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Proximate Analysis and Physical Characteristics of Analogue Rice Based on Breadfruit Flour and Anchovy

Analisis Proksimat dan Karakteristik Fisik Beras Analog Berbasis Tepung Sukun dengan Penambahan Ikan Teri Nasi

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ABSTRACT

Background: Rice serves as a fundamental dietary component for Indonesians, therefore several complete high-nutrition analogue rice developed. The composite flour used in this study is based on breadfruit flour, with the addition of anchovies to enhance the nutritional content in the formula.
Objectives: To determine the chemical and physical characteristics of analogue rice based on breadfruit flour and anchovies.
Methods: Experimental research with a one-factor Completely Randomized Design (CRD). Four treatments consisted of (0%, 2.5%, 5%, and 7.5%) addition of anchovies in analogue rice formula and three replication treatments. Chemical tests consisting of water, ash, fat, protein, and carbohydrate content. Physical tests included rice density, cooking time, water holding capacity (WHC), 1000 grain weight, and hardness level. Data analysis was performed using the Analysis of Variance (ANOVA) and Post Hoc Duncan Multiple Range Test (DMRT).
Results: Anchovies improve ash and protein, decrease fat and are not significantly different to carbohydrate and energy compared to the control. Analogue rice contained 4.94-8.41% protein. The water content meets the Indonesian National Standard (SNI) with a maximum limit of 14%. This study's formulation reduced WHC and increased bulk density. Cooking time, 1000 grain weight, and hardness level were not different compared to the control. The cooking time of analogue rice ranged from 15-16 minutes, and the weight of 1000 grains ranged from 16.33-17.57 g.
Conclusions: Anchovies in the analogue rice formula result in higher protein, lower fat, and carbohydrates compared to the control. The moisture content of the analogue rice meets SNI.

INTRODUCTION

Indonesian society is still very dependent on milled rice (white rice) as a staple food or main source of carbohydrates and has a high glycemic index[1]. Data from the Indonesian Food Composition Table (TKPI) showed that 100 g of rice contains 369 kcal of energy, 77.1% carbohydrates, 9.5% protein, and dietary fiber (0.4%)[2]. The nutritional content of rice is still low in dietary fiber, protein, vitamins, and minerals[3,4] and has a high glycemic index (IG>70) of 79.61[1,5–8]. The proportion of carbohydrate-source food consumption is significantly higher than that of protein, fat, and micronutrients[9]. Rice consumption has risen by 1.1% annually[10] and now ranks among the top three most frequently consumed foods, contributing to the rise in degenerative diseases, including type 2 Diabetes Mellitus[11]. Type 2 DM is characterized by chronic hyperglycemia where blood glucose exceeds 300 mg/dl and is uncontrolled. The national prevalence of DM was recorded at 8.5% in 2018[12], and increased to 10.6% in 2021[13]. The Indonesian population exhibits a relatively low consumption pattern regarding the quality and quantity of diversity, proportion, and inadequate intake of nutrients. Consumption of carbohydrate-based foods is significantly higher than that of protein, fat, and micronutrients[9]. Low-glycemic index foods positively influence glucose regulation, avoid insulin resistance, and prevent hyperglycemia[14,15]. Development of analogue rice based on breadfruit flour and the addition of anchovies as an alternative food with high nutritional value, a low-medium glycemic index, and high mineral nutrients. This product development results from a local non-rice food product (*Oryza Sativa*)[16].

Various alternative analogue rice is created to increase nutritional value and functional properties and provide alternative low glycemic index food products

