

Chemical and sensory characteristics of analog rice with a low glycemic index based on arrowroot (*Maranta arundinacea* L.) flour, sago (*Metroxylon* spp.) starch, and cowpea (*Vigna unguiculata* L.) flour

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Abstract

Type 2 diabetes is caused by unhealthy lifestyles. Prevention of increased type 2 diabetes can be approached by dietary regulation, which can be implemented by selecting the right amount and type of carbohydrates using the concept of the glycemic index (GI). Foods with a low GI cause a slow digestive process that can optimize blood sugar control. The development of analog rice with a low glycemic index can be an alternative to becoming a functional food for diabetics. This study aimed to determine analog rice's chemical and sensory characteristics with a low glycemic index developed from arrowroot flour, sago starch, and cowpea flour. This study used a completely randomized design with an arrowroot, sago, and cowpea composition comparison factor. There are four variations of the formula: control (70:30:0%), F1 (60:30:10%), F2 (50:30:20%), and F3 (40:30:30%). Based on the results, the analog rice with a higher proportion of cowpeas increased the levels of protein and dietary fiber content. The selected formula of analog rice was F2 with the composition of 50% arrowroot, 30% sago, and 20% cowpea. These F2 formulations had 85.81% carbohydrate, 22.55% amylose, 13.8% dietary fiber, 7.74% protein, and 2.3% fat content. The sensory evaluation had a value of around 4 (neutral) and was still acceptable to consumers. The analog rice F2 has a glycemic index of 54.9, is categorized as low GI food, and can be used as an alternative food product for diabetics.

1. Introduction

Diabetes mellitus (DM) is one of the most common degenerative diseases in Indonesia. According to the Indonesian Ministry of Health (2018), the prevalence of DM has increased from 6.9% in 2013 to 8.5% in 2018. DM is caused by abnormalities in insulin secretion or insulin action, which cause an increase in blood glucose levels, up to normal blood glucose, or called hyperglycemia. DM is classified become two types, DM type one and DM type two. DM type two is the most common type of diabetes that is caused by unhealthy lifestyles such as lack of physical activity and poor diet (Buss *et al.*, 2021). Dietary regulation has positively correlated with the control of blood glucose, which can be implemented by selecting the right amount and type of carbohydrates using the glycemic index (GI) concept. GI is a factor in determining the carbohydrates contained in food (Chiavaroli *et al.*, 2021) and how individual foods are expected to affect blood sugar levels.

Consuming foods with low GI can optimize blood sugar control (Soong *et al.*, 2015), caused by a slow digestive process.

An alternative product that can be developed is analog rice with a low glycemic index. Analog rice is artificial rice made from non-rice ingredients such as tubers and nuts. Rice is the staple food of the Indonesian people, and rice generally has a high GI value. White rice has a GI of 80 (Marsono, 2001). A high GI value is unsuitable for diabetics. Utilization of local carbohydrate sources can be used to develop analog rice and as an effort to diversify food. Arrowroot tubers are one of Indonesia's local tubers that can be used as a source of carbohydrates (Astuti *et al.*, 2018). Arrowroot tubers have a GI value of 14, categorized as a low GI, compared to taro, yam, edible canna, or sweet potato tubers (Marsono, 2002). Arrowroot flour has a high dietary fiber and amylose content but is low in protein, fat, and ash (Nogueira *et al.*, 2018). The raw materials

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for analog rice can be used in a mixture of flour and starch. Starch was used to be a textural modifier in food formulation (Adebooye and Singh, 2008) to obtain sturdy rice grains. One type of starch that can be used is sago starch, used as an adhesive that has 42.05% amylopectin content (Wahjuningsih *et al.*, 2020).

Arrowroot flour and sago starch, as a source of carbohydrates in the production of analog rice have a low protein content of 0.6% for arrowroot flour (Aprianita *et al.*, 2014) and 0.54% for sago starch, while the protein content in white rice is 7.39% (Putri and Sumardiono, 2020). To reach the same protein content as white rice, adding a protein source to the analog rice is necessary. The source of this protein can be obtained from nuts. Cowpea has a high protein content and functional properties that can be widely applied (Shevkani *et al.*, 2015). Cowpea contains 18-25% protein (Pratap and Gupta, 2021) and essential amino acids, such as lysine, histidine, and aromatic amino acids (Adjei-Fremah, 2019). Cowpea flour contains 24.1% of high protein, 14.1% of dietary fiber (Sreerama *et al.*, 2012), and low GI (46.64) (Oboh and Agu, 2010). This study aimed to determine analog rice's chemical and sensory characteristics with a low glycemic index developed from arrowroot flour, sago starch, and cowpea flour.

