Research Article

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Effect of Germinated Colored Rice on Bioactive Compounds and Quality of Fresh Germinated Colored Rice Noodle

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Abstract

The objectives of the study were 1) to investigate the effect of pH (pH 6 and 7) on bioactive compounds and antioxidant activity of germinated colored rice, and 2) to study the effect of adding various ratios of germinated colored rice (0, 10, 20, 30, 40 and 50%) on physicochemical property and sensory evaluation of fresh rice noodles. Two species of colored rice, namely Riceberry (RB) and Hom-Nil (HN) were employed as samples for germination. The results indicated that total phenolic content, total anthocyanin content, GABA content and antioxidant activity (FRAP and DPPH assay) were considerably higher when colored rice was soaked at pH 6 compared to pH 7 ($P < 0.05$). The bioactive compounds and proximate compositions of fresh rice noodles were significantly enhanced when addition of Germinated Colored Rice (GCR) increased ($P < 0.05$). However, texture profile analysis of the fresh GCR noodle had remarkable decrease in terms of cohesiveness, springiness and chewiness which had lowest values at 50% supplement of GCR. Lightness (L*) of the noodle reduced whereas redness (a*) and yellowness (b*) incresed significantly ($P < 0.05$) when GCR addition increased. Additionally, there was no distinct difference in sensory evaluation scores from thirty untrained panelists by adding 10 and 20% GCR in the fresh noodle ($P > 0.05$). This study concluded that the incorporation of GCR up to 20% into the formulation could be used to increase nutritional value of the fresh germinated colored rice noodle.

Keywords: Bioactive compounds, Colored rice, Germination, Rice noodle

1 Introduction

Nowadays, consumers focus on using the products from natural origin and require added nutritional value to common foods. Thus, the demand for consumption of rice products with high nutrition has been grown [1]. Subsequently, consumption of colored rice and brown rice has increased to improve and maintain health benefits for the consumers by the effect of bioactive compounds and antioxidant activity. These effects help for regulation of blood pressure and heart rate, inhibition of cancer cell proliferation and protection against oxidative stress [2].

Colored rice (pigmented rice) is a kind of brown rice obtained by removal of husk. It remains bran layers and germ, where exist bio-functional components, especially pigments called anthocyanins [3]. Due to limitation in term of hard texture, it requires longer cooking time thus colored rice is not much popular for consumption [4]. Germinated rice is growing interested recently throughout Asian countries because of its advantages. During germination, bran layers of the

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rice become soften, water absorption and organoleptic quality were also improved [5]. In addition, germinated colored rice are good source of nutritional value, such as vitamin B, E, beta-carotene, gamma oryzanol, anthocyanin and γ-aminobutyric acid (GABA). After being soaked, total phenolic contents and antioxidant activities of germinated rice had considerably higher than non-germinated rice [6], [7]. Moreover, intake of germinated rice instead of white rice is effective for the control of postprandial blood glucose concentration without increasing the insulin secretion in subjects with hyperglycemia [8].

The fresh rice noodles are served as the popular meal. However, little attention has been given on the antioxidative property by development of germinated colored rice noodles. Therefore, the objectives of this research were 1) to investigate the effect of pH conditions (pH 6 and 7) on bioactive compounds and antioxidant activity of germinated colored rice, and 2) to study the effect of adding various ratios of germinated colored rice (0, 10, 20, 30, 40 and 50%) on physicochemical property and sensory evaluation of fresh rice noodles.

2 Materials and Methods

2.1 *Materials*

Two types of colored rice (Riceberry and Hom-Nil variety) and white rice (Sao Hai variety) were purchased from the local store in Chiang Rai province, Thailand. They were stored at 4°C until use.

2.2 *Chemical*

Folin–Ciocalteu's phenol reagent and gallic acid (≥ 99%) were purchased from Fluka (Buchs, Switzerland). Trolox ((±)-6-Hydroxy-2,5,7,8-tetra methylchromane-2-carboxylic acid), DPPH (2,2-diphenyl-1-picryhydrazyl) and TPTZ (2,4,6- Tripyri dyl-s-Triazine) were purchased from Aldrich (Steinheim, Germany). Potassium chloride, sodium acetate, anhydrous sodium carbonate and gamma-aminobutyric acid (GABA) were purchased from Merck (Darmstadt, Germany). Ferric chloride ($FeCl_3$) was purchased from Ajax Finechem (Seven Hills, Australia). All other chemicals and solvents in this study were an analytical grade.