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from local food sources derived from composites of several types of non-rice cereals and tubers[17–19]. The utilization of breadfruit (*Artocarpus Altilis*) as an alternative staple food can increase food diversification and national food security, and be a potential source of carbohydrates that can be developed into various functional processed food products, one of which is analogue rice[20,21]. The glycemic index of breadfruit is low to moderate (23-60); the high content of dietary fiber and amylose can reduce blood glucose absorption and inhibit the *alpha-glucosidase* enzyme, which is useful for preventing an increase in blood glucose[7,8,21,22]. Breadfruit's highly resistant starch, amylose, and dietary fiber content contribute to its potential as a low glycemic index food product[8]. Based on research by Santosa et al.,2018, the appearance of analogue breadfruit rice is still dull brown and bitter; these results affect the acceptability of analogue rice. It is crucial to incorporate composite ingredients into the formula for analogue rice[20]. Sweet potatoes are a source of local ingredients that are easily available and affordable. The amylose content of sweet potatoes is 8.5-3.85%. In terms of physical characteristics, starch from sweet potatoes has excellent properties, including gelatinization, retrogradation, digestibility, the ratio of amylose and amylopectin, and the level of crystallinity[23].

Adding anchovies (*Stolephorus Commersonii*) in the analogue rice formulation can enrich the nutritional content. Anchovies have proteins that stimulate and increase the sensitivity of the insulin hormone[24]. Fish protein is more effective in preventing insulin resistance. At the same time, its mineral content acts as an antioxidant to prevent oxidative damage to the body, increases insulin sensitivity, and functions as a coenzyme in regulating energy metabolism[25]. The addition of red yeast rice/*angkak* (*Monascus Purpureus*) is needed to improve the appearance of analogue rice from breadfruit flour and anchovies. "*Angkak*" is easily accepted because the red color resembles red rice, commonly consumed by the community. Red yeast rice has lovastatin and mevinolin compounds that act as antioxidants and antidiabetics[26,27]. The analogue rice formula synergizes its nutritional content to enhance glucose metabolism. This study aimed to determine the nutritional content and physical characteristics of analogue rice made from composite flour from breadfruit flour and white sweet potato flour with the addition of anchovies.

METHODS

Design, Time, and Place

The experiment used a completely randomized design (CRD), with four treatments: adding anchovy rice flour (0%, 2.5%, 5%, and 7.5%) and three replications of each treatment. The analogue rice modification formula is based on research by Anggraeni, *et al* in 2016 on utilizing nano calcium from tilapia fish bones[28]. The research was carried out from July to August 2024. The formulation trial process, physical analysis (bulk density, cooking time, weight of 1000 grains), and drying process were carried out at the Food Technology Laboratory and the Food and Nutrition Chemistry Analysis Laboratory, STIKes Panti Rapih, Yogyakarta. The production and moulding of analogue rice were done at UKM Putri 21 Playen, Gunung Kidul, Yogyakarta. Proximate analysis (water content, ash, protein, fat, carbohydrate calculation, and energy) was carried out at the Chemistry Laboratory of the Food and Nutrition Study Center (PSPG), Gadjah Mada University (UGM). The Public Service of the Faculty of Agricultural Technology, UGM, conducted the Water Holding Capacity (WHC) and hardness analysis. The Health Research Ethics Commission of Respati University Yogyakarta granted ethical clearance under 100.3./FIKES/PL/VII/2024 on July 25, 2024.

Materials

The tools used in the production of analogue rice (Figure 1) include plastic containers, digital scales, plastic stirrers, millers, steaming pans, analogue rice moulding machines (twin screw extruders), tray dryers, and cabinet dyers. Breadfruit flour and white sweet potato, with a fine white powder, have the distinctive aroma of breadfruit and sweet potato, serving as analogue rice's main ingredients (Figure 2). Breadfruit flour was obtained from the Iels Organic Sleman Yogyakarta shop, and white sweet potato flour came from the Produk *Bumiku* shop, Sleman Yogyakarta; the anchovies used were dried anchovies, and the fresh ones came from the Mirota Campus Yogyakarta shop. Other ingredients include Glyceraldehyde Monostearate (GMS), sourced from *Riken DMG* (Rikevita Malaysia), which has a food-grade qualification, is odorless, tasteless, and consists of coarse white granules. These were obtained from the Asian Farma Semarang shop. *Angkak* is a fine red powder obtained from the Batavia Herbal online shop in Jakarta. Other ingredients include cornstarch (*MAMASUKA*, PT Daesang Agung Indonesia), *Barco* brand coconut oil (*BARCO*, PT Barco Indonesia), mineral water (*VIT*, PT Tirta Investama), and *Superindo* brown rice (PT Lion Super Indo), which serves as a comparative analysis material. All of the materials were obtained from the Superindo supermarket in Magelang. All chemical reagents used for analysis use the Pro Analysis specifications (*Pro Analyst Grade Merck*, Darmstadt, Germany).

