southern Africa) were purchased from the local market.

Methanol was purchased from Mallinckrodt Baker, Inc. (Phillipsburg, NJ, USA). Gallic acid, Folin-Ciocalteu's phenol reagent, 1,1-diphenyl-2-picrylhydrazyl (DPPH), α-amylase, protease (from *Bacillus licheniformis*), amyloglucosidase, and celite filter aid were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Anhydrous sodium carbonate and sodium hydroxide were purchased from Shimakyu's Pure Chemicals (Osaka, Japan). Ethanol was purchased from Taiwan Tobacco & Liquor Co. (Tainan, Taiwan). Potassium chloride and hydrochloric acid were purchased from Showa Chemical Co. Ltd. (Tokyo, Japan). Anhydrous sodium acetate was purchased from Katayama Chemical Co. Ltd. (Osaka, Japan). Sodium dihydrogen phosphate and disodium hydrogen phosphate were purchased from Merck (Darmstadt, Germany).

2.2. Preparation of chiffon cakes

The formula of control chiffon cake in this study was adapted from the work of Mau et al. (2015). The chiffon cake comprises batter and foam. The batter of control cake contained wheat flour (174 g), baking powder (3 g), sucrose (130 g), sodium chloride (2 g), soybean oil (87 g), egg yolk (87 g), distilled water (114 g), and nonfat dry milk (13 g). The foam of control cake contained egg white (174 g), sucrose (104 g), and cream of tartar (2 g). The black rice powder was used to substitute 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% (w/w) of wheat flour to make various chiffon cakes, assigned as BR10, BR20, BR30, BR40, BR50, BR60, BR70, B80, BR90, and BR100, respectively.

The black rice chiffon cakes were manufactured following the method used in Mau et al. (2015). After baking, the baked cakes were allowed to cool for 2 h at 25–27 °C and then were removed from their pans. Baked cakes were packed in polypropylene bags before analyses of physicochemical, antioxidant and sensory characteristics.

2.3. Physical characteristics of black rice, wheat flour and cake batters

The moisture of black rice powder, wheat flour and cake batters was determined by AACC International Approved Methods 44-40 (AACC International, 2000). The dietary fiber of black rice powder and wheat flour was analyzed following AOAC method 985.29 (AOAC International, 2003). The 400 mL of cake batter was poured into a 500 mL beaker and its viscosity was measured at 30 rpm with a spindle L4 on a rotational viscometer (Visco Basic Plus L, Fungilab S.A., GR Scientific, Spain) (Lu, Lee, Mau, & Lin, 2010). The specific gravity of cake batters was determined by dividing the weight of the 240 mL of cake batters by the weight of same volume of water (Lu et al., 2010). Each analysis was carried out in triplicate.

2.4. Physical characteristics of baked cakes

The physical characteristics of baked cakes, including moisture, water activity, cake volume, color, and texture profile analysis (TPA), were analyzed following the method used in Lu et al. (2010). The moisture, water activity, and cake volume analysis of baked cakes was carried out in triplicate. The Hunter *L*, *a*, and *b* values of crust and crumb, and TPA parameters were averaged from 10 replications.

2.5. Preparation of ethanolic cake extracts

The freeze-dried baked chiffon cakes were ground in a mill and screened through a 0.5 mm sieve. Each cake powder (10 g) was extracted with 100 mL of 50% (v/v) aqueous ethanol at 75 °C in a shaking water bath (SB302, Kansin Instruments, Kaohsiung, Taiwan) at 100 rpm for 30 min and then filtered through Advantec No. 1 filter paper (Toyo Roshi Kaisha, Ltd., Tokyo, Japan). The residue was then extracted with one extra 100 mL portions of 50% (v/v) aqueous ethanol as described above. The combined ethanolic extracts were rotary-evaporated at 40 °C, and then freeze-dried. The resultant dry extracts were stored at −20 °C before use.

2.6. Determination of total phenols, total anthocyanins and antioxidant activity of cake extracts

Total phenols of cake extracts were determined according to the method of Jun et al. (2012) with minor modification. Each extract (500 mg) was dissolved in 80% (v/v) methanol (6 mL) using an ultrasonic bath with 40 kHz for 5 min, and then the volume was adjusted to 10 ml. Folin-Ciocalteu's phenol reagent (0.4 mL) was added to each sample (0.2 mL), and stood for 1 min. Then, 6 mL of 5 g/100 mL sodium carbonate solution was added to the mixture, and stood for 1 h in dark place. The absorbance was measured at 760 nm using a spectrophotometer (U-1800, Hitachi High-technologies Co., Tokyo, Japan), with gallic acid used as a standard. The content of total phenols was calculated on the basis of the calibration curve of gallic acid [the equation of standard curve: absorbance at 760 nm = 0.0037 $C_{gallic\ acid}$ (μg/ml) + 0.0173, R^2 = 0.9996]. Results were expressed as milligram of gallic acid equivalents (GAE) per gram of cake extract.

Total anthocyanins of extracts were determined following the pH differential method used in Shao et al. (2014a) with minor modification. Each extract (200 mg) was extracted three times with 3 mL of methanol: 1 mol/L HCl (85:15, v/v) using an ultrasonic bath with 40 kHz for 15 min under dark conditions, and then centrifuged at 3600 *g* for 15 min, and then the volume was adjusted to 10 mL.