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SNACK BAR FORMULATION WITH BLACK GLUTINOUS RICE FLOUR AND RICE BRAN: REDUCING SUGARS, PROXIMATE COMPOSITION, AND SENSORY ACCEPTANCE

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Abstract

This study developed gluten-free, low-sugar snack bars by valorizing underutilized black rice flour (BR) and rice bran flour (RB) to address health concerns in conventional formulations. Employing a factorial completely randomized design (BR: 10-30%, RB: 10-20%), we evaluated six formulations through proximate analysis, reducing sugar assays, and organoleptic testing (n=75 untrained panelists). The 10% BR + 10% RB formulation emerged as optimal, demonstrating superior sensory acceptance across all parameters (overall hedonic score: 5.53±1.09) and favorable nutritional profile: 5.72% moisture, 25.54% fat, 9.61% protein, and 57.3% carbohydrates. Contrastingly, 20% BR + 10% RB showed the highest reducing sugar content (8.00±0.33 g/mL) but suboptimal sensory appeal. Nutritional variability was formulation-dependent: increased BR substitution elevated moisture ($p<0.05$) and ash content ($p<0.01$) due to amylose-mediated water absorption and mineral enrichment, while higher RB proportions reduced carbohydrate content ($p<0.01$) through nutrient displacement. Although the optimal formulation achieves sensory-nutritional balance, compositional refinement remains necessary for full compliance with Indonesian National Standards (SNI). This research establishes a sustainable framework for transforming agricultural byproducts into functional foods..
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Keywords: ***Snack Bar, Black Rice Flour, Rice Bran, Nutritional Content, Reducing Sugar***

INTRODUCTION

Snack bars represent solid convenience foods predominantly formulated from cereal or nut matrices. Their global ubiquity stems from portability and nutritionally dense profiles, characterized by substantial carbohydrate, protein, and dietary fiber content (Adiari et al., 2017). Indonesian market data reveal significant production growth of 1.83% (17,100 metric tons) during 2011-2016 (Kemendag, 2017), reflecting robust consumer demand. However, conventional formulations remain dependent on refined wheat flour and added sugars, contributing to adverse health attributes: elevated caloric density, high glycemic index, and gluten presence established risk factors for obesity, diabetes mellitus, and gluten-related disorders (WHO, 2020; Shewry & Hey, 2016). This necessitates developing innovative formulations aligned with contemporary health paradigms, including sugar reduction and gluten-free diets, while concurrently enhancing functional nutrient composition.

Black glutinous rice (*Oryza glutinosa*) and rice bran (*Oryza sativa* L.) present promising alternatives. Black rice bran anthocyanins exhibit anti-inflammatory and antidiabetic activities (Zhang et al., 2022), while its higher protein (8.5% vs. white rice's 6.8%), iron, and fiber content (Pereira-Caro et al., 2021) offer nutritional advantages. Rice bran, a milling by-product, provides 13–17% protein, 12–15% fiber, and hypolipidemic γ-oryzanol (Luthfianto et al., 2017). Despite Indonesia's annual production of 4.5–5 million tons, >70% is underutilized as animal feed (Kementan, 2021), representing lost opportunities for functional food applications. Although prior innovations include black rice with red bean flour (Cici, 2020) or rice bran substitutions (Fauziah & Siti, 2024), synergistic use of black rice flour and rice bran for sugar reduction without compromising sensory acceptance is unexplored. This gap is critical given WHO's recommendation to limit free sugars to <10% of daily calories for metabolic disease prevention – a benchmark unmet by commercial products. Here, we develop gluten-free, low-sugar snack bars leveraging both ingredients to address this need. This study transforms underutilized agricultural by-products into functional snack bars, advancing sustainable food systems and public health. It further provides an innovation framework for the snack industry through novel ingredient valorization

LITERATURE REVIEW

Snack bars are compact, bar-shaped light meals made primarily from cereals or legumes and may also include fruits. They are easy and practical to carry without requiring special storage conditions. Binders commonly used in snack bar products include syrup, caramel, chocolate, and others (Seno & Lewerissa, 2021). Black rice is a local variety that contains superior pigments compared to white or other colored rice. It has become increasingly popular and is consumed as a functional food due to its health benefits (Adiari et al., 2017). One of the unique characteristics of black rice is its color. It is now widely recognized in society as a health-beneficial functional food. Cooked black rice contains amino acids, vitamin B1, vitamin B2, folic acid, and essential minerals such as iron, zinc, selenium, calcium, and phosphorus. It has a pleasant taste and aroma and contains higher levels of protein, vitamins, and minerals than regular white rice. Black rice also contains essential amino acids like lysine and tryptophan, and a high amount of antioxidants, proteins, and dietary fiber, making it the most nutrient-dense among all rice types (Palupi et al., 2022).