2.3 *Effect of pH on changes of bioactive compounds and antioxidant activity during germination of colored rice*

The colored rice samples were germinated according to Jirapa *et al*. [9] with some modifications. Firstly, 100 grams of rice grains were sterilized with 0.1% sodium hypochlorite solution (1:5 w/v) for 30 minutes, and rinsed with distilled water. Next, rice was soaked by distilled water with the rice-water ratio = 1:5 (w/v) at 30°C for 24 hours with two pH conditions (pH 6 and 7) using citric acid. Then, the rice grains were drained and rinsed again. Soaked rice was placed into a plastic box covered with a lid and germinated at 35°C and 100% relative humidity by left these boxes in a water bath for 12 hours. Afterward, germinated rice were dried at 60°C with a tray dryer for 7 hours to get final moisture contents below 10% to stop germination. The optimal pH condition was determined depend on maximize total phenolic content, total anthocyanin content, total antioxidant activity and GABA contents in samples. This optimal pH condition was selected for making rice noodles.

2.4 *Preparation of the fresh rice noodles*

Fresh rice noodles were prepared by method of Hui, *et al*. [10] with some modifications. Germinated colored rice (200 g) were cleaned, washed and soaked in drinking water with the ratio of rice to water = 1:2 (w/v) for 3 hours. After that, soaked rice grains were wet ground for 5 minutes by blender (Philips HR 2020) into slurry with a smooth consistency. Next, mixed slurry was prepared by adding different ratios of germinated colored rice slurry into white rice slurry from 0 to 50% as shown in Table 1. Tapioca flour and salt were added at 4 and 0.5% of slurry mixture, respectively. Then, vegetable oil (0.5 g) was brushed on stainless steel tray (25×25 cm) and the mixed slurry (90 g) was poured onto the oiled tray. The sample was then steamed for 4 minutes at 100°C to allow starch to swell and gelatinize. Subsequently, the cooked rice sheet was transported by band carriers and cooled naturally to room temperature, then cut into 5 mm wide strips with rectangular shape noodles as the fresh rice noodles. Afterwards, the fresh rice noodle was used immediately as analysed samples for further analysis.

Table 1: The ratio of white rice and germinated colored rice for making fresh rice noodles

Treatment	White Rice Slurry (%)	Germinated Colored Rice Slurry (%)
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50

2.5 *Extraction*

All rice and noodle samples were extracted using the method by Jirapa *et al*. [9]. The sample was ground using the dry blender (Philips HR 2020), and then passed through a 500 µm sieve screen. Ground samples (1 g) were then extracted with 15 mL of 70% methanol and covered with aluminum coil at room temperature (28°C) for 12 hours, and then filtrated by filter papers (Whatman no.4). Extracts solution were then collected and used for further analysis.

2.6 *Determination of total phenolic content*

The Total Phenolic Content (TPC) was determined by spectrophotometry, using gallic acid (0–100 µg/mL) as a standard, according to the method described by the International Organization for Standardization (ISO, 2005) [11]. Sample extract (0.5 mL) and distilled water (0.5 mL) were put into a tube. Then, 2.5 mL of 10% v/v Folin-Ciocalteu reagent and 2.0 mL of 7.5% w/v sodium carbonate solution were added and mixed. Thereafter, the mixture was left for 1 hour at room temperature and the absorbance measured at 765 nm using methanol as blank. The TPC was expressed as Gallic Acid Equivalents (GAE) in mg GAE/g dry weight sample.

2.7 *Determination of total anthocyanin content*

Total Anthocyanin Content (TAC) was estimated by pH-differential method of Sutharut and Sudarat [3]. Each extract sample (1.0 mL) was transferred into 10 mL volumetric flasks for preparing two dilutions of the samples; one was adjusted a volume with potassium chloride buffer (pH 1.0), and the other was adjusted with sodium acetate buffer (pH 4.5). These dilutions was equilibrated for 15 minutes. Afterward, the absorbance of each dilution was measured at the 510 and 700 nm (to correct for haze), against a blank cell filled with distilled water. After 30 minutes, monomeric anthocyanin pigment concentration was calculated and then was converted into mg of total anthocyanin content/100 g sample by expressed mg cyanidin-3-glucoside per 100 g of rice.

Monomeric anthocyanin pigment (mg/l) =
$(A \times MV \times DF \times 1000) / MA$
Where,
A $= (A_{510nm} - A_{700nm})$pH 1.0 $- (A_{510nm} - A_{700nm})_{pH\ 4.5}$
MW = Molecular weight of Cyanidin-3-glucoside
= 449.2
DF = Dilution factor for sample
MA = Molar absorptivity, 26900

2.8 *Determination of GABA content*

GABA content was measured by spectrophotometry using a method of Karladeea and Suriyong [12] using GABA (0–1000 µg/mL) as a standard. Each extract sample (200 µl) was added into a test tube that contained 200 µl of 0.2 M borate buffer pH 9.6% phenol (1 mL) was added to each tube. Subsequently, the tubes were shaken and cooled in an ice bath for 5 minutes. Next, 0.4 mL of sodium hyper chloride (NaOCl) was added to each tube. The tubes were shaken again for 1 minute and cooled in ice bath for 5 minutes, then incubated in boiling water bath for 10 minutes and later allowed to cool at room temperature. Afterward, the absorbance of each sample was evaluated against a blank at 630 nm. The GABA content will be expressed as mg GABA/100 g db samples.