2. Materials and methods

2.1 Materials

The materials used for the production of analog rice were arrowroot flour produced by PT Pondasi Inti Sejahtera, Yogyakarta, cowpea obtained from Bantul, Yogyakarta, and sago starch produced by PT. ANJ Agri Papua and Gliserol Mono Stearate (GMS) received from CV Multi Jaya Kimia, Tangerang. The chemicals used were HCl, NaOH, H₂SO₄, boric acid, petroleum ether, buffer phosphate, α -amylase, pepsin, and pancreatin by Sigma-Aldrich, Co. (USA). The tools include an extruder (Koss 12038A2H6L, China), spectrophotometer UV-VIS, cabinet dryer, glucometer (General Life Biotechnologies, Taiwan), and glassware.

2.2 Production of analog rice

Analog rice was made by formulation of the three main ingredient mixtures (arrowroot flour, sago starch, and cowpea flour), with variations in the composition of arrowroot:sago:cowpea, F1 (60:30:10%), F2 (50:30:20%), F2 (40:30:30%), and control without cowpea (70:30:0%). Other ingredients were added in the form of 2% GMS and 30% water of the total weight of the ingredients. Then mixed and steamed for 15 mins at 100°C (Wahjuningsih and Susanti, 2018). The mixture of analog rice was extrusion using an extruder and dried in a cabinet dryer for 6 h at 60°C. Analog rice formulations

are shown in Table 1.

Table 1. Formulation of analog rice.

Formulation	Ratio of arrowroot:sago:cowpea (%)	GMS (%)	Water (%)
Control	70:30:0	2	30
F1	60:30:10	2	30
F2	50:30:20	2	30
F3	40:30:30	2	30

2.3 Chemical analysis

The chemical analysis was proximate (moisture (AOAC Official Method 934.01), ash (AOAC Official Method 942.05), fat (AOAC Official Method 920.39), protein (AOAC Official Method 990.03)) (AOAC INTERNATIONAL, 2000), carbohydrate content was calculated by difference (FAO, 1998), amylose content (Juliano, 1971), and dietary fiber content (Asp *et al.*, 1992) in analog rice.

2.3.1 Moisture content

Moisture content analysis used the gravimetric method (AOAC Official Method 934.01). The sample was weighed 1 g in the cup and dried in an oven at a temperature of 100-105°C until a constant weight was obtained. The sample was cooled in a desiccator and then weighed. The moisture content was determined by calculating the weight of dry and wet samples.

2.3.2 Ash content

Ash content analysis was carried out using the gravimetric method (AOAC Official Method 942.05, 2000). The sample was weighed 1 g in the pre-weighed crucible. The crucible was placed in a muffle furnace at 550-600°C for 5-6 h. The crucible was cooled within a desiccator and then re-weighed. The ash content was determined by calculating the weight of ash with the crucible and the weight of the empty crucible.

2.3.3 Fat content

Fat content analysis was carried out using the Soxhlet method (AOAC Official Method 920.39, 2000). The sample was weighed 2 g. The soxhlet extractor, connected to a round-bottom flask filled 3/4 with petroleum ether at 40-60°C. The sample was subjected to reflux extraction with petroleum ether for 3-4 h. The procedure was distillation until the petroleum ether evaporated. The extracted flask was heated in an oven at 105°C until the weight was constant. The dried sample was cooled in a desiccator and weighed.

2.3.4 Protein content

Protein content analysis used the Kjeldahl method

(AOAC Official Method 990.03, 2000). The Kjeldahl method was employed to determine crude protein, involving wet digestion, distillation, and titration. Protein content analysis used the Kjeldahl method to determine protein from carbon-containing materials and convert nitrogen into ammonia. Ammonia reacted with an acid to form ammonium sulfate, then ammonia was absorbed in a boric acid solution. The HCl titration step determined the amount of nitrogen in the sample using a burette. Multiplying the measured nitrogen content by 6.25 yielded the total protein content.

2.3.5 Carbohydrate content

Carbohydrate content (FAO, 1998) was estimated by different calculations. Carbohydrate was obtained by subtracting the number 100 from the percentage of moisture, ash, fat, and protein content.

