Physical, Chemical, Physicochemical, and Sensory Properties of Analog Rice Based on Purple Sweet Potato Flour (Ipomoea batatas L.) and Bambara Groundnut Flour (Vigna subterranea L.)

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Abstract. The aim of this study is to determine the best formulation based on sensory properties and to compare the physical, chemical and physicochemical properties of the analog rice with the analog rice of purple gray and red commercial sweet potatoes. Furthermore, a completely randomized design (CRD) with one factor was used, the Bambara Peanut Meal Difference in formulation 0% (F1); 15% (F2); 30% (F3); 45% (F4); and 60% (F5). 1.5% GMS, 1.5% CMC, 2% palm oil and 25% water were added to each formulation. The data were analyzed statistically by using one way ANOVA. The significant difference was further tested using Duncan's new multiple range test (DMRT) at a significance level of α = 0.05. The best sample was selected based on sensory evaluation made from 85% purple sweet potato flour and 15% bambara groundnut flour (F2 analog rice). The F2 analog rice is then compared with red rice and commercial purple sweet potato analog rice based on the physical, chemical and physicochemical properties. The results showed that F2 analog rice has an L 42.41; bulk density 0.57 g/ml; grain weight 0.02 g; moisture 6.55%; ash 4.34%; fat 4.82%; protein 5.77%; carbohydrate content 85.07%; total dietary fiber content 14.96%; water absorption 175.50%; swelling power 8.99 g/g; solubility 23.45%, and cooking time 11.54 minutes. The result has shorter cooking time and higher total dietary fiber content (F2 sample) than commercial analog rice and red rice.

1. Introduction
Rice is the primary source of carbohydrates in the diet of Indonesian society. According to the Indonesia’s Central Agency of Statistics data in 2018, in the last four years the average rice consumption was 113.44 kg/capita/year. Lack of domestic rice availability lead to importation of about 3,766,882.5 tons of rice. The effort that can be made to overcome this problem is to diversify food in the form of analog rice based on purple sweet potato flour and bambara groundnut flour. The bambara groundnut is a legume that can be used as a source of functional food. This plant has a high protein content (16-21%) and a total dietary fiber 10.3% [1]. The purple sweet potato is a source of carbohydrates that can be developed as the main food ingredient. The nutritional content of purple sweet potato per dry weight percent is 4.4% protein; fat 0.75%; water 61.64%; ash 1.62%, and carbohydrates 93.23% [2].

Extrusion technology is a technique that can be applied in the production of analog rice. According to Budi et al., [3], the extrusion method was selected because it can form the rice and is not easily broken.
because the construction method is designed in such way that the resulting extrusion is shaped like rice and analog rice-making materials are flowed forcibly through the barrel with one or more variations of the mixing, heating, and shearing to produce a more compact analog rice. This research was conducted to examine the physical, chemical, and physicochemical properties of analog rice based on bambara groundnut flour and purple sweet potato flour. The best sample was selected based on sensory evaluation. In addition, the sample was then analyzed and compared physically, chemically, and physicochemically with the commercial purple sweet potato analog rice and red rice.

2. Material and Methods

2.1 Materials

The raw materials used are bambara groundnut seeds, purple sweet potato flour branded “Hasil Bumiku”, glycerol monostearate (GMS), carboxy methyl cellulose (CMC), palm oil, and analysis materials. The bambara groundnut seeds were soaked in distilled water for 24 hours, and boiled for 10 minutes. The bambara groundnut seeds were reduced in size by cutting in half, and were dried using a cabinet dryer at a temperature of 50 °C for 9 hours. The dried bambara groundnut seeds are then milled and sieved through 80 mesh sieve to obtain flour [4].

2.2 Production of Analog Rice

Table 1 presents the formula of raw material’s compositions, purple sweet potato flour, bambara groundnut flour, GMS, CMC, water and palm oil. The production process started with the manufacture of composite flour, all material’s flour is mixed with certain composition using food processor. Then, the dough is steamed for 30 minutes. The cooking dough extrude in hot extrusion (T : 85-90 °C) and was cut using knife and therefore produced similar grain rice. A cabinet dryer at a temperature of 50 °C is used for the drying process for 5 hours [5].

