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Physical and Sensory Characteristics of Gluten Free Cookies Prepared from Black Glutinous Rice and MOCAF Flour Combination

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Abstrak

Cookies are a type of baked goods known for their relatively low moisture content. Extensive research has been conducted to investigate the formulation of a new generation of Gluten Free (GF) foods. MOCAF is known become the wheat flour substitute in gluten free cookies because its physical characteristics are comparable. Black Glutinous Rice Flour (BGRF) is one of the Indonesian food commodities that can be utilized in the formulation of gluten-free cookies along with MOCAF and can enhance the color characteristics of the resulting cookie products. Formulation of the combination of these two ingredients needs to be investigated to produce gluten free cookies that have good physical and sensory characteristics. The aims of these research was to investigate the effect of different ratio of Black Glutinous Rice Flour (BGRF) and MOCAF (MF) formulation (F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100) on physical and sensory parameter of resultant GF cookies. The results shows that, cookies with high amount of BGRF showed interesting physical properties with higher diameter, spread ratio, and ΔE of the cookies, lower weight, thickness, baking loss, L*, a*, b*, C* value, and the hedonic score of color, aroma, taste, texture, overall compared to cookies with 100% MF. The best formula that produces gluten free cookies with the highest taste score score is F4 (BGRF 25%:MF 75%) with physical characteristics weight 10.70 g, diameter 48.40 mm, thickness 8.60 mm, spread ratio 5.63, baking loss 17.37 %, L* 53.96, a* 0.63, b* 17.65, C* 17.66, ΔE 48.78.

INTRODUCTION

Cookies are a type of baked goods known for their relatively low moisture content. They are primarily made up of three key ingredients: flour, sugar, and fat. Additional ingredients that may be included in the cookie dough recipe are chemical leavening agents, syrups, salt, and emulsifiers (Pareyt & Delcour, 2008). Cookies are a popular bakery item that are convenient, have a relatively long shelf life, and are enjoyed by both children and adults. To specific health requirements, researchers have recently developed gluten-free cookies This has led to an increase in research focused on the development of gluten-free cookie products (Culetu et al., 2014; Olawoye et al., 2017; Santos et al., 2020).

Gluten-free cookie recipes typically rely on a combination of rice flour and other ingredients, such as high-protein substances, fats, fiber, hydrocolloids, and specific enzymes, to enhance the texture, taste, and nutritional value of the final product (Naqash et al., 2017). Modified Cassava

Flour (MOCAF) is a gluten-free flour derived from cassava starch that undergoes a fermentation process. This type of flour is gaining popularity as a substitute for wheat flour due to its gluten-free characteristics and considered beneficial for the body and digestion of the individuals with gluten allergies or sensitivities. The sensory and physical properties of MOCAF are comparable to those of wheat flour. (Anggraeni & Yuwono, 2014).

The utilization of pseudocereals have become a new trend in food industry Especially for the development of gluten-free products (Luo et al., 2017; Zhao et al., 2020). Black glutinous rice flour (BGRF) the promising alternative flour made from milled black glutinous rice. This is one of the Indonesian food commodities that can be utilized in the formulation of gluten-free cookies along with MOCAF. The presence of pigments in black glutinous rice flour can enhance the color characteristics of the resulting cookie products. BGRF are known contains anthocyanins pigments, sticky, and opaque after cooking (Awan et al., 2017). Anthocyanins pigments contained in the black and red rice grain can impact their color to purple-black (Kumar & Murali, 2020). The anthocyanins content in pigmented rice varied from 11.33 to 187.23 mg CGE/100g dry weight (Hanifa et al., 2020). The color produced by anthocyanins in black glutinous rice can be utilized as a natural food coloring to enhance the color of the resulting products.

The development of new formulation in gluten-free cookies making can result in products with different physical and sensory characteristics. Therefore, it is necessary to evaluate the appropriate formulation between MOCAF and BGRF to achieve physical and sensory characteristics that align with consumer perceptions. Sensory properties, also known as organoleptic properties, refer to the taste, texture, mouthfeel, aroma and appearance of a food item. The sensory properties of food are highly correlated with physical properties. The physical properties of a product can provide information on why a food item is preferred or not by consumers. Therefore, in further product development, researchers can predict consumer preference levels solely through physical analysis (Arifin et al., 2010).

Several studies have used MOCAF and its combination with other ingredients in making gluten-free cookies, such as Kristanti et al. (2020) with a combination of 75% MOCAF and 25% tempeh flour, Diniyah et al. (2019) with a combination of 75% MOCAF and 25% cornstarch, and Herawati et al. (2018) with a premix of red rice flour: MOCAF (1:3). The use of cowpea flour in cookie making has also been extensively evaluated, such as by (Eneche, 1999) who used a combination of millet flour and cowpea flour, and by Okpala, et al. (2013) who used a mixture of taro flour and fermented sorghum flour. Based on previous literature survey, the combination of Black Glutinous Rice and MOCAF flour and its effect on cookies physical and sensory quality have clearly never been investigated. This combination of these ingredients possesses promising prospects to enhance the utilization of MOCAF and black glutinous rice flour as distinctive commodities in Indonesia.

