

Research Article

Utilization of Black Rice (*Oryza sativa* L. Indica) and Black Soybean (*Glycine max* L. Merr) in the Production of Protein- and Fibre-rich Breakfast Flakes for School-age Children

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ABSTRACT

The development of flake products based on black rice and black soybeans is one of the practical breakfast food innovations that meets the nutritional demands of school-aged children, particularly their daily protein and dietary fibre requirements. This research uses 4 formulas of black rice and black soybean, namely F1 (80:20), F2 (60:40), F3 (40:60), and F4 (20:80). The analysis included organoleptic tests (hedonic test and quality), nutritional content analysis (proximate and dietary fibre content analysis), and physical characteristic analysis (water absorption, rehydration time, hardness and bulk density). The results showed that all black rice and black soybean flake formulae could meet nutritional content claims, such as protein and dietary fibre. Based on organoleptic tests, physical characteristics and nutritional content of black rice and black soybean flakes, F3 (with a proportion of 40% black rice and 60% black soybeans) was selected as the best formula in this study based on physical and organoleptic characteristics that the panellists preferred. This selected formula also provides 11.1 – 15.2% of the protein requirements and 11 – 13.4% of school-age children's daily dietary fibre requirements (7 – 12 years).

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1. Introduction

Nutritious food can help maintain health and support school-age children's growth and development. According to Widanti (2016), school-age children experience an increment in nutritional needs particularly protein, as well as increment in cognitive and motor skills. Their eating habits, especially in protein intake are beginning to be formed. Another concern is the easy access to snacks that are attractive to children but has questionable nutritional quality. Snacking could increase the risk of excess nutritional status by up to 7 times. Snacking correlates with low fibre intake; however, fibre consumption is necessary in maintaining nutrition and health status, especially in school-age children (Rahmad, 2018). Having breakfast is one way to meet the nutritional needs of school-age children. Fulfilling breakfast protein needs could help increase children's activity at school by 2,623 times higher than children whose protein intake was insufficient (Jauhari *et al.* 2019). Breakfast habits were also related to children's snack habits at school, where a child who skipped breakfast would increase their snack intake with a risk of 1.5 times, and possibly increasing risk of inadequate fibre intake (Mariza & Kusumastuti, 2013).

Around 44.6% and 35.4% of school-age children in Indonesia still eat breakfast with energy and protein intake of <15% of their daily nutritional needs (Hardinsyah & Aries 2012). Children could not have breakfast due to several reasons, including lack of available food, food served was uninteresting and boring, and insufficient time for serving or having breakfast (Khomsan, 2005). As a result, it was necessary to develop breakfast foods such as flake cereal products that could be served practically, and also met daily nutritional requirements. Efforts to boost the nutritional value of flake products include replacing or adding other foods with higher nutrient content, particularly protein and fibre (Galal *et al.* 2024; Cork *et al.* 2022). Local foods that have the potential to be used as functional food include black rice (*Oryza sativa* L. Indica) with the complement of black soybean (*Glycine max* L. Merr) as a protein source.

Black rice was chosen as a source of starch to form the flake structure. Black soybean was chosen not only as a source of protein but also as a complement to the amino acid profile of cereals so that products with better protein quality could be obtained (Tas & Shah, 2021). The protein content in black soybean ranges from 37 – 45% (Tyagi *et al.*, 2025), and dietary fibre content is 21.9% (Jing *et al.*, 2018). The formulation for the black rice and black soybean breakfast flakes was based on the Indonesian National Standard SNI 01-4270-1996 for cereal-based milk products. The SNI sets standards for nutrient content and product quality. Compliance with this standard ensures the flakes are safe, nutritious and suitable for school-age children. It is hoped that the flakes can provide extra choice for breakfast that has a good nutritional profile.

2. Materials and Methods

This research was carried out from January to June 2021. The production of flake formulae and several physical tests were carried out at the Food Experiment Laboratory, organoleptic tests were carried out at the Organoleptic Test Laboratory, and nutritional content analysis and several other physical tests were carried out at the Nutrient Analysis Laboratory, Department of Community Nutrition, Faculty of Human Ecology, IPB University.

