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Sensory Evaluation and Fiber Content Analysis of Analog Rice with Moringa Leaf Flour Substitution

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ABSTRACT

Analog rice, also known as artificial rice, is a rice substitute made from a combination of local flour, including sorghum flour, mocaf flour, and glucomannan. Incorporating Moringa leaves into analog rice flour offers potential health benefits due to its anti-diabetic and antihyperglycemic effects, which lowers blood sugar levels and HbA1C levels in individuals with Diabetes Mellitus. This study aims to develop analog rice using a combination of sorghum, mocaf, and glucomannan flour and to determine its sensory properties and fiber content. This study employed an experimental design, with Moringa leaf flour substitutions divided into P1 (0%), P2 (2%), P3 (4%), P4 (6%), P5 (8%), and P6 (10%), using a Completely Randomized Design (CRD). Sensory evaluation was done using the hedonic test, involving 25 trained panelists who assessed taste, aroma, color, and texture. Fiber content was analyzed using the enzymatic gravimetric test. Data were analyzed using a one-way ANOVA test, followed by Duncan's test if $p<0.005$. The results showed a significant effect of Moringa leaf flour substitution on sensory evaluation and fiber content ($p<0.001$ for all comparisons). Based on sensory evaluation, panelists preferred analog rice P2 (2%). The fiber content of analog rice with Moringa leaf flour substitution ranged from 11.16 to 13.65% for insoluble dietary fiber, 0.60 to 0.99% for soluble dietary fiber, and 11.80 to 14.62% for total dietary fiber. Moringa leaf flour substitution had a significant difference in sensory evaluation and fiber content of analog rice. The highest preference level was found in P2 (2%) analog rice, while the highest total fiber content was found in P5 (8%) analog rice.

Keywords: analog rice, sensory evaluation, dietary fiber, Moringa leaf flour

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INTRODUCTION

Diabetes Mellitus (DM) is a chronic disease caused by a metabolic disorder that leads to elevated blood sugar levels exceeding normal limits. This disease can also be a major cause of other chronic diseases, such as heart disease, blindness, and kidney failure (1). The International Diabetes Federation (IDF) stated that 463 million people have diabetes mellitus at the age of 20-79 years, with projections indicating a further increase to 578 million and 700 million by 2030 and 2045, respectively. Meanwhile, Indonesia ranks 7th among the top 10 countries with the highest sufferers, affecting approximately 10.7 million people (2).

The Indonesia Basic Health Research (RISKESDAS) report a 2% prevalence of diabetes mellitus at the age of 15 years and above based on medical diagnoses, while an 8.5% prevalence was based on blood sugar examination. Therefore, immediate action to control diabetes mellitus must be taken to prevent further increases in the number of sufferers, one of which is through dietary management (3).

Dietary management for patients with diabetes mellitus in Indonesia involves adjustments in the type of foods, amount, and meal timing (known as 3J, *Jenis, Jumlah, Jadwal*) (1). The recommended type of foods chosen mainly consists of low glycemic index foods, which can raise blood sugar levels slowly. The low or high glycemic index in food is mainly determined by dietary fiber, amylose, amylopectin, fat, protein content, and food processing method (4) Rice, as a carbohydrate source, is a staple food mainly consumed in many countries worldwide. However, rice also has a high glycemic index (54-97) and contains a low amount of insoluble dietary fiber (3.64%) (5). Therefore, there is a growing need for alternative food options that enables people with Diabetes to still consume rice without concern about elevated blood sugar levels.

Analog rice, or artificial rice, is produced by combining locally sourced flour and has almost the same carbohydrate content as that of regular rice (6). Therefore, the selection of raw materials used in the manufacturing process will greatly determine the nutritional value and characteristics of the analog rice. In this study, the raw materials used were sorghum and mocaf (modified cassava flour), which were substituted with Moringa and glucomannan. Most respondents expressed a preference for analog rice derived from sorghum and mocaf, with a 30%:50% ratio (7). The pleasant taste of mocaf makes the ratio of mocaf composition higher than that of sorghum.