Colored rice has a harder texture than white rice and contains pigments known as anthocyanins, which belong to the flavonoid group. Anthocyanins act as antioxidants that offer positive health effects. Antioxidants are compounds with molecular structures that freely donate electrons to free radicals without losing their function, thereby breaking the chain reaction of free radical formation (Adiari et al., 2017). There are many types of organic waste commonly found in nature, one of which is rice bran (bekatul), especially in rural areas. Rice bran is a by-product of rice milling. When paddy is milled, it yields about 70% rice from the endosperm, with the rest being by-products: about 5% bran, 5% rice bran, and 20% husk. Rice bran is often considered undesirable in rice due to its rancidity, which shortens shelf life and its brownish color, which affects rice appearance (Hidayah et al., 2017).

Rice bran is the outer layer of rice that is separated during the milling process. It is cream or light brown in color and is produced from the aleurone layer of rice, separated from the husk. Milling produces approximately 60–65% rice and 8–12% bran. Traditionally, rice bran has been used mainly as animal feed, but it is actually rich in nutrients that are beneficial for food industry applications. It contains protein (13.11–17.19%), fat (2.52–5.05%), carbohydrates (67.58–72.74%), and dietary fiber (370.91–387.3 calories), and is rich in B vitamins, particularly vitamin B1 (thiamine) (Hidayah et al., 2017). Rice bran also contains proteins, minerals, unsaturated fats, and high levels of vitamins essential for cellular metabolic activities. Its health benefits include promoting bone and tooth development, relieving constipation, supporting tissue growth, inhibiting diabetes, and preventing heart disease (Hayati & Saputra, 2023).

METHOD

This experimental study employed a factorial completely randomized design. Conducted between October 2024 and January 2025, the research took place across multiple facilities: the Culinary Nutrition Laboratory, Nutritional Food Laboratory, Agricultural Product Engineering Laboratory at Teuku Umar University, and the Industrial Service Standardization Center (BSPJI). The investigated factors comprised black rice flour (BR) (10%, 20%, 30%) and rice bran flour (RB) (10%, 20%), implemented in the factorial design with three replications.

Table 1. Formulation of Snack Bars with Black Rice Flour and Rice Bran Substitution

Ingredients (gram)	**Treatments (Black rice flour : Rice bran ratio)**					
	10:10	**10:20**	**20:10**	**20:20**	**30:10:00**	**30:20:00**
Black Rice Flour	16	16	32	32	48	48
Rice Bran	16	32	16	32	16	32
Peanuts	30	30	30	30	30	30
Low Cal. Sugar	3	3	3	3	3	3
Skim Milk	30	30	30	30	30	30
Margarine	30	30	30	30	30	30
Eggs	42	42	42	42	42	42
Salt	5	5	5	5	5	5
Baking Soda	5	5	5	5	5	5
Honey	15	15	15	15	15	15
Total	**192**	**208**	**208**	**224**	**224**	**240**

Hedonic method

Hedonic testing was employed to assess product preference levels using a standardized rating scale (Fitrayani, 2019). The panelists consisted of 75 untrained participants, selected from active students at Teuku Umar University who voluntarily agreed to participate. Prior to evaluation, panelists received instructions before tasting the product samples. Preference levels were measured on a 7-point hedonic scale, where a score of 1 indicated "strongly dislike" and 7 represented "strongly like".

Reducing sugar method

The quantitative analysis of reducing sugar content in snack bars made from black rice and rice bran was conducted using the method of Hernández-López et al. (2020) with slight modifications. Snack bar samples were dissolved in distilled water at a 1:10 ratio. Then, 0.5 mL of the liquid sample was taken and mixed with Benedict's reagent. The resulting mixture underwent a redox reaction with the reducing sugars after being heated at 70 °C for several minutes, producing an orange-brown color and a precipitate. After cooling the sample, the absorbance of the color change was measured using a spectrophotometer at λ = 740 nm. The reducing sugar content was expressed as milligrams of glucose equivalent per gram of sample.

