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# Formulation and Characterization of Analog Rice Using Arrowroot (*Maranta arundinacea* L.) and Hibiscus Flower (*Hibiscus rosa sinensis* L.)

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***Abstract***
***Background****: Efforts to reduce high-carbohydrate consumption from rice include the development of analog rice from alternative sources such as arrowroot tubers (Maranta arundinacea L.). Proper formulation is crucial for producing analog rice with optimal quality, taste, and characteristics resembling conventional rice, while maintaining functional properties to meet carbohydrate and nutritional needs. Hibiscus (Hibiscus rosa-sinensis L.), which is rich in flavonoids, saponins, and anthocyanins, can enhance these formulations.* ***Objective:*** *The objective of this study was to evaluate the composition of a blend of arrowroot tubers (M. arundinacea L.) and hibiscus (H. rosa-sinensis L.) as a rice substitute.* ***Methods:*** *This study used 50 untrained panelists to conduct organoleptic tests on the shape, color, aroma, taste, and texture of rice and analog rice using five formulas (F1, F2, F3, F4, and F5). Furthermore, physical characteristics were tested, including the color index, 1000-grain weight, bulk density, and starch digestibility.* ***Results:*** *The characteristics test proved that all analog rice formulas had an average hedonic score in the range of 3.73-3.90; lower bulk Density than rice with a bulk density of 0.83 ± 0.02 g/mL; starch digestibility in the range of 0.62-0.67 g/mL; and has a yellow-red color range.* ***Conclusion:*** *The best and most preferred rice analog is Formula 5 (F5), with a composition of arrowroot tubers 57.8%, hibiscus 5.1%, mocaf 12.6%, GMS 0.6%, and water 23.9%.*

***Keywords****: analog rice, arrowroot tuber, formulation, hibiscus, organoleptic*

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## INTRODUCTION

Rice is a staple food source of carbohydrates that most Indonesians consume, although it is known to be high in carbohydrates and has a high glycemic index (GI) value (Darmanto, 2017). Excessive consumption of rice as a carbohydrate source can affect blood glucose levels and the insulin response in the body, thus triggering diabetes mellitus (DM) (Septianingrum, 2016). Therefore, it is necessary to determine the appropriate amount and type of carbohydrate food to increase and maintain healthy food intake by consuming low-GI rice so that blood glucose levels can be controlled. Foods with low GI are known to be effective in improving insulin sensitivity and reducing the rate of glucose absorption, which is beneficial for people with DM, whereas foods rich in antioxidants can prevent the possibility of chronic complications (Septianingrum, 2016; Darmanto, 2017; Kumolontang, 2019).

One of the efforts to reduce the consumption of high amounts of carbohydrates in rice is to develop alternative food sources in the form of analog rice (Darmanto, 2017; Kumolontang, 2019). Analog rice is artificial rice made to resemble the shape of rice using non-rice raw materials. Analog rice grains are formed with the addition of the right raw materials and additives to meet the nutritional needs as well as those contained in rice. However, the addition of these ingredients is also intended to improve the benefits and efficacy, and reduce the negative impacts of using rice. Analog rice aims to diminish the intake of excessive carbohydrates associated with paddy rice by substituting it with alternatives that possess lower glycemic index values (Septianingrum, 2016; Darmanto, 2017; Kumolontang, 2019). One of them is by utilizing tubers that have high levels of protein, fat, crude fiber, amylose, and carbohydrates, but low GI, namely arrowroot tubers (*Maranta arundinacea* L.) ( Pertanian 2021).

Arrowroot tubers (*M. arundinacea* L.) are a local plant that is a source of carbohydrates rich in fiber and are beneficial for people with DM because of their low GI content compared to other types of tubers. Arrowroot tubers contain saponins, flavonoids, and folic acid (in 100 g of arrowroot there is 84% of folic acid needed per day), vitamin B complex (niacin, thiamine, pyridoxine, pantothenic acid, and riboflavin), several important minerals (copper, iron, manganese, phosphorus, magnesium, zinc, and potassium), and are gluten-free (a starch substance that has a shorter fiber chain, so it is easily digested) (Darmanto, 2017; Litbang Pertanian, 2021).