Sorghum is a functional food and is known to offer various benefits. According to Suarni, sorghum contains iron, fiber, oligosaccharides, and β-glucan, which are non-starch polysaccharide (NSP) carbohydrate components (8). In addition, sorghum also contains tannins and phytic acid. Tannins exhibit stronger antioxidant properties compared to vitamins E and C. Sorghum has 11.53% dietary fiber and 1.44 mg total phenolic compound (9). Phenolic compounds are antioxidants and have a role in α-amylase and α-glycosidase enzyme inhibition, potentially beneficial in managing hyperglycemia and diabetes-related complications (10). The glycemic index value of sorghum rice is 47.38 and is included in the low category (<55) (11).

Mocaf is flour made from cassava that undergoes a fermentation process (12). A study reported that the nutritional content and caloric value of mocaf rice are higher than those of regular white rice, with 212.53 kcal/100gr, 2.09% protein, and 46.45% carbohydrates (13).

In addition, Moringa leaves are widely cultivated in Indonesia, and their

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leaf extract is known to have antidiabetic and antihyperglycemic effects. A study has shown that Moringa leaf extract is also able to reduce blood sugar levels and HbA1C levels, which are parameters for the success of diabetes therapy (14). Consumption of boiled Moringa leaves water is known to lower blood glucose levels in people with diabetes mellitus (15). In addition, Moringa leaves that have been dried and ground into powder form (flour) have an increased concentration of nutrient content (16).

Furthermore, glucomannan, a type of dietary fiber found in *porang* tubers, is known to slow down the gastric emptying rate, restrain the absorption of glucose and lipids, and prolong the feeling of fullness (17). Glucomannan derived from *porang* tubers can be a nutraceutical component for type II diabetes management (18).

Therefore, this research aims to conduct sensory evaluations (taste, aroma, color, texture) and fiber content analysis of analog rice deriving from locally sourced ingredients that are sorghum, mocaf, and porang glucomannan extract substituted with Moringa leaf extract, which has a low glycemic index and rich in antioxidant. It is expected that this analog rice can serve as an alternative functional food for food diversification.

METHODS

The study utilized an experimental research design employing a single-factor Completely Randomized Design (CRD). Five treatment formulations and one control were used to perform sensory evaluation (taste, aroma, color, and texture) and dietary fiber content analysis in analog rice. The ratios of composite flour and Moringa flour are shown in Table 1. Composite flour ingredients consisting of sorghum flour, mocaf, and glucomannan extract from *porang* tuber were then substituted with Moringa leaf flour in each treatment group with varying amounts, ranging from 0 to 10 g.

Table 1. Analog Rice Composition

	Sorghum Flour (g)	Mocaf Flour (g)	Moringa Leaf Flour (g)	Glucomanan Powder (g)
P1(0%)	90	10	0	0.1
P2 (2%)	88	10	2	0.1
P3 (4%)	86	10	4	0.1
P4 (6%)	84	10	6	0.1
P5 (8%)	82	10	8	0.1
P6 (10%)	80	10	10	0.1

In the analysis of dietary fiber, the number of replications was calculated. This study consisted of six experimental groups, requiring two replications for each group (19). The sensory evaluation analysis was performed by involving trained panelists. The panelists in this study were students of the Undergraduate Program in Nutrition, Faculty of Health Sciences, Alma Ata University, classes of 2018 and 2019 (both regular and transfer students). The panelists had received theory in the sensory evaluation practicum test in the Food Nutrition Science Block or Advanced Culinary Course. Before performing the sensory evaluation, the panelists signed the consent form to participate in the research, and their identities were kept confidential. This research has received ethical approval from the Ethical Commission of Alma Ata University (KE/AA/IX/10622/EC/2021).

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The population in this study was the 25 trained panelists. The number of panelists was determined based on the maximum requirements of people with good enough sensitivity (20). Selected panelists were those who met the predetermined inclusion and exclusion criteria. The inclusion criteria for selecting the panelists were as follows: male or female with a minimum age of 18 years, in good health, had received sensory evaluation test theory, and were willing to participate by signing the consent form to become a panelist. On the other hand, the exclusion criteria were individuals who experienced sickness, withdrew from the sensory evaluation test, and have not/never received sensory evaluation test theory.

