Physicochemical Characteristics and Antidiabetic Potential In Vitro of Analog Rice Based on White Greater Yam (*Dioscorea alata*) and Yellow Pumpkin (*Cucurbita maxima*)

Darus Dina Imama, Priyanto Triwitono, Wahyu Dwi Saputra*

Departement of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jl. Flora No. 1, Bulaksumur, Yogyakarta 55281, Indonesia
*Corresponding author: Wahyu Dwi Saputra, Email: wahyu.dwi.s@ugm.ac.id

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ABSTRACT

Type 2 Diabetes Mellitus (T2DM) is a metabolic disease characterized by the presence of increased blood sugar due to insulin resistance and β-cell dysfunction maintaining the body homeostasis by lowering blood sugar levels. People with T2DM are advised to avoid consuming foods that can trigger an increase in blood sugar levels. However, daily consumption of Indonesians still depends on ordinary rice, which has a high glycemic index and can increase blood sugar levels. This shows the need to produce substitute such as analog rice, which is safe to consume by people with T2DM. Analog rice is artificial product that uses raw materials from grains or tubers. Therefore, this research aimed to produce high-antioxidant analog rice by using white greater yam and yellow pumpkin as the main ingredients. The results showed that increasing the concentration of yellow pumpkin caused a rise in physical properties such as water absorption and b value, which was the yellow color appearing in analog rice. Chemical properties such as water content, ash, and protein were increasing but starch, carbohydrates, amylose, and amylopectin levels decreased. Total phenolics, DPPH, and ABTS antioxidants, the percentage of inhibition activity of α-amylase enzyme, and descriptive sensory tests including appearance, aroma, texture, and flavor also showed an increase. The best formula was obtained in P1 treatment comprising 85% white greater yam and 15% yellow pumpkin. Specifically, P1 showed % α-amylase inhibition activity of 42%, DPPH antioxidant activity 82.39%, ABTS 86.47%, and a favorability test value of 4. This value was considered neutral, showing the potential to be well-received by panelists.

Keywords: Analog rice, antioxidant, pumpkin, white greater yam

INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a disease that occurs when sugar levels in the blood are excessively high. The causative factor of this disease is a combination of genetics and lifestyle, such as obesity, consumption of foods with high sugar content, stress, and a lack of exercise (Ozougwu, 2013). The prevalence of people with T2DM in Indonesia is known to increase every year. Therefore, people with T2DM are recommended to avoid eating foods that trigger an increase in blood sugar. Indonesian people fulfill their energy needs mostly by consuming rice due to the high caloric value of not less than 100 kcal per portion. However, rice has a high glycemic index (IG) of 73, which can trigger a rise in blood sugar and increase the risk of T2DM. Foods with a high glycemic index have a rapid digestion process, leading to a faster emptying rate in the stomach. This causes food suspension to reach the small intestine and glucose absorption to occur faster, leading to high

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fluctuations in blood glucose levels (Arif & Budiyanto, 2013). To address the challenge, producing analog rice using raw materials such as grains or tubers is an effective substitute safe to consume by people with T2DM. The purpose of making analog rice is to allow cooking and consumption, along with improved nutritional content. Common ingredients used in making analog rice include corn, cassava, wheat flour, tapioca flour, and other carbohydrate sources (Damat et al., 2020). White greater yam *(Dioscorea alata)* can be made in analog rice because of its carbohydrate content. Greater yam has a low sugar content which is approximately 2.53% of its dry weight, consisting of 1.66% sucrose, 0.36% glucose, and 0.51% fructose. It also has 6% soluble fiber (Kulaitien et al., 2014), which is very beneficial for digestion (Lebot et al., 2023). White greater yam has a low Glycemic Index (IG) value of 22.4 (Sari et al., 2013). However, making analog rice using white greater yam raw materials produces sensory properties not equivalent to ordinary rice. This shows the need for combination with other ingredients to increase the nutritional value and sensory value (Wuryantoro, 2020).

The design of analog rice formulas can be high in antioxidants to reduce free radical reactivity and prevent degenerative diseases, particularly T2DM (Noviasari et al., 2022). An agricultural food that contains high levels of antioxidants is yellow pumpkin, comprising carotenoids and polyphenolic compounds. Yellow pumpkin flour is also known to influence the sensory attributes of analog rice flavor, which is sweet, as well as the flavor of ordinary rice. In terms of appearance, yellow pumpkin is also able to improve the color of analog rice more attractive due to the presence of natural β-carotene dyes. The extract is known to reduce blood sugar levels in diabetic model rats due to phenolic compounds that can inhibit the activity of α-amylase enzyme and antioxidants lowering insulin resistance and repairing β cells (Fathonah et al., 2014). This makes yellow pumpkin and white greater yam a good combination for making high-antioxidant analog rice for people with T2DM because of low glycemic index. The price of both materials is very cheap and the nutritional content is suitable to be combined and processed into analog rice. Therefore, this research aimed to analyze the physicochemical characteristics and antidiabetic potential of analog rice of white greater yam and yellow pumpkin.