Formulating the appropriate composition is crucial for the production of analog rice from arrowroot tubers (*M. arundinacea* L.), enabling the creation of a high-quality product with taste and characteristics similar to conventional rice, while supporting its functional properties to meet the dietary needs of carbohydrates and other nutrients, particularly for individuals managing diabetes mellitus (DM) (USDA, 2021). Additional components may include hibiscus flowers (*H. rosa-sinensis* L.), which are rich in flavonoids, saponins, and anthocyanins (Oktiarni, 2013; Essiett, 2014; Silalahi, 2019; USDA, 2021). Previous research conducted by Arlita et al. (2017) proved that hibiscus flower extract (*H. rosa-sinensis* L.) can reduce blood glucose levels in patients with DM, thereby suppressing hyperglycemic conditions that cause inflammation.

The results of other studies conducted by Arlita et al. (2020) also prove that the use of analog rice flour combined with arrowroot (*M. arundinacea* L.) and hibiscus (*H. rosa-sinensis* L.) are both given at 800 mg/KgBB simultaneously with the consumption of metformin once a day can reduce blood glucose levels and hyperglycemic conditions and improve the score/ degree of damage to pancreatic and hepatic organs of patients with DM. However, that study only used a combination of arrowroot and hibiscus analog rice flour, not analog rice formulated from arrowroot and hibiscus, as developed in the study to be conducted.

Therefore, this study was conducted to test and evaluate the physical and sensory characteristics of analog rice made from a combination of arrowroot tubers (*Maranta arundinacea* L.) and hibiscus (*Hibiscus rosa-sinensis* L.).

## MATERIALS AND METHODS

This research was approved by the Research and Health Ethics Commission (KEPK) of the Faculty of Medicine, Diponegoro University (No. 108/EC/H/FK-UNDIP/IX/2021, and no. 405/EC/KEPK/FK-UNDIP/X/2021.

### Preparation of arrowroot tuber (*M. arundinacea* L.) and hibiscus flower (*H. rosa-sinensis* L.)

The initial process of material preparation was carried out by collecting fresh arrowroot tubers and hibiscus flowers, which were then wet-sorted and washed to remove dirt that was still attached. The clean ingredients were then chopped and dried at room temperature until dry with a moisture content of $\leq 10\%$. The dried material was then pulverized into a fine powder using a blender. The powder is stored in dry,

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clean, and sterile containers, and damp places should be avoided.

**Analog rice formulation**

The formulations of arrowroot tubers (*M. arundinacea* L.) and hibiscus (*H. rosa-sinensis* L.) as analog rice were determined according to Table 1.

**Preparation of analog rice**

The process of making analog rice includes ingredient preparation, mixing, pregelatinization, extrusion, and drying. The material preparation process involved flour preparation and weighing. Dry ingredients, such as arrowroot tuber flour, hibiscus flower powder, mocaf flour, and GMS, were mixed separately with water. The next stage involves mixing. Dry ingredients were mixed first until they were evenly distributed; then, water was added and remixed until they were evenly distributed. The next stage is the preconditioning process. The material was steamed at 80°C for 25 min. This stage improved the uniformity of particle hydration and reduced the residence time of the dough in the extruder, thereby accelerating the extrusion stage. The dough was then placed in an extruder machine until the rice was molded. Rice was dried in an oven at 65 °C for 2 h (Darmanto, 2017). The dried analog rice was stored in clean, dry, and sterile packaging.

**Cooking analog rice**

The method of cooking analog rice is not different from cooking rice. The tool used to cook analog rice in this study was a rice cooker. The amount of water added to the cooking of rice was 2/3 of the volume of analog rice. The cooking method was measured using 100 g of rice and then adding 70 mL of water, which can also be interpreted by adding water up to 0.5 cm above the rice. Before cooking, the analog rice was washed 1-2 times and put into the rice cooker, and then stirred well every 5 min.

**Characteristic test**

Characteristic tests on analog rice and rice were carried out using organoleptic testing and analysis of physical characteristics, including color index, 1000-grain weight, bulk density, and starch digestibility (Mahfuzhah, 2018).

