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Sorghum Flour and Coconut Flour Snack Bars as Functional Foods for Type 2 Diabetes Mellitus

Snack Bar Tepung Sorgum dan Tepung Kelapa sebagai Pangan Fungsional untuk Penderita Diabetes Melitus Tipe 2

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ABSTRACT

Background: People with type 2 diabetes mellitus (T2DM) can control blood sugar levels through adequate fiber consumption. Sorghum flour and coconut flour are non-gluten flours that have high fiber content. Developing functional foods, such as snack bars made from these flours, could help regulate blood glucose levels.
Objectives: This study aimed to examine the effect of the proportion of sorghum flour and coconut flour on the nutritional content, dietary fiber content, and organoleptic properties of snack bars.
Methods: This study used a completely randomized design with 3 formulations (70:30, 50:50, and 30:70 ratios of sorghum to coconut flour) and 2 repetitions. The gravimetric method was used to analyze water content and ash content. The Kjeldahl and Soxhlet extraction methods were employed to analyze the protein and fat content, respectively. Carbohydrate content was determined using by difference method, and fiber content was evaluated using the enzymatic method. ANOVA and the Kruskal-Wallis test were used to see the differences in proximate, fiber, and organoleptic properties, respectively.
Results: The results showed significant differences in ash content (p-value<0.001), protein (p-value=0.002), fat (p-value=0.047), carbohydrates (p-value=0.049), and dietary fiber (p-value<0.001). Taste is one of the hedonic test parameters that has a significant difference (p-value=0.005). The selected snack bar formula was F3 with energy, fat, protein, carbohydrate, and fiber content was 108 kcal, 5.18 g, 4.56 g, 10.85 g, and 10.91 g respectively.
Conclusions: Snack bars made from sorghum and coconut flour are rich in dietary fiber and suitable for consumption by individuals with T2DM.

INTRODUCTION

The International Diabetes Federation (IDF) estimates a potential increase in the global population of diabetes mellitus patients by 10.5%, from 537 million in 2021 to 783 million by 2045[1]. Meanwhile, Indonesia ranked fifth worldwide in 2021, with 19.5 million people diagnosed with diabetes[1]. According to Basic Health Research (RISKESDAS) data, the percentage of diabetes sufferers based on medical diagnosis in the population aged 15 years and over in Indonesia also increased by 0.5% from 2013 to 2% in 2018[2]. These figures highlight diabetes mellitus as a significant health threat, both nationally and globally.

Diabetes Mellitus (DM) is defined as a metabolic disorder characterized by hyperglycemia resulting from defects in insulin action, insulin secretion, or both[3]. Hyperglycemia is a condition where blood sugar levels are above 200 g/dl.[4]. This condition affects blood vessels in various organs, including the eyes, kidneys, nerves, and heart[5]. One of the complications that will arise is coronary heart disease which can potentially cause death[6]. Diabetes is known to cause 6.7 million deaths worldwide in 2021[1]. One of the factors that causes the high number of cases of diabetes mellitus is poor dietary habits influenced by changes in human lifestyle[7]. Dietary patterns that include foods with a high glycemic index (GI) and low fiber can increase blood sugar levels rapidly, resulting in insulin resistance and the onset of type 2 diabetes at the age of 30 to 59 years[8].

Type 2 DM needs to be treated properly by controlling blood glucose levels, one of which is nutritional therapy by consuming low glycemic index and high fiber foods[9]. This refers to meeting the recommended daily fiber requirement of 25-30 grams/day[3]. Fiber is a plant component that contains indigestible carbohydrates and has been shown to have an important impact on health by preventing the risk of chronic diseases including cancer, cardiovascular disease, and diabetes[10]. Fiber is also known to play a role in slowing down glucose absorption in the small intestine,

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which can cause decreased plasma glucose and postprandial insulin levels[11].

Fiber sources are found in local foods such as sorghum grains. Sorghum (Sorghum bicolor L.) is a plant that is safe for consumption by individuals with diabetes because it is classified as a having a low glycemic index[12]. Sorghum, as a functional food, is associated with antioxidants, fiber, iron, oligosaccharides, beta-glucan, as well as Non-Starch Polysaccharide (NSP) carbohydrate components, and others[13]. Sorghum fiber also has a hypoglycemic effect that inhibits glucose absorption[14]. Other potential sources of fiber can be found in coconuts. Coconut flesh (Cocos nucifera L.) contains essential nutrients, including 2.41% protein, 6.83% fat, and 36.57% carbohydrates. Meanwhile, coconut flour contains a total fiber content of 63.25% consisting of soluble fiber of 4.53% and insoluble fiber of 58.71%[15]. High fiber content has a positive effect on body weight and lowers blood sugar levels[16].

Based on the increasing prevalence of type 2 diabetes mellitus as a severe health issue affecting the quality of life, developing functional foods from local ingredients such as sorghum and coconut with high fiber content is crucial. Functional foods are fresh and/or processed foods whose ingredients have been scientifically proven to improve certain physiological functions, reduce the risk of disease, and provide benefits when consumed regularly as part of a daily diet[17]. The potential for developing food product innovations is increasingly diverse in meeting the needs of diabetes sufferers who continue to increase. Snack bars are one of the functional food products that are consumed as a snack, usually to delay hunger between main meals[18]. Previous studies have shown that providing a fiber-based snack bar made from fermented black sticky rice reduces blood glucose levels in type 2 DM patient[19]. However, this product needs further development using other high-fiber local food ingredients. Therefore, this study aims to examine the effects of varying proportions of sorghum flour and coconut flour on the nutritional content, dietary fiber, and organoleptic properties of snack bars. This study also examines the determination of the best formulation that is suitable for consumption as an alternative functional food for type 2 Diabetes Mellitus sufferers.