2.9 *Determination of DPPH radical scavenging activity (DPPH assay)*

The DPPH assay was determined according to the method of Molyneux [13] using Trolox (0–250 µg/mL) as standard. Each extract sample (50 µl) was mixed with 1.95 mL 60 µM DPPH solution and left in the dark place for 30 minutes at room temperature. The absorbance of the samples was measured at 517 nm using methanol as blank. The calibration curve was plotted between Trolox concentration (µM) and %

inhibition. The DPPH radical scavenging activity of sample was expressed as μmole TE/g db sample.

2.10 *Determination of ferric reducing antioxidant power activity (FRAP assay)*

FRAP was assayed by the method of Benzie and Strain [14] with few of modification and using ferric sulphate (0–140 μg/mL) as standard. FRAP reagent was prepared by freshly mixing 300 mm acetate buffer (pH 3.6), 10 mm TPTZ in 40 mm HCl and 20 mm $FeCl_3$ in a ratio of 10 : 1 : 1 (v/v/v) respectively. Each extract sample (400 μl) was mixed with 2.6 mL of the FRAP reagent and then incubate for 30 minutes at 37°C. Absorbance of mixtures was measured at 595 nm. Ferric reducing antioxidant power was expressed as mg $FeSO_4$/100 g db samples.

2.11 *Proximate compositions*

Chemical compositions of fresh rice noodles were determined following to AOAC methods [15].

2.12 *Color measurement*

Color of fresh rice noodles were measured following to method of Ai-Ling, *et al.* [16] with slight modifications by a colorimeter (HunterLab, MiniScan EZ) using the CIELAB system. Each fresh rice noodle (15 g) was ground using a mortar and pestle and packed into a small resealable plastic bag. This was then folded in half and then put it in font of reflectance port. The color of the sample was measured through the transparent bag.

2.13 *Texture Profile Analysis (TPA)*

A texture analyzer (TA.TX.Plus, Charpa Techcenter Co.Ltd.) was utilized to examine the texture of rice noodle samples according to Rungarun and Athapol [17] with some modifications. A strand of fresh rice noodle (45 mm width) with 1.0 mm thickness was compressed by a cylinder probe (P/36R, 36 mm diameter) with pre-speed of 1.0 mm/s until the deformation reached 75% at a speed of 1.0 mm/s. The pause between the first and second compressions was 0.5 s. From the force-time curve of the texture profile, textural parameters including chewiness, cohesiveness, hardness, springiness and adhesiveness were obtained. Ten measurements were made for each noodle sample.

2.14 *Sensory evaluatuion*

Sensory evaluation of the fresh noodles was carried out by 30 untrained panelists comprising of both technical staff and students at Mae Fah Luang University. The sensory quality of noodles is evaluated based on the preference for appearance, aroma, flavor, texture and overall acceptability using 9-point hedonic scale. The samples were tested within the day of producing. A sample size of 20 g was served in a small dish coded with three-digit random numbers. Samples were evaluated by the untrained panelists in individual booths.

2.15 *Statistical analysis*

Data were expressed as means ± standard deviation. All experiments conducted in this study were performed in triplicate. The general linear model procedure of the Statistical Analysis System (SPSS, version 16) was used for data analysis. Ducan's test was conducted to compare mean at 5% significance ($P < 0.05$).

3 Results and Discussions

3.1 *Effect of pH on changes of bioactive compounds and antioxidant activity during germination of colored rice*

Table 2 showed TPC, TAC, GABA and antioxidant activity of two colored rice varieties significantly increased after germination compared to that of the non-germinated rice ($P < 0.05$). Increasing in TPC of germinated colored rice both pH conditions due to hydrolysable phenolic content obtained from germination [18]. Moreover, the results showed that TPC in Riceberry at pH 6 was 4.18 mg GAE/g which significantly higher than that of at pH 7 germinated conditions (3.54 mg GAE /g). It could be explained by acidity or hydrogen ion concentration would be enhanced activation of hydrolytic enzyme than neutral condition [8]. In addition, it is due to increase of amount of free form enzyme hydrolysis in the phenolaropanoid pathway by degradation of cell wall during water absorption [19]. Then, germination