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Figure 1. Instruments of Analogue Rice Production Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*)

Figure 2. Ingredients of Analogue Rice Production Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*)

Processing of Analogue Rice

The dried anchovies are first crushed using a miller. All ingredients are weighed in equal amounts, except for anchovies. Analogue rice weighing refers to the formulation in Table 1. The dry ingredients that have been mixed are then added with coconut oil and mineral water so that the ingredients are hydrated. The dough is then steamed for approximately 30 minutes and moulded into a twin-screw extruder machine. Once the dough forms grains or resembles rice, it undergoes an 8-hour drying process in a cabinet dryer at 80°C. Figure 3 illustrates the process of producing analogue rice.

Table 1. Formulation of Analogue Rice Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*)

Material	Treatments			
	BAK	BA1	BA2	BA3
Breadfruit Flour (g)	300	300	300	300
White Sweet Potato Flour (g)	300	300	300	300
Anchovy (g)	-	15	30	45
Cornstarch (g)	60	60	60	60
Red Yeast Rice/*Angkak* (g)	24	24	24	24
Coconut Oil (ml)	1	1	1	1
Mineral Water (ml)	360	360	360	360
GMS (g)	7.2	7.2	7.2	7.2

g: g, BAK: control/analogue rice based on breadfruit flour without anchovy, BA1: analogue rice based on breadfruit flour with a 2.5% anchovy addition; BA2: analogue rice based on breadfruit flour with a 5% anchovy addition; and BA3: analogue rice based on breadfruit flour with a 7.5% anchovy addition.

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Figure 3. Flow Diag of Analogue Rice Processing Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*) (Based on Modified by Zhang[29], dan Santosa[20])

Figure 4. Analogue Rice Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*)

Proximate Analysis[30]

This research used proximate analysis, based on the Association of Official Analytical Chemists (AOAC) method standards, to analyze the nutritional content of analogue rice with anchovies. Proximate analysis consists of moisture, ash, protein, and fat content. Carbohydrate analysis refers to the AOAC calculation. The analysis was conducted at the Food Chemistry Laboratory of the Center for Food and Nutrition Studies, Gadjah Mada University, Yogyakarta.

Moisture Content Analysis[30]

After grinding the sample, dry the crucible in an oven at 105°C for 30 minutes, then place it in a desiccator for 15 minutes. Weigh the cruise and record its weight (B1) at the bottom of the vessel. 5 g samples were weighed and placed in the porcelain dish (B2). The crucible (B2) is dried in an oven at 105°C for 4 hours and then placed in a desiccator for 30 minutes. The samples are then weighed (B3).

$$\text{Moisture Content (Wb \%)} = \frac{W3}{W1} \text{ x } 100$$

W1 = Sample Weight before Drying (B2-B1) (g)
W2 = Sample Weight after Drying (B3-B1) (g)
W3 = Sample Weight Difference (W1-W2) (g)
Wb = *Wet Basis* (%)

Ash Content Analysis[30]

A crucible (B1) was used to hold a 5 g sample. Subsequently, the crucible should be placed in a furnace at 500°C for 5 hours, proceeding from when the furnace accomplishes this temperature. Lower the temperature below 100°C, remove the crucible from the furnace, and place it in a desiccator for 15 minutes. Then, weigh the porcelain dish and record its weight (B2).