2.3.6 Amylose analysis

Amylose content was estimated using the spectrophotometric analysis (Juliano, 1971). Approximately 100 mg of the sample was added to 1 mL of 95% ethanol and 9 mL of 1N NaOH. The solution was heated for 10 min and transferred to a 100 mL measuring flask with distilled water. The sample solution (5 mL) was taken and transferred to a 100 mL measuring flask, followed by adding 1 mL of 1N acetic acid and 2 mL of iodine solution. Then distilled water was added to the calibration mark. After 20 min of incubation at room temperature, the absorbance at 625 nm was analyzed by spectrophotometry, and the amylose content was calculated based on the standard curve.

2.3.7 Dietary fiber analysis

Dietary fiber was estimated using the enzymatic-gravimetric method (Asp *et al.*, 1992). Approximately 1 g of sample was mixed with 25 mL of 0.1 M phosphate buffer (pH 6) and 0.1 mL of α -amylase. The flask was covered with aluminum foil and incubated at 80°C for 15 min. After cooling, 20 mL of distilled water was added and adjusted to pH 1.5 with HCl. The 0.1 g of pepsin was added, and then incubated at 40°C for 60 min. After pH was adjusted to 6.8 with NaOH, 0.1 g of porcine pancreatin was added. The flask was re-incubated at 40°C for 60 min with pH adjusted to 4.5 with HCl. The solution was filtered through a 2-porosity crucible with 0.5 g of celite.

2.4 Sensory analysis

Evaluation of sensory characteristics of the analog rice was performed by 75 untrained panelists. The sensory analysis was tested by a preference test, to determine consumer response and acceptance of a

product with the subjective opinion of panelists. Attributes in the sensory test can be in the form of appearance, aroma, texture, and flavor in food products (Meilgaard *et al.*, 2016). The attributes of analog rice were color, texture, taste, aroma, and overall, with 1-7 scales (1 = dislike very much, 2 = dislike, 3 = dislike slightly, 4 = neutral, 5 = like slightly, 6 = like, 7 = like very much).

2.5 Glycemic index analysis

The glycemic index (GI) analysis on the selected analog rice used the finger-prick capillary blood test method (Jenkins *et al.*, 1981). The glycemic index (GI) analysis involved selecting volunteers with inclusion criteria: normal nutritional status with fasting capillary blood glucose concentrations <100 mg/dL, a body mass index (BMI) of 18.5-22.9 kg/m², and ages between 18 and 30 years. Exclusion criteria included illness, medication use, pregnancy or breastfeeding, smoking, or a history of chronic disease during the intervention (Brouns *et al.*, 2005).

GI determination was carried out using the method reported by Marsono (2002). Volunteers fasted overnight for 10 hours. In the morning, fasting blood glucose levels were measured. Volunteers consumed a standard glucose solution and an analog rice test food on different days. The reference food (glucose) and the test food contained 25 g of available carbohydrates. Capillary blood glucose concentrations were measured 30 min, 60 min, 90 min, and 120 min after consumption. The GI was calculated based on the blood glucose responses to the glucose and analog rice.

The Medical and Health Research Ethics Committee (MHREC), Faculty of Medicine, Universitas Gadjah Mada, has approved the nutritional studies on subjects (KE/FK/1433/EC/2022) dated November 14, 2022. All subjects gave signed informed consent to participate in the study.

2.6 Statistical analysis

The data obtained from the results were analyzed using the analysis of variance (ANOVA) test with a 95% confidence level (SPSS software for Windows 22.0). If there are significantly different results, then a further test was carried out using the Duncan Multiple Range Test (DMRT).

3. Results and discussion

3.1 Chemical properties

The chemical properties identified were moisture, ash, fat, protein, carbohydrates, amylose, and dietary fiber content (Table 2). The ratio of arrowroot, sago, and

Table 2. Chemical properties of analog rice.

