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Effects of purple rice ratio on anthocyanin, antioxidant activity and physicochemical characteristics of extruded snack

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ABSTRACT

Purple rice is rich in anthocyanins, which possess antioxidative properties and may help prevent cancer and diabetes. Extrusion is a high-temperature, short-time thermal process designed to minimize nutrient degradation. This study aimed to evaluate the effects of varying purple rice to ST25 ratios (20:80, 25:75, 30:70, and 35:65) on the physicochemical and sensory properties of extruded purple rice snacks. The evaluated parameters included hardness, color value (L), water absorption index (WAI), water solubility index (WSI), density (d), expansion, rheology, anthocyanin, and antioxidant activity (DPPH, 2,2-diphenyl-1-picrylhydrazyl), sensory attributes. Increasing the purple rice content in extruded snacks resulted in a darker color, greater hardness, and lower expansion ratio, likely due to the impact of fiber on starch gelatinization. Water absorption decreased, while water solubility increased. Pasting properties were reduced, whereas anthocyanin content and antioxidant activity increased, highlighting potential health benefits. Incorporating 30% purple rice enhanced both anthocyanin (3.73mg/100gDW), DPPH (1.38 mgTE/gDW) and hardness (34.31 N), expansion ratio (1.71), offering insights for developing purple rice-based snacks with optimal sensory attributes, with all values about 4.22/5.*

1. INTRODUCTION

Extrusion cooking is increasingly popular in the food industry for combining continuous cooking, mixing, and grinding into a single efficient, low-cost process. As defined by Pismag et al. (2024), extrusion is a short-term, high-temperature mechanical process that transforms powders or starches with low moisture content. During extrusion, raw materials experience significant structural and chemical changes—including starch gelatinization, protein denaturation, amylose-lipid complex formation, vitamin degradation, and pigment transformation (Singh et al., 2007). This versatility allows extrusion to convert common cereal ingredients such as wheat, oat, corn, and rice into a wide range of innovative products (Robin et al., 2012; Escalante-Aburto et al., 2013; Sandrin et al., 2018). Increasing the barrel temperature reduces the bulk density of the extrudates, while higher screw speeds further decrease bulk density by enhancing shear and expansion (Navale et al., 2015). Moreover, the growing demand among health-conscious consumers for natural bioactive compounds, such as dietary fibers, minerals, and pigments, further drives the development of extruded foods (Chassagne-Berces et al., 2011; Zhang et al., 2014).

Purple rice (*Oryza sativa* L.) serves as a valuable source of starch and protein to support expansion during extrusion (Navale et al., 2015), while also contributing its distinctive nutritional profile. This pigmented variety is particularly rich in antioxidants, dietary fibers, and a broad spectrum of phytochemicals, including tocopherols, tocotrienols, γ-oryzanol, B vitamins, and various phenolic compounds (Min et al., 2012). Its bran, rich in anthocyanins (Zheng et al., 2022), has been associated with reduced risks of serious diseases such as cancer and obesity, along with antiviral, anti-inflammatory, and anti-ageing benefits (Yamuangmorn et al., 2021). These unique qualities make purple rice an attractive ingredient for developing novel snack products via extrusion (Sulsomboon et al., 2011).

In contrast, ST25 rice is a premium long-grain Vietnamese rice celebrated for its pandan-like aroma and the subtle scent reminiscent of early sticky rice (Bui et al., 2023). Its white color, mild flavor, potential anti-allergic properties, and bland taste make it particularly well-suited for extrusion processing (Lai et al., 2023). Rice-based extruded products, such as snacks and puffed items, have already established their presence in the market due to their appealing characteristics and cost-effectiveness (Karun, et al., 2023).

There is limited research examining the interrelated physicochemical and antioxidant properties of extruded snacks made from purple rice. This study aims to develop an innovative snack product by blending purple rice with ST25 rice using a single-screw extruder. By investigating the physicochemical changes that occur with varying rice ratios, the research seeks to optimize the product's quality while leveraging the nutritional benefits and unique flavors of both rice varieties.