Proximate analysis method

The principle of proximate analysis is to separate food components into groups or nutritional value fractions, which include moisture content, ash content, protein, fat, and carbohydrates (Farhati & Rosid, 2022). The proximate test was conducted using the AOAC 2005 method.

RESULTS AND DISCUSSION

Hedonic Test and Reducing Sugar Results

Based on the results of the hedonic test and the reducing sugar content analysis of snack bars made from black rice flour and rice bran, the results for each snack bar are as follows:

Treatment	Hedonic					Reducing Sugar (g/mL)
	Colour	Taste	Aroma	Texsture	*Overall*	
Black Rice						
BR10	5.1±1.63[a]	4.62±1.59[a]	4.96±1.42[a]	4.79±1.39[a]	5.04±1.38[a]	3.32±0.73[c]
BR20	5.22±1.39[a]	4.47±1.58[a]	4.86±1.40[a]	4.80±1.39[a]	4.72±1.45[ab]	5.56±3.35[a]
BR30	4.72±1.58[b]	4.52±1.72[a]	5.02±1.56[a]	4.44±1.66[b]	4.57±1.60[b]	4.02±2.78[b]
Rice Bran						
RB10	5.28±1.40[a]	4.85±1.48[a]	5.12±1.46[a]	4.98±1.33[a]	5.12±1.31[a]	5.93±1.84[a]
RB20	4.73±1.63[b]	4.23±1.72[b]	4.77±1.45[b]	4.37±1.58[b]	4.43±1.57[b]	1.85±0.91[b]
Interaction Of Treatment						
BR10: RB10	5.92±1.12[a]	4.87±1.44[a]	5.13±1.50[a]	5.20±1.24[a]	5.53±1.09[a]	3.78±0.43[c]
BR10: RB20	4.28±1.66[c]	4.37±1.72[ab]	4.78±1.32[a]	4.38±1.42[ab]	4.54±1.47[ab]	2.63±0.73[d]
BR20: RB10	5.23±1.37[b]	5.08±1.32[ab]	5.04±1.32[a]	4.96±1.29[abc]	5.10±1.27[bc]	8.00±0.33[a]
BR20: RB20	5.21±1.44[b]	3.87±1.60[b]	4.68±1.47[a]	4.64±1.46[bc]	4.34±1.52[c]	1.92±0.62[de]
BR30: RB10	4.72±1.48[c]	4.61±1.64[bc]	5.20±1.55[a]	4.78±1.44[cd]	4.74±1.45[c]	6.02±0.31[b]
BR30: RB20	4.72±1.70[c]	4.44±1.80[c]	4.85±1.57[a]	4.10±1.81[d]	4.40±1.73[c]	1.01±0.78[e]

Reducing Sugar

The interaction between black rice flour (BR) and rice bran (RB) showed a complex pattern. The BR20:RB10 combination exhibited not only additive but also synergistic effects, with reducing sugar levels reaching 8.00 ± 0.33 g/mL. This confirms that the BR20 proportion provides sufficient starch substrate, while RB10 does not significantly interfere with enzymatic activity. In contrast, the BR30:RB20 combination resulted in the lowest reducing sugar content (1.01 ± 0.78 g/mL), indicating an antagonistic effect between the two factors. The high fiber content in RB20 and the non-carbohydrate components in BR30 are suspected to create a dual barrier, both physically and chemically (enzyme inhibition). The addition of insoluble fiber from rice bran affects starch properties through three primary mechanisms: structural alteration, enzymatic inhibition, and modification of water and oil retention capacity. Structurally, insoluble fiber increases the gelatinization temperature of starch a critical phase when starch granules absorb water and swell and reduces both setback and breakdown values, which are indicators of retrogradation (recrystallization after cooling) and thermal degradation during heating (Wang et al., 2025; Wu et al., 2021). These effects occur because the fiber forms a physical barrier that restricts starch granule expansion and reduces enzyme access, thereby not only slowing gelatinization but also stabilizing the starch matrix and modifying its rheological properties. Furthermore, insoluble fiber from rice bran exhibits inhibitory activity against the α-amylase enzyme by forming non-covalent complexes between fiber components (such as lignin or phenolic compounds) and the enzyme's active site, reducing the efficiency of starch hydrolysis into reducing sugars (Qi et al., 2016). The combination of physical and biochemical inhibition reinforces the role of fiber as a modulator of starch digestion. Additionally, bran fiber modification enhances water and oil holding capacities, where high water retention limits free water availability for gelatinization, and oil absorption affects lipid-starch interactions. These two factors synergistically reduce water mobility and substrate accessibility, thereby slowing enzymatic hydrolysis and starch degradation (Liu et al., 2021; Qi et al., 2015).

