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RESEARCH STUDY
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Sensory Characteristics and Glycemic Index of Biscuits Made from Sorghum Flour and Red Bean Flour

Karakteristik Sensori dan Indeks Glikemik Biskuit Berbahan Tepung Sorgum dan Tepung Kacang Merah

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ABSTRACT

Background: Diabetes mellitus is a significant nutritional problem faced by adults. Nutritional therapy is one approach to managing this condition. Functional foods, such as sorghum with a low glycemic index, help regulate blood sugar levels and are safe for diabetics. The combination of sorghum and red bean flour in a biscuit formulation provides a functional alternative for diabetics.
Objectives: This study analyzed the sensory characteristics and glycemic index values of sorghum and red bean biscuits.
Methods: This study used an experimental design with a completely randomized design (CRD), consisting of 3 treatments and 2 replications. The biscuit formulation ratios of sorghum flour, red bean flour, and wheat flour were F1 (50:30:10), F2 (40:30:20), and F3 (30:30:30). A sensory characteristics test was conducted by 30 panelists, and the data were analyzed using ANOVA and Duncan's Further Test. Furthermore, the selected formulas were analyzed for glycemic index values.
Results: The findings revealed that Formula F3, consisting of biscuits with a 30:30:30 ratio of wheat flour, sorghum flour, and red bean flour, was the chosen formula with the highest average sensory characteristics in terms of taste, aroma, texture, and color. The Anova test results showed no significant differences in the characteristics of color (p-value 0.065), aroma (p-value 0.520), taste (p-value 0.896), and texture (p-value 0.067). The selected formula (F3) had a glycemic index value of 9.38.
Conclusions: Selected sorghum and red bean biscuits (F3) have low glycemic index levels, so these biscuits are safe for consumption by people with diabetes mellitus.

INTRODUCTION

Diabetes mellitus, a collection of metabolic conditions, is characterized by elevated blood sugar levels (hyperglycemia) due to dysfunctional insulin, a hormone responsible for regulating blood sugar levels to maintain the body's equilibrium[1]. This condition poses a significant global health challenge, with its prevalence rising due to lifestyle and dietary changes. By 2022, the International Diabetes Federation projected that 537 million people worldwide would be living with diabetes. According to the 2023 Survei Kesehatan Indonesia (SKI), 10.7% of Indonesians across all age groups have been diagnosed with diabetes[2]. The World Health Organization predicts that the number of diabetes cases in Indonesia will rise from 8.4 million in 2000 to 21.3 million by 2030[1]. This alarming increase highlights a major health threat to the Indonesian population, emphasizing the urgent need for effective prevention and treatment strategies for diabetes[3].

Diabetics tend to experience metabolic disorders characterized by weight loss[4]. This is caused by insulin deficiency, resulting in disruption of protein and fat metabolism[5]. Dietary management that can be done in patients with diabetes mellitus is by consuming complex carbohydrate sources with a low glycemic index and foods that contain high fiber. Adequate fiber intake can improve the performance of the hormone insulin in regulating blood glucose levels, slow down gastric emptying, and cause a longer feeling of satiety[6]. The glycemic index (GI) indicates the rate at which a food raises blood glucose levels after being consumed[7]. Understanding the GI of foods, particularly those containing sugar, is crucial since foods with a high GI can lead to a swift increase in blood sugar levels. In contrast, foods with a low GI can slow the rise in blood sugar and may have a minimal effect. For individuals with diabetes, it is essential to prioritize the consumption of low-GI foods to better regulate blood sugar levels.

Snacks serve as a convenient food option that can help meet daily energy needs. Among the various types of snacks, biscuits are particularly popular and widely consumed. According to SNI 2973:2011, biscuits are dry-

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baked products made from dough, typically composed of wheat flour, with or without substitutes, oils/fats, and other food ingredients or additives. Wheat flour, a key ingredient in biscuits, has a high glycemic index, as it contains only 0.3 grams of fiber per 100 grams, classifying it as a low-fiber food. Additionally, many commercially available biscuits have high sugar content.