RESEARCH METHOD

Materials

The materials used in the study were MOCAF flour (MF), Black Glutinous rice flour (BGRF), full cream milk, fine sugar, sodium bicarbonate, salt, vanilla powder, margarine, egg, and water were purchased in local supermarket YAOYA. The formulation of gluten free cookies was shown in Table 1.

Table 1. Formulation of Gluten Free Cookies Prepared From BGRF and MF

Ingredients	Percentage from 100g Flour	Formulation (g)				
		F1	F2	F3	F4	F5
Black Glutinous rice flour	100%	100	75	50	25	0
MOCAF flour		0	25	50	75	100
Fine Sugar	45%	45	45	45	45	45
Sodium Bicarbonate	0.90%	0.9	0.9	0.9	0.9	0.9
Full cream milk powder	10%	10	10	10	10	10
Salt	1%	1	1	1	1	1
Margarine	50%	50	50	50	50	50
Water	10%	10	10	10	10	10
Egg	8%	8	8	8	8	8

Preparation of gluten free cookies

The ingredients used for gluten free cookies are presented in Table 1. The mixing process began by combining shortening and egg for a duration of 1 minute, followed by the addition a half of mixed powdered ingredients (MOCAF flour, Glutinous rice flour, full cream milk, fine sugar, sodium bicarbonate, salt, vanilla powder) mixed them all for 1 min and added with water for 1 minute. Next add the whole mixed powdered ingredients and mixed the all for 3 min to achieve a dough, and the mixture was left to rest for overnight (±8 hour) at 4°C. The dough was flattened into sheets of 0.5 cm thickness. Afterward the dough was shaped using a circular mold with a diameter of 4.7 cm and baked at a temperature of 150°C for 25 minutes. Subsequently, the cookies were allowed to cool and stored separately in sealed bags at room temperature. Three batches of each formulation were prepared and analyzed.

Physical Analysis

In accordance with the established method described by (Yang et al., 2022), physical properties such as weight, diameter, thickness, spread ratio, density, and baking loss of the cookies were evaluated to determine their physical characteristics. In order to determine the physical characteristics of the cookies, the weight and diameter were measured using an electronic analytical balance and a vernier caliper, respectively. The average values of three separate cookies were recorded for each measurement. In accordance with standard methods, the thickness of three stacked cookies was measured using a vernier caliper to calculate the average value. The spread ratio of the cookies, defined as the ratio between the diameter and thickness, was determined using the appropriate mathematical equation (1).

$$Spread\ ratio = \frac{Diameters\ of\ cookies}{Thickness\ of\ cookies} \quad (1)$$

The determination of baking loss, a parameter that measures the weight loss of cookies during baking, was conducted by weighing the cookies before (W1) and after (W2) baking using a precision balance. The percentage of baking loss was calculated using the formula. This method is commonly used in the food industry to assess the quality and texture of baked products (2).

$$Baking\ loss\ (\%) = \frac{W_1 - W_2}{W_1} \times 100 \quad (2)$$

The volume of the cookie dough and baked cookies was measure using mathematical equations for cylinders, using the equation previously used by Nursyahidah & Albab (2021) to identify the volume of cake. The first measurement taken was the diameter (d) of the sample in cm, from which the radius (r) was calculated. The height of the sample was also measured in cm. These measurements were then inputted into equation (4).

$$Volume\ (cm^3) = \pi r^2 t \quad (3)$$

Specific volume is a physical property that describes the amount of volume that a given mass of material occupies. In the context of cookies, specific volume refers to the volume occupied by a certain mass of cookie dough or baked cookie. The measurement of specific volume using method described by Mohammadi et al. (2022) were calculated using the equation (4) below.

$$Spesific\ volume\ \left({cm^3}/{g}\right) = \frac{volume\ (cm^3)}{weight\ (g)} \quad (4)$$

Density is a physical property that describes how much mass is contained in a given volume. In the context of cookies, density refers to how tightly packed the cookie dough is before and after baking, and how much mass the cookie has per unit volume. Density is calculated by dividing the weight of the cookies by their volume as describes by Yang et al. (2022) in equation (5).

$$Density\ \left({g}/{cm^3}\right) = \frac{weight\ of\ cookie(g)}{volume\ of\ cookie\ (cm^3)} \quad (5)$$

The color characteristics of the upper surface of the cookies were assessed using a colorimeter in the CIELab scale to determine the values for lightness (L*), chroma a* and chroma b*. Each test was conducted in triplicate with three replicates for each sample. The L*, a* and b* values were recorded, representing lightness, redness (+a*), greenness (-a*), yellowness (+b*) and blueness (-b*) respectively. Furthermore, the chroma (C*) and total color difference (ΔE) were calculated using the equation below.

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (4)$$

$$\Delta E = \sqrt{(L^* - L0^*)^2 + (a^* - a0^*)^2 + (b^* - b0^*)^2} \quad (5)$$

where $L0^* = 99.50$, $a0^* = 0.06$ and $b0^* = 0.19$, were the color parameters of the white standard plate.