2. MATERIALS AND METHOD

2.1. Materials

ST25 white rice contains approximately 78% starch (18.27% amylose content), 1.0% dietary fiber, 7.0% protein, 1.0% lipid, and anthocyanin 0%, whereas purple ST rice contains about 70% starch (13.73% amylose content), 10.1% dietary fiber, 10.1% protein, and 2.75% lipid, and 25.05mg% anthocyanin. Wheat flour (11% protein content, and gluten content 32% Baker's choice brand), dried coconut, sugar, extra refined sugar (Bien Hoa, Vietnam), salt, sodium bicarbonate were purchased from Bach Hoa Xanh store, Mau Than street, Ninh Kieu ward, Can Tho city.

2.2. Methods

2.2.1. Snack ingredient

The snack preparation process followed industrial practices. The mixtures of purple rice and ST25 rice, totalling 500 g, were prepared at ratios of 20:80, 25:75, 30:70, and 35:65, with 3 replicates. Each mixture contained 80 g of taro flour, 20 g of modified starch E1412, and 100 g of wheat flour. Additionally, sugar (2.0%), salt (1.0%), and baking powder (0.2%) were added. Water was incorporated into the flour mixture to achieve a moisture content of 15.5%, and the mixtures were thoroughly stirred before being fed into a single-screw extruder.

2.2.2. Cooking extrusion

Extrusion was performed using a single-screw extruder with a three-phase capacity of 50-70 kg/h, a screw speed of 700-800 rpm, an engine power of 5.5 kW, and a three-phase electricity requirement of 380V – 50Hz. The extruder featured a die diameter of 1.3 cm, a screw length of 12 cm, a screw diameter of 3.4 cm, a channel width of 1.4 cm, a flight width of 0.5 cm, and a screw pitch of 1.5 cm. The screw speed was set to 450 rpm for all four rice ratios.

2.2.3. Moisture content

The moisture content, or water content, was assessed by heating the ground sample (5 g) in an oven set to 105 °C for 24 hours, using the specified AOAC method (Luigi, 2004).

2.2.4. Textural properties

Texture analysis was performed using a TA-XT2 Texture Analyzer connected to a computer, equipped with a blade set. The testing parameters included a pre-test speed of 2.0 mm/s, a test speed of 1.0 mm/s, and a post-test speed of 10.0 mm/s, with a distance of 5.0 mm. A force-time curve was recorded and analyzed to determine the peak force, which was used to represent the hardness of the extrudate, following the method of Ding et al. (2005). The average value of ten samples per replicate was used for texture measurement.

2.2.5. L value*

The L* value of the extrudate (lightness) was determined using a high-quality colorimeter NR60CP (China).

2.2.6. Anthocyanin content

The anthocyanin content was determined using the differential method of Lee et al. (2005) [13]. The color absorption of anthocyanins in different buffer solutions (pH 1 and 4.5) was measured at wavelengths of 510 nm and 700 nm, respectively, using a UV-Vis spectrophotometer (Thermo Scientific Evolution Plus One, USA). The total anthocyanin content was calculated using cyanidin-3-glucoside as the standard.

$$a = \frac{A.M.K.V}{\varepsilon,l} \quad (1)$$

Where, $a = (A_{510.pH=1} - A_{700nm.pH=1}) - (A_{510.pH=4.5} - A_{700nm.pH=4.5})$, the difference in absorbance at wavelengths 510 nm and 700 nm at pH 1 and 4.5; *M*, molecular weight of anthocyanin (449.2 g/mol); *l*, cuvette path length (cm); *K*, dilution factor; *V*, volume of extract (L). Using these parameters, the total anthocyanin content can be calculated on a dry basis. Here, *m* represents the initial sample weight (g), and *w* indicates the moisture content (%) of the sample; C, anthocyanin content of the sample (mg/100g dried weight, DW).

$$C = \frac{a}{m.(100-w).10^{-2}}100 \quad (2)$$

2.2.7. DPPH

The antioxidant activity of the samples was measured using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method as described by Kim et al. (2002). The extracts (200 µL) were mixed with 4 mL of DPPH solution (0.0040 g DPPH in 100 mL methanol). After 30 minutes of dark incubation at room temperature, the absorbance of the reaction mixtures was measured at 517 nm using a UV-Vis spectrophotometer (Thermo Scientific Evolution Plus One, USA). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was used as the standard. The analysis was performed three times, and the results were expressed as mg TE/g DW.