Holistic Preference: Sensory Attribute Convergence and Key Drivers

Colour Preference: The BR 10% + RB 10% treatment elicited the highest colour preference. This combination produced a visually appealing light brown hue, attributed to the balanced ingredient ratio. This preference aligns with Anggraini (2014, cited in Widodo et al., 2024), who noted rice bran flour contributes to browning, a process intensified by longer heating durations (Setyawati, 2023). Setyawati (2023) further explains that anthocyanins in black rice bran and endosperm generate deep purple to near-black colours. Consequently, panelists favoured lighter brown snack bars. Conversely, BR 10% + RB 20% was least preferred, exhibiting a darker brown colour due to the dominance of rice bran. This suggests rice bran content significantly influences colour, consistent with Iriyani (2011, cited in Ersanti & Munir, 2024), who reported increased browning in cereal with higher rice bran substitution, primarily due to the Maillard reaction.

Taste Preference: Optimal taste preference was observed for BR 20% + RB 10%. The distinct, slightly sweet, and nutty flavour profile of black rice complemented the snack bar, enhanced by natural fats and aromatic compounds in rice bran, aligning well with panelist preferences. This finding is supported by Muktisari and Hartati (2018, cited in Pratiwi, 2018), highlighting black rice's beneficial components. In contrast, BR 20% + RB 20% was least favoured. The characteristic slightly bitter and beany taste of rice bran became overpowering at 20%, diminishing overall palatability. This indicates that simultaneously increasing both flours negatively impacts taste. Artaty (2015, cited in Ersanti & Munir, 2024) noted black rice's strong flavour (savory, slightly sweet, mildly bitter), suggesting its increased proportion can overpower desired sweet/savory notes from other ingredients. Setyawati (2023) further corroborates that rice bran's bitterness can reduce taste acceptance.

Aroma Preference: The BR 30% + RB 10% treatment demonstrated superior aroma preference. At 30%, black rice flour imparted a pronounced, distinctive nutty and mildly sweet aroma, providing a fresh, natural impression. This aligns with Widodo et al. (2024), who found increased black rice addition enhanced bread aroma preference, indicating panelist favour for this characteristic. Conversely, BR 20% + RB 20% exhibited the least preferred aroma. The equal composition allowed the characteristic bran-like or raw grain aroma of rice bran to dominate, further intensified during baking. This is consistent with Agustina and Anjani (2017), who observed excessive Maillard reactions from high black rice proportions can reduce aromatic components in baked goods. Rice bran's dominant aroma is linked to volatile compounds like alcohols and carbonyls (Hildayanti, 2017).

Texture Preference: Texture preference was highest for BR 10% + RB 10%. This combination yielded an optimal texture—potentially crispier or chewier depending on processing—where black rice flour contributed brittleness and rice bran added desirable chewiness. This finding concurs with Putri (2020) regarding balanced mixtures. Conversely, BR 30% + RB 20% was least preferred. The inherent coarseness of black rice flour, combined with rice bran, resulted in a drier, less palatable mouthfeel. This suggests rice bran addition impacts texture negatively, consistent with Sofianti et al. (2021), who attributed texture deterioration in cookies with excess rice bran flour to its lack of gluten.

Overall Preference: Across all sensory parameters (notably colour and texture), the BR 10% + RB 10% treatment emerged as the most preferred overall. This aligns with Widodo et al. (2024), where increased black rice flour in sweet bread enhanced preference due to factors like darker colour, enhanced aroma, crumblier texture, and improved flavour, with taste being the primary driver. In contrast, BR 20% + RB 20% was the least preferred overall. This combination produced snack bars perceived as dense, dry, and insufficiently crispy, reducing consumption enjoyment. This finding is supported by Hidayah et al. (2024), noting significant texture changes (increased fiber, decreased fat) with higher rice bran substitution in chips, and Widodo et al. (2024), reporting harder textures in sweet bread with greater black rice flour additions.