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$$\text{Ash Content (\%)} = \frac{\text{Weight of Ash (g)}}{\text{Weight of Sample before Ashing Process (g)}}$$

Ash Weight (g) = The Weight of The Sample After The Ashing Process

Protein Content Analysis (Kjeldahl Method)[30]

The analysis of protein content (%) consists of three main stages: destruction, distillation, and titration. Place 0.3 g of the sample into a flask to initiate the destruction stage. The flask containing the sample received 0.7 g of a catalyst containing 20:1 Na_2SO_4: HgO, along with 3.5 ml of H_2SO_4 (93–98% nitrogen-free). Heat the flask using an electric stove in the acid chamber until the sample solution becomes clear. Next, pour the clear sample into a Kjeldahl flask for the distillation stage. Add 150 ml of cold aquades and 20 ml of $NaOH\text{-}Na_2S2O_3$ (sodium thiosulfate) solution to the Kjeldahl flask. Filled the beaker glass with 5 ml of 4% boric acid and three drops of the BCG-MR indicator. Positioned the beaker beneath the condenser of the distillation apparatus. When the distillate reaches 80 ml, the distillation process stops. Next, titrate the samples in the glass beaker. The titrant reagent (HCl 0.02 N) was used to titrate. The titration stopped when the distillate showed a reddish color change. Aquades also function as a reference point for this step. The next step involves recording the volume of the titration results and calculations:

$$\%N = \frac{(\text{Sample Volume} - \text{Blanko Volume}) \text{ x N HCl x } 14.008}{\text{Sample Weight (mg)}} \text{ x } 100$$

$$\text{Protein Content (\%)} = \%\text{ N x Conversion Factor (6.25)}$$

Fat Content Analysis (Soxhlet Method)[30]

The empty soxhlet is weighed (B1). Weigh a g sample and then wrap it in filter paper, folding it into a cylindrical shape. Place the sample in a Soxhlet flask, add 50 ml of petroleum benzene (fat solvent), and set it up in the Soxhlet apparatus. The extraction process was carried out for 3 hours, and then the soxhlet flask was dried in an oven at 105°C for approximately one hour. After it dried, the flask was weighed and recorded. Continue drying until the flask's weight remains constant (B2). The fat content (%) can be calculated using the formula:

$$\text{Fat Content (\%)} = \frac{\text{Fat Weight (g)}}{\text{Initial Sample Weight (g)}} \text{ x } 100$$

$$\text{Fat Weight (g)} = B2 - B1$$

Carbohydrate Analysis (*Carbohydrate by Different*)[30]

The method used for carbohydrate analysis is Carbohydrate by Difference. This method calculates moisture, ash, protein, and fat content from previously tested samples. The percentage of carbohydrates is calculated as follows:

$$\text{Carbohydrate Content (\%)}$$
$$= 100\% - (\%\text{ Moisture} + \%\text{ Ash} + \%\text{ Protein} + \%\text{ Fat})$$

Energy Calculation (*Bombcalorimeter* Method)[31]

1 g of the sample is placed into the container. The wire and burning thread are weighed, recorded, and assembled in the bomb calorimeter. 1 ml of aquades is placed in the bomb calorimeter, then tightly closed. Introduce oxygen into the device at a pressure of 20-30 bar, and then place the bomb unit into a chamber filled with 2.1 kg of water. Run the stirrer, then observe the thermometer. Once the thermometer's number stabilizes, record the temperature. Pass an electric current by pressing the fire button for 5 seconds, then wait for the temperature to rise. Once stable, record it as the final temperature. Calculate the temperature increase (final temperature - initial temperature). Do the same with the benzoic acid standard. Record and calculate the calories in the sample using the formula below:

$$Q = Cv\,(Tf - Ti)$$

Q = Amount of Heat
(Temperature Measured in Joules/Second)
Cv = Calorimeter Heat Capacity
Tf = Final Temperature
Ti = Initial Temperature

Physical Characteristic Analysis

Bulk Density[32,33]

The calculation of the bulk density of analogue rice aims to determine the porosity of a material. Fill a 100 ml glass beaker with the sample until it is full and tightly packed. The sample is then weighed and documented. The bulk density is calculated using the formula:

$$\text{Bulk Density (g/ml)} = \frac{\text{Weight (g)}}{\text{Volume (ml)}}$$

Cooking Time[32,34]

2-g samples were placed in a beaker containing boiling water. Subsequently, 10 grains of the sample were deposited on the surface of a glass plate and then compressed with a second glass plate. This sampling was conducted at 30-second intervals. The cooking time at the rice maturity level is determined by the presence of a white core in the center of the grains, which indicates the sample's fading color or cooking time. Subsequently, the sample's cooking time is documented.

