Chemical and sensory properties of analogue rice based on kimpul flour (Xanthosoma sagitifolium)

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Abstract. Analog rice is artificial rice shaped like rice grains made from non-rice carbohydrate-rich flour with water, which can overcome food security in Indonesia. Taro kimpul is a local food rich in carbohydrates that cannot be widely used. Therefore, kimpul thread has the potential to be used as raw material in the manufacture of analog rice. This study aimed to determine the chemical characteristics of kimpul taro analog rice with dyes and binders. In addition, it is expected to increase consumer acceptance based on sensory testing. This research method uses an experimental laboratory method by making analog rice with 4 formulations. The analysis was water content, ash content, protein content, fat content, carbohydrate content, and sensory (hedonic) analysis, including colour, taste, texture, and overall aroma. The results showed that analog rice A was the best formula selected using the Bayes method based on the results of chemical and hedonic tests. Chemical and sensory characteristics of analog rice A with the use of 4% CMC and 32% beet are as follows: moisture 2.88%; ash 2.3%; fat 1.1%; 5.7% protein; carbohydrate 87.94% and a preference value with an average range of neutral-good.

1. Introduction

Analog rice is artificial rice shaped like rice grains made from non-rice carbohydrate-rich flour with water [1,2]. Analog rice can be a food diversification product with nutritional value that is not inferior to rice. Several previous studies related to analog rice are high protein analog rice made from a mixture of red beans, green beans, soybeans, corn, sesame, and barley with protein content ranging from 18.19-19.09% [3,4]; low glycemic index analog rice made from white corn and soybeans with a GI value of 50 [1,5]; Anticholesterol analog rice made from sago flour with the addition of red beans which is proven to reduce total blood cholesterol in rats[6].

Taro is one of Indonesia's local plants with a high carbohydrate content of 85% [7]. Taro is a food plant that can grow almost in all regions in Indonesia, including Aceh. The increased productivity of taro in Indonesia, reaching 9.52 tons/hectare[8], is expected to maintain food security in Indonesia. Taro kimpul is one of the varieties of taro with low sugar and fat content. It is suitable for diabetics, heart disease, and osteoporosis; besides that, taro contains low calories, 145 Cal/100 grams [9]. The above shows that taro kimpul can be developed into analog rice with the best characteristics. In addition to carbohydrate raw materials, analog rice can be added with dyes and binders in the manufacturing process to increase consumer acceptance.
The dyes that can be used are beets and dragon fruit skin. Beets and dragon fruit peels contain anthocyanin pigments, 23-77 mg/100 grams [10] and 12.4 mg/100 grams [11] Respectively. Utilization of dragon fruit peel and beets has been done. According to Munawaroh [12], the addition of beets by 32% to the donuts was favored by the panelist in terms of taste, aroma, texture, and taste, and according to [7] wet noodles with the addition of 38% dragon fruit skin were the most preferred wet noodles by the panelist. The binder/thickener used is CMC which functions to bind water and helps get the right thickness [13]. Besides CMC, carrageenan can also be used as a binder or thickener. Carrageenan can increase elasticity because it can interact with macromolecules to form a gel [14]. In addition, the addition of carrageenan in the manufacture of analog rice is still rarely done. Based on the pre-study, the best concentrations of CMC and carrageenan in the manufacture of analog rice were 4% and 2%, respectively.

In this study, a combination of the use of dyes and binders was carried out. The dyes used consisted of 32% beet and 38% dragon fruit skin. The binder used consisted of 4% CMC and 2% carrageenan. This study aimed to determine the chemical characteristics of taro analog rice with dyes and binders. In addition, it is expected to increase consumer acceptance based on sensory testing.

2. Materials and methods

The material used in this study is Sarisa kimpul flour from Yogyakarta, beet and dragon fruit peels from Banda Aceh, Kopoe-kopoe CMC, Indogum carrageenan, sago starch, and Gliseril Monostearate (GMS). The chemicals used for the analysis were obtained from the Laboratory of Food and Agricultural Product Analysis, Department of Agricultural Product Technology, Universitas Syiah Kuala. The chemicals used for the analysis were Hexane, H$_2$SO$_4$, Kjehldahl tablet, 0.02 N HCl, 3.25% NaOH and boric acid.

The equipment needed in this research includes drying oven, beaker glass, pan, stove, analytical scale, stainless steel knife, volume pipette, tissue, label, baking sheet, filter paper, furnace, porcelain cup, petri dish, electric furnace, Erlenmeyer, desiccator, stative, stirrer, boiling flask, soxhlet, condenser, sleeve, beaker, and aluminium foil.

2.1. Colouring extract [8]
The dragon fruit peels and beet were washed and then blended with 1:1 addition of water for 5 minutes. Then, it is filtered using a filter cloth to obtain a thick extract.