2.1 Materials

The main ingredients for making flakes, i.e. black rice (*Oryza sativa* L. Indica) were purchased from Kelompoktani, a local producer in Bekasi City and local black soybean (*Glycine max* L. Merr) was purchased from Bionic Farm, Kebun Kita. The other materials were tapioca flour, refined sugar, salt, water, milk powder, vanilla, and coconut oil. Chemicals used to analyse the nutritional content of flakes were distilled water, concentrated H₂SO₄, selenium mix, 10% and 40% NaOH, 4% H₃BO₄, Na₂CO₃, (NH₄)₂SO₄, hexane solvent, 0.1N and 4M HCl, 0.1M buffer phosphate pH 6, ethanol 95%, acetone, methyl red and methyl blue indicators, which were purchased from Merck, Germany. Enzymes used in this study were termamyl, pancreatin, and pepsin, which were obtained from Sigma Aldrich, USA.

2.2 Product Making

The research started with the preliminary stage: milling the main ingredients, black rice and black soybean into flour. The formula design for black rice and black soybean flakes was carried out using Sakinah (2017) and Pangestika (2017) methods with modifications based on trial and error. Four flake formulas were obtained. Formulas for black rice and black soybean are shown in Table 1.

Table 1. Formulation of black rice and black soybean flakes

Material	Unit	Formula (Black Rice: Black Soybean)			
		F1 (80:20)	F2 (60:40)	F3 (40:60)	F4 (20:80)
Black rice flour	g	80	60	40	20
Black soybean flour	g	20	40	60	80
Tapioca flour	g	15	15	15	15
Refined sugar	g	15	15	15	15

Material	Unit	Formula (Black Rice: Black Soybean)			
		F1 (80:20)	F2 (60:40)	F3 (40:60)	F4 (20:80)
Milk powder	g	10	10	10	10
Coconut oil	ml	20	20	20	20
Salt	g	1	1	1	1
Vanilla powder	g	0.5	0.5	0.5	0.5
Water	ml	50	50	50	50
Total (g)		211.5	211.5	211.5	211.5

2.2 Product Analysis

Organoleptic testing of flake products included an acceptance test using nine-point hedonic scale (1 = dislike very much, 9 = like very much) and a hedonic quality test using nine-point intensity scale (1 = very weak, 9 = very strong). Both organoleptic tests were carried out with 31 semi-trained panellists. Physical analysis conducted were texture, water absorption capacity, bulk density, and rehydration time. Texture analysis of the flakes was carried out using a Steven-LFRA Texture Analyzer with a modified three-point bending rig probe, at a speed of 2.0 mm/s and a distance of 3 cm. Water absorption capacity and bulk density were analysed based on the method of Valdez-Niebla *et al.*, (1993), while rehydration time analysis of the flakes was conducted according to the method of Munira *et al.*, (2020). Analysis of the nutritional content of flakes included proximate (AOAC 2005) and fibre content analysis (Asp, 2001). Calculation of the contribution of nutrients in the selected formula without the addition of milk was carried out to determine the adequacy of the product compared to the Recommended Dietary Intake (RDI) for school-age children (7 – 12 years) and the national standard for Nutrition Label Reference (NLR).

2.2 Data Analysis

The data obtained were displayed as mean \pm standard deviation from 3 replications. The data was tested using one-way ANOVA followed by Tukey's test. Level of significance was determined at 95% confidence interval. Statistical tests were conducted using SPSS version 25.0 for Windows applications.

3. Results and Discussion

3.1 Black Rice and Black Soybean Flakes Development

The flakes formulae were determined through preliminary studies with modifications through trial and error. High starch content was essential for achieving the desired crispiness (Astuti *et al.* 2019). The main ingredients were black rice and black soybean, which together provided a balanced amino acid profile. Soybean was chosen in this study because its protein closely resembled animal protein (Sun *et al.*, 2021; Jung *et al.*, 2024). Other ingredients included tapioca flour, milk powder, sugar, salt, vanilla powder, coconut oil, and water. Tapioca flour contributed to the crunchy texture due to its high starch content (Rosalinda *et al.*, 2025), while milk powder enhanced nutrition and flavour (Harisina *et al.*, 2016). Coconut oil provided fat, and produced a smoother dough (Rahmawati *et al.*, 2019). Sugar, salt, and vanilla balanced taste and aroma. The trial-and-error process refined ingredient ratios, material usage, and oven time.