Sensory Analysis

The sensory evaluation of the cookies was conducted according to the procedures outlined by Yang et al. (2022) with some adjustments made to accommodate the unique characteristics of the product. The evaluation was carried out by a panel of 35 healthy male and female participants between the ages of 20 and 49, primarily composed of students, lecturers, and staff from Bumigora University. The panelists used a five-point hedonic scale to rate various attributes, such as color, aroma, taste, texture, and overall acceptability.

Data Analysis

In this study, Minitab software version 16.0 (Minitab Inc, USA) was used to perform all analyses in triplicate. To identify significant differences between any pairs of means at a 95.0% confidence level, a one-way analysis of variance (ANOVA) was conducted, and multiple range tests were employed to determine which means differed significantly from each other. Moreover, a Least Significant Different test

(Fisher test) was utilized to compare means and determine significant differences at a significance level of P<0.05.

RESULT AND DISCUSSION

Physical Characteristics of Gluten Free Dough and Cookies

a. Weight and Density

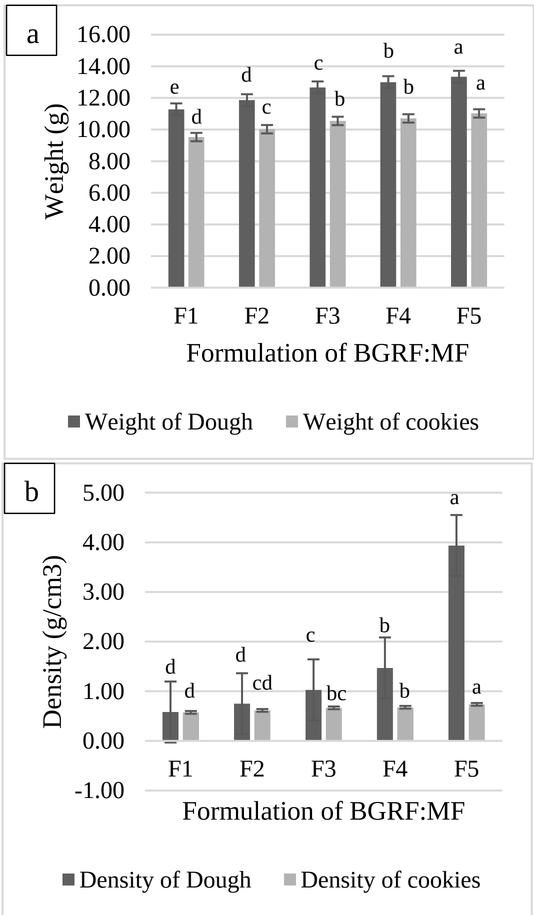

Figure 1. Weight (a) and Density (b) Characteristics of Gluten Free Dough and Cookies prepared with BGRF:MF. F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

The results related to the weight of the gluten-free cookies are presented in Figure 1. The results of the study showed a significant difference (p≤0.05) in weight between the cookie dough before and after baking, made from various formulations of BGRF and MF (F1-F5). During baking, the dough of cookies loses its moisture content due to evaporation of water, causing the weight of the cookies to be lower than the dough. The cookie dough weight decreased from 13.34±0.05 g to 11.28±0.12 g. The same result was found in the weight of the resultant cookies after baking the cookies weight decreased from 11.02±0.13 g to 9.52±0.07 g. A decrease in the weight of dough and baked cookies was observed as the amount of black glutinous rice flour used increased. In the other hand, the result shows that the density of both dough and cookies after baking was significantly (p≤0.05) affected by the difference in the ratio of BGRF and MF in cookies formulation.

The cookies dough density decreased from 3.94±0.07 g/cm^3 to 0.58±0.03 g/cm^3 as the increased in BGRF in cookies formulation, the same results were also found in the density of cookies after baking which showed a decrease in density from 0.74±0.03 g/cm^3 to 0.57±0.05 g/cm^3. The density tended to be lower after baking due to loss of moisture during the baking process, which resulted in a reduction in the weight of the dough, while the volume of the dough increased. Density of cookies refers to the amount of mass per unit volume of the cookie product. It is a measure of the compactness or concentration of the cookies and is calculated by dividing the mass of the cookies by their volume (Yang et al., 2022). The density of cookies can be influenced by a variety of factors, such as the ingredients used, the processing conditions, and the baking time and temperature. Density is an important quality parameter for cookies as it can affect their texture, mouthfeel, and overall sensory properties (Apotiola & Fashakin, 2013; Jemziya & Mahendran, 2017).

This low weight of the dough with high in BGRF content is due to the fact that the initial weight of cookies was lower compared to those that did not use it (MF-Cookies). Although the diameter and thickness of the cookies at the beginning of the process were the same, the dough produced by black glutinous rice flour had a lighter weight resulting in lower density because the resultant dough less cohesive and solid compared to MF-cookies. The type of flour used in a cookie recipe can have a significant impact on the density of the cookies. For example, Black glutinous rice contained high amount of starch component. The starch content in native the black glutinous rice are 71.75% ± 0.14, consisting of 10.12 ± 0.55 % amylose and 34 amylopectin 89.87 ± 0.55% (Rini et al., 2019).