Nutritional Profiling via Proximate Analysis: Compositional Variability and Functional Implications

Proximate analysis is a commonly used method to assess the quality or nutritional content of feed or food raw materials. It provides a general overview of the nutritional composition of a food ingredient (Hayati & Saputra, 2023). Proximate analysis examines several components, including moisture content, organic matter (ash), protein, fat, carbohydrates, and crude fiber (Kurnijasanti, 2016).

Table 2. Proximate Analysis

Parameter	(BR10:RB10)	(BR20:RB10)
Moisture content	5,72±0,49[a]	10,6±0,59[b]
Ash content	1,76±0,16[a]	2,06±0,20[a]
Fat content	25,54±1,20[a]	35,82±1,57[c]
Protein content	9,61±0,36[a]	9,95±0,02[a]
Carbohydrate content	57,3±0,91[a]	41,54±1,06[c]

The BR10%+RB10% formulation exhibited the lowest moisture content (5.72%), indicating superior dryness attributed to reduced water retention at lower black rice substitution levels. Conversely, BR20%+RB10% showed elevated moisture (10.6%), consistent with black rice flour's amylose-mediated water absorption capacity (Dewi, 2023). These values (5.72-10.6%) align with snack bar moisture ranges reported elsewhere: 8.49% (Andriani et al., 2018) and 14.72% (Listyaningrum, 2018), demonstrating formulation-dependent variability. Ash content increased significantly in BR20%+RB10% due to black rice flour's inherently higher mineral composition versus wheat flour (Wijayanti, 2018). Our results correspond with sorghum-based (3.75%; Mawarno & Karina, 2024) and soybean-pumpkin formulations (2.74%; Majid & Farida, 2024), confirming substitution-dependent mineral enrichment.

Elevated fat levels in BR20%+RB10% resulted from both higher black rice proportion (20% vs. 10%) and lipid contributions from eggs/margarine. This aligns with dose-dependent fat accumulation in black rice products (Basriman, 2021) and additive fat effects in composite formulations (Hendrasty, 2013). Values were consistent with pumpkin-red bean (27.96%; Dwijayanti, 2016) and adlay-peanut formulations (34.46%; Aminah et al., 2019). Protein content increased in BR20%+RB10% due to black rice flour's superior protein concentration (9.97% vs. white rice's 7.59%; Hidayat et al., 2019), though thermal denaturation during baking may modulate bioavailability (Sundari et al., 2015). Results paralleled pumpkin-corn (8.86%; Hartaty et al., 2017) and banana-jackfruit formulations (8.28%; Deseliani et al., 2019). Carbohydrates decreased progressively across treatments (BR10%+RB10%: 57.3% → BR20%+RB10%: 41.54%), inversely correlating with protein/fat accumulation. This trend mirrors red rice-red bean (41.13%; Arwin et al., 2018) and jackfruit-banana formulations (56.50%; Simanjorang et al., 2020), reflecting nutrient displacement in fiber-enriched matrices.

CONCLUSION

Comprehensive analysis of black rice flour (BR) and rice bran (RB) snack bar formulations through proximate analysis, reducing sugar assays, and organoleptic evaluation revealed that the BR10:RB10 interaction emerged as the optimal formulation. This treatment achieved the highest overall organoleptic preference across all sensory parameters while demonstrating favorable nutritional properties: 5.72% moisture, 1.76% ash, 25.54% fat, 9.61% protein, and 57.3% carbohydrates. Contrastingly, the BR20:RB10 formulation exhibited the highest reducing sugar content but suboptimal sensory acceptance, with nutritional values including elevated moisture (10.6%), ash (2.06%), and fat (35.82%) alongside reduced carbohydrates (41.54%). The BR30:RB20 interaction yielded the lowest reducing sugar levels. While the BR10:RB10 formulation excels in sensory-nutritional balance, compositional adjustments remain necessary to achieve full compliance with Indonesian National Standards (SNI).

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