METHODS

Materials

The materials used were white greater yam, yellow pumpkin collected from local market in Tuban-East Java, mung bean flour (Mama Kamoe Yogyakarta), Glycerol Monostearate (GMS) (CV Multi Jaya Kimia, Indonesia), NaOH 0.1 N (Merck, Germany), aquades, diphenyl-2-picrylhydrazil (DPPH) (Sigma-Aldrich, USA), Folin Ciocalteu reagents (Sigma-Aldrich, USA), and Na-metabisulfite (PT. Metabisulphite Nusantara, Indonesia). Other included 0.1 N HCl solution (Merck, Germany), Na_2CO_3 (Merck, Germany), petroleum ether (Merck, Germany), acetic acid (Merck, Germany), Nelson solution, arsenomolybdate reagent, phosphate buffer, α-amylase (Sigma-Aldrich, USA), 2,2- azinobis-3-Ethylbenzothiazoline-6-Sulfonic Acid (ABTS) (Sigma-Aldrich, USA), palm oil (Fortune), Carboximethyl Celullase (CMC) (Koepoe-koepoe, Indonesia), amylum (Merck, Germany), amylose (Sigma-Aldrich, USA), and anhydrous glucose (Merck, Germany).

Flour Making Process

White greater yam and yellow pumpkin were sorted, peeled, washed, and sliced using a slicer (Fujimak HS-17, Japan) with a thickness between 1-2 mm. Both materials were soaked with 0.3% Na-metabisulfite for 20 minutes to dissolve mucus and prevent browning reactions, maintaining the color. Subsequently, the materials were washed and dried in cabinet dryer (CV. Raja Pengering, Sidoarjo) for 5 hours with a temperature setting of 60°C. After obtaining pieces of dried white greater yam and yellow pumpkin, grinding was carried out using a grinder (Getra IC-04 A, China) and sifted with a 100-mesh sieve (Afidin et al., 2014).

Analog Rice-Making Process

The process of making analog rice included raw material preparation, weighing ingredients, and mixing dry ingredients for 5 minutes with the addition of GMS. This was followed by adding water slowly, mixing for 5 minutes, and steaming for 15 minutes at 100°C. The mixture was extruded using a single-threaded extruder machine (Koss 12038A2H6L, China), which would produce molds resembling rice grains. Extrudate was dried at 70°C for 3 hours in a cabinet dryer. Analog rice products were packed in plastic packaging and stored for further testing.

Analysis

In this research, physical analysis was carried out including rice color and analog rice using Chromameter (Konica Minolta). Texture analysis used texture analyzer (Universal Testing Machine model Z0.5, Zwick/Roell AG, Germany) and water absorption analysis. Proximate analysis included water content, ash (gravimetry), fat (Soxhlet Method), protein (Kjedahl Method), and carbohydrate (by difference). The chemical analysis

Table 1. Analog rice formula

Formula	The ratio of white greater yam and yellow pumpkin (%)	Water* (%)	Mung bean flour* (%)	GMS* (%)	CMC* (%)	Palm oil* (%)
P0 (Control)	100:0	30	7	2	1.5	5
P1	85:15	30	6	2	1.5	5
P2	75:25	30	6	2	1.5	5
P3	65:35	30	6	2	1.5	5

Note: *(% of total weight of flour). The addition of green bean flour in the control treatment was higher because pumpkin flour contains ±1% protein.

included levels of amylose, amylopectin, starch, the antioxidant activity of DPPH and ABTS (Hong & Betti, 2016), total phenolics, and inhibition activity of α-amylase activity (Aalim et al., 2019). The sensory test consisted of a descriptive test and a hedonic or favorability test including 70 untrained panelists who provided ratings on a scale of 1-7. The determination of the best formula for analog rice followed the procedures by DeGarmo et al., (1984).

Amylose, Amylopectin, and Starch

The analysis of amylose started with 100 mg sample, which was put into a test tube, followed by adding 1 mL of 95% ethanol and 9 mL of 1 N NaOH. The solution was heated for 10 minutes, and added with distilled water until indicated. A total of 5 mL sample solution was collected, added with 1 mL of 1 N acetic acid, and 2 mL iodine solution. Subsequently, distilled water was added to the indicated line. After 20 min of incubation at room temperature, the absorbance at 625 nm was analyzed by UV-Vis spectrophotometry (Shimidzu UV-1280, Japan), and amylose content was calculated based on a standard curve equation obtained, y=0.3635x + 0,0475. Amylose, Amylopectin, and Starch was calculated using equation 1,2, and 3.

$$\text{Amylose content (wb\%)} = \frac{x\left(\frac{mg}{ml}\right) \text{ x sample volume x dilution ratio}}{\text{sample initial weight (g)}} \quad (1)$$

$$\text{Amylopectin content (wb\%)} = \text{starch content} - \text{amylose content} \quad (2)$$