**Organoleptic test**

Organoleptic tests used respondents in the form of untrained panelists, as many as 50 people with the following criteria: 1) aged 20-60 years; 2) having good senses of sight, smell, and taste without interference; and 3) able to understand, distinguish, and give an assessment of each analog rice sample. Untrained panelists were chosen because they represent the end consumers targeted by the product and provide insights into the level of market acceptance. This assessment is typically conducted using a hedonic scale, where panelists rate their preference for the tested samples. This method is essential to ensure that the product not only meets technical standards, but is also generally favored by consumers. The results of the sensory test were then analyzed using descriptive statistics or hypothesis testing, such as ANOVA or Kruskal-Wallis tests, to evaluate differences in acceptance levels across formulas or samples.

Organoleptic tests were conducted by sensory analysis of the shape, color, aroma, taste, and texture using a hedonic rating. Panelists were presented with samples of rice and analog rice from the five formulations to be assessed by giving a score on the hedonic quality test form on a numerical scale, as shown in Table 2.

**Table 2.** Hedonic quality test scale

| Hedonic Scale | Numerical Scale |
|---|---|
| Very like | 5 |
| Like | 4 |
| Somewhat like | 3 |
| Dislike | 2 |
| Strongly dislike | 1 |

Source: Nazhifah (2018)

**Table 1.** Variations of analog rice formula made from arrowroot (*M. arundinacea* L.) tubers and hibiscus flowers (*H. rosa-sinensis* L.)

| Materials | Formula 1 (F1) | Formula 2 (F2) | Formula 3 (F3) | Formula 4 (F4) | Formula 5 (F5) |
|---|---|---|---|---|---|
| Arrowroot | 60.4% | 59.7% | 59.1% | 58.5% | 57.8% |
| Hibiscus flower | 2.5% | 3.2% | 3.8% | 4.4% | 5.1% |
| Mocaf | 12.6% | 12.6% | 12.6% | 12.6% | 12.6% |
| GMS (glyceryl monostearate) | 0.6% | 0.6% | 0.6% | 0.6% | 0.6% |
| Water | 23.9% | 23.9% | 23.9% | 23.9% | 23.9% |

**Hedonic quality test scale**

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A color determination test was conducted to analyze the color reflected by a surface in a tristimulus using a CS-10 colorimeter. Five tests were carried out 5 times for each test sample.

**Starch digestibility test**

One gram sample of rice and rice analog was placed in a 250 mL Erlenmeyer flask, followed by the addition of 100 mL of distilled water. The flask was then covered with aluminum foil, heated to 90 °C in a water bath while stirring, and subsequently cooled. Then, two mL sample solution was transferred to a test tube, and 3 mL of distilled water and 5 mL of phosphate buffer solution (pH 7) were added. Two sets of sample solutions, each with a volume of 2 mL, were transferred to separate test tubes. Three test tube, 3 mL of distilled water and 5 mL of a phosphate buffer solution (pH 7) were added. One test tube was used as blank. The tube was closed and incubated at 37 °C for 15 min. Five milliliters of α-amylase enzyme solution (1 mg/mL in phosphate buffer solution pH 7) and 5 mL of phosphate buffer pH 7 were added to the sample and blank solutions, and then incubated again for 30 min. One milliliter of the sample was transferred to a test tube containing 2 mL of DNS solution, heated in boiling water for 12 min, and immediately cooled with water. Next, 10 mL of distilled water was added to the sample and homogenized using ultrasonication. The absorbance of the sample and blank solutions was measured using a UV-Vis spectrophotometer at 520 nm (Mahfuzhah, 2018). The starch digestibility was calculated as follows:

$$\text{Starch Digestibility (\%)} = \frac{\text{Amount of glucose produced (mg)}}{\text{Amount of starch in the sample (mg)}}$$

## RESULTS AND DISCUSSION

Rice and rice analogs are shown in Figure 1. The demographics of the panelists who participated in the organoleptic testing of rice and analog rice are presented in Table 3. The percentage of male panelists was less than that of females, while the age of panelists was dominated by 41-50 years old (52%).