2.2. Experimental design

This research method uses an experimental laboratory method by making analog rice which consists of four formulations. The raw materials consist of kimpul taro flour and sago starch in a ratio of 70:30. The fixed components are 50% water and 2% GMS [15,16]. The dyes used are 32% beet and 38% dragon fruit peels subtracted from water. The binders are CMC 4% and carrageenan 2% of the total raw materials. The formulations of dyes and binders in analog rice are presented in Table 1.

2.3. Production of analog rice [17]
Taro flour was mixed with sago starch in a ratio (70:30) and then a dye was added according to the concentration of this research treatment. Then, 50% water and 2% GMS were added [18], and a binder was added according to the concentration of this research. GMS and binders (CMC and carrageenan) are first dissolved in hot water and then mixed into the dough, stirring until a smooth dough is formed. The dough was formed using noodle grinding machine number 2 and cut manually with a size of 0.5 cm to resemble rice. It was steamed at 80°C for 10 minutes and was dried using an oven at 60°C for 6 hours.

2.4. Observed parameters

Parameters observed in analog rice were proximate analysis (water, protein, ash, fat, carbohydrates) [19,20], and Hedonic test [21]. The data obtained were analysed descriptively. The best formula was selected based on the Bayes method on the results of chemical and hedonic tests. The criteria used to
choose the best formula in this study include (A) water content, (B) ash content, (C) protein content, (D) fat content, (E) carbohydrate content, (F) colour (G) aroma, (H) texture, (I) taste and (J) overall. The criteria are done subjectively. Score on a scale of 1 to 5 (1=poor and 5=very good). The scoring is based on the results of the analysis of chemical properties and hedonic tests.

**Table 1.** The formulation of dyes and binders in analog rice based on kimpul taro flour.

| Material                  | Analog rice A | Analog rice B | Analog rice C | Analog rice D |
|---------------------------|---------------|---------------|---------------|---------------|
| Beet (%)                  | 32            | 32            | -             | -             |
| Dragon fruit peels (%)    | -             | -             | 38            | 38            |
| Carrageenan (%)           | -             | 2             | -             | 2             |
| CMC (%)                   | 4             | -             | 4             | -             |

3. Results and discussion

3.1. Proximate analysis

The raw materials in analog rice can affect the proximate composition of the analog rice produced. The proximate analysis of analog rice is shown in Table 2. The proximate composition of analog rice consists of moisture (1.25-2.88%), ash (2-2.37%), fat (1.1-1.3%) protein (5.41-6.11%) and carbohydrates (87.94-89.69%).

**Table 2.** Proximate composition of analog rice.

| Analog rice  | Moisture | Ash | Fat  | Crude protein | Carbohydrate |
|--------------|----------|-----|------|---------------|--------------|
| Analog rice A| 2.88     | 2.37| 1.1  | 5.7           | 87.94        |
| Analog rice B| 2.63     | 2.00| 1.3  | 6.11          | 87.96        |
| Analog rice C| 1.38     | 2.12| 1.3  | 5.61          | 89.69        |
| Analog rice D| 1.25     | 2.12| 1.25 | 5.41          | 89.96        |

3.1.1. Moisture content. Water content of taro analog rice ranged from 1.25%-2.88%, with an average of 2.03%. The analog rice obtained must have a moisture content of less than 15% to have a long enough shelf life [1,22]. The water content that is too high has the potential for the emergence of Aspergillus ochraceus mold. The fungus Aspergillus ochraceus can grow well at a moisture content above 14% [23]. The water content of analog rice is influenced by the binder used. Analog rice with the addition of CMC has a higher water content than analog rice with carrageenan. According to Yudistira [24], carrageenan can bind more water than CMC so that the free water content contained in the product with the addition of carrageenan decreases. According to Herlina [25], the material's high and low water content is determined mainly by bound water and free water contained in the material. This bound water requires a higher temperature to evaporate when compared to free water, which requires a relatively low temperature to evaporate it. The dye used also affects the water content of the analog rice produced. Dragon fruit peel has a higher water content of 89.6% [26] than beet water content which is 87.4% [27]. However, the water content with the addition of dragon fruit peel is lower than beet, and this is presumably due to the pectin content in dragon fruit peel of 10.79% [28], while beet does not contain pectin. According to Isnanda [29], pectin can bind water so that free water is reduced; this causes the water content produced to decrease. According to SNI Rice (01-6128-2008), rice has a maximum water content of 14%. All treatments met the maximum water content of rice.
3.1.2. Ash content. Analog rice ash content ranged from 2-2.3%, with an average of 2.15%. The ash content in analog rice is influenced by the raw materials used. The addition of beets and dragon fruit peels did not produce different ash content differences in the analog rice produced; this is because the beets and dragon fruit peels contain ash content that is not much different, namely 1.4% [24] and 1.19% [30]. The addition of CMC hydrocolloids also did not affect the ash content of the analog rice produced. CMC was inert [24] and made from cellulose that did not contain minerals, while carrageenan was made from seaweed, which is included in foodstuffs with high enough minerals. The analog rice ash content with the addition of carrageenan is not higher than the addition of CMC. The concentration of carrageenan use is not too high.