2.3 Methods of Analysis

In the sensory analysis, only a consumer acceptance test with a numerical scale from 1 to 7 was used for the analog rice samples. The best sample based on sensory result will be compared with the red rice and commercial purple sweet potato analog rice for the physical, chemical and physicochemical properties analysis. Analog rice sample, red rice and commercial purple sweet potato analog rice were analyzed for brightness color, bulk density, water content, ash content, fat content, protein content, carbohydrate content, total dietary fiber content, water absorption, swelling power, solubility, and cooking time. The color analysis was carried out using Minolta Chromameter CR-300. Bulk density and one thousand grain weight used by Widara method [6]. The chemical properties include the detailed analysis of the AOAC method [7]. The total fiber content was used according to the enzymatic gravimetric method. The water absorption was calculated using the Dewi method [8]. In addition, swelling power and solubility was determined by Senanayake and Agil method [9].

2.4 Statistical analysis

This research was analyzed using analysis of variance (ANOVA) with level of significance (p < 0.05), and followed by Duncan’s Multiple Range Test (DMRT) at 5% level using IBM SPSS Statistics 26 software.

| Table 1. Design of composition rice analog consist of purple sweet potato flour, bambara groundnut flour, GMS, CMC, and palm oil |
|---------------------------------------------------------------|
| **Formula** | **Purple sweet potato Flour** | **Bambara Groundnut Flour** | **GMS** | **CMC** | **Palm Oil** |
| F1     | 100% | 0% | 1.5% | 1.5% | 2% |
| F2     | 85%  | 15% | 1.5% | 1.5% | 2% |
| F3     | 70%  | 30% | 1.5% | 1.5% | 2% |
| F4     | 55%  | 45% | 1.5% | 1.5% | 2% |
| F5     | 40%  | 60% | 1.5% | 1.5% | 2% |
3. Results and Discussion

3.1 Sensory Properties

Table 2 shows the average results of the analog rice sensory tests in different compositions of color, aroma, texture, flavor, and the composition of parameter. F1 sample is used as a reference, which is only 100% purple sweet potato flour. Analog rice with the highest value of color was obtained in F2 (5.32). The reddish-purple color from purple sweet potato flour because of existence anthocyanin compounds in such a way that the color of the rice is more similar to red rice, which is commonly consumed by many people and it is more preferred [6]. Analog rice with the highest value of aroma was obtained in F2 (5.00). The more the addition of bambara groundnut flour, the aroma of analog rice decrease, because the unpleasant aroma of bambara groundnut. Analog rice with the highest value of texture was obtained in F2 (5.04). F2 was preferred because it is smoother than other samples. Purple sweet potato flour has high levels of amylpectin, where amylpectin plays a role in the texture properties of rice [7]. Analog rice with the highest value of flavor was obtained in F1 (5.16) and F2 (5.04). F1 and F2 were selected because the taste of the two formulas was sweeter than analog rice with other formulations. This is due to the addition of purple sweet potato flour which has a higher sugar content in such a way that it is sweeter in taste. Generally, the highest value acceptance of analog rice is obtained in F1 (5.20) and F2 (5.20), F1 rice analog as standard panellist acceptance, therefore F2 analog rice was selected to be the best formula for the next analysis.

Table 2. Cooked Analog Rice Sensory Test Result

| Formula | Color     | Aroma     | Texture   | Flavor   | Overall  |
|---------|-----------|-----------|-----------|----------|----------|
| F1      | 5.04±0.79a| 4.64±1.19ab| 4.88±1.20cd| 5.16±0.94a| 5.20±0.65a|
| F2      | 5.32±0.75c| 5.00±1.08b| 5.04±1.17d| 5.04±1.21c| 5.20±0.65c|
| F3      | 4.52±0.96b| 4.56±0.92bc| 4.40±0.96bc| 4.48±0.82b| 4.48±0.65b|
| F4      | 4.00±0.87a| 4.52±0.77bc| 3.92±0.86bc| 4.04±0.89bc| 4.24±0.72bc|
| F5      | 3.76±1.09a| 4.20±1.19a | 3.20±0.96a | 3.44±1.00a | 3.52±0.92a |

Values represent the mean of duplicate measurements ± SD (Standard Deviation). Means within columns with different letters are significantly different (p < 0.05)