3.2 Organoleptic Characteristics

The acceptability of black rice and black soybean flakes was assessed through organoleptic tests, including acceptance test and hedonic quality tests. Four formulas (F1, F2, F3, and F4) were evaluated on a 9-point scale (ranging from 1 – "dislike very much" to 9 – "like very much") for colour, aroma, texture, taste, aftertaste, and overall preference using an acceptance test. The results (Table 2) showed that the flakes were generally accepted, with scores ranging from 5 (neutral) to 7 (like). The statistical analysis showed

no significant differences in all samples (F1 – F4), indicating all the panellists “liked” all the samples. F1 was the most preferred, while F4 received the lowest score. No significant differences ($p>0.05$) were observed except for texture ($p<0.05$), likely due to subjective panellist preferences (Astuti et al. 2019).

Table 2. Black rice and black soybean flakes organoleptic acceptability

Attributes	Formula (Black Rice: Black Soybean)			
	F1 (80:20)	F2 (60:40)	F3 (40:60)	F4 (20:80)
Appearance	6.33±1.4 ^a	6.08±1.5 ^a	5.46±1.4 ^a	6.34±1.6 ^a
Aroma	7.07±1.2 ^a	6.36±1.3 ^a	6.40±1.5 ^a	6.47±1.5 ^a
Texture	7.01±1.2 ^a	6.03±1.5 ^b	6.66±1.2 ^{a,b}	6.62±1.3 ^{a,b}
Taste	6.25±1.3 ^a	5.90±1.4 ^a	6.13±1.4 ^a	5.32±1.7 ^a
Aftertaste	6.26±1.5 ^a	6.17±1.4 ^a	5.85±1.5 ^a	5.32±1.8 ^a
Overall	6.51±1.4 ^a	6.36±1.3 ^a	6.45±1.1 ^a	5.89±1.6 ^a

^{a,b} Mean ± standard deviation, followed by different letters on the same row, shows a significant difference with p -value < 0.05

The hedonic quality test (Table 3) revealed significant differences ($p<0.05$) in colour and aftertaste. F4 had the lightest colour, while F1 and F2 were the darkest, influenced by anthocyanin content in black rice and soybean (Abdullah, 2017). Higher black soybean proportions increased aftertaste intensity due to saponin compounds contributing to bitterness (Shiojiri *et al.*, 2020) as shown in F4. Other attributes showed no significant variation among samples. This could be due to different sensitivity of the panellists. In a previous study, Astuti *et al.* (2016) showed a higher black rice proportion resulted in a stronger aroma, while texture ratings varied with changing black rice and soybean ratios, possibly due to panellists' sensitivity. The flakes' sweetness was mild, due to the carbohydrate content in black rice (Mangiri *et al.* 2016). In contrast, the savoury taste received higher scores in all samples, attributed to free amino acids (glutamate and aspartate) in black soybeans, which enhance umami flavour (Yu *et al.* 2018).

Table 3. Hedonic quality test results of black rice and black soybean flakes

Attributes	Formula (Black Rice: Black Soybean)			
	F1 (80:20)	F2 (60:40)	F3 (40:60)	F4 (20:80)
Colour (darkness)	7.7±1.4 ^a	7.7±1.1 ^a	6.5±1.3 ^b	5.2±2.0 ^c
Large pores	6.9±1.8 ^a	7.1±1.4 ^a	6.3±1.9 ^a	6.4±1.8 ^a
Aroma of black rice	5.4±2.1 ^a	5.1±2.1 ^a	4.6±1.9 ^a	4.6±1.9 ^a
Aroma of coconut oil	5.0±2.1 ^a	4.9±2.2 ^a	4.3±2.0 ^a	4.9±2.1 ^a
Beany aroma	2.5±1.6 ^a	2.7±1.6 ^a	2.9±1.9 ^a	3.3±1.9 ^a
Crispiness	7.3±1.3 ^a	6.5±1.6 ^a	7.3±1.2 ^a	6.9±1.6 ^a
Sweetness	4.7±1.8 ^a	4.6±1.7 ^a	4.7±1.4 ^a	4.3±1.7 ^a
Savoury taste	5.3±1.7 ^a	5.0±1.8 ^a	5.3±1.6 ^a	5.1±1.6 ^a
Aftertaste	2.7±1.8 ^b	3.0±1.9 ^b	3.3±2.2 ^{a,b}	4.2±2.1 ^a

