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The Effect of Substituting Wheat Flour with Rice Bran and Red Ginger (*Zingiber officinale var. rubrum*) on the Texture Profile of Cookies

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ABSTRACT

Cardiovascular disease is a major global health problem, with elevated cholesterol levels recognized as one of its important risk factors. Developing functional snack products using locally available ingredients represents a promising approach to support cholesterol management. In this context, the incorporation of rice bran and red ginger into cookie formulations offers a potential innovation due to their bioactive components. This study aimed to determine the effect of substituting wheat flour with rice bran and red ginger on various textural attributes of cookies, including hardness, cohesiveness, adhesiveness, fracturability, crispiness, and crunchiness. The research employed an experimental method using a completely randomized design (CRD) with three levels of wheat flour substitution: P0 (0%), P1 (25%), and P2 (50%). Cookie texture was measured using a texture analyzer, and the data were analyzed with a one-way ANOVA followed by Duncan's Multiple Range Test (DMRT) to identify significant differences among treatments. The results indicated that substituting wheat flour with rice bran and red ginger significantly influenced hardness, cohesiveness, crispiness, and crunchiness of the cookies ($p < 0.05$), while adhesiveness and fracturability were not significantly affected ($p > 0.05$). Overall, this study highlights the potential for developing functional cookie products utilizing locally sourced ingredients to support healthier dietary options.

1.INTRODUCTION

Cardiovascular diseases, including coronary heart disease, are a major public health concern and remain one of the leading causes of death worldwide [1] . The pathogenesis of this disease typically begins with elevated blood cholesterol, leading to lipid deposition within the coronary arteries. This condition impairs blood flow and may result in arterial narrowing [2]. Referring to the World Health Organization (WHO) data, heart disease accounts for approximately 17.8 million deaths worldwide. In Indonesia, coronary heart disease (CHD) is the major cause of death, accounting for 14.4% of all deaths. Around 50% of CHD sufferers are reported to have the potential to experience sudden cardiac arrest, as reported by the Institute for Health Metrics and Evaluation (IHME) [3]. One risk factor for CHD is dyslipidemia due to lipid metabolism disorders manifested by increased concentrations of total cholesterol, low-density lipoprotein (LDL), and triglycerides (TG), and decreased high-density lipoprotein (HDL). Older people with elevated total cholesterol levels have a significantly higher risk of developing CHD, with the likelihood increasing up to fivefold [4].

Rice bran can be an alternative food to reduce cholesterol levels. Rice bran, a byproduct of the rice milling process, is rich in dietary fiber that supports digestion and helps lower blood cholesterol levels [5,6]. Moreover, it contains various bioactive compounds such as oryzanol, phytic acid, coumaric acid, caffeic acid, ferulic acid, tricine, carotenoids (lycopene, lutein, and carotene), phytosterols (sitosterol, campesterol, and stigmasterol), and vitamin E isoforms (tocotrienols and tocopherols) [7]. Therefore, rice bran is considered a functional food. This local food ingredient is relatively more accessible and cheaper than wheat, oats (oatmeal), and soybeans, which are commonly used in various dietary baked products such as whole wheat biscuits, whole wheat bread, oatmeal cookies, and soy bars [8]. However, the utilization of rice bran remains limited due to its tendency to develop a rancid odor. Therefore, to extend its shelf life, rice bran should be roasted to inactivate the lipoxygenase enzyme responsible for lipid degradation [9].

In addition to rice bran, red ginger, which is a native Indonesian spice, can also lower cholesterol levels (*Zingiber officinale var. rubrum*). Red ginger has been widely used in traditional medicine and beverages. It contains volatile compounds (terpenoids) and non-volatile compounds (gingerol, paradol, shogaol, zingerone, flavonoids, and polyphenols) that help neutralize free radicals in the body [10]. It also contains a large number of flavonoid compounds such as shogaol and gingerol, with 6-shogaol and 6-gingerol, 8-gingerol, and 10-gingerol contents higher than those of Elephant ginger at 14.09, 4.61, 18.03, and 1.36 mg/g, respectively. Gingerol contains a bioactive compound that can inhibit cholesterol biosynthesis by obstructing access from the substrate to the active site of the HMG-CoA reductase enzyme [11]. Therefore, ginger can prevent elevated cholesterol levels.