Organoleptic tests of the shape, color, aroma, taste, and texture of the rice and rice analogs are shown in Table 4. The liking value of the five organoleptic test parameters showed that most panelists liked the rice and rice analog of Formula 5 (F5).


**Figure 1.** Rice analog produced (from left to right: F1, F2, F3, F4, and F5)

**Table 3.** Demographic of organoleptic test panelist

| Panelist Demographic | Frequency | |
|---|---|---|
| | Number | Percentage |
| Gender: | | |
| 1) Male | 18 | 36% |
| 2) Female | 32 | 64% |
| Age: | | |
| 1) 20-30 years old | 8 | 16% |
| 2) 31-40 years old | 11 | 22% |
| 3) 41-50 years old | 26 | 52% |
| 4) 51-60 years old | 5 | 10% |
| **Total Amount** | **50** | **100%** |

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**Table 4.** Organoleptic test results

| Mean of Hedonic Score | Parameter | | | | |
|---|---|---|---|---|---|
| | **Shape** | **Color** | **Aroma** | **Taste** | **Texture** |
| Analog Rice: | | | | | |
| 1) F1 | 3.77 | 3.73 | 3.83 | 3.74 | 3.73 |
| 2) F2 | 3.60 | 3.63 | 3.83 | 3.43 | 3.70 |
| 3) F3 | 3.77 | 3.77 | 3.77 | 3.77 | 3.70 |
| 4) F4 | 3.77 | 3.97 | 3.93 | 3.83 | 3.73 |
| 5) F5 | 3.70 | 4.13 | 3.83 | 3.87 | 3.77 |
| **P-*value*** | **0.675** | **0.004*** | **0.601** | **0.601** | **0.975** |
| Analog Rice: | | | | | |
| 1) F1 | 3.47 | 3.57 | 3.20 | 3.47 | 3.20 |
| 2) F2 | 3.37 | 3.57 | 3.27 | 3.43 | 3.40 |
| 3) F3 | 3.57 | 3.77 | 3.47 | 3.77 | 3.47 |
| 4) F4 | 3.77 | 4.10 | 3.60 | 3.83 | 3.90 |
| 5) F5 | 3.97 | 4.17 | 3.53 | 3.87 | 3.77 |
| **P-*value*** | **0.000*** | **0.000*** | **0.051** | **0.011*** | **0.000*** |

**Table 5.** 1000-grain weight test results

| Analog Rice Sample | 1000-grain weight (g) | Weight per grain (g) |
|---|---|---|
| F1 | 27.63 ± 0.20 | 0.02763 |
| F2 | 28.21 ± 0.06 | 0.02821 |
| F3 | 27.56 ± 0.28 | 0.02756 |
| F4 | 25.01 ± 0.52 | 0.02501 |
| F5 | 24.92 ± 0.04 | 0.02492 |

The color test using a colorimeter on the five analog rice formulas showed a range of ºHue values of 36.455–53.293. The range values show that the analog rice produced in the five formulas is in the yellow-red chromaticity range.

The 1000-grain weight test results for the five analog rice formulas are listed in Table 5. The smallest weight result was F5 (24.92 ± 0.04 g), and the largest value was F2 (28.21 ± 0.06 g).

The bulk density test conducted shows that all analog rice formulas have lower values compared to rice (IR-32), which has a bulk density of 0.83 ± 0.02 g/mL, as presented in Table 6.

The starch digestibility tests of the five analog rice formulas are presented in Table 7. Formula 4 (F4) had the lowest starch digestibility value, while the highest value was obtained in F2.