^{a,b} Mean ± standard deviation, followed by different letters on the same row, shows a significant difference with p -value < 0.05

3.3 Physical Characteristics

The physical characteristics of the flakes include water absorption capacity, rehydration time, texture, and bulk density. The results are presented in Table 4. Water absorption capacity was influenced by the product's water, starch, fibre, and protein content. Statistical analysis showed a significant difference ($p<0.05$) in absorption capacity for all samples. Rehydration time, which indicates how quickly a product absorbs water to reach its maximum size, was affected by water, starch, and fibre content (Munira *et al.*, 2020). The significant differences observed in the rehydration time and water absorption capacity of the flakes can be attributed to variations in raw material composition, processing conditions, and product

microstructure.

Using black soybean can also reduce rehydration time, as the protein and fibre components may create a more porous microstructure during processing (Hu *et al.*, 2025). These pores allow for water penetration, and the hydrophilic properties of soy proteins enhance rapid water uptake and distribution (Hu *et al.*, 2025). In contrast, black rice has starch granules that are more compact and less porous, which can slow the diffusion of water into the matrix and thereby extend rehydration time (Ou *et al.*, 2023). Processing conditions such as extrusion and drying also altered starch–protein interactions and product porosity, which directly influenced water penetration (Scott & Awika, 2023). Flakes with higher bulk density and lower porosity absorbed water more slowly, while those with a more open structure allowed rapid hydration (Galal *et al.*, 2024; Takhellambam *et al.*, 2016). Furthermore, the presence of lipids and protein–lipid interactions on the flake surface may have reduced hydrophilicity, further affecting water uptake (Scott & Awika, 2023; Xiang *et al.*, 2023). These compositional and structural factors collectively explain the differences in functional properties between formulations.

Table 4. Physical characteristics of black rice and black soybean flakes

Attributes	Formula (Black rice: Black soybean)			
	F1 (80:20)	F2 (60:40)	F3 (40:60)	F4 (20:80)
Water Absorption (%)	392.18±6.28 ^a	363.32±12.60 ^{a,b}	343.72±14.70 ^b	339.50±9.27 ^b
Rehydration time (seconds)	639.70±8.02 ^a	472.30±50.64 ^b	336.00±16.64 ^c	211.3±17.01 ^d
Texture (gF)	265.00±17.10 ^a	275.00±16.60 ^a	289.00±15.20 ^a	290.00±3.06 ^a

^{a,b} Mean ± standard deviation, followed by different letters on the same line, shows a significant difference with p-value < 0.05

Flake texture was evaluated based on its hardness, which is influenced by water, starch, protein, and fibre content. Statistical analysis found no significant difference in hardness ($p>0.05$), which indicates that moisture, starch, protein, and fibre effects balanced each other, resulting in similar textural properties across formulations. These structural differences may also influence functional properties such as rehydration time and water absorption capacity.

3.4 Nutrient Content

The nutritional content of all black rice and black soybean flake formulations, including water, ash, protein, fat, carbohydrate, and dietary fibre, were analysed and are shown in Table 5.

Table 5. Nutritional profile of black rice and black soybean flakes

Attributes	Formula (Black Rice: Black Soybean)				SNI*
	F1 (80:20)	F2 (60:40)	F3 (40:60)	F4 (20:80)	
Moisture (%wb)	1.39±0.19 ^b	1.63±0.17 ^b	1.81±0.24 ^b	2.30±0.12 ^a	Max 3
Ash (%wb)	2.58±0.05 ^c	2.85±0.03 ^{bc}	3.21±0.05 ^{ab}	3.61±0.05 ^a	Max 4
Fat (%wb)	13.3±1.1 ^b	18.00±0.60 ^a	18.20±0.89 ^a	19.90±0.17 ^a	Min 7
Protein (%wb)	12.9±0.13 ^d	16.00±0.40 ^c	20.30±0.20 ^b	22.30±0.30 ^a	Min 5
Total carbohydrate (%wb)	69.83±0.93 ^d	61.52±0.58 ^c	56.53±0.56 ^b	51.84±0.80 ^a	Max 60
Dietary fibre (%wb)	5.69±0.01 ^c	8.41±0.08 ^b	10.29±0.37 ^a	11.19±0.28 ^a	-

*Indonesian National Standard (SNI 01-4270-1996 for Cereal Milk); ^{a,b} mean values ± standard deviation, followed by different letters on the same line, shows a significant difference with p-value<0.05; wb: wet based.