3.2 Physical Properties

Physical properties analysis was carried out to determine the color (value L *, + a, + b), one thousand grain weight, and bulk density (g/ml) (Table 3). Color analysis of the three rice samples was carried out using Chromameter. Notation L* indicated the brightness level of a product. F2 analog rice with darker color product had lower value of L compared to red rice and commercial purple sweet potato analog rice. In the extrusion process involving a fairly high temperature (70 – 80°C) [8], in such a way that the Maillard reaction was accelerated [9]. Moreover, the color of purple sweet potato analog rice was influenced by anthocyanins and cyanidin contained in purple sweet potato flour [7]. Bulk density of analog rice was known to determine the rice volume and porosity. Based on Table 3, F2 analog rice and commercial purple sweet potato analog rice had a lower density than red rice, and therefore analog rice had a lighter weight and higher porosity than red rice at the same volume. The drying process in the processing of analog rice leads to the loss of water, then the analog rice matrix becomes more porous [10].

One thousand grain weight of rice was usually known to determine the uniformity of the rice grain. The results showed that commercial purple sweet potato analog rice has the highest weight. The grain weight of analog rice can be affected by extrusion process. The most influential parameter in the process is cutter speed. If cutter speed was reduced, size of analog rice will be large and vice versa. The cutter speed used in this research is 70-80 Hz or 4,225.13 rpm - 4,828.72 rpm.

3.3 Chemical Properties

Chemical properties were determined using proximate levels and total dietary fiber (Table 4). The moisture content of the three samples had lower than the safe moisture levels for storage, which is below 14% [11]. Meanwhile, the moisture content of the F2 analog rice was the lowest. This is due to analog
rice during exchanges and drying with a wardrobe dryer, in such a way that there was an increase in moisture loss. The highest in the ash content was reported in F2 analog rice. It is due to the use of bambara groundnut flour by 15% where the milling process is carried out using all parts of bambara groundnut including testa part. According to Ainia et al., [12], bambara groundnut flour was milled with whole seeds has an ash content of 4.36%. This shows that F2 analog rice contains high minerals.

Table 3. Physical Properties of Red Rice, Commercial Purple Sweet Potato Analog Rice, and F2 Analog Rice

| Properties           | Red Rice       | Commercial Purple Sweet Potato Analog Rice | F2 Analog Rice |
|----------------------|----------------|-------------------------------------------|---------------|
| Color                |                |                                           |               |
| L                    | 45.62±0.37b    | 53.97±0.28c                              | 42.41±0.58a   |
| a                    | 9.03±0.63c     | 11.56±0.34b                              | 8.42±0.25c    |
| b                    | 14.98±1.23c    | 1.63±0.31a                               | 4.82±0.52c    |
| Bulk Density (g/ml)  | 0.78±0.00d     | 0.54±0.00d                               | 0.57±0.00d    |
| One Thousand Grain Weight (g) | 17.58±0.29a | 21.61±0.29c                              | 19.50±0.20b   |

Values represent the mean of duplicate measurements ± SD (Standard Deviation). Means within rows with different letters are significantly different (p < 0.05)

In addition, F2 analog rice has highest Fat content. It is due to the use of bambara groundnut flour, which has a fat content of 5.9% and additional ingredients, palm oil [13]. A low fat content can prevent the rice to easily rancid and the storage time can be longer. The protein content of analog F2 was higher than that of commercial purple sweet potato analog rice but lower than that of red rice. The protein content of analog rice depends on the raw materials and the extruder operating conditions was used [14]. F2 analog rice has a protein content of 5.77 ± 0.47% due to the use of bambara groundnut flour, which has a protein content of 25.3 ± 0.4% [13]. The protein in F2 analog rice is less compared to red rice due to heat in extrusion process, which causes protein degradation [15]. Carbohydrate content of F2 analog rice has lowest value, and the carbohydrate in commercial purple sweet potato analog rice is due to drying processing. Carbohydrate content of the ingredients increases but at the same time the moisture content decreases [16]. The use of raw materials in commercial purple sweet potato analog rice also plays a role in raising carbohydrate level. Also, F2 has highest in total dietary fiber. The use of bambara groundnut flour has a total dietary fiber of 24.3 ± 1.4 (% db) [17]. It was lead to increase the total dietary fiber in rice.