The sensory evaluation data were analyzed using the hedonic test method, employing a preference scale consisting of the following levels: a) score 1: dislike very much; b) score 2: dislike slightly; c) score 3: neutral/like; d) score 4: like slightly; e) score 5: like very much (21). In addition, the dietary fiber test includes measuring total dietary fiber, soluble fiber, and insoluble dietary fiber using a gravimetric enzymatic method (22). The statistical analysis performed in this study was one-way ANOVA with a 95% confidence level (α = 0,05). Therefore, a p-value of less than 0.05 was considered a significant difference. If there were a significant difference, the data would be analyzed further using Duncan's test to determine which treatment group has the real difference.

RESULTS

Preference level for the color of analog rice substituted with Moringa leaf flour

Table 2 shows that there was no significant difference between P1 and P2 (notation d). This means the panelists gave no different taste ratings between analog rice with 2% Moringa leaves addition and without the addition. P2, with the addition of 2 g of Moringa leaves, has an average score of 3.32 (neutral/like). Likewise, P3 with the addition of 4 g of Moringa leaves has an average score of 3.04 (neutral/like), P4 with the addition of 6 g of Moringa leaves has an average score of 2.84 (neutral/like), and P5 with the addition of 8 g of Moringa leaves has an average score of 2.72 (neutral/like). However, P6, with the addition of 10 g of Moringa leaves, was less preferred by respondents, with an average score of 2.36 (dislike slightly).

This result may be due to the analog rice without the addition of Moringa leaf flour having a lighter color (white bone) than the analog rice added with Moringa leaf flour. Therefore, the addition of more Moringa leaf extract makes the analog rice have a darker green color which lowered the panelist's level of preference.

Statistical test results showed that the moringa leaf flour substitution in analog rice has significantly different results in the preference level for the rice color ($p<0.001$). The results of the significance test found that P6 was significantly different from P1, P2, P3, P4, and P5. However, P1 was not significantly different from P2 in color.

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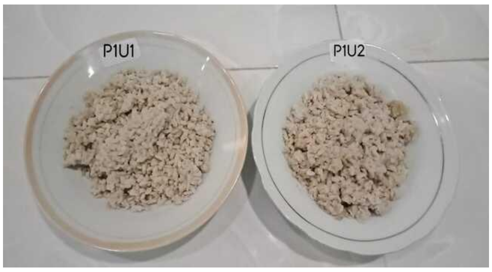

Substituted with moringa leaf flour (P1: 0%)

Substituted with moringa leaf flour (P4: 6%)

Substituted with moringa leaf flour (P2: 2%)

Substituted with moringa leaf flour (P5: 8%)

Substituted with moringa leaf flour (P3: 4%)

Substituted with moringa leaf flour (P6: 10%)

Figure 1. Analog rice products with Moringa leaf flour substitution

Preference level for the aroma of analog rice substituted with Moringa leaf flour

The sensory evaluation test results in Table 2 show the preference level of panelists for analog rice for aroma at different Moringa leaf flour substitution levels. At P1, P2, and P3, the aroma was rated as neutral/like with subsequent average scores of 3.06, 2.90, and 2.82, respectively. Whereas, at P4, P5, and P6, with the addition of 6 g, 8 g, and 10 g of Moringa leaves, the average scores declined to 2.42, 2.48, and 2.48, respectively. The panelist's feedback indicated "dislike slightly" for the aroma as more Moringa flour was added to the analog rice. This decline in preference could be attributed to the increased concentration of the aroma from Moringa leaf flour. The statistical analysis revealed a substantial impact of substituting Moringa leaf flour on the aroma preference of analog rice ($p<0.001$). Specifically, there were significant differences between P1 and P4, P5, and P6. However, no significant difference was observed between P1 and P2, as well as between P1 and P3 concerning aroma preference.

Preference level for the taste of analog rice substituted with Moringa leaf flour

As shown in Table 2, the sensory evaluation test results indicate that panelists displayed a preference for analog rice taste at P1 compared to the other treatment groups, with an average score of 3.62. Treatments P2, P3, and P4, which involved the addition of 2 g, 4 g, and 6 g of Moringa leaves, respectively, received average scores within the "neutral/like" category, with values of 3.02, 2.94, and 2.64, respectively. However, panelists exhibited "slight dislike" for analog rice at

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P5 and P6, where 8 g and 10 g of Moringa leaves were added, with average scores of 2.30 and 2.18, respectively.

The data suggests that as more Moringa leaf flour was added to the analog rice, the panelists' acceptance of the product decreased. This might be attributed to the increasing bitterness in the rice taste resulting from the higher levels of Moringa leaf flour.