Native starch has limitation in its functionality and poor performance in certain processing condition, for example have low solubility in cold water, poor stability during freezing and thawing, and low water holding capacity of the flour can negatively impact product quality by causing texture changes or loss of moisture over time. Furthermore, the native starch may have limited ability to form a cohesive dough related to the low ability to bind with other components such as water, oil and other component, which can limit its application in certain formulations (Gani et al 2012).

Water absorption is a critical parameter in the preparation of dough and is expressed as the amount of water required to produce a dough with the desired consistency depends on flour formulation (Monteiro et al., 2021). These limitations have led to the development and use of modified starches. Gani et al. (2012) mentioned that the modification of starch has been shown to enhance various properties, such as increased digestibility, emulsifying ability, emulsion stability, encapsulation capability, solubility in cold-water, the presence of charged starch molecules, improved cooking characteristics, film formation, improved gel characteristics such as freeze-thaw stability, viscoelasticity, viscosity, and adhesiveness, as well as water-holding capacity then produce a compact and dense dough.

b. Diameter and Thickness

The results related to the physical attributes of gluten-free cookies are presented in **figure 2**. Results of these study demonstrate that there were statistically significant differences ($p \leq 0.05$) observed among the various formulations with respect diameter of the cookies, however has no significant effect on diameters of the dough. The diameters of the dough varied from 47.23±0.35 mm to 47.60±0.17 mm. As the level of BGRF addition increased diameter of the resultant cookies increased from 47.10±0.52 mm (F5) to 53.23±0.95 mm (F1).

The increase in diameter of the cookies can also be seen visually as shown in **Figure 6**, the observed advancement in the development of the product can be linked to the functional attributes of native glutinous rice flour. Literature has reported several limitations associated with native starch, such as low solubility, low freeze-thaw stability, poor resistance to shear and thermal conditions, low susceptibility to enzymatic hydrolysis, high syneresis, high tendency towards retrogradation, high digestibility, and reduced water absorption capacity (Gani et al., 2012).

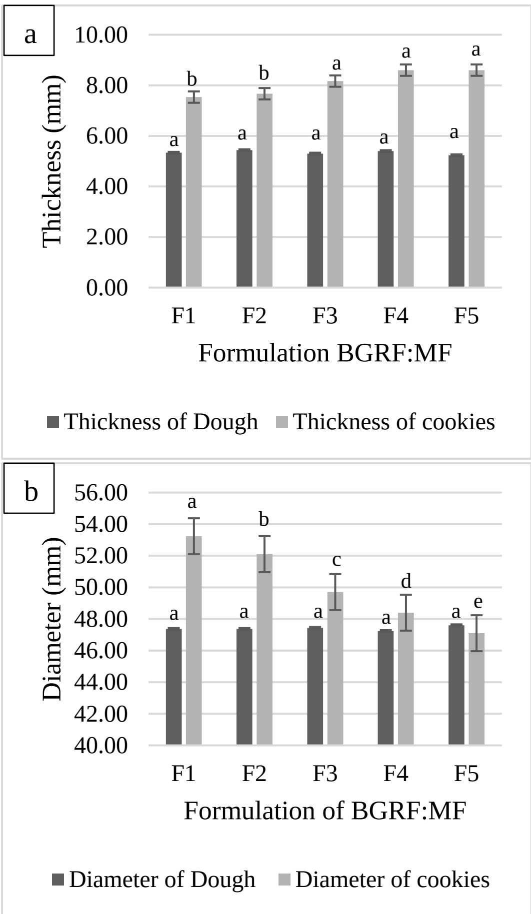

Figure 2. Thickness (a) and Diameter (b) Characteristics of Gluten Free Dough and Cookies prepared with BGRF:MF. F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

The thickness of the cookie dough initially was set to a same height, varied from 5.25±0.12 to 5.43±0.25 mm. After the baking process, the thickness of the cookies was increased due to expansion from the raising agent, results in increasing the thickness of the cookies. However, the differences in cookie formulation causing the differences in the thickness of cookies after baking. The thickness decreased significantly from 8.60±0.20 mm to 7.53±0.32 mm when the amount of BGRF in the formula increased. The increase in thickness observed in the gluten-free product may be attributed to the improved water absorption capacity of MOCAF. This enhanced capacity could have impacted the consistency and gluten dough network.