**Table 6.** Bulk density test results

| Analog Rice | Bulk Density (g/ mL) |
|---|---|
| F1 | 0.63 ± 0.02 |
| F2 | 0.67 ± 0.01 |
| F3 | 0.65 ± 0.01 |
| F4 | 0.62 ± 0.01 |
| F5 | 0.63 ± 0.02 |

**Table 7.** Mean results of starch digestibility

| Analog Rice | Mean of Starch Digestibility (%) |
|---|---|
| F1 | 57.1 ± 0.01 |
| F2 | 61.00 ± 0.01 |
| F3 | 55.96 ± 0.02 |
| F4 | 54.22 ± 0.02 |
| F5 | 56.60 ± 0.01 |

The formulation is the initial stage in the process of making analog rice, which aims to make a mixture of raw and additional ingredients with the desired composition to produce analog rice according to the purpose of its manufacture (Widara, 2012; Darmanto, 2017). The main raw materials used in the manufacture of analog rice in this study were arrowroot tuber flour and hibiscus flowers. Arrowroot tuber flour is used because it has nutritional content in the form of protein, fat, crude fiber, amylose, carbohydrate content (25-30%), and starch (± 20%). Arrowroot tubers also have lower GI levels than rice, wheat, potatoes, and cassava; therefore, they can be utilized as food alternatives for people with DM (Suhartini, 2021; USDA, 2021). In the production of analog rice, the flour formula used must contain sufficient starch fractions that gelatinize and bind strongly to the product.

The use of additional ingredients in the form of hibiscus dried flower/flour is due to the presence of

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compounds, such as steroids, alkaloids, phenolics, saponins, and tannins (Seyyednejad, 2010; Arullapan, 2013; Silalahi, 2019; USDA, 2021). These components are known to have a mechanism of action like sulfonylureas that can control hyperglycemic conditions to improve immune system abnormalities that occur in patients with DM. In addition, antioxidant compounds in hibiscus play an important role in reducing the reactivity of free radicals that can damage tissues and organs (Seyyednejad, 2010; Arullapan, 2013).

The addition of water to analog rice plays a role in the preconditioning process. The amount added was 23.9% of the total amount of the ingredients used. Preconditioning plays an important role in the extrusion process because it can improve the uniformity of particle hydration and reduce the residence time of the dough in the extruder. At this stage, the formulated raw material mixture was maintained at a warm (80-90ºC) and wet condition for a certain time and then flowed into the extruder. Good mixing is required to allow contact between the particle surface and the added water and steam. A sufficient residence time is required to allow the diffusion of water vapor and heat transfer from the surface to the inside of the particles so that the raw material mixture is plasticized in the preconditioning device and can flow into the extruder (Widara, 2012).

Arrowroot tuber starch flour is known to have low protein and fat content, which is excellent for inhibiting the formation of resistant starch. In addition, the interaction between proteins and starch can reduce the levels of RS. The interaction of fat and starch occurs during the heating of starch above 100ºC and forms an enzyme-degradable amylose-starch complex. Arrowroot tuber flour, which contains a lot of dietary fiber consisting of polysaccharide fractions, has an influence in changing the structure and physical and chemical properties of the resulting analog rice so that it will cause covalent and noncovalent bonds between carbohydrates that accompany the fiber to break and form more soluble molecules (Widara, 2012).

The mixture of water and flour that produces analog rice can maintain the shape of the rice well if several other additives are added, such as mocaf flour (modified cassava flour), which is a flour product from cassava processed by fermentation (Arimbi, 2013; Edma, 2015). The addition of mocaf flour of as much as 12,6% in this analog rice formulation was done to improve the texture of analog rice, so it is expected to reduce stickiness because mocaf flour has a high fat content (10,63%. In addition, mocaf flour has a high dietary fiber content (20%) and its characteristics resemble wheat flour, which is white, soft, and does not smell cassava, with a moisture content of 6.9 %, protein content of 1.2 %, ash content of 0.4 %, carbohydrates of 87.3%, fiber content of 3.4%, and fat content of 0.4% (Herawati, 2014; Edma, 2015). Therefore, its use in analog rice can increase the fiber content of food; therefore, it is expected to inhibit the activity of digestive enzymes and the rate of food intake in the gastrointestinal tract. This results in a slow digestive process and lower blood glucose response (Herawati, 2014; Edma, 2015; Darmanto, 2017; Rodianawati, 2021).