2.2.8. Water adsorption index (WAI) and Water solubility index (WSI)

The WAI and WSI of the extrudates were determined as described by Suksomboon et al. (2011). A suspension was prepared by mixing 2.5 g of ground extrudate sample (100 mesh) with 25 mL of distilled water at room temperature and gently stirring for 30 minutes. The mixture was then centrifuged at 3000 rpm for 15 minutes. The supernatant was carefully decanted into a pre-weighed aluminum dish, and the remaining gel was weighed. The WAI (g/g dried weight, DW) was calculated as the weight of the gel remaining after removal of the supernatant per unit weight of the ground sample. The supernatant from the WAI test was dried to constant weight at 105 °C, and the WSI (% in DW) was determined as the dried weight of solids from the supernatant in the initial sample.

2.2.9. Density

Volume of snacks (extrudates) calculated according to the method of Korkerd et al. (2016). Individual cylindrical extrudates were weighed, and the diameter and length were measured using a digital vernier calliper. The density of cylinder snacks can be calculated by mass (*m*, in g) over volume (v, in mL):

$$d = \frac{m}{V} = \frac{m.4}{\pi.L.(D_{out}^2 - D_{in}^2)} \quad (3)$$

Where, length (*L*, in cm), outer (D_{out}, in cm) and inner (D_{in}, in cm) diameters of the cylinder. For each replicate, the density was calculated by averaging the values obtained from ten individual samples.

2.2.10. Expansion ratio

Expansion of extrudates calculated according to Korkerd et al. (2016). The ratio of the outside dimeter of extrudate and the diameter of die. The average value of ten samples for each replicate was selected as the density measurement.

2.2.11. Pasting properties

Pasting properties were determined using a Rapid Visco Analyzer (Perten 4500, Australia). Extrudate samples were prepared as a 12% (dry basis) slurry in distilled water, and each sample was subjected to a standardized temperature–time protocol: an initial equilibration at 25°C for 10 s, heating from 25 to 95°C, maintaining at 25°C for 2 min, reheating from 25 to 95°C for 7 min, holding at 95°C for 10 min, and finally cooling from 95 to 25°C over 15 min. The paddle was operated at a constant speed of 160 rpm following an initial equilibration at 960 rpm for 10 s. Pasting viscosities were computed using the Thermocline software provided with the instrument (O'Shea & Gallagher, 2019). The pasting parameters included cold peak viscosity (CPV, representing the viscosity of gelatinized starch at 25°C), raw peak viscosity (RPV, corresponding to the viscosity of raw starch granules at 95°C), trough viscosity (TV, indicating the holding viscosity of the hot paste), final viscosity (FV), breakdown viscosity (BD, calculated as BD = PV – TV), and setback viscosity (SB, calculated as SB = FV – TV).

2.2.12. Sensory Evaluation

Color, texture, aroma, and taste were assessed using Quantitative Descriptive Analysis (QDA) following the procedure described by Poste et al. (1991). Twenty trained panelists, consisting of staff and students, were selected and instructed to evaluate and compare the coded samples under controlled sensory laboratory conditions.

2.3. Statistical analysis

The experiment was arranged in a completely randomized design with three replications. Data were analyzed using analysis of variance (ANOVA), and processing and graphing were performed with Statgraphics Centurion 15.1 and Microsoft Excel 2010

3. RESULTS AND DISCUSSION

3.1. L* value

The L* value of snacks was significantly influenced by varying rice ratios ($p < 0.05$). Specifically, an increase in climbing purple rice content from 20% to 35% resulted in a substantial decline in the L* value from 72.52 to 65.78 (Figure 1). The considered results have the same downward tendency and a higher L* value from 64.15 to 60.81 as the result of Ma et al. (2023), who researched extruded black/purple rice. The L* value exhibited an inverse relationship with the proportion of purple rice, likely due to the presence of anthocyanins. This finding is consistent with the report by Widyasaputra et al. (2019), which indicated that the color of cooked rice is dependent on the rice variety. The reduction in L* value with increasing purple rice content could be attributed to the anthocyanins present in purple rice, which contributed to its darker pigmentation