Table 4. Chemical Properties of Red Rice, Commercial Purple Sweet Potato Analog Rice, and F2 Analog Rice

| Properties                  | Red Rice       | Commercial Purple Sweet Potato Analog Rice | F2 Analog Rice |
|-----------------------------|----------------|-------------------------------------------|---------------|
| Moisture Content (%wb)      | 12.63±0.96c    | 9.40±0.20b                                | 6.55±0.25c    |
| Ash Content (%db)           | 0.91±0.10b     | 0.42±0.16a                                | 4.34±0.18b    |
| Fat Content (%db)           | 1.74±0.25b     | 4.13±0.17b                                | 4.82±0.23b    |
| Protein Content (%db)       | 8.66±0.15c     | 1.12±0.90b                                | 5.77±0.47b    |
| Carbohydrate Content (%db)  | 88.69±0.20a    | 94.33±0.18b                               | 85.07±0.53b   |
| Total dietary fiber (%db)   | 5.83±0.23a     | 10.89±0.38b                               | 14.96±0.56c   |

Values represent the mean of duplicate measurements ± SD (Standard Deviation). Means within rows with different letters are significantly different (p < 0.05)

3.4 Physicochemical Properties

The physicochemical propertie of the analog rice are shown in (Table 5). Due to the high water absorption capacity, water could easily be absorbed into the rice-filled cavity of the starch granule [18]. The F2 analog rice has the lowest water content when compared to other analog rice. According to Loebis
et al., [19], the ability of the material to absorb water is easier when it is low in moisture. The swelling power of F2 analog rice was higher than commercial purple sweet potato analog rice but lower than red rice. This is due to the influence of amylose content in the material. High levels of amylose will increase swelling power and vice versa. Polysaccharide molecules which contains high amylose will absorb water faster and expand compared to high amylpectin levels. This is due to the breaking of weak hydrogen bonds in the amorphous area composed of amylose in such a way that it can hydrate water until it reaches the maximum hydration volume [20].

F2 analog rice has the highest in the solubility. It is due to the heat in analog rice making process. Higher solubility was caused by heating the starch suspension, which is getting higher because the amylose has undergone depolymerization, and high temperatures cause depolymerization of molecules. This causes the resulting amylose molecule to be simpler, and therefore short straight chains is easily dissolved in water [21]. Amylose is a starch component that has a straight chain and dissolves in water [22]. The cooking time results show that F2 analog rice has the fastest cooking. F2 analog rice has a faster cooking time because it has the highest water absorption. This is confirmed by the statement of Yuwono ad Arida [5] which explains that higher water absorption caused shorter cooking time.

| Properties                     | Red Rice          | Commercial Purple Sweet Potato Analog Rice | F2 Analog Rice |
|--------------------------------|-------------------|-------------------------------------------|----------------|
| Water Absorption (%wb)         | 35.18±0.76        | 135.50±0.96                               | 176.50±1.08    |
| Swelling Power (g/g)           | 10.98±0.66        | 8.75±0.24                                 | 8.99±0.15      |
| Solubility (%)                 | 12.78±1.76        | 14.14±1.46                                | 23.45±1.85     |
| Cooking Time (min)             | 36.14±0.02        | 14.43±0.03                                | 11.54±0.04     |

Values represent the mean of duplicate measurements ± SD (Standard Deviation). Means within rows with different letters are significantly different (p < 0.05)

4. Conclusion
The best sample was selected based on sensory evaluation made from 85% purple sweet potato flour and 15% bambara groundnut flour (F2 analog rice). The results showed that F2 analog rice with a composition of 85% purple sweet potato flour and 15% bambara groundnut flour had a thousand grain weight (19.50 g), similar to that of a thousand grain weight of red rice (17.58 g). Furthermore, F2 analog rice has the highest water absorption (176.50%) in such a way that it has the shortest cooking time (11.54 minutes) compared to red rice (36.14 minutes) and commercial purple sweet potato analog rice (14.43 minutes). F2 analog rice has a protein content (5.77%) higher than commercial purple sweet potato analog rice (1.12%). Also, F2 analog rice contains the highest total dietary fiber (14.96%).

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