Another ingredient that also needs to be added to the manufacturing of analog rice is a binder in the form of glyceryl monostearate (GMS) (Herawati, 2014; Darmanto, 2017). This material is an emulsifier in the form of a non-ionic surfactant (amphiphilic substance whose molecule consists of two parts, hydrophilic and lipophilic) with the IUPAC name 2,4-dihydroxypropyl octadecanoate. This compound is naturally found in the human body and fatty products. When dissolved in water, this substance does not provide ions (as a stabilizer), and its solubility in water is due to the presence of parts of the molecule that have an affinity for the solvent (water). GMS is an ester of glycerol that contains stearic fatty acids. In the preparation of analog rice, GMS binds to amylose to form a helical inclusion complex that can prevent starch granules from expanding and reduce development strength and solubility. This is because a water-insoluble layer can form on the surface of the starch granules, which can delay water transport to the granules (Darmanto, 2017; Winarti, 2017). The amount of GMS added to the formula was 0.6%. This amount is in accordance with the patent stating that the amount of binder that can be added is 0.1-10% of the amount of flour and starch. The addition of GMS in the hot extrusion process can reduce the water solubility index and product development but increase the water absorption index, thus affecting the formation and quality of the analog rice produced (Darmanto, 2017; Winarti, 2017).

Organoleptic testing of analog rice and rice was performed based on the parameters of shape, color, aroma, taste, and texture. The extruder die determines the shape of the analog rice and is strongly influenced by the extrusion process owing to the molding stage (Tekpang Unimus, 2021). The analog rice that was successfully made was oval and short, with a panelist-liking score of 3,6 - 3,77 on F5 rice. This indicates that panelists, such as the shape of the analog rice, have been made. Similarly, when the rice has been cooked into rice, it is also known that F5 has the highest favorability

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value of the entire formula. The shape of analog rice is larger than that of uncooked (analog rice) or rice/rice from paddy rice. This is because most of the components of analog rice are starch carbohydrates, resulting in starch gelatinization during the swelling process. Swelling power is the ability of starch to expand when heated to a certain temperature and time. Starch heated with water absorbs water to break down the starch structure so that its viscosity increases. The heating process also binds water molecules to the starch so that the water is absorbed, which causes its size to be larger than that of rice.

Regarding the color parameter, the favorability value was highest at F5, with a bright purple, maroon color. The color is produced from anthocyanins contained in hibiscus, whereas the brightness level of rice is influenced by additional ingredients mixed when making rice. The excessive addition of mocaf flour gives the product a dull color because of the presence of polyphenol enzyme content. However, when rice was cooked, the result became dark purple. In addition, the dark color change was due to the gelatinization of starch during the cooking process.

Aroma is another visual parameter that is important for product acceptance (Unimus 2021). The resulting rice and rice analogs have a sugar-like aroma derived from hibiscus. However, the distinctive aroma was stronger in analog rice than in analog rice. panelists' highest level of fondness for scent also occurred at F5.

An assessment of the taste of analog rice conducted by panelists showed that F5 analog rice was preferred. Analog rice has a slightly sweeter taste than rice derived from rice. The sweet taste caused by hibiscus is still in the safe category if consumed by DM patients because the IG value of the ingredients made is included in the low category. In addition, this has been proven by previous research conducted by Arlita et al. (2020), which proved that analog rice flour made from arrowroot tubers (*M. arundinacea* L.) and hibiscus (*H. rosa-sinensis* L.) can reduce blood glucose levels of DM patients and suppress hyperglycemia conditions caused by DM, and can repair the degree of damage to liver and pancreas organs of DM sufferers.

The organoleptic parameter that was also assessed was the texture. The texture with the highest favorability value was F5. The texture of analog rice includes fineness and brittleness, whereas in analog rice, the assessment is based on fluffiness and stickiness. The fineness and brittleness of analog rice are affected by the molding and drying processes. Analog rice has a fluffy and sticky texture; however, it has a good grain of rice and resembles it in general. However, it can be obtained if the cooking is as recommended, namely, by using water as much as 2/3 part of the volume of analog rice used/cooked. The texture of food can be influenced by water content, fat content, amylose, amylopectin, the amount and type of carbohydrates, and the protein contained in it (Tekpang Unimus, 2021).