The analysis of starch started by weighing a 2.5 g sample (flour) and putting in an erlenmeyer flask, which was added with distilled water to 250 mL and shaken. Approximately 20 mL of 30% HCl was added and the sample was heated with reverse cooling for 2.5 hours and cooled. After cooling, it was neutralized with 40% NaOH solution and diluted to a volume of 500 mL, filtered with filter paper. Starch solution was diluted with a dilution factor of 100, another 1 mL solution was taken, added with 1 mL Nelson-Somogy reagent, heated in boiling water for 20 minutes, and cooled. After cooling, 1 mL distilled water and 1 mL arsenomolybdate were added, vortexed, and analyzed by UV-Vis spectrophotometry (Shimadzu UV-1280, Japan) absorbed at a wavelength of 540 nm. Amylose content was calculated based on a standard curve equation of y=1,387x + 0,0631.

$$\text{Starch content (wb\%)} = \frac{x\left(\frac{mg}{ml}\right) \text{ x sample volume x dilution ratio}}{\text{sample initial weight (g)}} \text{ x } 0{,}9 \text{ x } 100 \quad (3)$$

Total Phenolics

The sample extract was obtained using the maceration method, where 1 g sample was dissolved in 80% ethanol and shaken in waterbath shaker at 37°C for 15 minutes. Ethanol extract of analog rice of each treatment was taken at 0.5 mL and placed into a test tube. The sample was added with 2.5 mL Folin reagent and 2.5 mL of 7.5% Na_2CO_3 incubated in a dark room for 30 minutes. UV-Vis spectrophotometry was used to measure absorbance with a wavelength of 765 nm. The readable absorbance value was calculated in the gallic acid standard curve equation using y= 0.1237x + 0.3528. Total Phenolics was calculated using equation 4.

$$\text{Total Phenolics} = \frac{x\left(\frac{mg}{ml}\right) \text{ x sample volume x dilution ratio}}{\text{sample initial weight (g)}} \quad (4)$$

DPPH Antioxidant

Each analog rice extract consisting of 0.2 mL was poured into a test tube and added with 2 mL of 1,1-diphenyl-2-picrylhydrazil solution 2mM (DPPH). The blank solution was made by using DPPH solution pipetted at 2 mL, followed by insertion into a test tube, and added with 0.2 mL ethanol. DPPH absorbance was measured with UV-Vis spectrophotometer at a wavelength of 517 nm, after incubating in a lightless chamber for 30 minutes. Antioxidant ability was measured as a decrease in DPPH solution uptake due to sample addition. The absorption value of DPPH solution before and after the addition of the extract was calculated as percent of antioxidant activity using equation 5.

$$\%\ \text{Antioxidant activity} = (1- \frac{\text{Sample Absorbance}}{\text{Blank Absorbance}}\ \text{x}\ 100\%) \quad (5)$$

ABTS Antioxidant

A stock solution of ABTS of 7 mM and 2.4 mmol/L potassium persulfate was allowed to stand in a dark room for 16 hours at room temperature. The solution was diluted with aquades until an absorbance of 0.7 ± 0.02 was obtained at 734 nm. Approximately 100 µL extract was mixed with 3 mL aqueous ABTS solution and incubated for 3 min at room temperature. The control solution was prepared using an extract solvent rather than the sample. Absorbance was measured at 734 nm and the antioxidant activity of ABTS was calculated using equation 6.

$$\%\ \text{Antioxidant activity} = (1- \frac{\text{Sample Absorbance}}{\text{Blank Absorbance}}\ \text{x}\ 100\%) \quad (6)$$

α-Amylase Inhibition Activity

Sample testing started with 1 mL analog rice water extract of each treatment, which was put into a test tube. This was followed by adding 1 mL starch solution, 1 mL α-amylase solution in phosphate buffer pH 6.9 (0.1 mg/mL), and incubated at 37°C for 20 minutes. The reaction was stopped by adding 1 mL HCl 1 N, followed by 0.1 mL iodine-iodide indicator, and the absorbance was measured at 636 nm. The blank and acarbose testing steps are the same as sample testing. However, sample extract was replaced with aquades of 1 mL, and acarbose test was conducted by taking 1 mL acarbose solution. The percentage of inhibition activity was calculated using equation 7.

$$\%\ \text{inhibition activity} = (1- \frac{\text{Sample Absorbance}}{\text{Blank Absorbance}}\ \text{x}\ 100\%) \quad (7)$$

Sensory Analysis

Sensory analysis or organoleptic evaluation included using human senses to rate the texture, appearance, aroma, and taste of food products. This analysis was carried out using a hedonic and a descriptive test (scoring acceptance test) to determine the response and acceptability of consumers towards a product through the subjective perceptions of panelists (Kartika et al.,1998). Sensory analysis used 70 untrained panelists, who were asked to provide ratings based on liking and intensity towards attributes of color, texture, taste, aroma, and overall analog rice served with values on a numerical scale (1-7).