Chemical Properties	Control	F1	F2	F3
Moisture (%wb)	6.07±0.58 ^a	6.11±0.41 ^a	6.28±0.49 ^a	6.60±0.40 ^a
Ash (%db)	3.65±0.22 ^c	4.35± 0.29 ^{bc}	4.15±0.09 ^b	3.91±0.20 ^a
Fat (%db)	1.52±0.14 ^a	1.98±0.19 ^b	2.30±0.21 ^c	2.77±0.26 ^d
Protein (%db)	3.76±0.36 ^a	5.54±0.42 ^b	7.74±0.66 ^c	10.55 ±0.74 ^d
Carbohydrate (%db)	90.21±0.42 ^d	88.13±0.56 ^c	85.81±0.65 ^b	82.76±0.71 ^a
Amylose (%db)	25.82±0.95 ^d	24.60±0.21 ^c	22.55±0.49 ^b	20.02±0.48 ^a
Dietary fiber (%db)	10.78±1.02 ^a	13.41±1.01 ^b	13.80±0.81 ^b	15.62±0.26 ^c

Values are presented as mean±SD. Values with different superscripts in the same row are statistically significantly different ($p<0.05$).

cowpea had no significant effect on the moisture content of analog rice. On the contrary, the ash, protein, fat, carbohydrate, amylose, and dietary fiber content were significantly different. The ratio of arrowroot, sago, and cowpea affected the chemical properties of analog rice. The National Standardization Body SNI 6128:2020 governs the maximum moisture content of rice to be 14% (BSN, 2020). The current study revealed that all the analog rice had moisture content below 14%, which was approximately 6.07% to 6.60%. According to Dlamini and Solomon (2016), the moisture content affected the product's shelf life. Analog rice was dried at 60°C for 10 h. It acts to reduce moisture content and inhibit microorganism activity.

The fat and protein content of analog rice had increased significantly ($p<0.05$). The variety of analog rice with the highest fat and protein content was F3 (40% arrowroot, 30% sago, and 30% cowpea), whereas the lowest one was found in control analog rice. The higher the amount of cowpea flour added, the higher the content of fat and protein in analog rice was. It was influenced by the fat and protein content of the cowpea, which was 1.50% and 25.69% (Naiker et al., 2019). Besides, the ash and carbohydrate content of analog rice decreased significantly ($p<0.05$). The ash content was influenced by the addition of arrowroot flour; the mineral content of the arrowroot flour was 4.14% (Wahjuningsih dan Susanti, 2018), whereas an increase in fat and protein content would decrease the carbohydrate content in the analog rice.

The amylose content of analog rice showed significant differences ($p<0.05$) with the arrowroot, sago, and cowpea formulation ratios. The addition of cowpea flour decreases the amylose content. The ratio of amylose and amylopectin indicated the texture, hardness, and adhesiveness levels of analog rice. The amylose content of analog rice with a ratio of arrowroot, sago, and cowpea formulation was approximately 20.02% to 24.60%. Amylose cannot be directly absorbed as glucose and is difficult to digest by the digestive enzymes. The high amylose content in analog rice was associated with

a low glycemic index (Sumardiono et al., 2022). The characteristics of amylose, which had a straight chain and were tightly bound by hydrogen bonds, made amylose relatively difficult to break down. The higher the ratio of amylose and amylopectin in foods, the lower the glycemic response (Meynier et al., 2015).

The dietary fiber content of analog rice had increased significantly ($p<0.05$) with a ratio of arrowroot, sago, and cowpea formulation. The highest dietary fiber content was F3 (15.62%) with a ratio of 40% arrowroot, 30% sago, and 30% cowpea, while the dietary fiber content of F1 and F2 was not significantly different, around 13%. The results of the dietary fiber content were quite high when compared to the dietary fiber content of common rice at 0.80% (Liu et al., 2011). Dietary fiber was part of a food that could not be hydrolyzed by digestive enzymes. Soluble dietary fiber reduces blood glucose response due to an increased viscosity in the stomach and intestines, which causes the digestion and absorption of carbohydrates to decrease (Alvarez and Sanchez, 2006).

3.3 Sensory evaluation

Sensory evaluation is shown in Table 3. The attributes tested were aroma, color, texture, and overall attributes in analog rice. The ratio of arrowroot, sago, and cowpea had no significant effect on the sensory attributes (aroma, color, texture, taste, and overall). This may be due to the appearance of analog rice, which was almost similar between formulations; it cannot be distinguished by the panelists' senses. Values 1 (dislike) to 7 (like very much) indicate the level of preference for analog rice, where the greater the number shows the higher the level of preference for analog rice. All sensory attributes had a value range of 4-5, which indicates a neutral value towards rather like. This shows that the analog rice formula was still acceptable to consumers.