METHODS

Research Design

This research design used a factorial Completely Randomized Design (CRD) and was repeated twice. The experimental design analyzed the effect of the proportion of sorghum flour and coconut flour on three snack bar formulations, namely 70:30 (F1), 50:50 (F2), and 30:70 (F3) which came from the modified research of Zaddana et al (2021)[7]. The research comprised several stages, including preparing the main ingredients (coconut and sorghum flours), determining formulations, and mixing both flours to make a snack bar. Subsequently, the products were analyzed for their nutritional content, dietary fiber, and hedonic test. The best formulation was selected based on these evaluations. The production, formulation, sample preparation, and hedonic test were conducted at the Nutrition Laboratory of the Faculty of Health Sciences. Proximate analysis of snack bars was conducted at Saraswanti Indo Genetech (SIG) Laboratory. Fiber content analysis was conducted at Vicma Lab Laboratory. This study was conducted from February to June 2024 and received ethical approval from the Ethics Committee of Universitas Pembangunan Nasional "Veteran" Jakarta on March 21, 2024 (Approval No. 91/III/2024/KEP).

Snack Bar Formulation

The formulation design and production of the snack bar were based on previous studies with modifications[7]. Snack bar formulations are grouped into 3 types, consisting of main ingredients and complementary ingredients, that are often applied to make snack bars to suit the nutritional needs of diabetics. Table 1 presents the snack bar formulations.

Table 1. Formulation of Sorghum Flour and Coconut Flour Snack Bars in 100 Grams

Material Name	Material Weight		
	70:30 (F1)	50:50 (F2)	30:70 (F3)
Sorghum Flour (g)	24.8	17.7	10.6
Coconut Flour (g)	10.6	17.7	24.8
Margarine (g)	10.6	10.6	10.6
Skim Milk (g)	7.8	7.8	7.8
Chicken Eggs (g)	35.5	35.5	35.5
Zero Calorie Sugar (g)	1.8	1.8	1.8
Salt (g)	0.4	0.4	0.4
Water (g)	8.5	8.5	8.5
Total (g)	100	100	100

F1= 70 g sorghum flour : 30 g coconut flour, F2=50 g sorghum flour : 50 g coconut flour, F3= 30 g sorghum flour : 70 g coconut flour

Apparatus and Materials for Snack Bar Production

The production of snack bars requires a main ingredient, which is sorghum flour made from the milling of whole sorghum grains (Sorghum bicolor L.) purchased from PT. Nusaraya Indonesia. Meanwhile, coconut flour is derived from drying and grinding coconut meat (Cocos nucifera L.) sourced from PT. Khas Jaya Nusantara Both flours were procured through e-commerce platforms. Additional ingredients included margarine, skim milk, chicken eggs, salt, "Diabetasol" zero-calorie sugar, and water The production of snack bars uses several equipment, including a digital scale, mixing bowls, oven, rectangular molds, mixer, spatula, spoon, fork, food brush, and knife.

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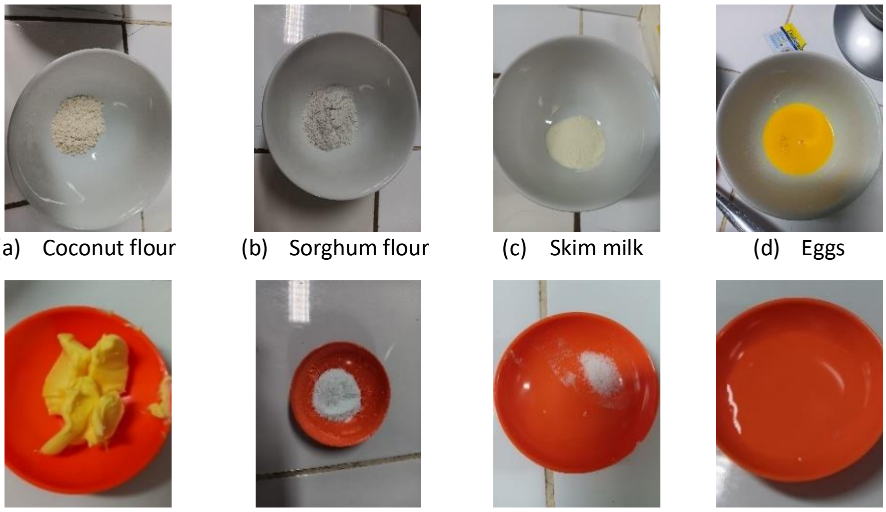
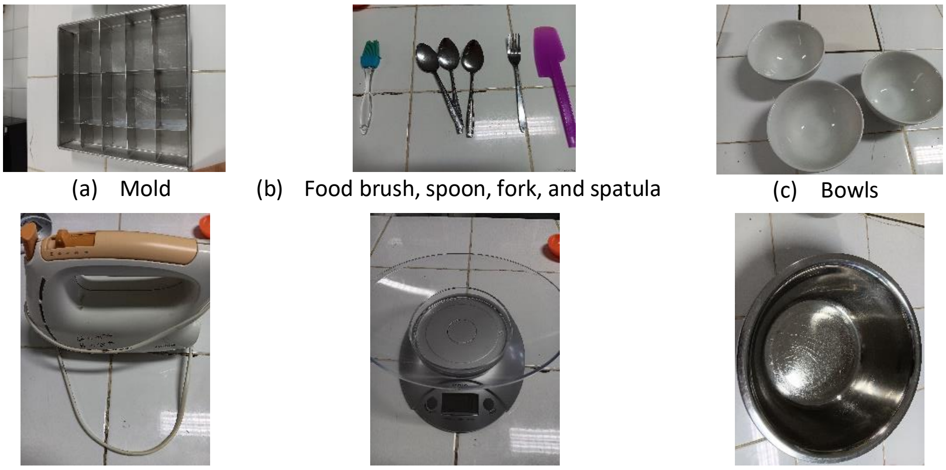