Weight of 1000 Grains (Thousand Grain Weight)[35]

The weight of 1000 grains is used to determine the density level of the sample. Place 1000 granules of analogue rice in a container. The sample is subsequently weighed using an analytical balance. The procedure was repeated three times. The sample weight (g) was then recorded.

Water Holding Capacity[36]

A g of the sample was added to 10 ml of aquades, then placed in a test tube and homogenized using a vortex for 1 minute. The sample was subsequently centrifuged at 2200 rpm for 30 minutes. The sediment's weight is subsequently determined. Here is the formula for calculating the water holding capacity:

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$$\text{Water Holding Capacity (\%)} = \frac{\text{Wet Sediment Weight} - \text{Sample Weight Used}}{\text{Sample Weight Used}} \, x \, 100$$

Hardness-Level (Compression Test)[37]

Hardness-level testing uses a Universal Testing Machine (UTM). Condition the UTM tool in the ON position. 50 g samples are taken, and then the sample is positioned in the UTM tool. Adjust the parameters in line with the test type, particularly the hardness level (compression test), and place the tool panel in the ON position. The sample data has been completed in line with the test specimen. The instrument will automatically execute the testing. Next, wait for the sample analysis to complete. The computer monitor displays the results, adjusts the data to the graphic image, and then prints the test results.

Data Analysis

Data processing used Microsoft Excel, and data analysis was carried out using The International Business Machines Corporation Statistics Product and Services Solution Statistics version 25 (IBM SPSS version 25) software. The data obtained consisted of univariate and bivariate data. Univariate data describes descriptive results expressed in Mean±Standard Deviation (SD). Bivariate data will determine the effect of differences in the treatment of four formulations of anchovy addition. Data distribution was carried out to see the distribution of initial data. This test uses the Shapiro-Wilk normality test. Proximate and physical data were analyzed using the ANOVA parametric test to determine differences between treatments, followed by the DMRT post hoc test with a confidence level of 95%.

RESULTS AND DISCUSSIONS

Proximate Analysis of Analogue Rice

Proximate analysis of analogue rice (Table 2) shows that adding anchovy affects the treatment groups based on the results of moisture, ash, protein, fat, and carbohydrate analysis (p-value≤0.05). The moisture content of the analogue rice ranges from 9.32% to 11.14%. Analogue rice has a lower moisture content than the comparison rice (BM), which has a moisture content of 11.82%. The moisture content of analogue rice in all treatment groups and BM meets the SNI rice standard No. 6128: 2020, which is a maximum of 14%[38]. Referring to the SNI, a maximum moisture content of 14% is beneficial to prevent the growth of mold, which is one of the quality parameters of rice and determines its shelf life[39]. Several factors during processing, such as the addition of water, steaming, extrusion, and drying, influence the moisture content of analogue rice[21,39]. Adding anchovy flour in treatments BA1, BA2, and BA3 in the analogue rice formula reduces the moisture content. This is because adding anchovy flour increases the total solids in the analogue rice formula, affecting its water-binding capacity[40]. Moisture content affects the physical characteristics of analogue rice[41]. Ash content is expressed as an inorganic substance resulting from the residue of organic compounds.

The ash percentage of the analogue rice varies between 2.19% and 2.73%, above the reference rice, which is 1.2%. The ash content of the analogue rice complies with SNI standards; according to SNI 2715:2013, the maximum ash content of fish products is 20%[42]. Adding anchovy significantly elevated the ash content of the analogue rice (p-value≤0.05). Ash content indicates the total mineral content in a material[43]. The formulation ingredients for making analogue rice affect the ash content. The high ash content in analogue rice based on breadfruit flour and anchovy indicates a high mineral content in the product. The ash level in 100 g of dried anchovy flour is 20 g[2]. Furthermore, the drying process leads to decomposing components that bind water molecules inside the material, resulting in an elevated ash concentration[44].