Determination the Best Formula of Analog Rice

The best formula was determined using the effectiveness index method according to the procedure by DeGarmo et al, (1984). First, parameters were selected based on their ability to influence the quality of analog rice. A total of 15 parameters were selected and scored, where higher values suggested greater influence on analog rice quality. The hedonic test parameters were put in first because it was related to panelists acceptance. Each parameter is rated 0-1 (Normal Parameter Index) and Effectiveness Index (EI) is calculated using equation 8.

$$\text{Effectiveness Index (EI)} = \frac{\text{Total Treatment Value-Lowest Value}}{\text{Higher Value-Lowest Valiue}} \quad (8)$$

The parameters are divided into two groups, namely positive and negative. Total Value was calculated using equation 9.

$$\text{Total Value} = \text{EI x Total Treatment Value} \quad (9)$$

The results of all parameters for each treatment were accumulated and the best formula was shown by the highest Total Value.

Statistical Analysis

A Completely Randomized Design was used in this research with a variation factor in the ratio of white greater yam and yellow pumpkin flour (100:0 as control, 85:15, 75:25, and 65:35). The data obtained from the test results were analyzed using Analysis of Variance (ANOVA) test with a significance level of 95% (SPSS Software for windows 25.0). When there is an influence, further tests are carried out using the Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Physical Attributes of Analog Rice

The higher ratio of yellow pumpkin flour correlates with the increase in the percentage of water absorption. This is not in accordance with the previous research by Sari et al. (2022), where the water absorption capacity of instant porridge decreases when the ratio of yellow pumpkin is higher. The variation is because yellow pumpkin has a higher water content that inhibits water from filling cavities in starch granules. The difference in the results of this research is because the binding power of water is influenced by several factors, such as crude fiber content contained in the raw materials. Water that is strongly bound in food fiber is relatively

Table 2. Physical attributes of analog rice

Physical attributes	The ratio of white greater yam and yellow pumpkin (%)			
	100:0 (P0)	85:15 (P1)	75:25 (P2)	65:35 (P3)
Water absorption (%db)	254.04±8.91[a]	293.19±6.70[b]	289.85±10.40[b]	300.16±1.15[b]
Analog rice color (before cooked)				
L*	70.75±0.15[b]	66.15±1.11[ab]	62.89±2.65[a]	64.84±4.00[a]
a*	1.94±0.11[ab]	2.34±0.24[b]	1.79±0.10[a]	1.88±0.47[ab]
b*	18.73±0.09[a]	25.91±0.27[b]	24.93±1.02[b]	25.84±1.93[b]
Analog rice color (after cooked)				
L*	45.72±0.01[d]	43.13±0.02[c]	38.61±0.01[a]	38.91±0.01[b]
a*	4.21±0.01[a]	6.41±0.01[b]	6.66±0.01[d]	6.50±0.01[c]
b*	6.11±0.01[a]	12.66±0.01[d]	12.14±0.01[c]	11.45±0.01[b]
Hardness (N)	15.93±2.01[a]	32.58±3.15[b]	41.64±0.01[c]	17.56±0.96[a]
Cohesiveness	0.48±0.01[a]	0.56±0.01[b]	0.76±0.01[d]	0.64±0.01[c]
Adhesiveness	0.66±0.01[c]	1.34±0.01[d]	0.10±0.01[a]	0.53±0.01[b]

Note: This research used three times replication. Data are presented as mean ± SD (n=12). Different letters in the same row show significant differences ($p \leq 0.05$)

difficult to re-evaporate, through a high-temperature drying process. The fiber content in greater yam is 6% (Kulaitien et al., 2014). The increase in water binding power can also be caused by free hydroxyl groups due to the breakage of hydrogen bonds during gelatinization (Abiodun Oa, 2014). Water will bind to the hydroxyl groups of amylose and amylopectin molecules on the surface of the granules (Wariyah et al., 2007).

L value in the control analog rice showed the highest compared to other treatments. An increase in the value of b or yellow color caused a decrease in L value or brightness. The value of color b produced in both analog rice before and after cooking was high along with the increase in the concentration ratio of yellow flour. Similarly, Saeroji, et al. (2023) stated that instant porridge with variations in the addition of yellow pumpkin would be marked by an increased b value. The color that appears more yellow is due to the presence of carotenoid antioxidant compounds, namely β-carotene, which also acts as a yellow pigment in pumpkin. L value in the control analog rice after cooked showed the highest value compared to other treatments and decreased along with a higher ratio of yellow pumpkin. However, at the *a value, the reddish color of analog rice is higher than in analog rice before cooking. This was in line with research by Saeroji et al. (2023), where the degree of reddish color was higher when followed by the ratio of adding yellow pumpkin in making instant porridge. The visible color, namely redness and brownish found in analog rice, is caused by the high-temperature cooking process, causing β-carotene to experience a browning process or Maillard reaction (Saeroji et al., 2023).