Utilizing rice bran as a food ingredient is an innovation in the food sector, as it has mainly been used as animal feed [12]. The combination of rice bran and red ginger can be potential and functional food rich in fiber and bioactive compounds, offering health benefits by helping to prevent increased blood cholesterol levels. The utilization of rice bran and red ginger in cookie formulation has not been extensively explored and remains limited in practice. This innovation is expected to be popular and increase consumption in the community. Cookies' texture can be assessed through sensory assessments, such as biting, chewing, swallowing, and through finger touch, but this can be inconsistent or subjective. A more consistent assessment can use tools to assess hardness and crispness [13,14]. This study aims to investigate the impacts of substituting wheat flour with rice bran and red ginger on cookies' texture profile, covering hardness, cohesiveness, adhesiveness, fracturability, crispiness, and crunchiness, for better consumer acceptance.

2.MATERIALS AND METHODS

1.1. Experimental design of the study

This research used a completely randomized design (CRD) with two experimental replications and two analytical replications. This research has received ethical approval from the Ethics Committee of Alma Ata University (No: KE/AA/VII/10111882/EC/2024). The combination of rice bran and ginger flour used a 4:1 ratio. The treatments were the concentration of wheat flour substitution of P1 (25% substitution), P2 (50% substitution), with a control of P0 (0% substitution). This research was conducted in April – May 2024. The production of rice bran and red ginger flour cookies was carried out at the Food Technology Laboratory of Alma Ata University. Then, the cookies' texture was analyzed at the Laboratory of the Department of Food Technology and Agricultural Products, Gadjah Mada University. In this research, the independent variable was the substitution of wheat flour with rice bran and red ginger flour, while the dependent variable was the texture profile of the cookies. The formula of cookies with wheat flour substitution is presented in Table 1.

Table 1. Substitution formula for wheat flour with a combination of rice bran and red ginger flour

Ingredients (g)	P0(0%)	P1(25%)	P2(50%)
Wheat flour	228	171	114
Mixed flour (rice bran +red ginger 4:1)	0	57	114
Margarine	175	175	175
Butter	25	25	25
Palm sugar	200	200	200
Granulated sugar	45	45	45
Baking Powder	4,8	4,8	4,8
Egg	50	50	50

1.2. Preparation of cookies

This research used tools such as a scale, frying pan, bowl, mixer, wooden spatula, baking pan, spoon, oven, and a Texture Analyzer (TA-XT plus texture analyzer, Lloyd type TA1). The ingredients used were red ginger flour, low-protein wheat flour, butter, margarine, granulated sugar, palm sugar, baking powder, and eggs. Cookies were made by mixing roasted rice bran with margarine, butter, egg yolks, and palm sugar. Then, the low-protein wheat flour, baking powder, rice bran, and red ginger flour were added to the mixture. The dough was shaped and added with chocolate chips, and then baked in an oven at 180°C for 20 minutes.

1.3. Texture profile analysis

Texture was assessed by applying pressure to cookie samples using a texture analyzer. This process produced a texture profile in the form of a graphic representing the relationship between the applied force and the distance of the tester's movement. This profile allows for the identification of specific texture parameters such as hardness, the maximum force required to break the sample; cohesiveness, which is the sample's ability to maintain structural integrity after being subjected to force; adhesiveness, which is the energy required to detach the sample from the tool surface; fracturability, which is the force required to cause the first fracture in the sample; crispiness, which is the fracture characteristic that produces a high-pitched sound; and crunchiness, which is the fracture characteristic that produces a low-pitched sound [15]. This method produced an accurate quantitative description of the texture quality of cookies produced from various formulations.

1.4. Statistical analysis

All research data were presented systematically in tables with mean and standard deviation (SD) values for ease of interpretation. Data processing and analysis used SPSS software version 23.0 (IBM Corp., Armonk, NY, USA). The main statistical test used was One-Way Analysis of Variance (ANOVA) with a significance level of 5% ($p < 0.05$) to determine differences between treatments. When the ANOVA results show significant differences, the analysis is continued with Duncan's Multiple Range Test (DMRT) as a post hoc test to determine which treatment groups are significantly different. This aims to ensure that the observed differences in cookie texture parameters are due to the formulation treatment and not random variation.

3. RESULTS AND DISCUSSION

The visual appearance of rice bran and red ginger cookies can be seen in Figure 1. Visually, P0 is slightly lighter brown than P1 and P2. In terms of texture, P0 is crispier and denser, and does not break easily, while P1 and P2 are more brittle, break easily, and have a different crispness than P0. The flour substitution affects the texture of cookies [16].

P0 **P1** **P2**

Fig 1. Cookies made from a combination of red ginger and rice bran flour at 0% (P0), 25% (P1), and 50% (P2) substitutions.