Table 2. Nutrient Analysis of Analogue Rice Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*)

Treatments	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy (Kcal)**
BAK	11.14±0.64^{a}	2.19±0.10^{b}	4.94±1.09^{b}	1.79±0.12^{b}	80.05±1.11^{bc}	366.17±7.73^{a}
BA1	9.80±0.92^{b}	2.45±0.08^{c}	5.45±0.29^{b}	1.61±0.12^{c}	80.67±1.11^{b}	380.67±9.27^{a}
BA2	9.32±0.42^{b}	2.55±0.10^{d}	7.57±0.80^{c}	1.67±0.11^{bc}	79.05±0.77^{c}	376.83±17.72^{a}
BA3	9.74±1.75^{b}	2.73±0.06^{e}	8.41±0.42^{d}	1.30±0.15^{d}	77.92±1.94^{c}	385.67±20.23^{a}
BM (Comparison)	11.82±0.08^{a}	1.20±0.04^{a}	10.31±0.48^{ad}	2.27±0.10^{a}	74.40±0.59^{ac}	375.69±13.25^{a}
p-value	0.001*	0.001*	0.001*	0.001*	0.001*	0.235

BAK: control/analogue rice based on breadfruit flour without anchovy, BA1: analogue rice based on breadfruit flour with a 2.5% anchovy addition; BA2: analogue rice based on breadfruit flour with a 5% anchovy addition; and BA3: analogue rice based on breadfruit flour with a 7.5% anchovy addition. p-value≤0.05 indicates a difference in treatment followed by the Post Hoc Duncan test; superscripts with different notations indicate a difference in treatment at a 95% confidence level. The energy calculation is based on the bombcalorimeter method

The protein content of the analogue rice is between 4.94 and 8.41%. Adding anchovy significantly increases the protein content of analogue rice (p-value≤0.05), with the highest protein content found in the BA3. The basic ingredient composition of analogue rice, specifically in 100 g of anchovy flour, determines the protein content, which ranges from 24-48.8 g[2,45]. The protein content of the analogue rice is not significantly different from the protein content of the comparison rice (BM). The protein content of analogue rice helps reduce the glycemic response, as protein may prolong the duration of meal processing in the stomach, thereby decreasing absorption in the small intestine[46]. Analogue rice based on breadfruits flour and anchovies has the potential to be one of the functional food sources.

Adding anchovy significantly reduces fat content (p-value≤0.05). The outcomes of this research similar to Yogeshwari *et al.*'s research aligns[34], but contrast with the findings of Darmanto *et al.*, which revealed a positive association between fat percentage and protein content. The higher fat content was positively associated with higher protein content[43]. The fat content of the analogue rice ranges from 1.3-1.79%, which is lower than the reference rice's 2.27%. The polyunsaturated fatty acid (PUFA) content will degrade during the grinding of anchovies[47,48], and heating process[49]. The influence of temperature and time in moulding and drying analogue rice affects the low-fat content. The heating process accelerates the movement of fat molecules, thereby increasing their distance and facilitating their release from the starch[23]. Low-fat content reduces the risk of rancidity in analogue rice and extends its shelf life. The main fat source in the analogue rice formula comes from coconut oil (Table 1). The process of moulding analogue rice uses coconut oil as a lubricant and emulsifier. The stability of the rice extrusion process occurs when the fat content added to the rice formula is 1-2%[50]. Adding fat sources enhances analogue rice's glossiness and soft texture[51].

Analogue rice has a carbohydrate content ranging from 77.92% to 80.67%. The BA3 has the lowest carbohydrate content, which is 77.92%. The carbohydrate content of analogue rice with 7.5% anchovy flour (BA3) is similar to brown rice (BM) at 74.4%. The moisture, ash, protein, and fat levels influence the calculation results of the carbohydrate content in Table 2. The starch content in the composite analogue rice flour formulation impacts the carbohydrates. The carbohydrate composition of the primary raw materials (per 100g) is as follows: breadfruit flour (77.09%)[21], and white sweet potato flour (20.6%)[2]. Breadfruit flour has a low-medium glycemic index (GI) (31.25-53.75)[52] and sweet potato GI (<55)[53]. The high fiber content and amylose levels influence food's glycemic index (GI), restricting the digestion and absorption processes in the gastrointestinal system[21].