Hardness, cohesiveness, and adhesiveness values, are important in determining the quality of analog rice. This is related to the texture and panelists' acceptance when consuming analog rice. Hardness value is the force required to press the sample, which is affected by the binding power of water. Moreover, hardness value is correlated with a lower percentage of water binding. The more amylose is dispersed, the higher the chance of the retrogradation process, affecting the improvement of hardness texture (Monica et al., 2018). These results vary from the literature because the type of carbohydrate in yellow pumpkin is not amylose. Therefore, the retrogradation process is low due to reduced amylose and amylopectin content in yellow pumpkin (Wahidin, 2018). Cohesiveness is the ability of a product to accept pressure when held together in the mouth. Cohesiveness result is statically different ranging from 0.48 to 0.76, with a higher value representing a firmer texture. The increase in cohesiveness value was shown in P1 and P2 analog rice, which decreased in P3. Adhesiveness is the degree to which the sample can stick to the mouth. Based on the results, there was an increase in adhesiveness value of P1 analog rice, which decreased in P2 and rose in P3. However, Rachma Sari & Siqhny (2022) reported that low amylose content in yellow pumpkin caused the binding power between molecules to be weak, leading to loss of material density. slow retrogradation process, and

Table 3. Chemical attributes of analog rice

Chemical attributes	The ratio of white greater yam and yellow pumpkin (%)			
	100:0 (P0)	85:15 (P1)	75:25 (P2)	65:35 (P3)
Moisture (%wb)	3.91±0.11[a]	4.51±0.18[b]	4.89±0.23[c]	6.33±0.13[d]
Ash (%db)	2.67±0.10[a]	3.17±0.11[b]	3.68±0.20[c]	4.04±0.57[c]
Protein (%db)	7.09±0.11[a]	7.97±0.09[b]	9.84±0.12[c]	10.04±0.24[c]
Fat (%db)	13.47±0.84[a]	11.86±0.85[a]	12.93±0.33[a]	12.32±1.09[a]
Carbohydrate (%db)	75.83±0.90[a]	75.91±0.72[a]	72.20±0.12[b]	71.81±1.01[b]
Starch (%db)	87.70±0.96[a]	76.38±0.25[b]	78.28±4.94[b]	70.66±1.09[c]
Amylose (%db)	17.90±0.23[a]	14.77±1.26[b]	13.50±0.57[b]	12.14±0.26[c]
Amylopectin (%db)	69.79±0.82[a]	61.61±1.10[ab]	64.78±4.70[b]	58.52±1.05[a]

Note: This research used three times replication. Data are presented as mean ± SD (n=12). Different letters in the same row show significant differences ($p \leq 0.05$)

decreased adhesiveness. Adhesiveness value ranged from 0.1 Nmm to 1.34 Nmm and tended to increase when yellow pumpkin flour was added. One significant factor affecting the stickiness value is amylose level. This is because lower amylose content correlates with high adhesiveness value. Amylose that is released from the starch granules because of the high-temperature cooking process forms a free hydroxyl group that can absorb water, thereby allowing starch granules to swell. Hardness, cohesiveness, and adhesiveness values in this research showed irregular increases or decreases. This is influenced by other factors such as the storage time of analog rice and the time of texture testing carried out. The longer storage time and when the rice is left in contact with room temperature contributed to the texture of rice (Kusnandar et al., 2017).