The °Hue value in the overall analog rice formula is in the range of 36,455 - 53,293. This shows that the resulting analog rice is in the yellow-red range. The addition of arrowroot tuber flour and yellowish white mocaf resulted in the color of the rice. In addition, the addition of dried hibiscus flowers results in a reddish color, so the combination of the two causes a color spectrum, such as the results of color analysis tests, namely yellow red.

The weight test of one thousand grains of rice can show the weight and size of the rice per grain. A test on the weight of 1000 grains was carried out to determine the uniformity of the rice size (Budijanto, 2018). The test results that have been carried out prove that the weight of one thousand grains of rice analogues F1, F2, and F3 is higher than IR-32 rice, while F4 and F5 are lower than IR-32 rice (24,92 ± 0.04). The difference in the weight of each formula was influenced by the analog rice printing process using an extruder. The weight of rice has synergistic similarities with the shape and size of rice, as well as the speed of the screw and cutter; thus, the weight of large rice with the shape and size of large rice will result from the addition of the speed of the screw and cutter (Budijanto, 2018).

Bulk Density is the amount of product mass per unit volume and is used to determine the volume and porosity of a product. Bulk Density is inversely proportional to volume; therefore, if the bulk density is greater, the volume is smaller (Budijanto, 2018). High porosity is influenced by nutritional content and manufacturing/drying processes. Drying can cause analog rice to lose water and the analog rice matrix to become more shaft. High porosity facilitates the transfer of water and heat during cooking, resulting in soft rice texture.

The digestibility of starch provides an indirect representation of the ease of starch hydrolysis by human digestive enzymes. The analysis of starch digestibility is one of the parameters used to determine the effect of starch modification. Starch is hydrolyzed into simpler molecules using α-amylase. The result of the enzymatic reaction was maltose, which is a disaccharide molecule (Faridah, 2014; Noviasari, 2015; Darmanto, 2017; Budijanto, 2018). The decrease in digestibility of starch

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indicates a low concentration of maltose in the sample, making it more difficult for starch to be hydrolyzed by α-amylase.

The digestibility of starch in the whole formula was lower than that of natural arrowroot starch (84,35%). Starch has a hydrogen group that can form complex starch-polyphenol bonds. These bonds can inhibit hydrolysis by α-amylase enzymes because polyphenol bonds inhibit them; thus, starch is more resistant to digestibility and can reduce its digestibility value. Polyphenols can inhibit the activity of digestive enzymes, particularly trypsin and amylase, which can reduce starch digestibility. The enzyme α-amylase is involved in the breakdown of starch into disaccharides and oligosaccharides, and α-glucosidase in the intestine catalyzes the breakdown of disaccharides to free glucose, which is then absorbed into the blood circulation. Inhibition of this enzyme slows down the breakdown of starch in the gastrointestinal tract, thereby reducing hyperglycemia (Faridah, 2014; Noviasari, 2015).

The amylose content of starch is also thought to correlate with the digestibility of starch. Amylose is a glucose polymer with an unbranched structure that can easily bond to each other to form a compact structure through hydrogen bonds. This structure makes amylose more difficult to hydrolyze by digestive enzymes, resulting in lower starch digestibility. This can cause the glucose levels in the blood to not increase drastically shortly after food is digested and metabolized by the body (Faridah, 2014; Noviasari, 2015; Darmanto, 2017; Budijanto, 2018). The inhibition of carbohydrate digestion may be correlated with the addition of anthocyanins. Anthocyanins can delay the hydrolysis of starch so that the structure of starch becomes complex and changes in enzyme susceptibility will occur. This shows that the addition of hibiscus, which contains anthocyanins, can be one of the factors affecting the decrease in the digestibility value of starch (Noviasari, 2015; Darmanto, 2017).

## CONCLUSION

The optimal and most preferred formulation for analog rice combines arrowroot tubers (*M. arundinacea* L.) and hibiscus (*H. rosa-sinensis* L.), as shown in Formula 5 (F5).

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## AUTHOR CONTRIBUTIONS

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## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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