(a) Coconut flour (b) Sorghum flour (c) Skim milk (d) Eggs

(e) Margarine (f) Zero calorie sugar (g) Salt (h) Water

Figure 1. Snack Bar Ingredients



(a) Mold (b) Food brush, spoon, fork, and spatula (c) Bowls

(d) Mixer (e) Digital scale (f) Mixing bowl

Figure 2. Snack Bar Making Equipment

Snack Bar Preparation Process

First, all ingredients were weighed. The two flours were mixed with dry ingredients, including zero-calorie sugar, skim milk, and salt. Meanwhile, wet dough was prepared by whisking eggs, margarine, and water using a mixer until well combined. Then, the wet dough was added to the dry ingredient mixture gradually and stirred until the dough had a smooth texture. The dough was then placed in rectangular molds and baked for 45 minutes at 130°C. The cooked snack bars were left for 30 minutes at room temperature. Afterward, the product was ready to be served.

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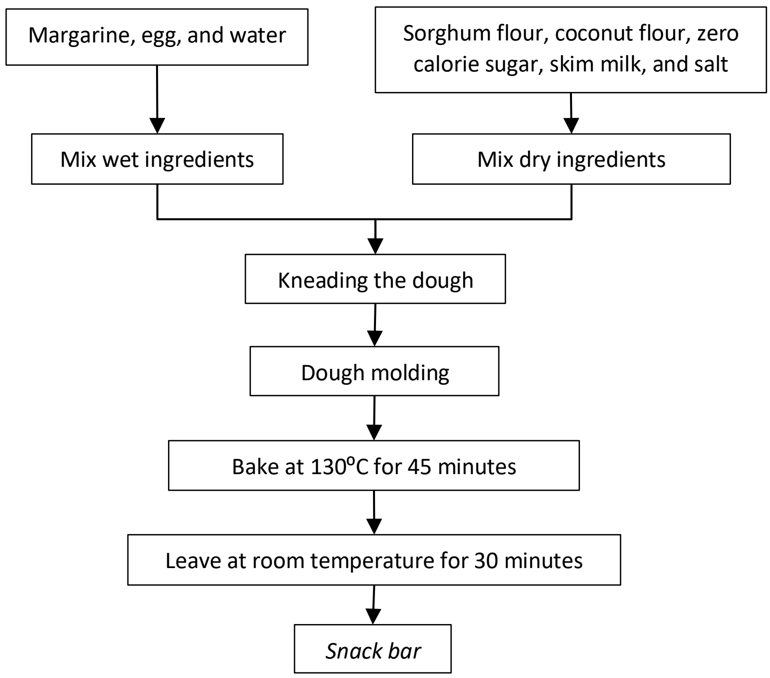

Figure 3. Snack Bar Making Process Flow Chart

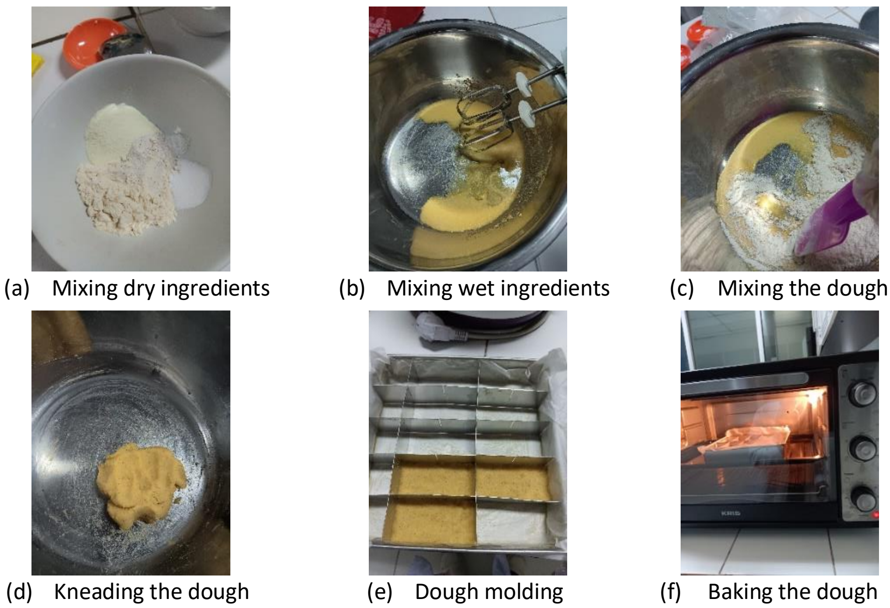

Figure 4. Snack Bar Making Process

Hedonic Test

Hedonic tests were conducted on snack bars to determine the level of consumer preference for snack bars. Hedonic tests, also known as preference tests, mean that participants provide personal responses related to their preferences of liking or disliking, as well as their level of preference[20]. Semi-trained panelists used in this test consisted of 30 active students of the Nutrition Study Program, FIKES UPN "Veteran" Jakarta who had studied and conducted hedonic tests before. Panelists were asked to taste all three snack bar formulations and complete a sensory evaluation form. Inclusion criteria required participants to be willing and able to perform the sensory test. Exclusion criteria include panelists who are sick, undergoing treatment, colorblind or have a history of allergies to ingredients in the snack bar, such as eggs and cow's milk. The hedonic test assessment used a hedonic scale of 1-5 from the parameters of color, taste, texture, and aroma, where 1 represents "very dislike,", 2 represents "dislike", 3 represents "neutral", 4 represents "like", and 5 represents "very like".