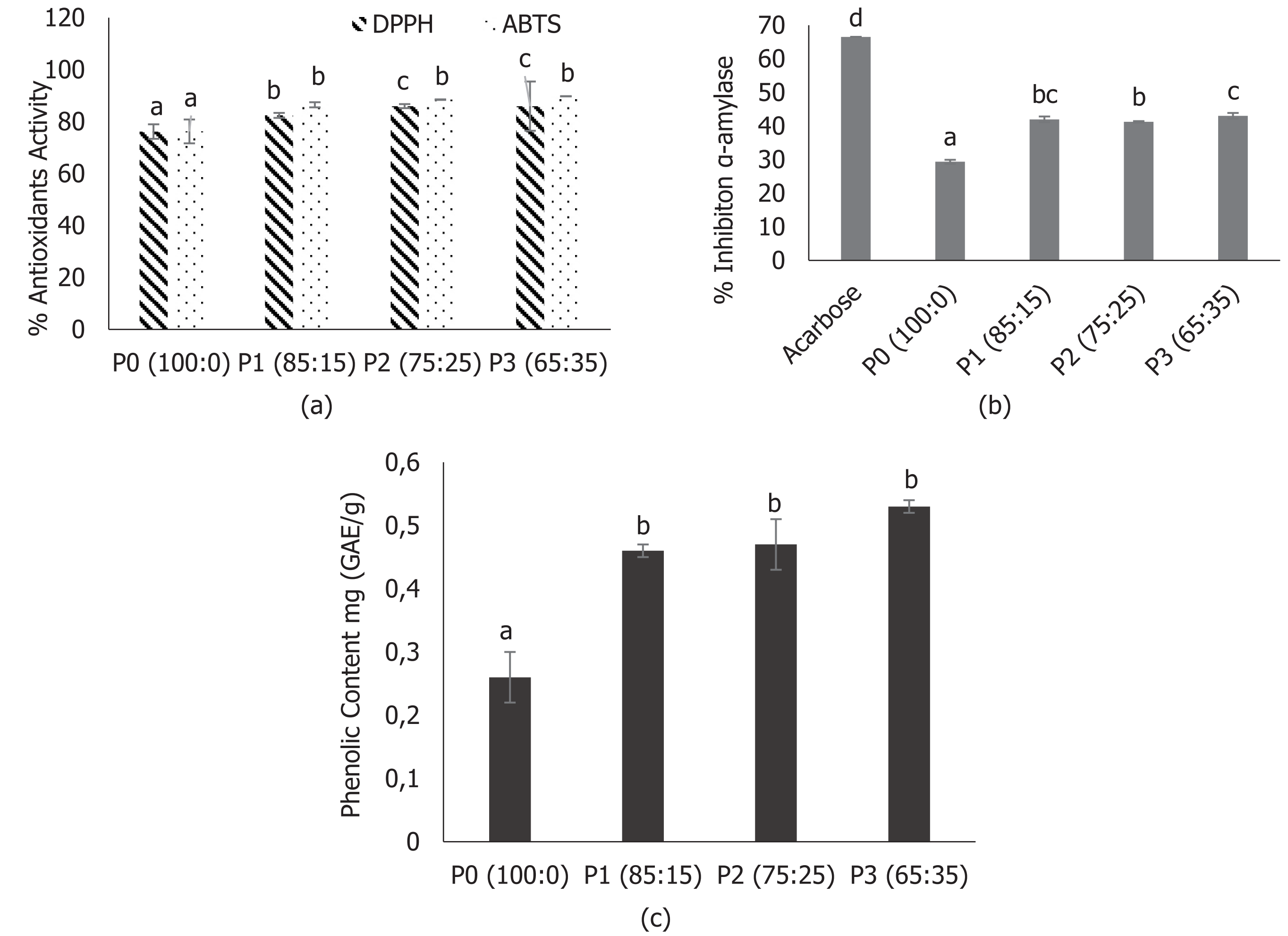
Chemical Attributes of Analog Rice

Moisture content tends to increase when the concentration ratio of yellow pumpkin flour is higher. This is due to the characteristics of yellow pumpkin flour, which has a high moisture content value of approximately 14% (Mardiah et al., 2020). Ash levels also increase due to the mineral content of white greater yam, including calcium 45 mg/100 g, phosphorus 280 mg/100 g, and iron 1.8 mg/100 g (Prawiranegara, 1996). Meanwhile, minerals in yellow pumpkin include phosphorus 64 mg/100 g, calcium 45 mg/100 g, and iron 1.40 mg/100 g (Purnamasari & Putri, 2015). The results showed that analog rice based on white greater yam and yellow pumpkin in each treatment had equivalent protein levels compared to ordinary rice, which ranged from 6–8% (Meylani, 2016). The protein content of analog rice was obtained from the addition of mung bean flour as a protein source material. The addition of mung bean flour in the control treatment was higher than the addition of yellow pumpkin. This is because yellow pumpkin also contains protein ranging from 1.44% to 2.02% (Astuti, 2022). Meanwhile, greater yam have a protein content of 1.3% (Lebot et al., 2023). The results of carbohydrate content (by difference) have a value that tends to decrease when the concentration of yellow pumpkin flour increases. This is due to the reduction in the ratio of white greater yam flour used as a source of carbohydrates. Analog rice of white greater yam and yellow pumpkin had lower amylose levels compared to ordinary rice in each treatment. Generally, rice has amylose content of 20% (Hernawan & Meylani, 2016). The low content of amylose and amylopectin is due to the lower starch levels along with the decreasing ratio of white greater yam because it has high starch and carbohydrate levels. A higher ratio of yellow pumpkin flour shows a lower amylose value produced and a greater amylopectin value, contributing to softer texture of rice.

Antioxidant, Total Phenolic Content, and α-Amylase Inhibiton Activity

The percentage of total phenolic, antioxidant activity DPPH, ABTS, and inhibition activity of α-amylase increases with high ratio of yellow pumpkin flour

The percentage of antioxidant activity increases with a rise in the ratio of yellow pumpkin flour (Figure 1a). This is due to an increase in the phenolic compounds contained in yellow flask (Figure 1c). The presence of hydroxyl groups in phenolic compounds



Note: This research used three times replication. Data are presented as mean ± SD (n=12). Different letters on the same color bar show significantly different data according to the Tukey HSD test ($p \leq 0.05$)

Figure 1. %Antioxidant Activity Diagram (a); %Inhibition activity of α-amylase (b); Total Phenolics Content (c).

can act as antioxidants, where hydroxyl groups function as hydrogen atom donors when reacting with radical compounds through electron transfer mechanisms and suppressing the oxidation process. Antioxidants help neutralize free radicals, prevent oxidative damage to pancreatic beta cells, and maintain their function to produce insulin, which controls blood sugar levels in the body. Furthermore, high antioxidant activity values can slow down oxidative damage and cell death by interfering with ROS (free radicals).