An alternative ingredient that can help reduce the amount of wheat flour in biscuits is sorghum. Sorghum is a cereal grain that is packed with macronutrients, micronutrients, and bioactive compounds, and is known for its low glycemic index compared to other cereals. In 100 grams of sorghum flour, there are 73 grams of carbohydrates, 3.3 grams of fat, 11.3 grams of protein, 6.3 grams of fiber, and 10.26 grams of water. The mineral content in 100 grams of sorghum includes 28 mg of calcium, 287 mg of phosphorus, 4.4 mg of iron, 123 mg of magnesium, 324 mg of potassium, 3 grams of sodium, 0.3 mg of vitamin B6, and 0.5 mg of vitamin E[10]. Sorghum flour has a higher fiber content than wheat flour. Foods with a low glycemic index are typically derived from ingredients rich in fiber, and sorghum is composed of 93% resistant starch[11].

Aside from sorghum, foods that have a low glycemic index are kidney beans[12]. Fiber found in kidney beans can be useful in lowering blood sugar levels[13]. In a study, it was also mentioned that kidney beans contain inhibitors that can slow down the process of carbohydrate digestion in the small intestine. Therefore, sorghum flour and red kidney beans are food ingredients that are often used as mixed ingredients in various food innovations such as crackers, cookies, beverage products, and various types of cake products. A possible product to create is biscuits made from a blend of sorghum flour and red bean flour, formulated to reduce the glycemic index and enhance fiber content. This makes it a viable, healthy snack option for individuals with diabetes mellitus. Based on the explanation provided above, the formulation of this research problem is to analyze the sensory characteristics and glycemic index of biscuits made from sorghum flour and red bean flour, which contain energy, carbohydrates, protein, and fat with high fiber content and low glycemic index, so as to increase energy intake without worsening the condition of people with diabetes mellitus.

METHODS

Design/Research Design

The research utilized a completely randomized design (CRD) in which sorghum flour was combined with red bean flour in the formulation, with various treatment levels applied: 30%, 40%, and 50%. The response variables of this study were organoleptic tests, protein content, and glycemic index of sorghum and red bean flour biscuit formulations. The following is the linear model of the design: $Yij = \mu + Ti + \varepsilon ij$. Biscuit formulation was carried out by mixing sorghum flour and red bean flour with other ingredients to make biscuits. The sorghum biscuit formulation can be seen in the following table.

Tools and Materials

The main materials that will be used in this research are sorghum from the Indonesian Sorghum Farmers Union (SEPASI) and Red Beans from the market in Tasikmalaya City. In addition, the chemicals used are distilled water, dilute $CuSO_4$, concentrated H_2SO_4, crystalline K_2SO_4, dilute NaOH, 0.1 N HCl, 1% phenolphthalein, 0.1 N NaOH, crystalline $CuSO_4$. The equipment that will be applied in this analysis consists of three parts, namely instruments for handling sorghum and red beans, tools for organoleptic tests, and tools for glycemic index analysis.

Table 1. Biscuit Formulation

Ingredients	F1	F2	F3
Wheat Flour (%)	50	40	30
Sorgum Flour (%)	30	30	30
Red Bean Flour (%)	10	20	30
Stevia (g)	5	5	5
Margarine (g)	80	80	80
Egg Yolk (g)	10	10	10
Cornstarch (g)	10	10	10
Skim Milk (g)	10	10	10