3.1.3. Fat content. Fat content of the taro analog rice produced ranged from 1.1-1.3%, with an average of 1.23%. The fat content in analog rice can be influenced by the raw material with the most significant proportion, namely taro flour. The raw material used in the manufacture of analog rice is taro flour, with a fat content of 1.20% [31]. In line with research [32], analog rice made from 55% taro flour, 30% sweet potato flour, and 15% corn starch yields 1.01% fat content. The addition of dyes and binders in analog rice showed that the fat content was not much different. The dye used contains a low-fat content of 0.3%[24] in beet and 0.61%[33] in dragon fruit peel. According to research Munawaroh [12], analog rice made from purple yam with 20% beet flour also has a relatively low-fat content of 0.71%. The addition of CMC and carrageenan did not affect the fat content.

3.1.4. Protein content. High protein content in analog rice will affect blood glucose levels by lowering the glycemic response [34]. In this study, the protein content of taro analog rice ranged from 5.4-6.1%, with an average of 5.71%. The protein content of analog rice in this study can be influenced by the raw material and additional raw materials. Taro has a protein content of 6.8%[31]. According to Srihari [32], analog rice made from 55% taro flour, 30% sweet potato flour, and 15% corn starch produced a protein content of 1.78%. The protein content of analog rice in this study was much higher because the proportion of taro flour used was higher at 70%. The added dye also affects the protein content produced. Analog rice with beet has a higher protein content than analog rice with dragon fruit skin. The beet has a higher protein content of 1.35% [24] than dragon fruit skin which is 0.41-1.45% [30]. The addition of CMC and carrageenan did not affect the protein content produced.

3.1.5. Carbohydrate. Determination of carbohydrates used in this study is by rough calculation or carbohydrate by difference. Carbohydrates have an essential role for the body, namely as the primary energy producer for carrying out activities. In this study, the carbohydrate content in taro analog rice ranged from 87.94-89.96%, with an average of 88.89%. The most significant carbohydrate contributor to analog rice is starch as raw material, so the carbohydrate content produced depends on the starch source raw material used. In this study, taro is the raw material for starch sources used, and taro contains a carbohydrate content of 80%[31]. In addition, this study also uses sago starch as the raw material, which also has a relatively high carbohydrate content of 89.22% [35]. Analog rice with the addition of dragon fruit skin contains higher carbohydrates than analog rice with beets. The dragon fruit peel contains a higher carbohydrate content of 8.1%[30] than the 7.5% carbohydrate content of beet [24]. The carbohydrate content in this research was higher when compared to previous studies [13], which was 73.33%. The research used raw materials in 70% taro flour and 30% rice flour. Rice flour contains fewer carbohydrates when compared to sago starch, which is 78.9%[36].

3.2. Sensory analysis
Rice is the staple food of Indonesian people. The level of consumer acceptance of the analog rice produced was tested by a sensory test using a hedonic test. In this study, the hedonic test uses five scales (poor - very good). The sensory analysis of analog rice is shown in Table 3.
Table 3. Sensory evaluation of analog rice.

| Analog rice | Colour | Taste | Aroma | Texture | Overall |
|-------------|--------|-------|-------|---------|---------|
| Analog rice A | 4      | 3     | 4     | 3       | 3       |
| Analog rice B | 3      | 3     | 3     | 3       | 3       |
| Analog rice C | 3      | 3     | 3     | 3       | 3       |
| Analog rice D | 2      | 2     | 3     | 2       | 3       |

Note: poor (1), not good (2), neutral (3), good (4), and very good (5).

3.2.1. Colour. Colour is a fundamental food quality attribute because colour has an attraction that can affect consumer acceptance of the food [37]. In this research, the assessment for analog rice colour attributes ranged from 2 (not good) - 4 (good). Analog rice colour A has the highest value of 4 (good), while analog rice colours B and C have values of 3 (neutral) and 3.1 (neutral), and analog rice D has the smallest value. i.e., 2 (not good). This difference in panelist preferences was due to the effect of adding dye; analog rice A uses the addition of beet, which has high anthocyanin and betacyanin pigments, namely 23-77 mg/100g [10] and 430 mg/L [38] compared to fruit peels. Dragons with lower colour pigments, namely anthocyanin 12.4 mg/100gram [11] and betacyanin 5,301 mg/L [39]. In addition to dyes, binders also affect the panelist’ preference for colour. The use of carrageenan in analog D rice resulted in the lowest preference value of 2 (not good). According to Harijono[40], a high concentration of carrageenan will produce a solid product, but the colour intensity will decrease. According to research [24], jelly candy with 2% carrageenan makes a jelly candy value with an unfavorable colour level with a value of 2.00. The use of CMC does not affect the colour because it is a stabilizer[24].