3.4 Glycemic index

Based on the sensory and chemical properties, the samples tested were analog rice with a ratio of 50%

Table 3. Sensory evaluation of analog rice.

Sample	Aroma	Color	Texture	Taste	Overall
Control	4.71±1.30 ^a	4.33±1.35 ^a	4.59±1.47 ^a	4.60±1.16 ^a	4.60±1.36 ^a
F1	4.75±1.40 ^a	4.24±1.30 ^a	4.21±1.39 ^a	4.07±1.33 ^a	4.32±1.29 ^a
F2	4.59±1.32 ^a	4.29±1.28 ^a	4.29±1.34 ^a	4.24±1.17 ^a	4.44±1.13 ^a
F3	4.67±1.32 ^a	4.31±1.40 ^a	4.17±1.42 ^a	4.12±1.40 ^a	4.40±1.17 ^a

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p < 0.05$).

arrowroot, 30% sago, and 20% cowpea and control analog rice (without cowpea). Ten healthy volunteers between 24 and 28 years of age with an average body mass index (BMI) of 20.93 participated in this study. The number of samples given to volunteers was determined based on the total content of available carbohydrates equivalent to 25 g of glucose. Figure 1 showed that increased blood glucose levels after ingestion of pure glucose were higher than the analog rice. The area under the curve of the glucose was 4015.5, whereas the area under the curve of control and F2 analog rice were 2127 and 2203.5. The GI can be calculated based on this data. The glycemic index of the control and F2 analog rice were 53 and 54.9. This glycemic index value was considered a low glycemic index value since the value was below 55.

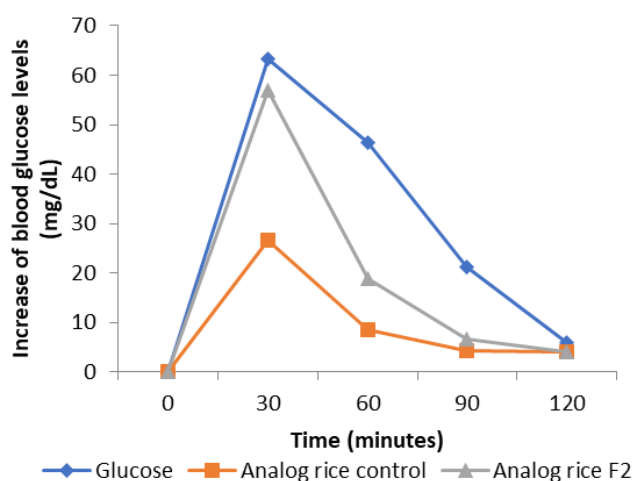


Figure 1. Increase in blood glucose levels.

The glycemic index of analog rice was lower than the glycemic index value of rice. Idril *et al.* (2013) reported on the glycemic index values of brown and white rice, which were 97.28 and 99.26. It shows that the average glycemic index of several rice varieties was above 55. A different result of control analog rice (without cowpea) and the selected analog rice F2 (ratio 50% arrowroot, 30% sago, and 20% cowpea) may be attributed to the lower increase in blood glucose levels at 30 min in the control analog rice. Control analog rice had a higher amylose content of 25.82% than the selected analog rice. The high content of amylose can reduce the glycemic response because amylose has several characteristics that make it relatively difficult for

amylose to be hydrolyzed by digestive enzymes. Amylose is a straight-chain polymer of glucose that has a relatively small number of long-chain branches and moderate molecular weight (Cao *et al.*, 2022). Amylose molecules with short and moderate chains are more susceptible to retrogradation by forming a denser hydrogel matrix, which significantly slows starch digestibility (Gong *et al.*, 2019). In addition, another factor that affects the low glycemic index value of the control analog rice is the proportion of arrowroot which is higher without the addition of cowpea, arrowroot has a glycemic index of 14 (Marsono, 2002) which is lower than the glycemic index of cowpea of 46.64 (Obloh and Agu, 2010), although both are included in the low glycemic index category.

4. Conclusion

The results showed that the ratio of arrowroot and cowpea flour had significant differences ($p < 0.05$) in ash, fat, protein, carbohydrate, amylose, and dietary fiber of analog rice. However, the sensory evaluation was not significantly different; it had a value of around 4 (neutral), which was still acceptable to consumers. The selected analog rice F2 had a low glycemic index value (54.9) and can be used as an alternative food product for diabetics.

Conflict of interest

The authors declare no conflict of interest.

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