Table 2: Chemical analysis of colored rice before and after germination at different pH condition

Sample	TPC (mg GAE/g db)	TAC (mg C3G/g db)	GABA (mg/g db)	FRAP (µmol Fe(II)/g db)	DPPH (µmol TE/g db)	MC (%)
RB	1.24±0.03[d]	0.28±1.74[a]	1.24±0.44[c]	24.25±1.75[d]	8.56±0.38[e]	10.87±0.12[a]
GRB pH6	4.18±0.30[a]	0.25±2.42[ab]	5.36±0.18[b]	54.51±0.82[a]	16.55±2.42[a]	9.65±0.06[b]
GRB pH7	3.54±0.27[b]	0.23±2.41[b]	5.20±0.26[b]	52.78±0.68[a]	13.52±0.64[b]	9.56±0.08[b]
HN	1.29±0.05[d]	0.11±1.15[c]	1.67±0.19[c]	18.66±0.93[e]	6.78±0.38[e]	10.63±0.26[a]
GHN pH6	3.41±0.09[bc]	0.13±1.37[c]	6.06±0.06[a]	45.32±1.72[b]	10.79±1.18[cd]	6.31±0.12[c]
GHN pH7	3.17±0.07[c]	0.12±1.42[c]	5.64±0.09[b]	41.72±1.66[c]	10.06±0.66[d]	6.20±0.21[c]

Values are expressed as mean ± SD (n=3).
Different letters in the same column indicate significant different at $P < 0.05$.
RB = Riceberry, GRB pH 6, GRB pH 7 = Germinated Riceberry at pH 6 and pH 7, respectively. HN = Hom-nil, GRB pH 6, GRB pH 7 = Germinated Hom-nil at pH 6 and pH 7, respectively.

induced saccharolytic enzyme breakdown cell wall polysaccharides, endosperms and protein that cause the release of bound phenolic [18].

Anthocyanin is water-soluble vacuolar pigments, which belong to phenolic groups that responsible for different color basing on the pH [20]. TAC in Riceberry (0.28 mg/g) had significantly higher than Hom-Nil (0.11 mg/g) ($P < 0.05$) because of different varieties contained different amount of naturally occurring anthocyanin [21] and black rice was also reported more abundant in anthocyanin than others, about 1.50–1.72 mg/g contained in Riceberry [22]. However, anthocyanin content was not significantly difference after germination in dark condition during germination ($P > 0.05$), which similar to the study by Pasko *et al.* [23]. In contrast, Sutharut and Sudarat [3] found total anthocyanin content in Hom-Nil significantly decrease from 0.97 to 0.43 mg/g after germinated 12 hours.

The average values of GABA content were 1.24 and 1.67 mg/g in non-germinated Riceberry and Hom-Nil rice, respectively and it significantly increased approximately four times after germination ($P < 0.05$). It can been seen that stored amino acid as storage proteins in rice were degraded by water absorption, changed into amides and transported to the growing parts of rice to supply for growth of sprout and seedling [24]. At that time, GABA was increased by glutamate decarboxylase activation, which synthesized glutamic acid to convert glutamate to GABA [9]. Comparison with regular brown rice, the GABA content in germinated brown rice increased 9.43–16.74 times [9]. Interestingly, GABA contained in Hom-Nil had considerably higher than Riceberry when rice was germinated at pH 6, ($P < 0.05$), meaning that they had different characteristics of water absorption to take part in rapid enhancement of residual GABA in response of hypoxia condition. Actually, hypoxia occurred by the limited availability of oxygen that was agreeable in anaerobic condition of this germination method [25].

From Table 2, a germination process at pH 6 was able to increase dramatically FRAP to 124.78 and 142.87% in GRB and GHN, respectively compared to non-germinated samples ($P < 0.05$). In addition, DPPH of GRB and GHN significantly increased to 93.34 and 59.85%, respectively at pH 6 compared to non-germinated samples ($P < 0.05$). This significant increase should be the same trend with phenolic compounds. This may partially due to the strongly activity of hydrolytic enzymes in optimum acidity condition decomposed macro molecules such as biopolymers and biomolecules, which were developed bioactive compounds during germination [9]. The second reason was increase of amount of a lipophilic antioxidant as tocopherol that acted as antioxidant after germination [26]. In addition, Frias *et al.* [27] presented that the formation of various Reactive of Oxygen Species (ROS) such as superoxide radicals (O_2^-), hydrogen peroxide radicals ($H_2O_2^-$) and hydroxyl radicals (OH^-) resulted in accumulation of lipid hydroperoxides. Hence, this accumulation could be hypothesized that related to enhance of antioxidant activity in germinated colored rice. Therefore, germinated rice sample from pH 6 condition was used for the making the fresh noodle in the next step.