Native cassava flour exhibits unfavorable functional characteristics that limit its application in food products, primarily due to its poor water binding capacity and solubility. However, modifying the starch has been reported to enhance its functional properties, resulting in increased solubility (Sugih et al., 2019; Sumardiono et al., 2019; Titic et al., 2018; Zambelli et al., 2018) this phenomenon occurs as a result of the weakening of hydrogen bonds within the starch granule, leading to increased expansion of the amorphous region, higher water absorption capacity, and enhanced solubility (Sumardiono et al., 2019). The findings of this study regarding the thickness, diameter, and spread ratio of the cookie are consistent with those reported in previous literature (Chung et al., 2014).

c. Volume and Spesific Volume

The results related to the volume of the gluten-free cookies are presented in Figure 3. The ratio BGRF and MF in the cookies formulation has no significant differences ($p \leq 0.05$) both in the volume of the dough and the cookies. However, after the baking process, the volume of cookies increases due to the content of raising agent, namely sodium bicarbonate. This insignificant results might be due to the fact that both Black Glutinous Rice Flour and MOCAF flour do not contain gluten which has a role in dough development and cannot trap the gas produced by sodium bicarbonate so that the volume expansion that occurs does not change significantly even though the proportions of BGFR and MF are different. Although it does not contain gluten protein, black glutinous rice flour is known to contain protein ranging between 2.55 ±

0.3689% and 9.45 ± 0.7663% (Rini et al., 2019) while MOCAF contains protein of 1.38 ± 0.00% (Deyana et al., 2019).

Rice grains typically contain proteins that are hydrophobic and insoluble in nature. This insolubility hinders the formation of viscoelastic dough, which in turn prevents the effective trapping of carbonic gas from leavening agents during the leavening process. As a result, achieving optimal dough consistency and final product quality can be challenging when working with rice-based ingredients (Padalino et al., 2016). However, cookies volume tends to increase with increasing use of BGRF in gluten free cookie formulations. The same results were obtained in a study conducted by Herawati et al. (Herawati et al., 2018) here the higher proportion of brown rice flour in the brown rice-MOCAF gluten free cookies formulation resulted in a higher volume.

The specific volume of cookies is an important physical property because it can affect the texture, mouthfeel, and overall quality of the baked goods. The specific volume of the gluten free cookies was shown in **Figure 3.** The results of the study implicate that there were statistically significant difference differences ($p \le 0.05$) observed among the various formulations of the cookies with respect specific volume both in dough and cookies. The specific volume of the cookies tends to increase as the increase the incorporation of BGRF into the formulation. Cookies with a higher specific volume tend to be lighter and more porous, while cookies with a lower specific volume tend to be denser and more compact. Specific volume is an objective parameter that is closely related to density, as it provides information on the relationship between the amounts of solids in the dough and the proportion of air present in the baked product.

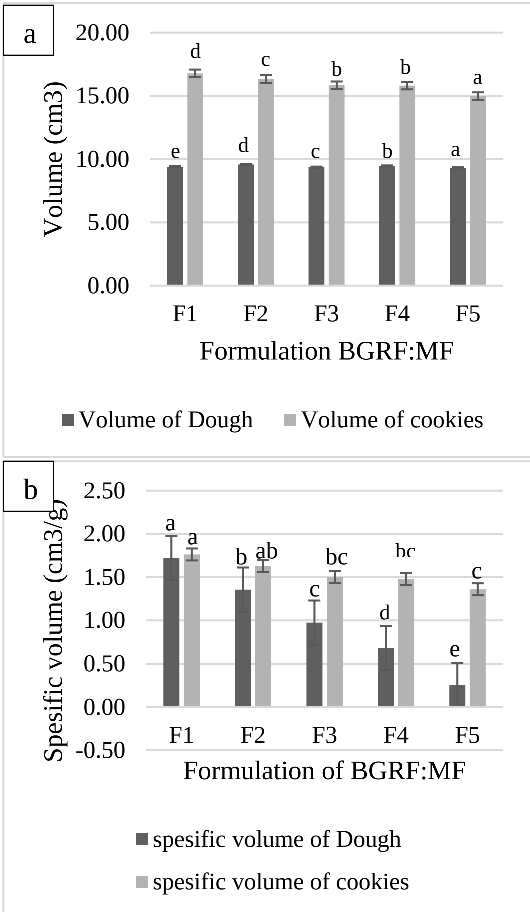

Figure 3. Volume (a) and Spesific Volume (b) Characteristics of Gluten Free Dough and Cookies prepared with BGRF:MF. F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

Accurate measurement of spesific volume is essential for evaluating the quality and overall acceptability of bread products, as it is an important indicator of their texture, crumb structure, and overall appearance (Aoki et al., 2020; Bravo-Núñez et al., 2019). The specific volume of cookie dough can be influenced by the ingredients and their ratios, as well as the mixing process. Typically, cookie dough has a lower specific volume than the baked cookie due to the presence of air pockets and other gases produced during the baking process. The specific volume of the baked cookie can be influenced by the amount of dough used, the shape and size of the cookie, and the baking conditions such as temperature and time. In this study, the difference of specific volume related to the changes of cookies diameters, thickness resulted the changes in volume and also the weight of cookies.