The statistical test results showed a significant difference in the panelists' preference for analog rice taste for each treatment group substituting with Moringa leaves (p<0,001). P1 was significantly different from the other five treatment groups.

Preference level for the texture of analog rice substituted with Moringa leaf flour

The results of the sensory evaluation test in Table 2 show that the panelists preferred the analog rice texture at P1, P2, P3, and P4, which included in the "neutral/like" category with an average score of 3.46, 3.24, 3.06 and 2.62, respectively. This was because the analog rice in P1, P2, and P3 had a chewier consistency. However, for P5 and P6, the panelists did not like the texture of the analog rice because it was hard and brittle, referred to as "*nasi pera*" in Indonesian. The average scores for these treatments were 2.42 and 2.48, respectively.

The statistical test results showed a significant difference in the panelists' preference for analog rice texture for each treatment group substituting with Moringa leaves (p=0,001). P1 did not differ from P2 and P3 but was significantly different from P4, P5, and P6 concerning texture preference.

Preference level for the overall characteristics of analog rice substituted with Moringa leaf flour

The sensory evaluation test results in Table 2 show that the panelists' preference level for the overall characteristics of analog rice substituted with Moringa leaf flour was "neutral/like." The treatment group P1 obtained the highest average score (3.50) due to its desirable overall characteristics, which included a sticky, chewy texture, and a pleasant taste. Similarly, P2, P3, P4, and P5 were included in the "neutral/like" category with an average score of 3.14, 3.12, 2.72, and 2.52, respectively. However, the panelists showed a slight dislike for the analog rice on P6, with an average score of 2.42, because it was slightly hard and brittle and tasted slightly bitter. These characteristics could be attributed to the higher substitution level of Moringa flour (10%) in P6.

The statistical test results showed a significant difference in the panelists' preference level for the overall characteristics of analog rice with Moringa leaf flour substitution (P< 0.001). The results of the significance test found that P1 was significantly different from P2, P3, P4, P5, dan P6.

Dietary Fiber

The results of the one-way ANOVA test for soluble dietary fiber content, as shown in Table 3, demonstrated a highly significant effect (p<0.001) resulting from the addition of Moringa leaf flour to analog rice made from sorghum flour, mocaf, and glucomannan.

The lowest average soluble dietary fiber content value in analog rice was in the group without moringa flour (P1) substitution at 0.64%. In contrast, the highest average value (0.97%) was obtained in the P5 group with Moringa leaf flour substitution. These results were followed by Duncan's test, which obtained significant differences between P3 and P1, P2, P4, P5, and P6.

Insoluble Dietary Fiber

The results of the one-way

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ANOVA test for insoluble dietary fiber in Table 3 showed *p*<0.001, which means that H0 was rejected. Therefore, the addition of Moringa leaf flour had a significant impact on the insoluble dietary fiber content of analog rice made from sorghum flour, mocaf, and glucomannan.

The lowest average value of insoluble dietary fiber content in analog rice was found in the group without moringa flour (P1) substitution (11.18%). On the other hand, the highest average value (13.63%) was obtained in the P5 group with Moringa leaf flour substitution. These results were followed by Duncan's test, which showed significant differences in all treatment groups P1, P2, P3, P4, P5, and P6.

Total Dietary Fiber

Table 4 shows a significant difference resulting from the addition of Moringa leaf flour to the total dietary fiber content of analog rice made from sorghum flour, mocaf, and glucomannan

The group without Moringa leaf flour substitution (P1) exhibited the lowest average total dietary fiber content in analog rice, measuring 11.82%. In contrast, the highest average value was observed in the group with Moringa leaf flour substitution (P5), at 14.61%. Duncan's test further confirmed significant differences among all treatment groups (P1, P2, P3, P4, P5, and P6) in terms of total dietary fiber content.