Proximate Analysis

The proximate analysis of the sorghum flour and coconut flour snack bars includes moisture content testing using oven drying, ash content using direct ashing, protein content using the Kjeldahl method, fat content using Soxhlet extraction, and carbohydrate content using

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the by difference method[21]. Dietary fiber content was analyzed using the enzymatic-gravimetric method[21].

Moisture Content Analysis

Moisture content was analyzed using the oven method, which is based on the principle of calculating the weight difference of the sample before and after the drying process[22]. The procedure began with drying a porcelain crucible in an oven at 105°C for 30 minutes. The crucible was then placed in a desiccator for 30 minutes to cool. Afterward, the crucible was weighed, and the weight was recorded. A 2-gram sample was then placed in the crucible. Then, the crucible was dried in an oven at 105°C for 3 hours and placed back into a desiccator for 30 minutes, before being weighed again. Finally, weigh the crucible containing the sample. This process was repeated until a constant weight was achieved. The moisture content was calculated using the following formula:

$$\text{Moisture Content Percentage} = \frac{B - C}{B - A} \times 100\%$$

Notes:
A = Initial weight of the crucible (g)
B = Weight of the crucible and sample before drying (g)
C = Weight of the crucible and sample after drying (g)

Ash Content Analysis

The determination of ash content was conducted using the dry ashing method. This method is based on the principle that the ash content of a sample is determined by weighing the residue left after high-temperature combustion of organic components in a muffle furnace[22]. The procedure began with drying an empty porcelain crucible in an oven at 105°C for 30 minutes. The crucible was then cooled in a desiccator for 30 minutes before being weighed. A 3-gram sample was placed into the crucible and subjected to initial combustion in a fume hood until smoke ceased. After that, the crucible was then ashed in an electric muffle furnace at 400–600°C for 4–6 hours until a complete ash residue was formed. After ashing, the crucible containing the sample was cooled in a desiccator for 30 minutes and weighed. This process was repeated until a constant weight was achieved. The ash content was calculated using the following formula:

$$\text{Ash Content Percentage} = \frac{W2 - W1}{W} \times 100\%$$

Notes:
W = Weight of the Sample (g)
W1 = Initial Weight of the Crucible (g)
W2 = Weight of the Crucible and Sample After Ashing (g)

Protein Content Analysis

Protein content was analyzed using the Kjeldahl method by determining the total nitrogen content. The procedure began by preparing a 1 g homogeneous sample and placing it into a Kjeldahl flask. After that, add a catalyst of 4 g of mercury oxide and 0.19 g of potassium sulfate and 0.38 ml of concentrate to be burned using a Bunsen burner. Next, the destruction stage is to decompose the elements of the sample until the sample is clear green. Then, the digestion flask was cooled before transferring the solution to the distillation flask and adding 100 ml of distilled water to dilute the solution. After that, 500 µL of boric acid solution was added along with 4 drops of indicator. After that, position the destruction flask under the condenser and slowly insert the top of the condenser into the boric acid solution. The next process was the addition of 8 to 10 ml of NaOH-$Na_3S_2O_3$ solution into the distillation apparatus until 15 ml of distillate was obtained in the titration flask. Finally, the solution was titrated using 0.02 N hydrochloric acid solution, resulting in a color change to blue.

$$\text{Nitrogen Percentage (\%N)} = \frac{(\text{mL HCl sample} - \text{mL HCl blank}) \times \text{N HCl} \times 14{,}007}{\text{sample weight (mg)}} \times 100\%$$

$$\text{Protein Percentage} = \%N \times 6{,}25$$

Fat Content Analysis

Fat content was directly analyzed using the Soxhlet extraction method with organic solvents such as hexane, diethyl ether, or ethyl acetate[22]. The procedure began by drying a round-bottom flask in an oven at 105°C. The flask was then cooled in a desiccator for 30 minutes, and its weight was recorded. Next, a 5 g dry sample was prepared, wrapped in filter paper, and placed into the Soxhlet extraction apparatus. The Soxhlet apparatus was set up by connecting the condenser, hot plate, and round-bottom flask, which contained boiling stones. Hexane was used as the solvent, filling half the volume of the boiling flask. The extraction process lasted 6 hours or approximately six cycles. After extraction, the solvent was separated from the extracted fat in the flask. The extracted fat was separated from the solvent in the round-bottom flask through distillation for 30 minutes. The extracted fat was then dried in an oven and placed back into the desiccator. Finally, the weighing was carried

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out until a constant weight was achieved. The calculation or determining the fat content is as follows:

$$\text{Fat Content Percentage} = \frac{W1 - W2}{W} \times 100\%$$

Notes:
W = Weight of the Sample (g)
W1 = Weight of the Round-Bottom Flask Before Extraction (g)
W2 = Weight of the Round-Bottom Flask After Extraction (g)