An increase in the ratio of yellow pumpkin flour can improve the percentage inhibition of the activity of enzyme α-amylase. In this analysis, analog rice water extracts from each treatment were used. The activity of enzyme α-amylase was observed as a decrease in the intensity of the iodine-starch complex blue due to the reduction of starch substrate through hydrolysis by α-amylase. The anti-diabetic properties of yellow pumpkin with inhibition activity of α-amylase are due to the high phenolic compounds possessed by yellow pumpkin. According to Zdunic et al. (2016), pumpkin fruit contains phenolic compounds of 905.3 µg GAE/g. The inclusion of acting as antioxidants by counteracting free radicals, phenolic compounds play a role in enzyme inhibition by binding to the reactive side of enzyme and changing its catalytic effect (Kwon et al., 2007). The percentage of inhibition is still lower compared to acarbose, which is a drug commonly prescribed for diabetics to inhibit the activity of α-amylase. The percentage of inhibition of α-amylase from analog rice is still not equivalent to acarbose However, analog rice formulated with yellow pumpkin flour has a higher percentage of inhibition value than the control treatment (Figure 1b). α-amylase catalyzes α-(1,4)-D-glycosidic bond present in starch to hydrolyze into smaller fragments and other glucose polymers. It is also responsible for converting amylum into maltose, which is a simple disaccharide consisting of two glucose units. This enzyme cuts α-glycoside bonds in the amylum structure and produces smaller fragments, including maltose, to enhance easy absorption by the body and increase blood glucose levels when the breakdown of starch molecules is massive. By inhibiting α-amylase, hyperglycemia levels in the body can be reduced (Kaur et al., 2021). Based on the results, the control treatment showed the lowest inhibition because it was not combined with yellow pumpkin flour. The use of a higher yellow pumpkin flour ratio correlates with greater percentage value of inhibition. This is because yellow pumpkin has phenolic compounds, which act as antioxidant and inhibitor of α-amylase, showing antidiabetic potential. The synergistic mechanism of action of phenolic compounds found in yellow pumpkin has a positive effect on reducing fasting blood sugar levels as an antidiabetic by inhibiting the activity of α-amylase. It also functions as an antioxidant by helping neutralize free radicals, preventing oxidative damage to pancreatic beta cells, and maintaining their normal function.

Sensory Attributes

The results of the sensory evaluation with 70 untrained panelists showed that in the descriptive test, the increasing ratio of adding yellow pumpkin flour tended to improve the attributes of appearance, aroma, and flavor. The increase in appearance attributes became more yellow along with a higher ratio of yellow pumpkin flour due to the natural pigment β-carotene. Furthermore, the flavor attribute is increasing because yellow pumpkin has a sweet flavor. The increase in aroma attributes produced is earthy, and the sweetish aroma is due to the combination of white greater yam ingredients and yellow pumpkin. However, the hedonic or favorability test showed no significant difference in each attribute. The assessment given by panelists in the favorability test is in the number range of 4 (neutral).

Table 4**.** Sensory attributes of descriptive test

Sensory attributes of descriptive test	The ratio of white greater yam and yellow pumpkin (%)			
	100:0 (P0)	85:15 (P1)	75:25 (P2)	65:35 (P3)
Appearance	1.97±1.10[a]	4.49±1.37[b]	5.40±1.01[c]	5.66±0.98[c]
Aroma	3.37±1.76[a]	4.81±1.41[bc]	5.14±1.44[b]	5.29±1.09[c]
Texture	3.94±1.61[a]	4.40±1.27[a]	4.40±1.35[a]	4.64±1.69[a]
Flavor	3.06±1.14[a]	5.03±1.22[b]	5.36±1.17[b]	5.24±1.36[b]

Note: Sensory attribute values with 1-7 scales, Aroma attribute 1= Very weak 2= Weak 3= Somewhat weak 4=Neutral, 5=Somewhat strong, 6=Strong, 7=Very strong, appearance 1= Very not yellow, 2= Not yellow, 3= Slightly not yellow, 4=Medium/neutral, 5= Slightly yellow 6= Yellow, 7=Very yellow, texture 1= Very not sticky, 2= Not sticky, 3= slightly sticky, 4= neutral, 5= slightly sticky, 6= sticky, 7= very sticky, flavor 1=very not sweet, 2= not sweet, 3= slightly not sweet, 4= neutral, 5= slightly sweet, 6= sweet, 7=very sweet. This research used three times replication. Data are presented as mean ± SD (n=75). Different letters in the same row show significant differences ($p \leq 0.05$)