Table 3: Chemical analysis of fresh germinated colored rice noodles

	Germinated Colored Rice Slurry (%)	White Rice Slurry (%)	TPC (mg GAE/g db)	TAC (mg C3G/100g db)	GABA (mg /g db)	FRAP (µmol Fe(II)/g db)	DPPH (µmol TE/g db)
Control	0	100	0.37±0.06^{g}	ND*	ND*	2.34±0.24^{g}	1.57±0.08^{d}
Germinated Riceberry	10	90	0.71±0.03^{f}	0.65±0.21^{d}	1.40±0.18^{d}	5.79±1.14^{f}	3.83±0.45^{c}
	20	80	0.97±0.11^{e}	1.28±0.28^{c}	1.32±0.17^{d}	9.45±0.60^{e}	4.67±0.24^{c}
	30	70	1.31±0.05^{d}	1.54±0.31^{c}	1.51±0.20^{d}	15.98±0.78^{bc}	6.23±0.38^{b}
	40	60	1.74±0.16^{b}	2.06±0.42^{b}	2.25±0.31^{bc}	17.46±1.90^{b}	7.07±0.50^{b}
	50	50	2.14±0.06^{a}	3.08±0.27^{a}	2.57±0.13^{b}	19.75±0.92^{ab}	7.68±0.52^{a}
Germinated Hom-Nil	10	90	0.65±0.02^{f}	0.20±0.14^{e}	2.08±0.22^{c}	6.44±0.53^{f}	2.50±0.24^{d}
	20	80	0.94±0.04^{e}	0.33±0.06^{de}	2.12±0.08^{c}	8.99±0.75^{e}	4.20±0.23^{c}
	30	70	1.25±0.03^{d}	0.48±0.06^{de}	2.27±0.12^{bc}	13.10±1.35^{d}	5.90±0.11^{b}
	40	60	1.52±0.07^{c}	0.46±0.14^{de}	3.15±0.09^{a}	15.42±1.15^{c}	6.70±1.87^{b}
	50	50	1.68±0.19^{bc}	0.67±0.06^{d}	3.04±0.25^{a}	17.90±1.64^{a}	6.42±0.24^{b}

* Not detected

Values are expressed as means ± SD (n=3).

Different letters in the same column indicate significant difference at $P < 0.05$.

3.2 *Effect of germinated colored rice on quality of fresh rice noodle*

3.2.1 Bioactive compounds and antioxidant activity

Both bioactive compounds and antioxidant activity of fresh germinated colored rice noodle, which was formulated by substitution of white rice slurry with germinated colored rice 10–50% significantly increased ($P < 0.05$) when germinated colored rice increased (Table 3). TPC, TAC, GABA and antioxidant compounds were noticeably improved in germinated colored rice noodles with amount of germinated colored rice substitution ($P < 0.05$). The enhancement of these compounds is directly related to germination as explained above. A daily intake of 10–20 mg of GABA showed pre-hypertension prevention in human intervention studies [28]. Hence, a daily consumption of GABA of 100 g germinated colored rice noodle (Riceberry or Hom-Nil added 10–50%) would provide enough GABA for health benefits.

The antioxidant activity (FRAP and DPPH assay) of rice noodle was increased when germinated colored rice was added to noodle ($P < 0.05$). The highest bioactive compounds and antioxidant activity was found in the fresh noodle which substitute with 50% germinated colored rice in the recipe (Table 3).

3.2.2 Proximate analysis

Table 4 showed that protein, fat, ash and fiber of fresh rice noodle formulated from addition of germinated Riceberry and Hom-Nil rice were notable increased when added these germinated colored rice varieties from 10 to 50% in the recipe compared to the control ($P < 0.05$). It might be due to fact that germination process improved these nutritional components in colored rice [29]. Rice lipids mainly include triacylglycerol and occur in the spherosome located in bran layers which are responsible for deterioration of rice flavor. During germination, stored triacylglycerol in rice was required to provide energy for growth of embryo and protein synthesis [30]. Similar results occurred in study by Caceres *et al*. [31], who suggested that protein, lipids, ash and available carbohydrate ranged from 7.3–10.4%, 2.0–4.0%, 0.8–1.5% and 71.6–84.0%, respectively in germinated brown rice. This increase was also in agreement with studies of Yodmanee *et al*. [32]. However, carbohydrate of fresh rice noodle formulated from addition of germinated Riceberry and Hom-Nil rice were notable decreased when added these germinated colored rice varieties from 40 to 50% in the recipe compared to the control ($P < 0.05$). This finding was similar to the studies of Cornejo *et al*. [33], who reported that germination