Carbohydrate Content Analysis

By difference is one of the carbohydrate analysis methods that calculate the result by subtracting the combined percentages of moisture, fat, protein, and ash from the total percentage of the tested sample. The formula for carbohydrate content calculation is as follows:

$$\text{Carbohydrate Content Percentage} = 100\% - (\text{Moisture Content} + \text{Protein Content} + \text{Fat Content} + \text{Ash Content})\%$$

Dietary Fiber Analysis

Dietary fiber analysis was conducted using the enzymatic-gravimetric method. Before testing for dietary fiber, enzymatic treatment was applied to remove fat, protein, and starch from the sample using amyloglucosidase, Termamyl (heat-stable α-amylase), and protease to eliminate protein and starch. The first step involved drying an empty filter paper in an oven and weighing it to obtain the initial weight. Next, a 0.5 g fat-free sample was placed in an Erlenmeyer flask. The sample was then incubated by adding 25 ml of 0.08 M phosphate buffer at pH 6 and 50 µl of Termamyl for 30 minutes at 95°C. The sample was stirred every 5 minutes during incubation, followed by cooling. After cooling, the sample was incubated again by adding 5 ml of 0.275 N NaOH and 0.1 ml of protease for 30 minutes at 60°C.

Next, 0.325 N HCl was added to adjust the pH to 4.5 after the sample had cooled. Then, 150 µl of amyloglucosidase was added, and the sample was incubated again for 30 minutes at 60°C. Subsequently, 95% ethanol preheated to 60°C was mixed into the sample and left undisturbed for 1 hour to form a residue. The residue was then filtered using a vacuum filter with 140 ml of ethanol. Celite was weighed in a crucible to a precision of 0.1 mg. The residue was then continuously washed with 78% ethanol (3 × 20 ml), acetone (2 × 10 ml), and 95% ethanol (2 × 10 ml). The sample residue in the crucible was dried in an oven at 105°C overnight. Afterward, it was cooled in a desiccator. The dry residue weight was determined by subtracting the weight of the crucible and Celite. The sample residue is also analyzed for residual protein using the Kjeldahl method. Additionally, the duplicate sample is ashed for 5 hours in a muffle furnace at 525°C. The resulting ash is placed in a desiccator. The residue is then weighed with an accuracy of up to 0.1 mg. Subsequently, the weight of the crucible and celite is measured to determine the ash residue weight.

$$\text{Total Dietary Fiber} = \frac{\text{W Dry residue} - \text{W Ash residue} - \text{W Protein residue}}{\text{W Sample}} \times 100\%$$

Data Analysis

The chemical test was analyzed using One-Way ANOVA, with conclusions drawn based on a significance level of 0.05. If significant, Duncan's Multiple Range Test (DMRT) was conducted for further analysis. Meanwhile, the data analysis for the hedonic test used the Kruskal-Wallis test, with conclusions drawn from a significance level of 0.05. If significant, the Mann–Whitney U test was performed for additional comparison. The De Garmo method selected the best snack bar formulation based on nutritional content, dietary fiber, and hedonic test results.

RESULTS AND DISCUSSIONS

Snack Bar Nutritional Analysis Results

Food contains chemicals called nutrients that are needed to maintain the normal functioning of the body and live a healthy, intelligent, and productive life[23]. The nutritional components analyzed in the snack bars included moisture, ash, protein, fat, and carbohydrates. Table 2 presents the chemical composition of the snack bars.

Table 2. Chemical Analysis Results of Sorghum Flour and Coconut Flour Snack Bars

Parameter	Chemical Analysis Results			p-value	USDA*[24]	Commercial
	F1	F2	F3			
Water (%)	35.5 ± 0.063^{a}	35.4 ± 0.120^{a}	35.2 ± 1.067^{a}	0.889	11.3	10.67[25]
Ash (%)	2.28 ± 0.000^{a}	2.63 ± 0.049^{b}	2.97 ± 0.021^{c}	0.000	1.72	2.65[25]
Protein (%)	11.70 ± 0.155^{a}	12.53 ± 0.219^{b}	13.68 ± 0.021^{c}	0.002	9.38	16.6[26]
Fat (%)	13.52 ± 0.360^{a}	15.17 ± 0.749^{b}	15.55 ± 0.063^{b}	0.047	10.9	29.9[26]
Carbohydrate (%)	36.47 ± 0.120^{a}	34.23 ± 1.131^{ab}	32.56 ± 1.039^{b}	0.049	66.7	39.9[26]
Dietary Fiber (%)	21.01 ± 0.120^{a}	30.07 ± 0.127^{b}	32.74 ± 0.127^{c}	0.000	7.5	16.6[26]

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Numbers accompanied by the same letter in the same column indicate that there was no significant difference at the Duncan test level with a value of 5% *USDA = United States Department of Agriculture

Moisture Content

Moisture content refers to the physical characteristics of a material that indicates the amount of water in a product or food[27]. Moisture content was determined using the oven drying method. Table 2 presents the average moisture content of the sorghum and coconut flour snack bars was 35.5%. 35.4%. and 34.2% for F1, F2, and F3, respectively. Based on Table 2, ANOVA results indicated no significant differences in moisture content across the formulations (p=0.889). The results also showed that the percentage of coconut flour was inversely proportional to its moisture content, meaning that as the percentage of coconut flour increased, the moisture content decreased. Coconut flour contained 4.18% moisture, which was lower than the moisture content of sorghum flour at 10.81%[28,29]. Additionally, the fiber in coconut flour could not bind water in the mixture, causing water to evaporate more easily during the heating process[30].