Table 2. Sensory Evaluation Test of Analog Rice

	Color	Aroma	Taste	Texture	Overall Characteristic
P1	3.52±0.83[d]	3.06±0.89[c]	3.62±0.90[d]	3.46±0.81[b]	3.50±0.73[c]
P2	3.32±0.76 [cd]	2.90±0.99 [bc]	3.02±0.915[c]	3.24±1.00 [b]	3.14±0.80 [b]
P3	3.04±0.85 [bc]	2.82±1.04 [abc]	2.94±1.03 [c]	3.06±1.14 [b]	3.12±0.94 [b]
P4	2.84±0.89 [b]	2.42±0.97[a]	2.64±1.10 [bc]	2.62±0.98 [a]	2.72±0.88 [a]
P5	2.72±0.90 [b]	2.48±0.95 [ab]	2.30±0.95 [ab]	2.42±1.05 [a]	2.52±0.93[a]
P6	2.36±1.04 [a]	2.48±1.09 [ab]	2.18±1.13 [a]	2.48±0.95 [a]	2.42±1.03 [a]
	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001

Note: Different letters in the notation column indicate significant differences between treatment groups P < 0.05, while the same letters indicate no notation differences in the treatment level P < 0.05 in the one-way ANOVA test followed by Duncan's test. The value of each sensory evaluation score in the table shows that score 1 = dislike very much, 2 = dislike slightly, 3 = neutral/like, 4 = like slightly, 5 = like very much.

Table 3. Dietary and Insoluble Fiber Contents of Analog Rice

	Dietary Fiber	P *Value*	Insoluble Fiber	P Value
P1 (0%)	0.64±0.0563564[a]		11.18±0.0212839[a]	
P2 (2%)	0.71±0.0014849[a]		12.52±0.0670337 [c]	
P3 (4%)	0.82±0.0339411[b]		13.14±0.0217789 [d]	
P4 (6%)	0.90±0.0034648 [c]		13.52±0.0653367 [e]	
P5 (8%)	0.97±0.0265165[c]		13.63±0.0149907[f]	
P6 (10%)	0.70±0.0200111[a]		12.25±0.0021213 [b]	

Note: Different letters in the notation column indicate significant differences between treatment groups P < 0.05, while the same letters indicate no notation differences in the treatment level P < 0.05 in the one-way ANOVA test followed by Duncan's test.

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Tabel 4. Total Dietary Fiber Content of Analog Rice

	Total Dietary Fiber	P *Value*
P1 (0%)	11.82±0.0350018[a]	
P2 (2%)	13.24±0.0685186[c]	
P3 (4%)	13.96±0.0556493[d]	
P4 (6%)	14.43±0.0688722 [e]	
P5 (8%)	14.61±0.0114551[f]	
P6 (10%)	12.96±0.0178191[b]	

Note: Different letters in the notation column indicate significant differences between treatment groups $P < 0.05$, while the same letters indicate no notation differences in the treatment level $P < 0.05$ in the one-way ANOVA test followed by Duncan's test.

DISCUSSION

Color Sensory Evaluation Test of Analog Rice

Moringa leaf flour substitution in analog rice has significant differences in the level of color preference (p<0.001). Particularly, treatment group P6 showed a distinct difference from the other treatment groups.

Analog rice (P1) without Moringa leaf flour exhibited a white bone color, which aligns with the traditional appearance of rice. Conversely, the inclusion of Moringa leaf flour in the formula imparted a green color to the analog rice, with the intensity of green increasing as more Moringa leaf flour was added. This vibrant green hue is attributed to the chlorophyll content present in Moringa leaves. Chlorophyll is a green pigment found in chloroplasts along with carotenes and xanthophylls (23). Color plays a crucial role in sensory evaluation tests, reflecting freshness and ripeness. An even and uniform color can be indicative of the quality of mixing or processing methods. For individuals with Diabetes mellitus who adhere to strict diet control, an appealing color can enhance food choices. In this study, the color of analog rice was paid close attention, and a sensory evaluation test using hedonic scales was conducted to assess color preferences (24).

A study found that analog rice with the 10% substitution of Moringa leaf extract has 2.723% greater chlorophyll content than analog rice with the addition of 5% broccoli extract (1.260%)(25). This is because the total chlorophyll content in Moringa leaves was higher (12.68 g/L) than that in broccoli (6.21 mg/L). Furthermore, factors such as pH, pigment sources, and processing methods can influence the total chlorophyll content in leaves, along with sunlight exposure and leaf age.

This study was in line with a study that found that panelists preferred wet noodles without the addition of Moringa leaf flour compared to noodles added with Moringa leaf flour with various concentrations (26). Additionally, an increase in Moringa leaf flour addition negatively impacted the general acceptance of sponge cake (27).