d. Spread Ratio

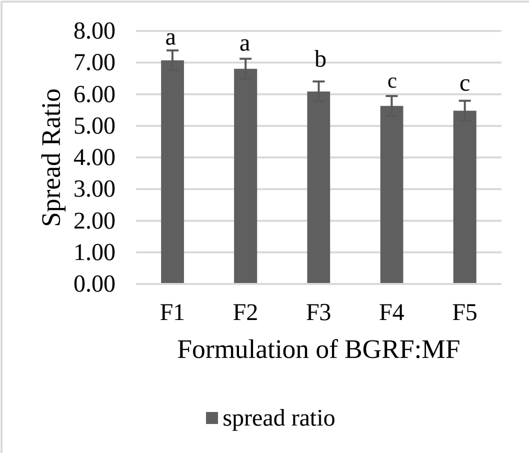

Figure 4. Spread ratio of Cookies prepared with BGRF:MF. F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

The results of this study for the spread ratio parameters of gluten-free cookies are presented in **Figure 4**. Results of these study demonstrate that there were statistically significant differences (p≤0.05) observed in spread ratio of the cookies. The increase in spread ratio, from 5.48±0.14 to 7.07±0.18, was observed due to the change in the ratio of diameter and thickness of the cookies (Pareyt et al., 2009).

The spread ratio is an essential parameter for assessing the quality of cookies, with higher ratios being more desirable. In this study, cookies made from 100% BGRF (F1) and BGRF-MF blends (F2-F4) exhibited higher spread ratios than those made with only MF (F5). These findings are consistent with previous research on cookies containing 10 or 20 g/100 g rice flour (Kim et al., 2002). Previous research has reported an increase in both the spread ratio and diameter of cookies with the addition of untreated rice flour to the formulation (Chung et al., 2014). The spread factor is known to be influenced by the viscosity of the dough (Pareyt & Delcour, 2008). The addition of rice flour was found to reduce the dough viscosity, resulting in an increased spread factor. The spread ratio is a measure of a cookie's rising ability, with a lower ratio indicating better rising capacity (Oladunjoye et al., 2021).

e. Baking Loss

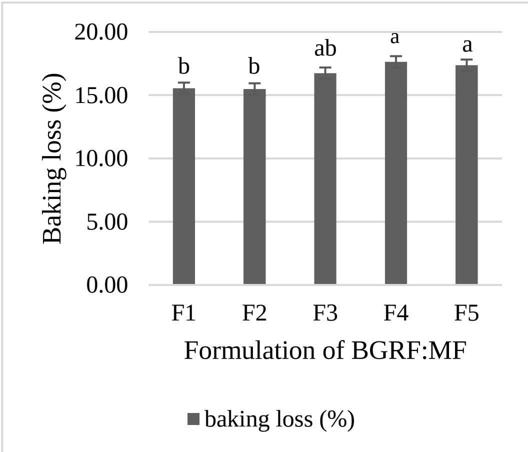

Figure 5. Baking loss of Cookies prepared with BGRF:MF. F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

The results related to the physical attributes of gluten-free cookies are presented in **Figure 5**. Results of these study demonstrate that there were statistically significant differences (p≤0.05) in case of baking loss of the cookies after baking process. The percentage of baking loss during baking of cookies among 5 formulation directly with the difference in BGRF-MF ratio. The baking loss of cookies was decreased from 17.64±1.17% to

15.55±0.61% when the amount of BGRF in the formula increased.

During the baking process of cookies at 150°C, heat is transferred from the surface to the inside, causing a transfer of mass from the interior to the surface. Consequently, water within the cookie structure is released into the air, and free water is evaporated, leading to weight loss of the cookies. These findings are consistent with a report by (Charoenphun et al., 2019) who found that cookies made from glutinous rice had lower baking loss than cassava flour. Budzaki et al. (Budžaki et al., 2014) The relationship between the moisture content in cookie dough and the weight loss during baking was investigated, and it was found that weight loss tended to increase with increasing moisture content. Moreover, the difference in weight loss among different types of flour was attributed to their distinct chemical composition and structure (Charoenphun et al., 2019).

The properties of the network structure within the starch granules, including its strength and characteristics, are determined by the amount and type of bonds present. The number of bonds at the molecular level is influenced by various factors such as size, shape, amylose to amylopectin ratio, molecular weight, number of branch chains, arrangement, length of branch chains in amylopectin, and composition and distribution of the network within the starch granules. These factors ultimately affect the ability of starch to retain water during the baking process (Sriroth et al., 2000).

Tabel 2. Color Characteristics of Gluten Free Cookies prepared with BGRF:MF

Percentage of BGRF:MF	**Color characteristics**				
	L*	**a***	**b***	**C***	**ΔE**
F1	37.56±0.52[e]	-1.89±0.34[d]	7.68±0.31[c]	7.91±0.30[c]	62.42 ±0.54[a]
F2	38.80±0.86[d]	-0.17±0.10[c]	8.51±0.89[c]	8.51±0.89[c]	61.27 ±0.97[a]
F3	43.43±0.70[c]	0.08±0.03b[c]	8.52±0.45[c]	8.52±0.45[c]	56.69 ±0.70[b]
F4	53.96±0.30[b]	0.63±0.21[b]	17.65±0.91[b]	17.66±0.91[b]	48.78 ±0.56[c]
F5	67.16±0.20[a]	6.88±0.77[a]	29.09±1.43[a]	29.90±1.57[a]	43.92±1.01[d]

Note: Means in the same line with different letters are significantly different ($p \leq 0.05$) according to Least Significant Different test. Data expressed as mean ± S.D. of triplicate determinations.