The moisture content of the snack bars, as shown in Table 2, decreased due to water evaporation during baking. However, the values still classify them as high-moisture products, potentially decreasing product shelf life. The formulation of the three snack bar products contained more water content than the USDA snack bar (11.3%) and the commercial snack bar (10.67%). This showed that the snack bar in this study did not meet the applicable standards. The moisture content results were following the research of Sarifudin et al. (2015), which indicated that the higher the amount of eggs added, the higher the water content in the snack bar. However, the moisture content of the snack bar in this study was considered appropriate because it was categorized as a semi-wet product containing around 20 to 50%[32].

Ash Content

Ash content is an important parameter in the evaluation of nutritional value, as it represents the total mineral content in food ingredients[33]. Determination of the ash content of snack bars using the enzymatic gravimetric method. The results of the analysis showed that the average ash content of sorghum flour and coconut flour snack bars were 2.28%, 2.63%, and 2.97%, respectively. The highest water content was shown by snack bar F3, inversely proportional to the lowest water content shown by snack bar F1. ANOVA results showed that the proportion of sorghum and coconut flour had a significant difference in the ash content of the snack bar (p-value<0.001). Further DMRT analysis was performed to determine the smallest level of difference in the average ash content of the products. The results showed a significant difference in ash content among the three treatments.

Based on the results of the analysis, An increase in ash content was observed with the higher composition of coconut flour. The ash content of coconut flour was higher at 1.97%, as compared to the ash content of sorghum flour, which was 1.49%[28,29]. The high ash content was related to the highest mineral content found in coconut, such as potassium, sodium, and calcium[11]. In addition, water content can affect the ash content of food ingredients because high water content causes an increase in the amount of minerals in a food[34]. This study is in line with the increase in water content in snack bar products from F1 to F3. Based on Table 7, the three snack bar formulas exceed the USDA snack bar ash content standard, which is a maximum of 1.72% and commercial snack bars 2.65%.

Protein

Protein is a polymer of amino acids linked through α-peptide bonds[35]. Table 2 shows an increase in snack bars from F1 to F3. The ANOVA results showed that there was a significant difference in the proportion of sorghum flour and coconut flour on the protein content of snack bars (p-value=0.002). DMRT follow-up tests were conducted to determine the smallest difference in the average protein content of snack bars. The results showed a significant difference in protein content among the three treatments.

Previous studies revealed that the protein content of coconut flour was higher at 14.79%, compared to 9.49% for sorghum flour. thus contributing to an increase in the protein content of snack bars[36,29]. This means that the protein content of snack bars will increase as the amount of coconut flour increases. Sorghum flour and coconut flour snack bars contain between 11.7-13.68% protein, which is higher than the USDA standard of at least 9.38%. However, the protein content results were lower than those of commercial snack bars, which have a protein content of 16.6%. Protein plays an important role in controlling diabetes mellitus. Protein can affect the decrease in the Glycemic Index (GI) of food by slowing down the absorption of dietary carbohydrates so that it can stabilize blood glucose levels[37]. Protein consumption can stimulate the secretion of incretin peptides, such as Glucagon-Like Peptide-1 (GLP-1) to increase the release of insulin from pancreatic beta cells so that it can help control blood sugar levels[38].

Fat

Lipid is biological compounds that are usually soluble in organic solvents and insoluble in water[39]. The fat content was determined using the Soxhlet method. Treatment F3 was the treatment with the highest fat content, while treatment F1 was the treatment with the lowest fat content. ANOVA analysis results showed that the proportion of sorghum flour and coconut flour had a significant difference in the fat content of snack bars (p-value=0.047). The results of the Duncan analysis showed that the fat content of F1 and F2 and F1 and F3 were significantly different, while the fat content in treatment F2 did not differ significantly from F3.

Increasing the proportion of coconut flour has an effect on increasing the fat content in snack bars. This is related to coconut flour containing 33.56% more fat than sorghum flour fat content of 3.52%[40,29]. The snack bar products in this study had a fat content ranging from 13.52% to 15.55%, which is slightly higher than the USDA snack bar fat content standard of 10.9%. However, the fat

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content results were lower than those of commercial snack bars, which have a fat content of 29.9%. Fat is related to controlling blood sugar levels in the body. Fat also plays a role in coating carbohydrates in the digestive tract, thereby slowing the absorption of glucose into the blood[41]. Fat has several mechanisms that can increase satiety and cause delayed gastric emptying such as stimulation of PYY and CCK hormones and increased GLP-1 secretion[42].

Carbohydrate

Carbohydrates are macromolecules that have carbon, hydrogen, and oxygen atoms as the main components and generally have a hydrogen-oxygen atom ratio of 2:1[43]. Table 1 shows a decrease in carbohydrate levels in each treatment. ANOVA analysis showed that the proportion of sorghum flour and coconut flour had a significant difference in the carbohydrate content of snack bars (p-value=0.049). The results of Duncan's analysis showed that the carbohydrate content of treatment F1 was significantly different from F3, while treatments F1 and F2 and treatments F2 and F3 did not have a significant difference.

The study showed that the carbohydrate content of sorghum flour was 74.95% higher than coconut flour at 54.2%[44,29]. The carbohydrate content of sorghum flour and coconut flour snack bars ranged from 32.56-36.47%. Based on Table 7, these results are lower than the USDA standard for snack bars, which is 66.7%, and the commercial snack bar, which is 39.9% per 100 gram. The by-difference analysis method relies on the presence of other nutritional components; the smaller the proportion of other components, the higher the carbohydrate content[45]. The role of carbohydrates in blood sugar management depends on the type of carbohydrate consumed. Complex carbohydrates can help control blood sugar levels as they tend to have a low glycemic index[46]. The amylose content in sorghum flour and coconut flour is higher than amylopectin, making the snack bars suitable for consumption by individuals with diabetes[29,47].