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Research Steps

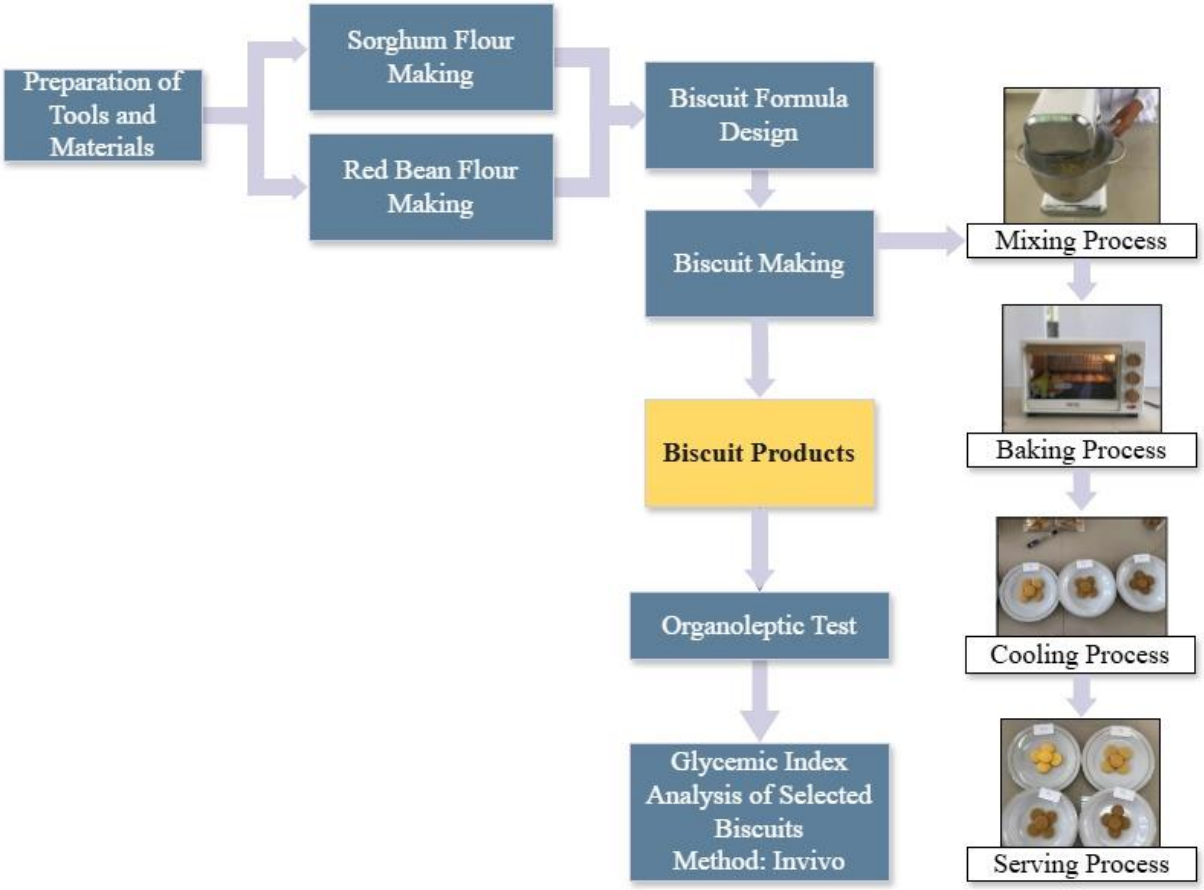

Figure 1. Flowchart of Research Stages

Preparation of Sorghum and Red Bean Flour

Sorghum seeds that have been obtained are then sorted to separate dirt, dry leaves, and dust. Next, the sorghum seeds are shredded to release the epidermis from the whole sorghum seeds and produce sorghum rice. Next, the sorghum rice was soaked using water in a ratio of 1:1 for 24 hours. Then, the soaked sorghum rice was drained with a drying machine until the water content was around 12-14%. The last stage is the flouring process, where the dried sorghum rice is ground with a slippery iron cylindrical slender so that fine flour is produced according to the standard. The process of making red bean flour is the same as the stages of making sorghum flour[14].

Sensory Evaluation

An organoleptic test will be conducted on sorghum biscuits. The organoleptic test conducted is the hedonic test. According to Lawless and Heymann (2013)[15], panelists for organoleptic tests should use panelists who often consume similar products. The hedonic test is conducted to evaluate the level of acceptance or preference for a food product, carried out by 30 participants[15]. The requirements for panelists to be able to conduct hedonic testing are that they are willing to become panelists, have free time to conduct organoleptic tests, are in good health, are not color blind, and are not allergic to sorghum flour and red beans. The rating scale for the hedonic test was carried out by giving values ranging from 1 to 5, with criteria for 1 = very dislike, 2 = dislike, 3 = normal, 4 = like, and 5 = very like.