The findings of this study indicate that anchovy-based analogue rice, which supplies sufficient carbohydrates and energy, is suitable as a staple food source. The carbohydrate content in this study has similarities to that in other research exploring similar analogue rice varieties, including cassava (86.53%)[39], kodo millet (74.34–79.96%)[54], kimpul (*Xanthosoma sagittifolium*) (87.94–89.96%)[16], sweet potato and pumpkin composite flour(78.3–81.1%)[55] and combination of taro and seaweed with fish collagen (69.06-76.55%)[43]. The total energy from the analogue rice ranges from 366-385 kcal/100 g, and the comparison rice is 375 kcal/100 g. Adding anchovy flour does not show a difference in energy from all treatments or the control rice (p-value>0.05). The protein, fat, and carbohydrate profile of the basic components influences the energy content of analogue rice.

Physical Characteristics of Analogue Rice

The bulk density is calculated based on the mass-to-volume ratio and is related to the porosity of rice grains. Bulk density is a physical characteristic that indicates the quality of a product, particularly that of rice grains. The bulk density of the analogue rice (Table 3) ranges from 0.61 to 0.68 g/ml. Adding anchovy significantly elevates the bulk density (p-value≤0.05). The BA3 had the highest bulk density at 0.68 mg/dl, but was still lower than the control/BAK (0.84 g/dl). This indicates that the analogue rice has a lower weight and higher porosity than the control rice at the same volume. These results align with the findings of Noviasari's research, which suggested that the bulk density of sorghum-based analogue rice with added starch ranges from 0.65 to 0.7 g/ml[56], and with the findings of Sumardiono *et al.*, 2020 who claimed that the density of fish-fortified analogue rice is 0.51 g/ml. The minimum standard density of the rice analogue ranges from 0.40 to 0.42 g/ml. Below this ranges, the rice will result in a mushy rice characteristic like porridge texture[3]. The bulk density and porosity of the material are influenced by the moisture content, extrusion temperature, and residence time of the dough in the extruder; the drying process reduces the moisture content of the material, making the rice matrix more porous[51,56]. Greater bulk density correlates with improved rice quality, as the grains present a compact and non-porous structure[32]. The rice moulding process in this study did not utilize a standard hot extrusion tool, which operates at high temperatures and incorporates a temperature regulator. The extrusion machine continues to use a manual steamer and does not have the capability to measure temperature.

Table 3. Physical Characteristics of Analogue Rice Based on Breadfruit Flour (*Artocarpus Altilis*) and Anchovy (*Stolephorus Commersonii*)

Treatment	Bulk Density (g/ml)	Cooking Time (minute)	Thousand Grain Weight (g)	Water Holding Capacity (%)	Hardness (N)
BAK	0.61±0.02[b]	15.00±2.65[a]	17.27±1.03[b]	176.70±0.91[b]	122.08±14.19[a]
BA1	0.63±0.03[b]	16.00±2.65[a]	17.57±0.97[b]	162.04±2.07[c]	85.12±13.41[a]
BA2	0.68±0.01[c]	16.33±2.31[a]	17.25±0.58[b]	154.90±0.61[d]	66.01±1.24[a]
BA3	0.68±0.01[c]	16.33±3.21[a]	16.33±1.05[b]	159.09±1.98[e]	92.84±2.58[a]
BM (Comparison)	0.84±0.01[a]	20.00± 0.001[a]	19.6±0.04[a]	89.84±0.89[a]	104.26±8.58[a]
p-value	0.001*	0.198	0.008*	0.001*	0.47

BAK: control/analogue rice based on breadfruit flour without anchovy, BA1: analogue rice based on breadfruit flour with a 2.5% anchovy addition; BA2: analogue rice based on breadfruit flour with a 5% anchovy addition; and BA3: analogue rice based on breadfruit flour with a 7.5% anchovy addition.