Aroma Sensory Evaluation Test of Analog Rice

Substitution of moringa leaf flour in analog rice has a significant difference in the level of preference for aroma (p<0.001). A test of difference showed that treatment 1 was significantly different from P4, P5, and P6 but not significantly different from P2 and P3.

Analog rice with Moringa leaf flour substitution offers rice with a

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specific aroma of Moringa. The intensity of this characteristic aroma increases with higher amounts of Moringa leaves added to the analog rice. This is attributed to the drying process of Moringa leaves at 50°C, which activates phenolic compounds responsible for the distinct Moringa aroma (28).

In this study, the panelists disliked the analog rice aroma substituted with moringa leaf flour, compared to analog rice with fresh Moringa leaf and brown algae (*Sargassum* sp). This is due to the lower intensity of the Moringa leaf. Aroma plays a crucial role in consumer food preferences as it stems from the olfactory sensing process. The presence of volatile compounds in food products contributes to their distinctive aromas, significantly influencing consumer preferences and related to the sense of smell (29).

In addition, Moringa also contains lipoxidase enzymes found in the leaves. These enzymes hydrolyze or break down fats into compounds that can cause unpleasant odors, particularly in the hexanal and hexanol groups. As a result, an increase in Moringa leaf flour added to the product can lead to a stronger unpleasant smell (30). However, the aroma can be reduced by blanching, picking, washing, and storing the Moringa leaves at room temperature (30°C to 32°C) (31).

Taste Sensory Evaluation Test of Analog Rice

Substituting Moringa leaf flour in analog rice resulted in a significant difference in the preference level for taste (P< 0.001). A test of difference showed that P1 significantly differed from the other five treatment groups. In the sensory evaluation test with the level of taste preference, 13.98% of the panelists expressed a liking for the taste of P1 analog rice.

Products substituted with Moringa leaves have a slightly bitter taste, and this bitterness increases with higher levels of Moringa leaf flour added (32). This is because Moringa leaves contain tannins which produce a bitter taste (33). Additionally, tannins are astringent compounds with a bitter taste due to the presence of polyphenolic groups, which can bind and precipitate or shrink the protein components. This polyphenol group also gives a dry and puckering sensation in the mouth (34). However, the bitter taste in Moringa leaves will disappear if it is regularly harvested for consumption (35).

Texture Sensory Evaluation Test of Analog Rice

Substitution of moringa leaf flour on analog rice has a significant difference in the level of preference for texture (P<0.001). A difference test showed that P1, P2, and P3 significantly differ from P4, P5, dan P6.

The texture of analog rice can be influenced by the levels of amylose and amylopectin present in the rice ingredients. As explained in a previous study (25), high amylose levels could make the rice texture harder and more brittle, while higher levels of amylopectin can result in a nicer and stickier texture. In addition, the fat content also affects the texture of the analog rice. Fats or oils can weaken the dough, reduce the hardness of the extruded product, and increase the plasticity of the product. This finding aligns with a previous study, which indicated that the panelists expressed a dislike for the texture of analog rice when combined with moringa leaf flour and Sargassum sp (28).

Dietary Soluble Fiber Test

Moringa leaf flour substitution on analog rice made from sorghum flour,

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mocaf, and glucomannan, had a significant difference (P<0.001) in the soluble dietary fiber content. Duncan's test further revealed a significant difference between P3 and P1, P2, P4, P5, and P6.

The decrease in soluble dietary fiber content observed in P6 can be attributed to the cooking process, where heating causes the fiber component to dissolve in the water, resulting in the hydrolysis of water-insoluble protopectin compounds into pectinate (pectin). This phenomenon leads to a reduction in soluble dietary fiber levels (36).

Soluble dietary fiber is a dietary fiber that is fermented in the large intestine, which can increase the concentration of good bacterial metabolites such as short-chain fatty acids (SCFA). These SCFAs provide a fecal bulking effect, enhancing bowel movements by increasing intestinal transit time (37). Water-soluble dietary fiber also has viscosity properties that can delay the absorption of glucose and lipids, which can positively impact postprandial metabolism (38).