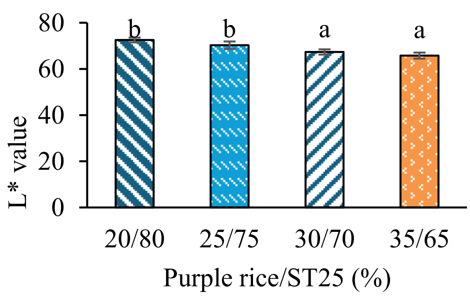

Figure 1. L* value of snack changing with the ratio of purple rice

3.2. Expansion ratio

Expansion ratio plays a crucial role in snack quality and is significantly influenced by the proportion of purple rice ($p < 0.05$). An increase in purple rice content from 20% to 35% reduced the expansion value from 1.83 to 1.70 (Figure 2). Lower compared to the study of Suksomboon et al. (2011), the combination of soybean and purple rice, increasing moisture content and the same barrel temperature, screw speed caused a plummet in expansion ratio in a range of 2.74 to 2.53. This result is evaluated as the same with research of Hernandez-Diaz et al. (2007), who studied extrudates prepared with blends of wheat flour/ Pinto bean with added wheat bran. the expansion of extrudates ranged between 1.0 and 2.0.

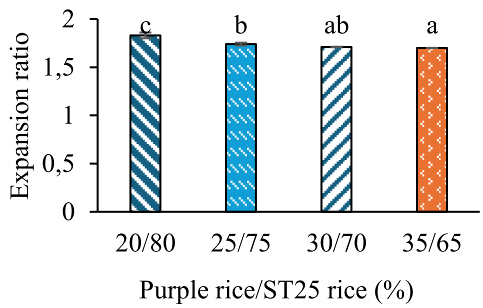

Figure 2. Expansion ratio of the snack changes with the ratio of purple rice

Expansion is primarily determined by the composition of raw materials, particularly starch and fiber content. A higher fiber content might hinder starch gelatinization, as fiber interacts with proteins, affecting the swelling capacity of ingredients and the thickness of the cell wall. This observation aligned with the findings of Leonard et al. (2020), who reported that expansion is negatively impacted by the protein and fiber composition of raw materials.

3.3. Density

The density of snacks was significantly influenced by the proportion of purple rice ($p < 0.05$). Increasing the purple rice content from 20% to 35% increased density from 0.19 g to 0.28 g (Figure 3).

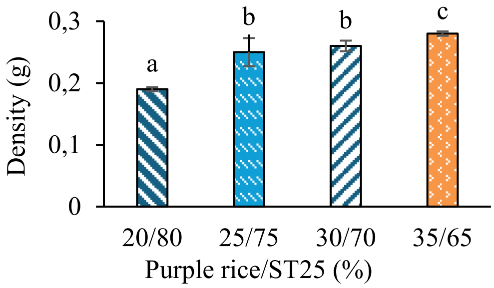

Figure 3. Density of snack changing with ratio of purple rice

This result has the same comparative result as the report of Suksomboon et al. (2011), increasing moisture content that leads to a change in density from 0.22 (g) to 0.29 (g) at the same temperature and screw speed. This effect could be attributed to the bran present in purple rice, which competed for water absorption and consequently hindered starch gelatinization. Brennan et al. (2008) reported that higher levels of wheat bran were associated with increased snack density.

Additionally, an increased proportion of purple rice was found to reduce the expansion ratio, thereby contributing to higher density, as snacks with lower expansion ratios tended to be heavier and more compact (Senevirathna et al., 2022). This may be due to the higher sugar and fiber contents, which tend to reduce expansion and increase product density.

3.4. Hardness

Extruded snack hardness is considered as a critical parameter influencing consumer acceptance. Snack hardness was significantly affected by varying rice ratios ($p < 0.05$). Specifically, increasing the proportion of purple rice from 20% to 35% increased hardness from 30.42 N to 38.87 N (Figure 4).