Glycemic Index Analysis

Glycemic Index assessment is obtained by dividing the value of the area under the test food by the area under the test standard multiplied by one hundred percent, known as IAUC (*Incremental Area Under Curve*). The reference food standard is 50g of pure glucose. Inclusion criteria are willingness to be a subject, the subject is in good health, and not allergic to sorghum flour and kidney beans. 10 subjects were selected, and each subject was asked to undergo testing by consuming 2 types of treatment (including control) within 2 weeks, namely Mean Standard Blood Plasma (MP DS) 0% the first week, MP DS 80% the second week. To determine the Glycemic Index of each treatment product, every time after consuming biscuit products within two hours, blood samples were taken from the subjects[16] . The procedure for determining the glycemic index of food is as follows:

a. Test food and reference food equivalent to 50 g available carbohydrate were given to research subjects who had undergone overnight fasting, except water.
b. For two hours after administration (healthy subjects), blood samples (1-2µL) finger-prick capillary blood sample method consecutively, taken

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at minutes 0 (before administration), 15, 30, 45, 60, 90, and 120 after administration of the test food.

c. At different times (7 days later/week), the same thing is done by giving the reference food, 7 days later the 2nd test food is provided.
d. Blood glucose levels (at each sampling time) were plotted on two axes, the x-axis (time in minutes) and the y-axis (blood glucose level).
e. The glycemic index was determined by comparing the area under the curve with the baseline (Incremental Area Under Curve, IAUC) between the food measured by the glycemic index with the reference food (glucose)[17].

The IG value of the test food is calculated based on the formula:

$$GI = \frac{\text{The area under the test food curve}}{\text{The area under the reference food curve}} \times 100\%$$

Data Analysis Procedure

Data processing in this study will use Microsoft Excel 2016 and then be statistically analyzed using SPSS Version 16 for Windows. Data from the organoleptic (hedonic) test will be analyzed by statistical tests using the *Kruskal-Wallis* test, while data on glycemic index levels will be analyzed by the ANOVA variance test. If significant results are obtained from the Kruskal-Wallis test, further tests will be conducted using the Mann-Whitney test. If significant results are obtained from the ANOVA test, the Duncan test will be continued.

Ethical Approval

This research has received ethical approval from the Research Ethics Commission of the University of Mataram on August 21, 2024, with Number DP.04.03/F.XLVIII.14/532/2024.

RESULTS AND DISCUSSIONS

Results of Sensory Characteristic Analysis

Formula F1 Formula F2 Formula F3

Figure 2. Biscuit Formula

Analysis of sensory characteristics was carried out by organoleptic tests on 30 panelists, namely students of the Nutrition Study Program, Faculty of Health Sciences, Siliwangi University. Organoleptic tests assessed included color, aroma, texture, and taste. The organoleptic test aims to get the highest acceptability of the sorghum biscuit formula with the addition of red beans as a low glycemic index functional food. The *Kruskall-Wallis* test results of each parameter are in Table 2.

Table 2. Results of Organoleptic Tests

Treatment	Color	Aroma	Texture	Taste	Average
F1	3.73[a]	3.8[a]	3.43[a]	3.47[a]	3.60
F2	3.67[a]	3.63[a]	3.33[a]	3.40[a]	3.50
F3	3.33[a]	3.87[a]	3.80[a]	3.47[a]	3.63

Numbers followed by different letters in the average values indicate significant differences between treatments.

Color

Color is the initial characteristic that panelists can immediately observe. Food quality assessment generally depends on its color. The appropriate color should give the impression of a different assessment from the panelists[18]. The results of the Kruskal-Wallis test indicated no significant difference (p-value 0.065) in the color parameter across the treatments (Table 2). This finding indicates that the variation of sorghum biscuit formula added with red bean had no effect on the sensory characteristics related to the color parameter of the biscuits.

The average value of the color parameter of organoleptic results is in the range of 3.33 to 3.73, which is included in the moderately like and like groups. The average value of the highest color parameter, or the most preferred by the panelists, was in formula F1, and the average value of the lowest color parameter was in formula F3 (Table 2). These findings are consistent with the study by Simanjuntak et al. (2022)[19] This shows that there is no significant difference in the color characteristics of snack bars made with sorghum flour and kidney beans. Formula F1 was preferred because its color was more brownish yellow compared to the other formulas. The results of the color liking assessment showed that with the increase in the proportion of red bean flour, the average color score for formulas F1, F2, and F3 decreased. Food color can be influenced by

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natural pigments from plant and animal sources, or by artificial colorants added during food processing[20].

The color of the biscuits is influenced by the basic ingredients in making biscuits, namely the brown color of the product is influenced by sorghum flour which is high in starch content, and the addition of red bean flour which has a high tannin content. The greater the tannin content in the product, the darker and more vivid the brown color[19]. In addition, changes during the roasting process can cause the surface of the product to become darker due to the large reduction and the process of reducing the water content[21].