Dietary Fiber

Dietary fiber is a complex mixture of plant carbohydrate polymers resistant to digestion by gastrointestinal enzymes and subsequent absorption in the human small intestine[48]. The F3 formulation had the highest dietary fiber content at 32.74%, while the F1 formulation had the lowest at 21.01%. ANOVA analysis results found that the proportion of sorghum flour and coconut flour had a significant difference in the dietary fiber content of the snack bar (p-value<0.001). The DMRT analysis showed a significant difference in dietary fiber among the three treatments. Studies indicate that sorghum flour has a lower fiber content (2.72%) compared to coconut flour (60.41%)[36,29]. These findings align with Jiamjariyatam et al. (2022), who reported that a higher proportion of coconut flour in food production increases dietary fiber content[36]. The dietary fiber content of the sorghum and coconut flour snack bars ranged from 21.01% to 32.74%, which is higher than the USDA standard snack bars (7.5%) and commercial snack bars (16.6%) per 100 grams.

Fiber is an essential component in managing type 2 diabetes mellitus, both through soluble and insoluble fibers[49]. Soluble fiber is more effective in controlling blood sugar levels by mediating the interaction between diet and the microbiota to enhance glucose homeostasis compared to other types of fiber that achieved through the fermentation of Short-Chain Fatty Acids (SCFAs) in the gut[50]. SCFAs promote the release of Peptide YY (PYY) and Glucagon-Like Peptide-1 (GLP-1), which increase satiety, enhance insulin secretion, inhibit glucagon release, improve insulin sensitivity, boost intestinal gluconeogenesis, and reduce inflammation associated with diabetes mellitus[51]. Meanwhile, insoluble fiber can indirectly minimize the risk of type 2 diabetes by controlling body weight and increasing fecal glucose excretion[52].

Snack Bar Hedonic Test Results

The hedonic test aims to analyze panelists' preference levels for a product based on specific test parameters. Sensory attributes need to be considered such as appearance, texture, taste, and aroma so that they become determinants of the consumer's preference level (hedonic) for a food[53]. Based on the hedonic test, sorghum flour and coconut flour snack bars in median value can be seen in Table 3.

Table 3. Median Value of Hedonic Test of Sorghum Flour and Coconut Flour Snack Bars

Parameter	Median Value of Snack Bar Hedonic Test			p-value
	F1	F2	F3	
Color	4 (2-5) ^{a}	4 (2-5) ^{a}	4 (1-5) ^{a}	0.673
Taste	3.5 (2-5) ^{a}	4 (3-5) ^{b}	4.5 (2-5) ^{c}	0.004
Texture	3 (2-5) ^{a}	4 (2-5) ^{a}	4 (2-5) ^{a}	0.453
Smell	4 (2-5) ^{a}	4 (3-5) ^{a}	4 (2-5) ^{a}	0.105

1 indicates very dislike; 2 indicates dislike; 3 indicates neutral; 4 indicates like; 5 indicates very like, numbers accompanied by the same letter in the same column indicate that there was no real difference at the Mann-Whitney Test level with a value of 5%

Color

Color is the first visual characteristic perceived by consumers before evaluating other attributes, making it a crucial factor in attracting consumer interest[54]. The appearance of the snack bar is presented in Figure 5. The hedonic test results indicate that the color of the snack bars received a fairly good evaluation from the panelists, with a median score of 4, indicating "like". The Kruskal-Wallis analysis revealed no significant differences in color perception among varying proportions of sorghum flour and coconut flour in the snack bars (p-value=0.673), so no further Mann-Whitney test was conducted. The three

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snack bar formulations were influenced by the use of coconut flour. An increase in the proportion of coconut flour will affect the brightness of the snack bar color[55]. This is because the whiteness value of coconut flour is 90% compared to sorghum flour 60% so it can provide a bright color to food products[56,57]. Additionally, the brownish color is influenced by the carbohydrate and protein content in sorghum flour, which can lead to non-enzymatic browning reactions that cause browning during the baking process[58].

Figure 5. Snack Bar of Each Formulation

Smell

Food aroma has a significant influence on consumer preference[59]. Table 3 shows that the median value for aroma preference across the three snack bar formulations is 4, indicating "like". The Kruskal-Wallis analysis indicates no significant differences in aroma based on the proportions of sorghum flour and coconut flour in the snack bars (p-value=0.105), so no further tests were conducted. The aroma parameter of this product may be influenced by the proportions of the two flours. The fat content in coconut flour contributes to the formation of a distinctive food aroma[28]. Increasing the amount of coconut flour used enhances the noticeable coconut flour aroma[60]. This aligns with previous product studies, where formulations with a higher proportion of coconut flour were generally more preferred by panelists for their aroma[61].

Texture

Texture is a complex sensory attribute as it combines multiple physical properties through touch, hearing, and vision[53]. Table 3 shows that the median value for texture were 4 (like) for F2 and F3 and 3 (neutral) for F1. The Kruskal-Wallis analysis indicated no significant differences in texture based on sorghum flour and coconut flour proportions in the snack bars (p-value=0.453). The texture formation of snack bars is influenced by fiber content. Increased fiber sources reduce the hardness and brittleness of the product[36]. The relatively high crude fiber content in coconut flour (60%) can also create a grainy texture in snack bars, meaning that a higher substitution ratio of coconut flour results in a coarser texture in the mouth[15,58]. Other ingredients in the snack bar mixture, such as margarine, can affect the crispness of the snack bar[58]. The higher the addition of margarine, the lower the hardness and breaking strength[62]. In addition, water content can also affect the texture of the snack bar. The crispiness of the snack bar is lower when the water content is higher[63].