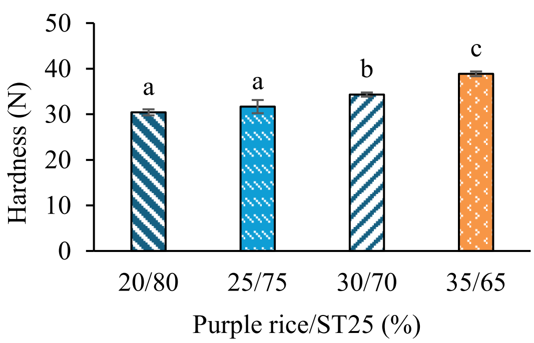

Figure 4. Hardness of snacks changing at different proportions of purple rice and ST25

Hardness was observed lower comparatively report of Sebastião et al. (2023) extruded breakfast cereals from blends of broken rice and vegetable flours from 37.49 (N) to 51.68 (N). This trend may be attributed to the higher protein and fiber content in the rice bran, which adversely affects snack tenderness. Chaiyakul et al. (2009) reported that incorporating protein into formulations reduces swelling and increases product hardness, while Alam et al. (2016) demonstrated that elevated fiber levels contribute to higher hardness.

Additionally, the increased proportion of purple rice was associated with a lower expansion ratio, resulting in a more compact structure and consequently higher hardness.

3.5. Pasting properties

The pasting properties of the snacks were significantly influenced by the proportions of purple rice and ST25 rice ($p < 0.05$).

As shown in Figure 5, increasing the purple rice ratio from 20% to 35% reduced all key pasting parameters, including cold peak viscosity, raw peak viscosity, trough (hold) viscosity, breakdown viscosity, final viscosity, setback viscosity, and cold peak area. These reductions align with trends reported in earlier studies.

However, compared with Singh et al. (2009), the viscosity values in this study are generally lower than the ranges they reported for cold and raw peak viscosities across various food products.

The higher incorporation of purple rice, which contains more fiber and lipids but less starch, led to an overall reduction in viscosity parameters (Evangelista & Schönlechner, 2025). These reductions in peak viscosity, setback, and breakdown are likely due to interactions between fibers and starch molecules (Wang et al., 2018).

Setback viscosity, defined as the viscosity recovered during the cooling of heated starch and indicative of the recrystallization of gelatinized starch (Dalbhagat et al., 2019), decreased under the conditions tested.

Wu et al. (2021) reported that the setback value significantly declines with increasing fiber content. In addition, the observed reduction in peak viscosity suggests enhanced solubility and reduced swelling, as noted by Laishram et al. (2017).

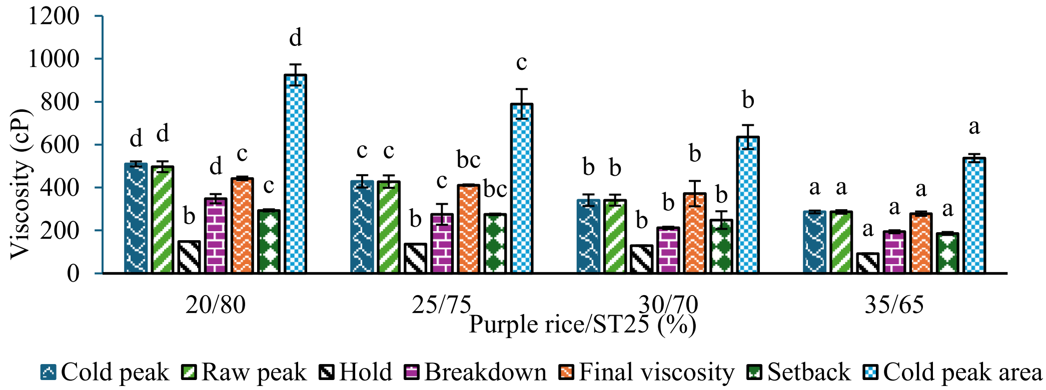

Figure 5. Pasting properties of snacks changing at different proportion of purple rice and ST25

3.6. Water absorption index (WAI)

The WAI of the snacks was significantly influenced by the rice composition ($p < 0.05$). Specifically, increasing the purple rice content from 20% to 35% reduced the WAI from 5.25 g/g to 4.50 g/g (Figure 6). The result showed a higher reported value of Wang et al. (2021), ranging from 2.40 (g/g) to 5.71 (g/g).