Table 5. Sensory attributes of hedonic test

Sensory Attributes of Hedonic Test	The ratio of white greater yam and yellow pumpkin (%)			
	100:0 (P0)	85:15 (P1)	75:25 (P2)	65:35 (P3)
Appearance	4.00±1.69[a]	4.41±1.22[a]	4.74±1.28[a]	4.60±1.36[a]
Aroma	4.44±1.52[a]	4.16±1.57[a]	3.87±1.51[a]	4.01±1.41[a]
Texture	4.69±1.38[a]	4.47±1.40[a]	4.07±1.36[a]	4.09±1.67[a]
Flavor	4.89±1.31[a]	4.43±1.29[a]	4.13±1.43[a]	4.23±1.55[a]
Overall	4.71±1.30[a]	4.47±1.27[a]	4.27±1.42[a]	4.26±1.33[a]

Note: Sensory attribute scores with 1-7 scales, 1=dislike very much, 2=dislike, 3=dislike slightly, 4=neutral, 5= like slightly, 6=like, 7= like very much (The favorability test score is higher, indicating the product is getting more liked). Data are presented as mean ± SD (n=75). Different letters show significant differences α= 0.05

Table 6. Determination of the best formula for analog rice

Parameters	Score	Total treatment value	Effectiveness index				Total value			
			P0	P1	P2	P3	P0	P1	P2	P3
Flavor	15	0.13	1.00	0.39	0.00	0.13	0.13	0.05	0.00	0,02
Texture	14	0.12	1.00	0.65	0.00	0.03	0.12	0.08	0.00	0.00
Aroma	13	0.11	1.00	0.51	0.00	0.25	0.11	0.06	0.00	0.03
Appearance	12	0.10	0.00	0.55	1.00	0.81	0.00	0.06	0.10	0.08
Overall	11	0.09	1.00	0.47	0.02	0.00	0.09	0.04	0.00	0.00
Antioxidants	10	0.08	0.00	0.71	0.94	1.00	0.00	0.06	0.08	0.08
Antidiabetic	9	0.08	0.00	0.92	0.87	1.00	0.00	0.07	0.07	0.08
Fenolic content	8	0.07	0.00	0.74	0.78	1.00	0.00	0.05	0.05	0.07
Carbohydrate	7	0.06	0.98	1.00	0.10	1.00	0.06	0.06	0.01	0.00
Amylose	6	0.05	0.00	0.46	0.24	1.00	0.00	0.02	0.01	0.05
Amylopectin	5	0.04	0.00	0.27	0.56	0.00	0.00	0.01	0.02	0.00
Protein	4	0.03	0.00	0.30	0.93	1.00	0.00	0.01	0.03	0.03
Fat	3	0.03	0.00	1.00	0.66	0.29	0.00	0.03	0.02	0,01
Hardness	2	0.02	1.00	0.65	0.00	0.06	0.02	0.01	0.00	0.00
Adhesiveness	1	0.01	0.45	1.00	0.00	0.35	0.00	0.01	0.00	0.00
Total score	120	1.00	6.43	9.62	6.10	6.92	0.52	0.60	0.39	0.45

This indicated that analog rice based on white greater yam and yellow pumpkin showed the potential to be well received by panelists or customers.

Determination the Best Formula of Analog Rice

Determination of the best analog rice formula was performed using the DeGarmo et al. (1984). Parameters are ordered based on the most important in determining the quality of analog rice. Panelists' acceptance of sensory tests including taste, texture, aroma, and color was the most important parameter. Therefore, analog rice innovation can be accepted by potential consumers in the future (Mardhiyyah et al., 2024). This is followed by supporting parameters in antidiabetic properties such as antioxidants, α-amylase inhibition, total phenolics, and chemical properties including levels of carbohydrates, amylose, amylopectin, protein, and fat, as well as hardness and adhesiveness. Calculations are carried out to obtain the total value and the results are shown in Table 6. Based on the results, P1 treatment is the best formula, with the highest total score of 0.60. Analog rice has a percentage of α-amylase inhibition of 42%, DPPH antioxidant activity of 82.39%, ABTS 86.47%, and a hedonic sensory test value of 4, which is neutral and is well received by panelists.

CONCLUSION

In conclusion, this research showed that increasing concentration of yellow pumpkin flour caused a rise in the physical properties (color of the b value and water absorption), chemical properties (water, ash, and protein), antioxidant activity, total phenolics, and inhibition of α-amylase of the resulting analog rice. However, the increase in the concentration of yellow pumpkin decreased carbohydrate, starch, amylose, and amylopectin levels. Analog rice tended to increase descriptive sensory test values, including appearance, aroma, texture, and flavor. There was no significant difference in the favorability test, with a value range of 4 indicating neutral showing the potential to be accepted by panelists or customers. P1 analog rice consisting of 85% white greater yam flour and 15% yellow pumpkin was the best formula with α-amylase inhibition activity of 42%, DPPH antioxidant activity of 82.39%, and ABTS 86.47%.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this research.

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