Table 5 indicates that increasing the proportion of black soybean significantly affected the flakes' nutritional profile ($p<0.05$). Moisture, ash, fat, protein, and dietary fibre content increased with higher soybean proportions, while carbohydrate content decreased. The nutritional composition of the flakes was influenced by the raw materials used (Galal *et al.*, 2024). These attributes comply with SNI 01-4270-1996 for cereal-based milk products, which stipulates a maximum moisture content of 3% and ash 4%, protein

content of at least 5%, and fat content of at least 7%. The formulated flakes, therefore, align with national standards in terms of proximate composition while providing additional dietary fibre and protein beneficial for school-age children.

3.5 Nutritional Claim of Black Rice and Black Soybean Based Flakes

Based on the Indonesian FDA, a food product can be claimed as a protein source if it contains at least 20% NLR per 100 grams of solids or 10% NLR per 100 ml of liquids. A high-protein claim requires at least 35% NLR per 100 grams of solids or 17.5% NLR per 100 ml of liquids. Protein content data for black rice and black soybean flakes are shown in Table 6. For dietary fibre claims, a product must contain at least 3 grams per 100 grams of solids or 1.5 grams per 100 kcal of liquids. A high-fibre claim requires at least 6 grams per 100 grams of solids or 3 grams per 100 kcal of liquids. Dietary fibre contents for black rice and black soybean flakes are shown in Table 6. The final formula selection considered organoleptic tests, physical characteristics, and nutritional content. Based on these factors, F3 was chosen as the optimal formulation of the black rice and black soybean flakes.

Table 6. Protein and dietary fibre content claims of black rice and black soybean flakes

Formula (Black rice: black soybean)	Protein			Dietary Fiber	
	Protein content	Protein Nutrition Label Reference (% per 100 g product)*	Claim*	Total dietary fibre content (g per 100 g product)	Claim*
F1 (80:20)	12.9	21.5	Source	5.69	Source
F2 (60:40)	16.0	26.7	Source	8.41	High
F3 (40:60)	20.3	33.8	Source	10.29	High
F4 (20:80)	22.3	37.2	High	11.19	High

*based on Indonesian FDA Regulation No. 1 of 2022

3.5 Contribution of Nutrition Content to RDI of School-Age Children

The standard serving size for flake products is 30 grams, typically consumed with milk (Chepulis *et al.*, 2019). The nutritional contribution of black rice and black soybean flakes compared to the RDI of school-aged children per serving is shown in Table 7. It presents the nutrient content of the selected F3 formula (40% black rice: 60% black soybean) and its contribution to the RDI, based on Health Ministry Regulation (Permenkes) No. 28 of 2019.

Table 7. Contribution of nutrients from F3 formula of black rice and black soybean flakes to RDI

Nutrient	Nutritional content of the chosen product* (30 g)	% RDI of School-Age Children*		
		7-9 years	10-12 years (boys)	10-12 years (girls)
Energy (kcal)	141	8.60	7.10	7.40
Fat (g)	5.46	9.90	8.40	8.40
Protein (g)	6.09	15.20	12.20	11.10
Carbohydrate (g)	16.96	6.80	5.70	6.10
Dietary fibre (g)	3.09	13.40	11.00	11.4

*based on Health Ministry Regulation (Permenkes) No. 28 of 2019

4. Conclusion

The proportions of black rice and black soybean significantly influenced organoleptic attributes, including texture, colour, and bitter aftertaste, as well as physical properties such as water absorption, rehydration

time, bulk density, and overall nutritional profile. F3, which contained 40% black rice and 60% black soybean was the optimal formula due to its superior nutritional profile, physical characteristics, and panellist

acceptance. Each serving contained 142 kcal, 5.4 g fat, 6.09 g protein, 16.96 g carbohydrates, and 3.09 g dietary fibre, which contains higher protein and fibre content than commercial products. The selected formula is both high in protein and fibre content, meeting the 11.10 – 15.20% of protein and 11.00 – 13.40% of dietary fibre needs for school-aged (7 – 12 years) children.

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Conflict of Interest

There is no potential conflict of interest among the authors.

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