Table 4: Proximate values of fresh germinated colored rice noodles

	Germinated Colored Rice Slurry (%)	White Rice Slurry (%)	Protein Content (% db)	Fat Content (% db)	Fiber Content (% db)	Ash Content (% db)	Carbohydrate Content (% db)	MC (%)
Control	0	100	7.32 ± 0.11^{fg}	2.13 ± 0.63^{c}	1.41 ± 0.04^{de}	0.34 ± 0.02^{f}	88.81 ± 0.58^{a}	61.44 ± 1.25^{de}
Germinated Riceberry	10	90	8.14 ± 0.19^{d}	1.76 ± 0.47^{c}	1.59 ± 0.19^{cd}	0.50 ± 0.01^{de}	88.01 ± 0.07^{abc}	63.04 ± 0.13^{b}
	20	80	8.45 ± 0.18^{c}	2.98 ± 0.21^{bc}	1.14 ± 0.12^{f}	0.59 ± 0.06^{bc}	86.84 ± 0.26^{c}	61.29 ± 0.28^{e}
	30	70	8.54 ± 0.09^{bc}	4.11 ± 0.60^{ab}	1.27 ± 0.06^{ef}	0.65 ± 0.01^{b}	85.43 ± 0.48^{d}	65.31 ± 0.52^{a}
	40	60	8.75 ± 0.13^{ab}	4.84 ± 1.17^{a}	1.37 ± 0.04^{e}	0.70 ± 0.01^{a}	84.26 ± 1.23^{de}	62.69 ± 0.36^{bcd}
	50	50	8.91 ± 0.08^{a}	4.17 ± 0.51^{ab}	1.77 ± 0.15^{bc}	0.80 ± 0.06^{a}	84.35 ± 0.35^{de}	62.59 ± 0.76^{bcd}
Germinated Hom-Nil	10	90	7.12 ± 0.20^{g}	2.20 ± 0.71^{c}	1.86 ± 0.03^{b}	0.30 ± 0.10^{f}	88.52 ± 0.98^{ab}	61.70 ± 0.38^{cde}
	20	80	7.25 ± 0.11^{g}	3.02 ± 1.13^{bc}	1.90 ± 0.03^{b}	0.34 ± 0.02^{f}	87.49 ± 1.24^{bc}	62.13 ± 0.23^{bcde}
	30	70	7.57 ± 0.10^{f}	2.77 ± 0.58^{c}	1.98 ± 0.03^{b}	0.44 ± 0.04^{e}	87.24 ± 0.49^{c}	65.13 ± 0.15^{a}
	40	60	7.84 ± 0.07^{e}	4.49 ± 0.24^{a}	2.41 ± 0.19^{a}	0.50 ± 0.05^{de}	84.76 ± 0.19^{de}	66.37 ± 0.96^{a}
	50	50	8.06 ± 0.15^{de}	5.11 ± 0.43^{a}	2.50 ± 0.19^{a}	0.53 ± 0.03^{d}	83.80 ± 0.31^{e}	62.85 ± 1.08^{bc}

Values are expressed as means ± SD (n=3).
Different letters in the same column indicate significant difference at $P < 0.05$.

decreased carbohydrate in brown rice bread due to degradation of the starch by the enzyme activity.

3.2.3 Color measurement

Commonly, the fresh rice noodles have been expected high-quality with white or translucent color appearance [34]. Table 5 showed that the L* value as lightness decreased gradually in the fresh rice noodles prepared from germinated Riceberry and Hom-Nil compared to the control ($P < 0.05$). Increasing concentration of germinated colored rice slurry into white rice slurry, the noodles got darker. a* value of germinated Riceberry rice noodle increased remarkably compared to the control and showed more reddish than Hom-Nil rice noodle. On the other hand, noodle made from the addition of germinated Hom-Nil had more yellowness (b* value) than Riceberry noodle. It has been reported that Riceberry and Hom-Nil had naturally different anthocyanin pigments that also caused darker noodle [33]. Therefore, the percentage of anthocyanin in rice affected a* and b* values determining the increase of red and yellow color of noodles. These results were similar to those reported by Lee and Lee [35], who revealed lightness (L*) decreased, but redness (a*) increased in noodles made from incorporation of germinated brown rice flour and wheat flour.

3.2.4 Texture Profile Analysis (TPA)

The texture analysis of the fresh rice noodles containing germinated colored rice in different amounts was presented in Table 5. No significant difference was observed in term of hardness of the germinated rice noodle compared to the control ($P > 0.05$) while, adhesiveness substantially increased when concentration of germinated rice increased ($P < 0.05$). Adhesiveness, which determinates surface stickiness of noodle and related to negative noodle quality, reflected that the noodle became sticky texture and too soft [36]. It can be explained due to degradation of starch by amylase during germination released smaller chain fragments on the surface of noodle [36]. Similarly, protein was degraded by protease into smaller sugars and amino acids leading to weak net-works [37]. Interestingly, amylase activation during germination would be lowered level of amylose content [38], implying that high Glycemic Index (GI), because amylase has been shown negative correlation with GI. Hence, food contained low GI can develop as functional food for diabetics [39].