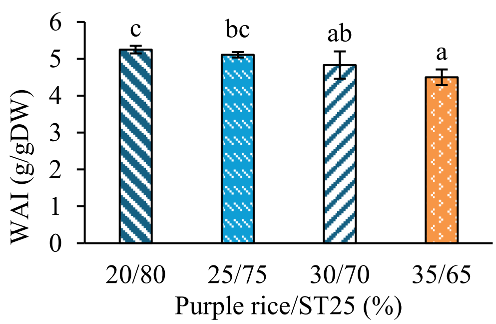

Figure 6. WAI of snacks changing at different the proportion of purple rice and ST25

The reduction in WAI can be attributed to the high fiber content of purple rice bran, which reduces starch availability and impedes starch water absorption (Yadav et al., 2024). This observation aligns with Dumchaiyapoom et al. (2019), who demonstrated that WAI is adversely affected by the incorporation of coconut meat. Similarly, Charunuch et al. (2014) reported that an increased proportion of rice bran in the mixture leads to diminished starch gelatinization, resulting in lower viscosity and WAI due to the substitution of starch with dietary fiber.

3.7. Water solubility index (WSI)

The WSI of snacks is significantly affected by different rice levels ($p<0.05$). Increasing purple rice from 20% to 35% cause WSI value climbing at 8.69 (%) to 14.10 (%) respectively (Figure 7).

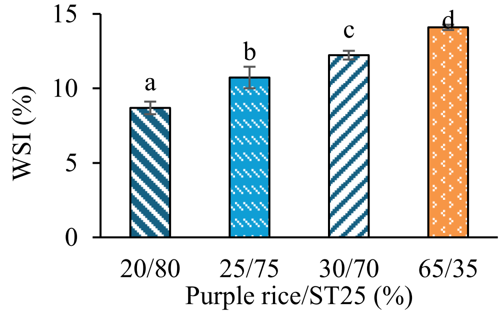

Figure 7. WSI of snacks changing at different the proportion of purple rice and ST25

WSI evaluated higher the result of Wang et al., (2018) researched from 2.13% to 9.68%. and same result with Sahu et al., 2022 from 12.76% to 20.97%.

In this case, purple rice is affected by great shear force, which leads to an increase in insoluble fibre composition. Suksomboon et al., (2011) reported that WSI depends on a number of soluble ingredients. Hence, less amylose content affecting higher starch degradation in the extrusion make increasing WSI (Dalbhagat et al., 2019). In this case, purple rice is affected by great shear force, which leads to an increase in insoluble fibre composition. Suksomboon et al. (2011) reported that WSI depends on a number of soluble ingredients. Hence, less amylose content affecting higher starch degradation in the extrusion make increasing WSI (Dalbhagat et al., 2019).

3.8. Anthocyanin content

Anthocyanin content of snacks is importantly affected by other rice levels ($p<0.05$). Basically, increasing purple rice from 20% to 35% cause anthocyanin rising from 2.02 (mg/100g) to 6.47 (mg/100g) (Figure 8). The amount of anthocyanin showed the same value as that of Soison et al. (2014), who researched extruded sweet potato flours from 1.71 (mg/100g) to 9.10 (mg/100g). The anthocyanin content in the snacks depends largely on the anthocyanin level present in the purple rice. Based on the results of Chen et al. (2012), the anthocyanin content of black and red rice was detected. In contrast, white and green rice were not found.

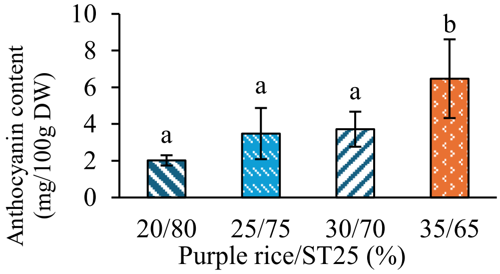

Figure 8. Anthocyanin of snacks changing at different the proportion of purple rice and ST25

3.9. DPPH

DPPH was used to measure the antioxidant activities of purple rice and ST25 rice extruded snacks. The DPPH of snacks has increased trend from 1.24 (mgTE/g DW) to 1.45 (mgTE/g DW) (Figure 8). DPPH was evaluated higher the result Phomkaivon et al. (2018) reported antioxidant activity of purple sweet potato flours from 0.78 (mgTE/g DW) to 2.2 (mgTE/g DW).