The texture profiles of rice bran and red ginger cookies are presented in Table 2. The substitution significantly affected almost all tested texture profile variables, with the exception of fracturability (p=0.580) and adhesiveness (p=0.300), which showed no significant differences between the control and treatment groups. This indicates that the fracturability and adhesiveness of the cookies remained relatively stable despite the change in flour composition. On the other hand, other texture parameters, such as hardness, crispiness, cohesiveness, and chewiness, significantly changed due to the addition of rice bran and red ginger. Rice bran can influence water distribution in the dough, increase water absorption capacity, and modify the network structure of the cookies, affecting the product's cohesiveness and hardness. Red ginger, contributing bioactive compounds, also has the potential to influence the rheological properties of dough through the interaction of its chemical components with the flour matrix. This change in texture is in line with Lau & Ismail (2024) that the physical and chemical properties of raw materials, including fiber, protein, starch, and bioactive compound content, can influence the final characteristics of food products. Therefore, the formulation of rice bran and red ginger-based cookies requires adjustments in ingredient proportions and baking process to get a preferred texture [17].

Table 2. Texture of rice bran and red ginger-based cookies

Treatment	Indicator of Texture Profile					
	Hardness bite I	***Cohesiveness***	***Adhesiveness***	***Fracturability***	***Crispiness***	***Crunchiness***
P0	410.05 ± 89.78^{b}	0.32 ± 0.31^{a}	30.92 ± 16.42	20.54±16.86	1614.05±485.71^{b}	618.21±235.38^{b}
P1	266.96±42.83^{a}	0.45±0.22^{b}	-12.06 ± 57.49	25.63±17.70	975.13±166.15^{a}	237.03±55.80^{a}
P2	165.99±62.85^{a}	0.47±0.57^{b}	25.79 ± 35.17	39.80±19.43	602.78±183.26^{a}	115.78±43.16^{a}
P-value	**0.020**	**0.010**	0.300	0.580	**0.040**	**0.020**

Description: Numbers with different superscript letters $^{(a,b,c)}$ in the same column indicate a significant difference in the One-Way ANOVA test ($p<0.05$) followed by the Duncan test. Treatments P0 (0%), P1 (25%), and P2 (50%).

Hardness bite 1 is a texture profile to determine the resistance of a material to pressure during the first bite or the amount of pressure required to break a food product. In this research, the developed product has a significantly lower hardness value compared to the control (p=0.020), but there is no significant difference between P1 and P2. Previous research revealed that rice bran contributes to a harder texture [17] because it can absorb water, which can disrupt the gelatinization process, resulting in a dense and hard texture [18]. In this study, the hardness was lower when substituting wheat flour with rice bran, but the concentration of rice bran added did not affect the level of hardness. This is because the large amount of water bound within the product fibers increases the drying load (baking time and temperature). Therefore, with the same drying time, P1 and P2 produced wetter cookies than P0, resulting in softer products [5]. Wheat flour contains gluten, which acts as an elasticity enhancer, water absorber, coagulant, and leavening agent when mixed with water, facilitating the formation of soft dough [19,20]. These findings indicate that reducing gluten content by substituting wheat flour with rice bran and red ginger flour manages to reduce cookie hardness. However, different substitution concentrations do not significantly affect the final result.

Cohesiveness is a material structure that remains strong and compact when subjected to force. Cohesiveness is often referred to as the bonds between the ingredients in a product. Substituting wheat flour with rice bran and red ginger significantly affected cohesiveness (p=0.010). The DMRT test showed that P2 did not differ from P1, but differed from P0. However, the addition of rice bran flour and red ginger at 25% and 50% concentrations did not affect cohesiveness. This can be due to the addition of fiber, which increases water content and helps form bonds with other molecules, resulting in greater cohesiveness. Compact or dense food ingredients are often considered to have a better texture or can affect the sustainability of product storage and processing [21]. On the other hand, Iswara et al. (2020) found high cohesiveness values in products containing a high amount of wheat because wheat contains gluten, which can form a cohesive product when heated [19]. Therefore, rice bran and red ginger flour can be an alternative to improve cookie cohesiveness without relying on wheat.

Adhesiveness is the force required to detach food from a surface. The adhesiveness value for P1 is negative, whereas P2 is positive. However, there is no difference between the control and treatment groups (p = 0.300). A negative adhesiveness value indicates a relatively low force required to separate food from a surface, such as the surface of the tool used in the test [22]. A higher and closer to positive adhesiveness value indicates that food tends to stick more to other surfaces [23]. Substituting wheat flour with rice bran and red ginger flour did not affect adhesiveness (p = 0.300). Although P1 tends to be less sticky compared to P0 and P2, there is no difference in stickiness between all samples. This finding is in line with previous research that the use of flour does not affect the adhesiveness of cookies. Furthermore, it is also in line with the cohesiveness value obtained, which was higher when given the wheat flour substitution treatment. Rice bran contains fiber that can strengthen the bonds between ingredients and prevent surface stickiness [24]. Adding sugar can create a surface stickiness area like syrup [25]. Therefore, substituting wheat flour with rice bran and red ginger does not affect the cookie stickiness level and tends to maintain the desired non-sticky properties of cookies.