In contrast, significant decreases in springiness, cohesiveness and chewiness were noticed with the addition of germinated colored rice in the noodle ($P < 0.05$). The springiness as elasticity of noodles varied from 0.97 to 0.65 mm in 10 to 50% germinated

Table 5: Color measurement and texture profile analysis of fresh germinated colored rice noodles

Treatment	Texture Profile Analysis							Color		
	Germinated Colored Rice Slurry (%)	White Rice Slurry (%)	Hardness (N)	Adhesiveness (N.s)	Springiness (mm)	Cohesiveness (ratio)	Chewiness (N.mm)	L*	a*	b*
Control	0	100	20.65 ± 2.68^{a}	-0.21 ± 0.19^{d}	1.11 ± 0.28^{a}	0.85 ± 0.04^{a}	19.33 ± 7.01^{a}	76.00 ± 0.41^{a}	-1.56 ± 0.30^{f}	0.40 ± 0.04^{e}
Germinated Riceberry	10	90	18.34 ± 3.77^{a}	-0.31 ± 0.19^{cd}	0.97 ± 0.11^{ab}	0.78 ± 0.05^{ab}	13.80 ± 2.71^{b}	60.60 ± 0.30^{b}	4.65 ± 0.13^{cd}	0.94 ± 0.43^{de}
	20	80	18.44 ± 4.18^{a}	-0.36 ± 0.17^{cd}	0.91 ± 0.03^{b}	0.79 ± 0.08^{ab}	13.1 ± 2.78^{b}	58.85 ± 2.15^{b}	4.25 ± 0.64^{de}	0.82 ± 0.38^{e}
	30	70	18.87 ± 2.80^{a}	-0.82 ± 0.49^{a}	0.86 ± 0.24^{b}	0.74 ± 0.08^{bc}	11.72 ± 2.83^{bc}	53.43 ± 0.76^{c}	5.79 ± 0.92^{ab}	0.87 ± 0.65^{e}
	40	60	18.31 ± 3.58^{a}	-0.99 ± 0.66^{a}	0.68 ± 0.22^{c}	0.75 ± 0.08^{bc}	9.20 ± 2.94^{cd}	45.11 ± 0.73^{e}	6.62 ± 0.61^{a}	0.80 ± 0.02^{e}
	50	50	18.26 ± 2.31^{a}	-1.07 ± 0.51^{a}	0.65 ± 0.19^{c}	0.68 ± 0.09^{cd}	8.12 ± 3.06^{d}	44.05 ± 1.60^{e}	6.48 ± 0.24^{ab}	1.15 ± 0.50^{cde}
Germinated Hom-Nil	10	90	19.35 ± 2.64^{a}	-0.35 ± 0.43^{cd}	0.93 ± 0.07^{b}	0.74 ± 0.08^{bc}	13.30 ± 1.77^{b}	60.35 ± 0.20^{b}	3.49 ± 0.32^{d}	1.81 ± 0.26^{bcd}
	20	80	18.78 ± 3.26^{a}	-0.41 ± 0.23^{cd}	0.98 ± 0.06^{ab}	0.77 ± 0.08^{b}	14.10 ± 2.14^{b}	51.76 ± 0.74^{c}	4.56 ± 0.41^{cd}	1.91 ± 0.92^{bc}
	30	70	18.48 ± 1.05^{a}	-0.64 ± 0.42^{bc}	0.94 ± 0.06^{b}	0.69 ± 0.09^{cd}	12.03 ± 2.09^{bc}	48.19 ± 0.73^{d}	5.47 ± 0.35^{bc}	2.01 ± 0.33^{bc}
	40	60	18.43 ± 1.25^{a}	-0.68 ± 0.27^{ab}	0.92 ± 0.07^{b}	0.65 ± 0.08^{d}	11.11 ± 2.17^{bcd}	48.19 ± 2.51^{e}	5.68 ± 0.10^{ab}	2.31 ± 0.51^{ab}
	50	50	18.12 ± 1.71^{a}	-0.95 ± 0.24^{a}	0.83 ± 0.11^{b}	0.57 ± 0.09^{e}	8.87 ± 2.70^{cd}	42.86 ± 2.94^{e}	5.61 ± 0.47^{abc}	3.11 ± 0.77^{a}