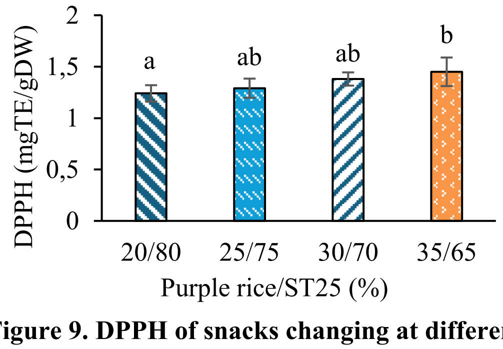

Figure 9. DPPH of snacks changing at different the proportion of purple rice and ST25

These antioxidant compounds may be concentrated in the bran fractions, which are associated with the outer layers, particularly the aleurone layer Zhu et al., 2024). The result of Thammapat et al. (2016) showed that antioxidant compounds, including phenolic acids and γ-oryzanol, are increased after steaming. Following the results of Charunuch et al. (2014), the antioxidants in rice bran, increasing the content of defatted bran, resulted in higher phenolic synthesis and antioxidant activity.

3.10. Correlation between characteristics

Based on Table 1, the proportion of purple rice supplementation showed a strong positive relationship with hardness, WSI, and density ($p < 0.001$). Purple rice contains a considerable amount of fiber beyond the bran layer, which increases the hardness of the snack and consequently leads to higher WSI values. In addition, the increasing density of snacks is relevant to the bran layer. Lobato et al. (2011) reported that the fibre added into extrudates increases density and hardness. In contrast, purple rice supplemented had a strong negative relationship ($p<0.001$) with L*, WAI, expansion. Fakfoung (2018) the color of purple rice is not transparent which makes the product darker. Besides, increasing purple rice makes a rise in a few fibres and dilutes amylose content, which impedes starch gelatinisation, leading to expansion, WAI, and viscosity decreases. Qiu et al. (2015) the fiber alters starch gelatinization by competing with starch for water absorption and preventing water blinding to the amorphous parts of the starch granules. Hardness had a strong positive relationship ($p<0.001$) with WSI and d. Hardness and crispiness of extrudates indicate relevant expansion and cell structure (Sharma et al., 2015). Besides, hardness has a strong negative relationship with L*, viscosity, increasing hardness results in a reduction of both L* and viscosity. WSI has a strong positve relationship ($p<0.001$) with density and a strong negative relationship ($p<0.001$) with expansion and viscosity. Moreover, Density has a strong negative relationship with expansion and viscosity ($p<0.001$). Furthermore, expansion has a strong positive relationship ($p<0.001$) with viscosity.

Table 1. Correlation coefficients between purple rice and ST25 rice for extrudate characteristics.

	Rice ratio	HD	L*	AC	DPPH	WAI	WSI	Density	ER
HD	0.94***								
L*	-0.92***	-0.87***							
AC	0.77**	0.74**	-0,67*						
DPPH	0.70*	0.66*	-0.46	0.76**					
WAI	-0.83***	-0.78**	0.80**	-0.62*	-0.36				
WSI	0.98***	0.91***	-0.87***	0.82**	0.74**	-0.80**			
Density	0.87***	0.83***	-0.86***	0.64*	0.53	-0.70*	0.86***		
ER	-0.87***	-0.75**	0.83***	-0.62*	-0.51	0.71**	-0.89***	-0.93***	
CPV	-0.98***	-0.93***	0.94***	-0.71**	-0.68*	0.75**	-0.94***	-0.89***	0.88***
RPV	-0.97***	-0.93***	0.93***	-0.72**	-0.70*	0.74**	-0.93***	-0.88***	0.85***
TV	-0.84***	-0.87***	0.80**	-0.82**	-0.61*	0.66*	-0.84***	-0.69*	0.67*
BD	-0.91***	-0.84***	0.87***	-0.59*	-0.63*	0.67*	-0.85***	-0.89***	0.84***
FV	-0.90***	-0.91***	0.85***	-0.83***	-0.65*	0.72**	-0.89***	-0.73**	0.71*
SB	-0.88***	-0.90***	0.84***	-0.82**	-0.66*	0.68*	-0.88***	-0.71*	0.69*
CPA	-0.96***	-0.93***	0.91***	-0,68*	-0.69*	0.70*	-0.92***	-0.88***	0.85***