3.2.2. Taste. Taste is one of the factors that can affect consumer acceptance of the resulting product[41]. In this study, the level of consumer preference for the taste of analog rice ranged from 2 (not good) - 3 (Neutral). Based on Table 3, analog rice A, B and C have the same preference value of the panelist, neutral, while analog rice D produces a “not good” result. The use of carrageenan can affect the panelist preference value. Carrageenan has a higher viscosity level than CMC [24] the higher the product viscosity, the lower the product's taste [42] In addition, the use of dragon fruit skin which has an unpleasant taste, also affects the preferences of the panellist to “not good” the analog rice formulation D.

3.2.3. Aroma. Aroma is a chemical stimulus experienced by a smell that can affect a consumer's level of product acceptance. In this study, the level of consumer preference for the aroma of analog rice ranged from 3 (neutral) to 4 (good). The aroma of analog rice A has the highest preference value, which is like compared to analog rice B, C, and D with neutral values. The combination of CMC and beets has a lower viscosity than carrageenan so that the aroma can be detected well in the panelist sense of smell (Basito et al., 2018). The beet and dragon fruit peel has an unpleasant aroma, but the concentration of the use of beet is less than that of the dragon fruit skin, so the panelist prefers analog A rice with a combination of beet and beet CMC. Panelist can still accept analog rice B, C, and D with a neutral value.

3.2.4. Texture. Texture is one of the critical food quality parameters for accepting analog rice, including the rice's elasticity and stickiness[18]. In this study, the level of consumer preference for the texture of analog rice ranged from 2 (not good) - 3 (neutral). Based on Table 3, the texture of analog rice A, B, and C was favoured by the panelist with a neutral value. Still, the panellists did not like the analog rice D. The difference in the binder used in analog rice is thought to affect the preference for texture attributes. In analog D rice, carrageenan is used as a binder. According to Basito[24], carrageenan has a rougher texture when in the mouth because carrageenan has a rough texture when dissolved in water. At the same time, CMC can bind water, dissolve quickly and maintain a smooth texture. That’s why the use of CMC is preferred in analog rice. In addition to the influence of the binder, the colouring agent also affects the resulting texture. Analog rice with the use of dragon fruit peel has a smaller value than
analog rice using beet. This difference in texture value is caused by the dragon fruit peel, which has pectin of 10.79% [43] causing the analog rice texture to become harder. According to Kusuma [36], the increase in pectin can increase the viscosity; the higher the viscosity, the harder the texture.

3.2.5. Overall. Overall assessment of sensory characteristics was carried out to determine the general acceptance of analog rice. In this study, the overall consumer preference for analog rice ranged from 3 (neutral) to 3 (neutral). The panellists prefer all-analog rice with a neutral value, indicating that the panellist can accept all-analog rice. The use of stabilizers, namely CMC and carrageenan, has the characteristics of being odourless, colourless, odourless, and in solid form to not affect food ingredients [13]. The added colouring matter, namely beet and dragon fruit skin, was also well received by the panellist.

3.3. The best formulation
The decision to select the best formula was taken based on the Bayes method. The first rank chosen is the formula that has the highest alternative value. The decision matrix is shown in Table 4. Criteria: (A) moisture content, (B) ash content, (C) protein content, (D) fat content, (E) carbohydrate content (F) crude fiber, (G) total phenol, (H) anthocyanins, (I) antioxidant activity, (J) calories, (K) colour (L) aroma, (M) texture, (N) taste and (O) overall. The highest total alternative value is ranked 1, which is the best formulation in this study. The best formulation was achieved by analog rice A (4% CMC and 32%).

| Criteria | A | B | C | D | Value |
|----------|---|---|---|---|-------|
| Alternatif value | 7.2 | 5.8 | 5.2 | 5 | | 
| Rangked | 1 | 2 | 3 | 4 | |

Note: (A) moisture content, (B) ash content, (C) protein content, (D) fat content, (E) carbohydrate content, (F) crude fiber, (G) total phenol, (H) anthocyanins, (I) antioxidant activity, (J) calories, (K) colour (L) aroma, (M) texture, (N) taste and (O) overall

4. Conclusions
The use of taro flour with binders (CMC and carrageenan) and colouring agents (dragon fruit peel and beet) in analog rice production can produce analog rice that the panellists as a real favour. Analog rice A with 32% beet and 4% CMC is analog rice with the best chemical and sensory characteristics. Chemical and sensory characteristics of analog A rice are as follows moisture 2.88%; ash 2.3%; fat 1.1%; 5.7% protein; carbohydrate 87.94% and a preference value with an average range of neutral-good.

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