F1 = 100:0, F2= 75:25, F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

Color Characteristics of Gluten Free Cookies

The color parameters of gluten free cookies was observed in composite cookies (Table 2). Color is an crucial attribute of cookies, which primarily takes place in the final stages of the process (Culetu, Stoica-Guzun, & Duta, 2021). The color of cookies was significantly influenced by the proportion of glutinous rice flour, MOCAF, and gluten-free flour used in the formulation as seen in **Figure 6**. The cookies containing high black glutinous rice flour lower lightness (L*) and redness (a*), yellowness (b), chroma (C*) but higher in color difference (ΔE) values than the whole MOCAF cookie. In this study, the lightness and darkness of cookies were measured using the L* value. A value of 0 on the L* scale indicates black, while a value of 100 indicates white. The dark color of the cookies is caused by anthocyanins pigments content are in the black and red rice grain which impact their color to be dark (Kumar & Murali, 2020).

Pigmented rice grain is a rich in vitamin E; black varieties are high in protein, fat and crude fiber (Kumar & Murali, 2020; Rathna Priya, Eliazer Nelson, Ravichandran, & Antony, 2019). Pigmented rice grains are known to contain high levels of vitamins, trace elements, and polyphenols including flavonoids and anthocyanins, which are associated with various health benefits (Xiong et al., 2022; Zhang et al., 2022). Previous findings have demonstrated that the addition of brown rice flour resulted in a darker color (Chung et al., 2014). The observed color change may be attributed to the presence of natural pigments like polyphenols and carotenoids in brown rice (Choi et al., 2007). Other study was shown a similar results, the incorporation of black rice flour into the cookie formulation resulted in a significant decrease in L* value, indicating a decrease in lightness, while there was a significant increase in a* value, indicating an increase in redness. This suggests that the addition of black rice flour darkened the color of the cookies (Yangsun et al., 2006). The decrease in L* color values in cookies containing black glutinous rice flour also might be due to the Maillard reaction, which is caused by the interaction between reducing sugars and proteins, as well as sugar caramelization, occurring during baking (Usman et al., 2020).

Compared to the MF-cookies, the b* value and C* value of all cookies with black glutinous rice flour addition significantly decreased as the increased in BGRF addition. According to Sulieman et al. (Sulieman et al., 2019), cookies with low L* values tend to have low b* values. ΔE is a significant quality parameter used to measure color variations in food products. The present study showed a significant increase in ΔE values with high amounts of BGRF in cookie formulations. F1 exhibited the highest ΔE value of 62.42 ±0.54, indicating the greatest color variations, which could be attributed to the stronger Maillard reaction, caramelization, and higher anthocyanin content in cookie dough (Yang et al., 2022)

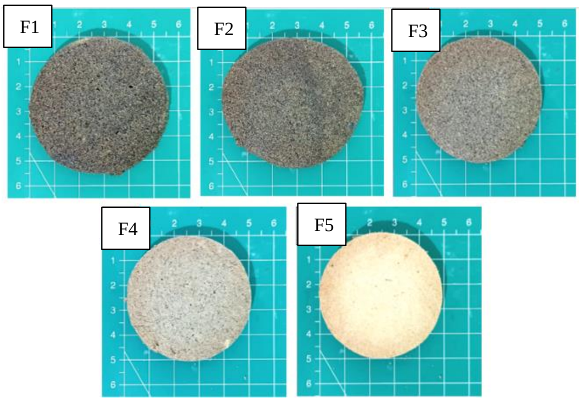

Figure 6. Cookies made from the different ratios of BGRF:MF. (F1=100:0; F2=75:25; F3= 50:50; F4=25:75; F5=0:100) (F1, F2, F3, F4, F5 represented cookies made from different formula of BGRF:MF)