Fracturability is a textural assessment to see how a product breaks when being tested or pressed with the front teeth. Fracturability value can be influenced by the composition of the ingredients used to make cookies [26]. Substituting wheat flour with rice bran and red ginger flour does not affect cookie fracturability (p=0.580). Theoretically, fracturability values correlate with hardness, meaning that higher forces required to crush a material indicate a harder texture [16]. In this study, the hardness value was lower with the substitution of wheat flour with rice bran and red ginger, which theoretically should be followed by a decrease in fracturability. However, the finding indicates a insignificant increase in fracturability. Adding fiber causes more water to be absorbed into the material, resulting in increased hardness and fracturability [27] This difference may be due to suboptimal drying, resulting in a higher water content in samples P1 and P2, leading to reduced firmness while not affecting crispness.

Crispiness is a food texture characterized by dryness, stiffness, and the tendency to break easily when pressed or bitten. This characteristic is usually accompanied by a loud, high-pitched, or crunchy sound when biting or breaking the food. The texture of cookies creates a sensation of pressure that can be felt in the mouth when biting, chewing, and swallowing [28]. Substituting wheat flour with rice bran and red ginger significantly affected crispiness (p=0.040). A DMRT test indicates that substituting wheat flour with rice bran and red ginger decreased crispiness, but increasing the substitution concentration did not result in any difference in crispiness (P1 and P2). It can be said that the use of rice bran and red ginger influences the crispiness of cookies, but the effect remains constant at different substitution concentrations.

Previous research indicates that crispness value is inversely proportional to hardness, where the higher the crispness value, the lower the hardness level due to the smaller pressure and force to break a product [29]. This is inconsistent with this research, which suggests a comparable correlation between hardness and crispiness. The addition of rice bran can reduce the crispness of cookies because rice bran has different properties than wheat flour [30]. The crispy texture of wheat cookies can be due to retrogradation during the cooling process. This process causes amylose molecules to emerge from the starch particles that break down due to the decrease in temperature. Amylose molecules are linked to each other and to the amylopectin on the outside of the granules, forming starch grains again, which swell and form a kind of network that forms microcrystals

[24]. The more rice bran flour added to cookies, the less crispy they are.

Crunchiness refers to a dense texture indicated by a relatively low-pitched sound when chewing foods with molars. Biting or pressing cookies with teeth produces a crunchy sound, resulting from the cookies' brittle or crispy structure [31]. Crispness is important in food products, indicating their resistance to fracture under applied pressure [32]. Therefore, the level of crispness is an important indicator in assessing texture quality and consumer acceptance.

Substituting wheat flour with rice bran and red ginger significantly affected crunchiness (p=0.020). DMRT test for rice-bran and red ginger-based cookies obtained lower crunchiness compared to wheat-based cookies. Nadimin et al (2019) revealed that crunchiness is largely influenced by wheat flour, which contains gluten. Gluten is an elastic and hard compound that determines the texture of food. Rice bran does not contain gluten [33]. Therefore, rice bran flour can affect the crispy texture of cookies [33]. Besides, crunchiness is also influenced by the water content in the ingredients [34], and increased fiber content results in denser cookies [16]. In this case, the substitution increased the water and fiber content, resulting in denser cookies with reduced crunchiness.

Rice bran has been sieved, but its texture is still not smooth enough, requiring repeated sieving to achieve a finer grain. The use of poor cookie-storing media, such as plastic, requires tight closure to maintain their texture. This research offers the potential of rice bran as a functional food ingredient. Rice bran contains dietary fiber, B-complex vitamins, antioxidants (such as ferulic acid and oryzanol), and other bioactive compounds that contribute to maintaining body health, reduce cholesterol levels, and improve digestive function. The substitution of wheat flour with rice bran and red ginger results in a nutritious product with added functional and sensory values for supporting the development of locally-based healthy foods.

4.CONCLUSION

The substitution of wheat flour with rice bran and red ginger flour results in decreased hardness, cohesiveness, crunchiness, and crispiness of the cookies. The findings of this study are expected to promote the utilization of rice bran not only as animal feed but also as a functional food ingredient in cookie production, considering their potential health benefits.

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