Values are expressed as means ± SD (n=3).
Different letters in the same column indicate significant difference at $P < 0.05$

Riceberry and slightly decreased from 0.93 to 0.83mm in 10 to 50% germinated Hom-Nil. The cohesiveness ranged narrowly between 0.78 and 0.68 in 10 to 50% germinated Riceberry and from 0.74 to 0.57 in 10 to 50% Hom-Nil that reduced probably resulting in changes of structure of starch and protein [36]. The chewiness was combination of hardness × springiness × cohesiveness determined by change in any one these parameters [17] that leaded to reduction of chewiness of noodles by decrease of springiness and cohesiveness. This parameter was in agreement with the previous observation in the addition of germinated brown rice to replace wheat flour [36]. Similar findings were shown by Lee and Jung [40] which texture of cooked noodles (except adhesiveness) decreased with the increase of supplemented brown rice and colored rice flour (not germinated) into wheat noodle. Generally, germinated colored rice was incorporated with white rice prepared rice noodle which significantly affected ($P < 0.05$) on almost texture parameters of fresh noodles, exception of hardness.

3.2.5 Sensory evaluation

Table 6 showed that the noodles supplemented with 10–20% germinated colored rice slurry received the same appearance, aroma, taste, texture and overall acceptability scores compared to the control ($P > 0.05$), implying that fresh germinated colored rice noodle was most-liked (higher than 6) by the panelists. It means that fresh rice noodle prepared from 10–20% germinated colored rice had more preferred compared with higher concentration added germinated colored rice (30–50%). This finding might conclude that using germinated Riceberry and Hom-Nil rice as a proportional substitution for white rice up to 20% could achieve the similar quality and pleasant appearance as regular noodles.

4 Conclusions

There was a significant difference in bioactive compounds and antioxidant activity when colored rice was germinated at pH 6 compared to pH 7 and non-germinated colored rice ($P < 0.05$). Addition of germinated colored rice in a fresh noodle could be enhanced more nutritional values, which unaffected hardness but increased adhesiveness, decreased springiness, cohesiveness and chewiness. Furthermore, substitution of germinated colored rice up to 20% into rice noodle received good nutritional quality and sensory acceptability. Consequently, the fresh germinated colored rice noodle may have benefit for consumption and should be developed further to be employed in food industry as healthy product and added value to rice product.

Table 6: Sensory evaluation of fresh germinated colored rice noodles

	Germinated Colored Rice Slurry (%)	White Rice Slurry (%)	Appearance	Aroma	Taste	Texture	Overall Acceptability
Control	0	100	7.03±2.19^{a}	6.13±1.85^{abc}	6.20±1.63^{a}	7.03±1.94^{a}	6.90±1.58^{a}
Germinated Riceberry	10	90	6.77±1.59^{ab}	6.50±1.57^{a}	6.37±1.45^{a}	6.67±1.65^{a}	6.87±1.38^{a}
	20	80	6.77±1.36^{ab}	6.40±1.67^{ab}	6.70±1.74^{a}	6.53±1.66^{a}	6.60±1.40^{ab}
	30	70	6.00±1.39^{bc}	5.50±1.61^{bcd}	5.43±1.72^{bc}	5.13±1.57^{b}	5.87±1.31^{bc}
	40	60	5.33±1.86^{cd}	5.30±1.91^{cd}	5.33±1.99^{bc}	4.63±1.96^{bc}	5.17±1.51^{cd}
	50	50	5.07±1.72^{d}	5.13±2.03^{d}	4.77±1.68^{c}	4.27±1.68^{c}	4.90±1.47^{d}
Control	0	100	7.00±1.68^{a}	6.40±1.45^{a}	6.60±1.81^{a}	7.17±1.44^{a}	7.03±1.38^{a}
Germinated Hom-Nil	10	90	7.17±1.18^{a}	6.27±1.14^{ab}	6.47±1.55^{a}	6.93±1.17^{a}	7.00±1.23^{a}
	20	80	7.03±1.33^{a}	6.43±1.33^{a}	6.37±1.87^{a}	6.83±1.12^{a}	7.03±1.10^{a}
	30	70	6.03±1.35^{b}	6.20±1.52^{bc}	6.07±1.44^{ab}	5.63±1.43^{bc}	6.33±1.32^{b}
	40	60	6.17±1.44^{b}	5.90±1.49^{bc}	5.80±1.61^{ab}	5.83±2.02^{b}	5.40±1.69^{bc}
	50	50	5.60±1.61^{b}	5.53±1.38^{c}	5.30±1.56^{b}	4.93±1.68^{c}	4.97±1.61^{c}

Values are expressed as means ± SD (n=3).
Different letters in the same column indicate significant difference at $P < 0.05$.

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