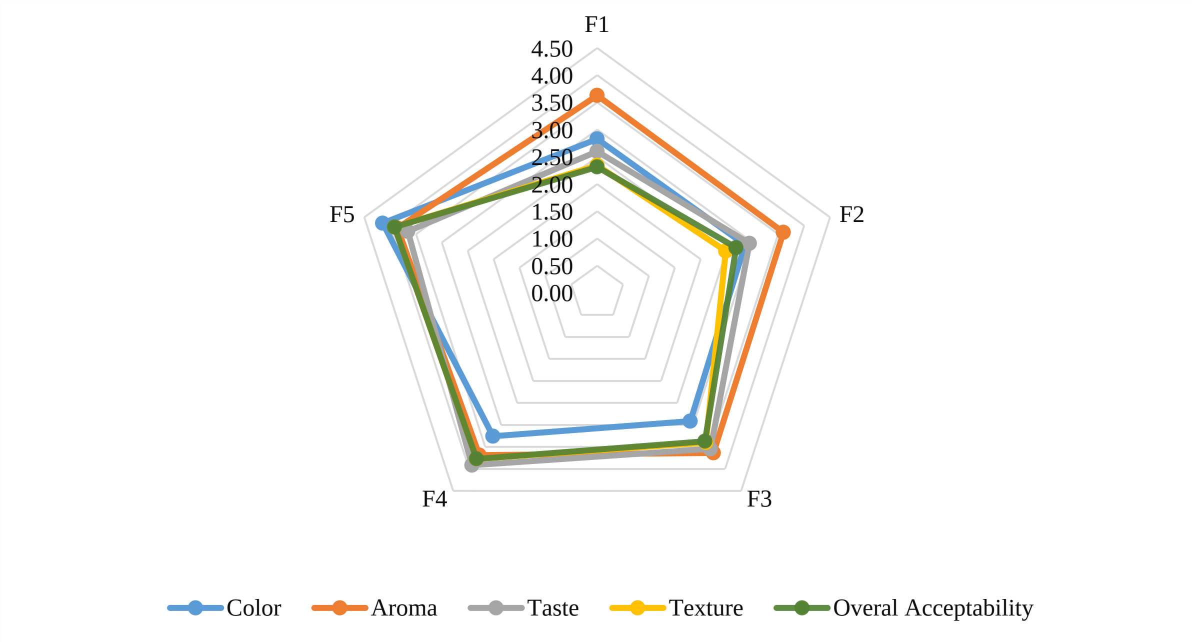

Figure7. F3=50:50, F4= 25:75, F5= 0:100 (F1, F2, F3, F4, F5 represented cookies made from different formulation of BGRF:MF)

Sensory Characteristics of Gluten Free Cookies

Obtaining the desired sensory characteristics has been a significant hurdle in creating gluten-free bakery goods. Typically, gluten-free baked goods have a unique appearance, color, texture, aroma, and taste compared to those made with wheat flour. The use of different ratios of gluten-free flour, glutinous rice flour, and MOCAF in the formulation significantly ($p \leq 0.05$) influenced the attributes of color, taste, texture, and overall acceptability, but it did not have a significant ($p \geq 0.05$) effect on the aroma attribute. The spider plot (**Figure 7**) shows the sensory evaluation of gluten free cookies prepared from different formula of BGRF and MF. Compared to cookies made from with whole BGRF (F1) and the combination of BGRF and MF (F2, F3, F4), the MF-cookies (F5) showed higher colour (4.14), Aroma (3.86), Texture (3.91) and overall acceptability (3.91) scores this led to lower Taste (3.66) score compared to F2 (3.91). In the sensory evaluation, cookies made with 100% MF showed the highest scores for most attributes, including color, aroma, texture, and overall acceptability. However, cookies formulated with 25% BGRF and 75% MF (F2) received the highest score for taste attribute. However, there is no significant difference ($p \geq 0.05$) between F5 and F4 in taste, aroma, and texture attribute.

As the amount of BGRF in the cookie formulation increased, the hedonic scores for color, aroma, taste, texture, and overall acceptability decreased. The decrease in color and appearance scores of cookies with the addition of BGRF could be attributed to the natural black color of BGRF, which resulted in a darker appearance and lower overall acceptability. The darker color of gluten-free bakery products can be attributed to the complex formulation of black glutinous rice flour, which contains natural pigments such as anthocyanins (Kumar & Murali, 2020). Panelists disliked moderately the color, taste, texture, and overall acceptability cookies made from

100% to 75% of BGRF because of its unusual characteristics of resultant cookies. In their evaluation, the cookies were characterized by dark colors, an undesirable aftertaste, and an unpleasant sandy texture. However, the aroma profile of the cookies remained moderately acceptable.

These findings suggest that cookies with high levels of BGRF may not be well-received by panelists due to their sensory attributes. The sensory properties of gluten-free bakery products are highly variable and depend on the type of gluten-free flours and formulations used. For example, incorporation of quinoa in the formulation of food products has been reported to negatively affect the sensory acceptability due to its inherent bitterness (Bhaduri, 2013) Furthermore, it is widely acknowledged that rice flour possesses a taste profile that is inherently mild and lacking in distinct flavor (Kadan et al., 2008). The increased levels of phenolic compounds in pigmented rice, which are present in cookies made with BGRF compared to MF-cookies, may result in a bitter taste, potentially leading to negative effects on consumer preferences (Pang et al., 2018; Pradipta, Ubaidillah, & Siswoyo, 2020).

CONCLUSION

The combination of Black Glutinous Rice and MOCAF flour in gluten free formulation significantly affected on cookies physical and sensory properties. Increasing BGRF in cookies formulation affect the increasing in diameter, spread ratio, and ΔE of the cookies, however decreasing in weight, thickness, baking loss, L*, a*, b*, C* value, and the hedonic score of color, aroma, taste, texture, overall acceptability leading to decreased. The best formula that produces gluten free cookies with the highest taste score score is F4 (BGRF 25%:MF 75%) with the acceptable physical and sensory quality. Further studies should focus on the effect of hydrocolloids, proteins, enzymes, and modified flour ingredients on the physical, chemical, resistant starch content, sensory evaluation, and effect on glycemic index of gluten-free bakery product.

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