Taste

Taste is one of the sensory attributes that significantly influences the final evaluation of a product through consumer acceptance of food or beverages[64]. Table 3 shows that the median scores for the snack bars F1, F2, and F3 reached the maximum value of 5 (strongly like). The Kruskal-Wallis analysis indicated a significant difference in taste based on the proportion of sorghum flour and coconut flour in the snack bars (p-value=0.004), justifying further Mann-Whitney tests. Based on further testing, the level of liking the taste of the snack bar had a difference between F1 and F2 (p-value=0,043) and F1 and F3 (p-value=0.002). However, no significant difference was found between F2 and F3 (p-value=0.118). These results suggest that a higher proportion of coconut flour tends to make the product preferred by panelists, while the opposite is true for sorghum flour. The savory flavor characteristic of coconut flour influences the panelists' preference for the snack bars[65]. Additionally, the sweetness of coconut flour, enhanced by added sugar and starch breakdown, also contributes to the panelists' preference for the snack bars[66].

Determination of Selected Formulation

The selected formulation was determined using the De Garmo method[67]. The expected product is a product with the highest dietary fiber content. The selected formulation from the calculation results of the De Garmo method is the F3 formula which has the highest total productivity value with a proportion of sorghum flour and coconut flour of 30:70.

Determining Serving Size and Nutritional Composition of Snack Bars

The serving size is the amount of processed food that is appropriate to consume in one serving[68]. Commercially sold snack bars typically have a serving size ranging from 25 to 50 grams. In this study, sorghum and coconut flour snack bars yielded three bars totaling 100 grams, making the serving size for one bar 30 grams. Food labels contain information about the nutritional value of the food. This nutritional information is calculated based on Acuan Label Gizi (ALG) and expressed as a percentage of Angka Kecukupan Gizi (AKG). Table 4 shows that the energy, protein, fat, and carbohydrate content do not meet the 10% ALG nutritional requirements for a single snack serving in one day. However, the nutritional needs for a snack can be met by consuming 2 bars or 60 grams per day.

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Table 4. Nutritional Content of Sorghum Flour and Coconut Flour Snack Bars in Serving Sizes

Nutritional Content	Nutritional Content/100 g	Amount of Nutrients/Serving (30 g)	ALG[69]	%ALG/Serving (30 g)
Energy (kkal)	325.03	108.34	2150	5.04
Protein (g)	13.68	4.56	60	7.60
Fat (g)	15.55	5.18	67	7.74
Carbohydrate (g)	32.56	10.85	325	3.34
Dietary Fiber (g)	32.74	10.91	30	36.38

In this study, the serving size was also determined to meet the fiber needs of individuals with type 2 diabetes mellitus. The analysis showed that the dietary fiber content of the selected snack bar formulation (F3) was the highest among all treatments, at 32.74 g. The daily fiber requirement for individuals with diabetes is 20-35 g per day[3]. Meanwhile, the need for snack foods accounts for 10% of total daily energy requirements. Assuming a daily fiber need of 35 g, consuming one snack bar (30 g) per day could meet 31.17% of the daily fiber requirement. In addition, the snack bar product has also met the requirements for products containing high fiber. This is following BPOM Regulation No. 13 of 2016 explaining that a food product can be determined to be high in fiber based on the weight of 100 grams of solid material containing at least 6 grams of dietary fiber (6%)[69].

High-fiber snack bars can help regulate blood glucose levels and promote longer satiety[70]. The product developed in this study meets the fiber requirements for individuals with type 2 diabetes mellitus (T2DM), making this one of its primary strengths. Another strength of the study lies in the use of locally sourced ingredients, such as sorghum flour and coconut flour, which are high in fiber and have potential as functional food components. In addition, the product formulation underwent chemical analysis and hedonic testing, both of which yielded statistically significant results. However, this study has several limitations. As the glycemic index was not evaluated, the product's potential classification as low-glycemic remains unsubstantiated at this stage. Physical property analysis and effectiveness testing in the community were also not conducted due to budget constraints. Future research is recommended to evaluate the glycemic index, shelf life, physical characteristics, and clinical effectiveness of the snack bar in individuals with diabetes mellitus.

CONCLUSIONS

The chemical analysis of sorghum and coconut flour proportions in the snack bar showed significant differences in ash, fat, protein, carbohydrate, and dietary fiber content (p-value≤0.05). The hedonic test also revealed significant differences in organoleptic properties, especially taste (p-value≤0.05). Formula F3, with a 30:70 ratio of sorghum to coconut flour, was selected as the best formulation based on nutritional value, dietary fiber content, and sensory acceptance. A 30 g serving of the selected snack bar provides 108.34 kcal energy, 4.56 g protein, 5.18 g fat, 10.85 g carbohydrates, and 10.91 g dietary fiber—meeting the criteria for a high-fiber food claim. This snack bar has the potential to serve as a functional food to help manage blood glucose levels. Further research is recommended to analyze its glycemic index, effectiveness in people with diabetes mellitus, shelf life, and physical characteristics for further product development.

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AUTHOR CONTRIBUTIONS

RSZ: writing–original draft; AF dan IMBI: supervision, writing–review and editing.

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