*Note: The values designated with *, **, and *** indicate significant correlations at p less than 0.05, 0.01, and 0.001, respectively. Abbreviations: WAI; water absorbance index; WSI, water soluble index; ER, expansion ratio; AC, anthocyanin content; BD, breakdown viscosity; PR, purple rice ratio; FV, final viscosity; CPA, cold peak area; CP, cold peak viscosity; HD, hardness; RPV, raw peak viscosity; SB, setback viscosity; TV, trough viscosity*

3.11. Sensory evaluation

The sensory evaluation showed that the blending ratio of purple rice ST with white rice ST25 significantly influenced consumer perception of color, aroma, flavor, and texture (Table 2). Increasing the proportion of purple rice from 20% to 30% improved most attributes, particularly color (4.47), aroma (4.50), odor (4.51), but texture was still good (4.22), indicating that moderate incorporation levels enhance the sensory quality of the snack. This aligns with previous findings that moderate inclusion of pigmented rice can improve flavor complexity and visual appeal due to anthocyanins and aromatic volatiles (Ma et al., 2023)

Table 2. Evaluation scores of snacks at different proportions of purple rice and ST25

Purple rice (%)	Colour	Aroma	Odour	Texture
20	$4.31^{bc}\pm0.25$	$4.35^{b}\pm0.06$	$4.29^{b}\pm0.18$	$4.70^{a}\pm0.26$
25	$4.80^{a}\pm0.06$	$4.39^{b}\pm0.34$	$4.59^{a}\pm0.08$	$4.97^{a}\pm0.60$
30	$4.47^{ab}\pm0.60$	$4.50^{ab}\pm0.10$	$4.51^{ab}\pm0.05$	$4.22^{ab}\pm0.12$
35	$2.17^{c}\pm0.29$	$4.57^{a}\pm0.15$	$4.43^{ab}\pm0.06$	$2.33^{c}\pm0.29$

Note: The average data were aggregated over [1]the proportion of purple rice and ST25 according to the column. Different letters in the same column (a, b or c) indicate a significant difference at $p < 0.05$ between the average data in the same column.

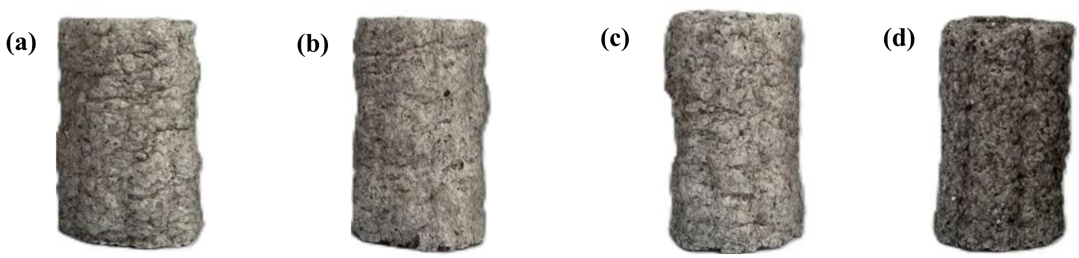

Figure 10. Purple rice and ST25 snack at different extrusion ratios (a) 20% purple rice, (b) 25% purple rice, (c) 30% purple rice, (d) 35% purple rice

At 35% purple rice, the color score dropped significantly to 2.17, and texture decreased to 2.33, suggesting an undesirable darkening and a harder, less acceptable structure. High levels of bran and fiber in purple rice are known to interfere with starch expansion, resulting in denser, harder extrudates that negatively affect texture and consumer acceptance (Ding et al., 2005). Similar trends were reported in pigmented rice and whole-grain snacks, where excessive fibre reduces crispness and increases hardness, lowering sensory scores.

4. CONCLUSION

The study showed that increasing the purple rice ratio from 20% to 35% to ST25 rice significantly impacted the physical, chemical, and sensory properties of extruded snacks. Higher purple rice content led to a darker color (lower L* value). Water absorption and pasting properties were also decreased. The increase in anthocyanins and antioxidant activity highlighted the potential health benefits of purple rice. Overall, incorporating 30% purple rice was determined to be optimal based on integrated nutritional, physicochemical, and sensory evaluations. The results also highlight potential applications for developing functional, antioxidant-rich snack products and point to opportunities for future research and commercial development.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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