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Gelatinization time and a reduced color to a more translucent and adhesive state determine the cooking time[34]. The cooking time for analogue rice is between 15 and 16.33 minutes, but comparison rice (BM) requires 20 minutes for preparation. The statistical test findings revealed no significant effect (p-value>0.05) on cooking time throughout all treatment groups. Preliminary treatments, such as heating the dough for 30 minutes, affect the cooking time of analogue rice by inducing starch gelatinization[39,57]. According to Sumardiono *et al*.,2020[58], adding anchovy does not affect cooking time, contradicting results that show an increase in cork fish flour prolongs cooking time (20-25 minutes). The higher the protein content in the rice, the longer it takes for the protein to form gelatin and denature. An increased protein content requires an extended cooking time for the analogue rice. The gelatinization temperature of the materials used influences the duration of the cooking process for analogue rice. The amylose content influences the gelatinization temperature; the higher the temperature, the longer the cooking time. Amylose exhibits improved water-holding capacity compared to amylopectin[51].

The weight of a thousand grains is utilized to assess the homogeneity of grain size[56]. The addition of anchovies did not show a significant effect (p-value>0.05) on the weight of 1000 grains of analogue rice. The weight ranges from 16.33 to 17.27 g, similar to the kodo millet-based analogue rice (16.03-18.23 g)[54]. The results show that the weight of 1000 analogue rice grains is lower than BAK (19.64 g). Water holding capacity (WHC) refers to the maximum quantity a substance can absorb and retain. The addition of anchovy affects water holding capacity (p-value≤0.05). The water-holding capacity of all treatments ranged from 89.84% to 176.70%. The water-holding capacity decreases as the addition of anchovy increases. Protein denaturation alters the structure of rice and its ability to bind water[59]. The water holding capacity rises with an increase in extrusion temperature. The interaction between water and protein increases, leading to changes in the protein structure of analogue rice[60]. This phenomenon affects the texture of rice products. Increased water holding capacity leads to a higher moisture content, which causes greater swelling of protein molecules, ultimately resulting in mushy rice.

Adding anchovies does not influence the hardness level of the rice (p-value>0.05). The measurement of hardness was conducted using a UTM device. The extrusion temperature and the amylose content of the material influence the hardness level. The increase in extrusion temperature enhances the number of bonds between particles, thereby increasing the hardness of the analogue rice grains[57]. The rice's high water absorption capacity and structural strength balance its hardness, indicating its resistance to damage[32].

This research provides an advantage because the raw material formula for producing analogue rice is readily available. Adding anchovy to the analogue rice formula results in a higher nutritional content than BAK and BM. The resulting analogue rice maintains a moisture level consistent with SNI criteria, an elevated ash content indicative of high mineral levels, an increased protein content, and a reduced fat content, all while maintaining an equivalent calorie value. The study's limitations include the physical properties of the analogue rice's density, which falls short of the general standards for rice. Additionally, the water retention capacity of the analogue rice is still higher. However, the addition of anchovy tends to reduce it, thereby affecting the texture quality of the produced rice, making it softer than the general brown rice. This research's limitation stems from using a non-standard extrusion tool in the rice moulding process, necessitating manual steaming of the dough without precise measurement and setting of the extrusion temperature. These limitations affect the physical characteristics of the foam density and the water-holding capacity of the resulting analogue rice.

CONCLUSIONS

The addition of anchovy in the formula increases the ash and protein, decreases the fat content, and does not affect the carbohydrate and energy. The moisture content meets SNI requirements. Despite the addition of 7.5% anchovy flour, the protein, carbohydrate, and energy levels of BA3 formula do not significantly differ from those of the comparison rice (BM). The weight of 1000 grains, the hardness level, and the cooking time within the range of 15–16.33 minutes are not substantially different across all treatment groups. The bulk density increased, and WHC decreased with the increasing use of anchovy in the analogue rice formula. Still, it remained relatively high compared to the comparison rice. Further research requires measurement of the extrusion temperature during the analogue rice-making process. The proximate analysis results recommend the BA3 as a formula for further research to determine the glycemic index of analogue rice.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

VIP: conceptualization, investigation, methodology, formal analysis, writing–original draft; MAL: methodology, formal analysis, investigation, writing–review; DHF: visualization, formal analysis, editing.

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