In addition to its role in delaying digestion in the small intestine, water-soluble dietary fiber contributes to a prolonged feeling of fullness, slowing down blood glucose release, reducing the amount of insulin required to transfer glucose into cells, and limiting its conversion into energy (39). According to a study by Hernawan dan Meylani (2016), white rice has the lowest fiber content; both organic white rice (0.5746% w/w) and non-organic white rice (0.4021% w/w). These results indicate that the chemical characteristics of rice (fiber content) differ from one variety to another. The general properties of water-soluble dietary fiber compounds include large polymeric molecules, complex structures, lots of hydroxyl groups, and large water-binding capacities.

A large number of polar free hydroxyl groups and the multiple matrix structure provide great opportunities for water binding through hydrogen bonds. The water-binding property of dietary fiber is important in retaining water in the stomach, increasing the viscosity of food in the small intestine, and influencing nutrition and body metabolism. These reactions include an increase in stool mass, a decrease in plasma cholesterol levels, and a decrease in the glycemic response to food. Soluble dietary fiber is widely used in water-based foods, such as soups, drinks, and puddings, while insoluble dietary fiber is widely used in solid foods (41).

Insoluble Dietary Fiber Test

Moringa leaf flour substitution on analog rice had a significant difference (p<0.001) in the insoluble dietary fiber content. Subsequent Duncan's test demonstrated significant differences among all treatment groups, including P1, P2, P3, P4, P5, and P6.

Insoluble dietary fiber consists of cellulose, hemicellulose, and lignin. The interaction of insoluble dietary fiber with the heating process causes damage to the gel structure of pectin and hemicellulose, leading to a decrease in fiber content observed in P6. Among dietary fibers, insoluble dietary fiber cannot be adequately fermented by bacteria in the large intestine. Instead, it acts as a laxative, promoting an increase in fecal mass and bile acid excretion, while also reducing intestinal transit time (37)

Total Dietary Fiber Test

Moringa leaf flour substitution in analog rice resulted in a significant difference (p<0.001) in the total dietary fiber content. This result was followed by Duncan's test, which showed

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significant differences in all treatment groups P1, P2, P3, P4, P5, and P6.

Each treatment group in this study exhibited a distinct total dietary fiber content value. A study by Augustyn et al. (2017) found that the higher the addition of moringa leaf flour, the higher the fiber content. However, P6, with the addition of 10% moringa leaf flour, the highest among other treatments, experienced a decrease in fiber content. This decrease can be attributed to insufficient attention to the heating temperature during the cooking process for P6, which caused a decline in the total dietary fiber content. Total dietary fiber is calculated as the sum of insoluble and soluble dietary fiber. Based on the observations and analysis results, the interaction between the heating method and temperature has a significantly different effect on the total dietary fiber content (43).

In addition, the decrease in fiber content in P6 is due to soluble dietary fiber as part of insoluble and total dietary fiber. During the cooking process, heating causes the fiber component to dissolve in the water, leading to the hydrolysis of water-insoluble protopectin compounds into pectinate (pectin), which further dissolves in water and reduces the soluble dietary fiber levels (36). Insoluble dietary fiber consists of cellulose, hemicellulose, and lignin. The interaction of insoluble dietary fiber with the heating process causes damage to the gel structure of pectin and hemicellulose, contributing to the overall fiber content decrease in P6 (36).

Dietary fiber causes some alterations in hormone levels in the digestive tract, influencing nutrient absorption, and regulating insulin secretion. Dietary fiber helps increase insulin sensitivity and stabilizes blood glucose levels, thereby protecting against complications due to Diabetes. Moreover, dietary fiber can help prevent or reduce the risk of degenerative diseases like coronary heart disease, diabetes, and cancer. Therefore, analog rice, with Moringa leaf flour substitution, formulated from sorghum flour, mocaf, and glucomannan, can serve as a valuable food source of dietary fiber (44).

CONCLUSION

Analog rice with substitution of Moringa leaf flour mixed with sorghum flour, mocaf, and glucomannan extract from porang tuber, showed significant differences in preference level among panelists, encompassing color, aroma, taste, and texture. As the proportion of Moringa leaf flour increased, the overall preference level decreased. The most preferred analog rice variant was P2 (2%). Substitution of moringa leaf flour in analog rice led to significant differences in total dietary fiber, soluble dietary fiber, and insoluble dietary fiber content; P5 (8%) demonstrated the highest total dietary fiber content among all variants.

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