Aroma

Aroma is a fragrance created by chemical signals that are sensed by the olfactory nerves in the nose. It is an evaporative substance that can be released while chewing [18]. The Kruskal-Wallis test results indicated that the addition of red beans to sorghum biscuits did not significantly impact the aroma assessment (p-value 0.520) (Table 2). The data revealed no significant differences in aroma preference among the treatments F1, F2, and F3 of sorghum biscuits with red bean added.

The average favorability of biscuit aroma ranged from 3.63 - 3.87 which is included in the like category (Table 2). The most preferred biscuit aroma by panelists was formulation F3 (30% sorghum flour: 30% red bean flour) with an average value of 3.87 and the formula that had the lowest aroma assessment was F2 (30% sorghum flour: 20% red bean flour) with an average value of 3.63 (Table 2). The variation in mean values between the two treatments may be due to the different ratios of sorghum flour and red bean flour. The aroma of sorghum has three distinct aromas: a dusty aroma, which is a musty or earthy odor; a woody aroma, similar to the aroma of damp wood; and a green aroma, similar to the aroma of food sacks. On the other hand, kidney beans have a subtle nutty aroma, caused by the action of the lipoxygenase enzyme commonly found in nuts, which results in a slightly unpleasant or languid aroma[22].

The aroma arising from sorghum flour and red bean flour biscuits can be influenced by various components of other ingredients in the dough such as margarine, eggs, sugar, and cocoa powder with the same amount in each formulation. This is consistent with the study carried out by Setyadjid and Setiyaningrum (2022)[23] which states that variations in the formulation of sweet potato flour and mocap flour have no significant difference in the aroma of steamed brownies because the aroma of brownies is determined by adding food additives, namely margarine, eggs, sugar, cocoa powder, and chocolate bars which are added in the same amount.

Texture

Texture is a sense that is associated with feeling or touching[24]. Texture is one of the prerequisites in the acceptance of food products which includes consistency, thickness, brittleness, chewiness, and the shape or size of particles in food products[25]. The Kruskall Wallis test results showed a significance value of p-value 0.067 > 0.05 (Table 2). Kruskall Wallis test data showed that there was no significant difference between treatments F1, F2, and F3 of sorghum flour and red bean flour biscuits on texture acceptability.

The average liking for the texture of the biscuits ranged from 3.33 to 3.80, which is included in the moderately liked and liked categories (Table 2). The texture most favored by panelists was the texture of formula F3 (30% sorghum flour: 30% red bean flour) with an average value of 3.80 and the texture that had the lowest average value was formula F2 (30% sorghum flour: 20% red bean flour) with an average of 3.33 (Table 2). The texture of F3 was preferred because it had a dense texture and was also crunchy. This is influenced by raw materials, supporting materials, mold thickness, length of baking time, and temperatures that are too high. Sorghum flour which is high in starch content, and the addition of red bean flour which has a high tannin content. The increasing starch content will make the texture of the product denser[26].

Taste

Taste plays a crucial role in determining whether a product is acceptable to consumers[24]. It is perceived by the tongue and is typically categorized into four basic flavors: sweet, salty, sour, and bitter. It is detected by the tongue and is generally classified into four basic flavors: sweet, salty, sour, and bitter. The results of the Kruskal-Wallis test showed a p-value of 0.896, which is above the 0.05 significance level, suggesting that there was no significant difference in the flavor acceptability of the sorghum flour biscuits with red bean flour across the treatments F1, F2, and F3.

The average liking for the taste of biscuits ranged from 3.40 to 3.47 which is included in the moderately liked category (Table 2). The most preferred flavors by panelists were formulas F1 and F3 with an average value of 3.47 (moderately liked category). The formula that had the lowest taste assessment was F2 with an average value of 3.40 (Table 2). Sorghum flour biscuits with the addition of red beans are slightly sweet and slightly astringent. This is due to the tannin content in sorghum flour[27]. The presence of tannins causes the digestibility of carbohydrates and protein to decrease so that the absorption rate of both nutrients becomes low or not comparable to the carbohydrates and protein available in sorghum seeds. To reduce the astringency in processed sorghum flour products, it can be done by selecting flour that has gone through the shucking process[19].

In addition, the flavor of sorghum flour biscuits with the addition of red beans can be influenced by ingredients such as sugar, milk, eggs, and margarine that are included in the same proportion. This finding is in accordance with research conducted by Setyadjid and Setiyaningrum (2022)[23] mentioned that the variation in the formulation of purple sweet potato flour and *mocap* flour had no significant difference in the taste of steamed brownies. This is because in making steamed brownies, the taste is influenced by the use of ingredients such as sugar, eggs, cocoa powder, chocolate bars, and margarine in the same amount in each formulation.

Selected Formula

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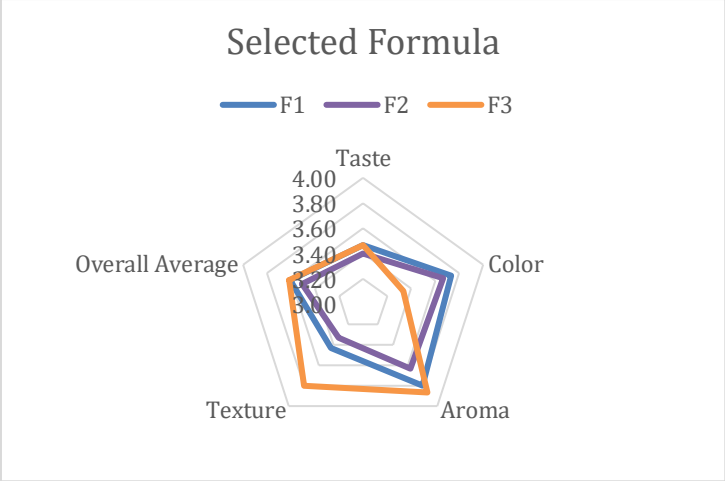

Figure 3. Overall Average

The overall average results of the organoleptic test, evaluating the sensory characteristics of sorghum flour biscuits with added red bean flour in terms of color, aroma, texture, and taste, are shown in Figure 1. According to these results, formula F3 achieved the highest overall average score of 3.63, which falls into the "like" category. The selected formula (F3) consists of 30% wheat flour, 30% sorghum flour, and 30% red bean flour.

Glycemic Index Analysis

The glycemic index (GI) is a scale that indicates how quickly carbohydrate-rich foods raise blood sugar levels[28]. Foods with a low GI are digested and converted into glucose more slowly, helping to avoid sudden increases in blood sugar. The glycemic index is divided into three categories: low (≤55), medium (55-69), and high (≥70)[29]. GI testing was performed on the widely preferred sorghum flour biscuits containing red bean flour, specifically Formula F3, which consists of 30% wheat flour, 30% sorghum flour, and 30% red bean flour. The results of this analysis are shown in Table 3.

Table 3. Glycemic Index Analysis

Replicate	Glycemic Index Value	Average
Replicate 1	8.89	
Replicate 2	9.38	9.38
Replicate 3	9.88	

Biscuits made from sorghum flour with added red bean flour had a low glycemic index value of 9.38 (Table 3). The glycemic index value can be influenced by several factors, including the fiber and protein content of food ingredients, the ratio between amylose and amylopectin, as well as starch digestibility and food processing[30]. Foods that have a higher proportion of amylose than amylopectin tend to have lower GI values, and vice versa[28].

While few studies have explored the development of sorghum products into biscuits, particularly as a functional food with a low glycemic index, this potential presents promising opportunities for innovation in the healthy food industry. However, further research is needed to develop a more optimal biscuit formulation, as well as subclinical interventions to evaluate the health benefits of sorghum biscuit consumption in more depth.

CONCLUSIONS

The conclusion that can be obtained from the results of this study is that sorghum flour and red bean flour biscuits formula 3 with a concentration of sorghum flour: red bean flour = 30: 30 is the best formula based on hedonic test by panelists. Selected sorghum and red bean biscuits (F3) have low glycemic index levels, so these biscuits are safe for consumption by people with diabetes mellitus. Further research is needed to develop a more optimized formulation and assess the health benefits of consuming these biscuits.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

There is no conflict of interest in this research.

AUTHOR CONTRIBUTIONS

TFA: conceptualization, investigation, methodology, supervision, writing–review and editing; NAQ: data curation, formal analysis, writing–original draft.

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