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Physicochemical Characteristics of Mocaf Flour and Rice Flour-Based Gluten-Free Cookies

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ABSTRACT: This study investigated the effects of mocaf flour (modified cassava flour) concentration and baking temperature on the surfacestructure, color, moisture content, and hardness of gluten-free cookies. Cookies were prepared using mocaf flour and rice flour, withmocaf concentrations of 30%, 50%, and 70%, and baking temperatures of 150°C, 160°C, and 170°C. The results demonstrated thathigher mocaf flour concentrations and increased baking temperatures significantly influenced the cookies' physical properties. Higher mocaf concentrations and baking temperatures resulted in greater hardness values and lower moisture content. Specifically,cookies with 50% mocaf flour baked at 170°C exhibited the highest hardness (3.08 kgf) and the lowest moisture content (4.53%). Color analysis revealed that lightness (L*) decreased as both mocaf concentration and baking temperature increased, while redness(a*) and yellowness (b*) values rose, indicating darker cookies due to the Maillard reaction and caramelization. Additionally, the surface analysis showed that the inclusion of mocaf flour contributed to a rougher texture compared to the smoother surface of control cookies. These findings suggest that mocaf flour is a promising alternative to wheat flour in gluten-free cookie formulations, providing enhanced shelf stability, distinct textural characteristics, and appealing color properties. Future studies could optimize mocaf flour usage to improve product quality while addressing consumer preferences for gluten-free baked goods.

KEYWORDS: bakery product, cookies, modified cassava flour, rice flour.

INTRODUCTION

The snack commonly referred to as "dry cakes" has garnered significant popularity across various countries. These cakes are favored for their appealing texture, distinctive flavor, and extended shelf life (Abdel-Moemin, 2015). Traditionally, cakes are made using wheat flour, which contains gluten, a component that may pose health risks to certain individuals. Moreover, the heavy reliance onwheat imports can lead to economic challenges, including fluctuations in import prices. To address these concerns, alternatives to wheat flour have been explored for developing healthier cake options. Cassava flour has emerged as a promising substitute for wheat flour. Widely consumed in Sub-Saharan Africa, South America, and the Caribbean, cassava flour is considered a cost-effective and sustainable alternative for various baked goods, including bread (Abbas et al., 2018). Compared to wheat flour, cassava flour exhibits superior composition, thickening ability, water absorption capacity, and gelatinization properties. Furthermore, cassava flour is naturally gluten-free, low in protein (10–30 g/kg), and rich in starch. However, it is limited in sulfur-containing amino acids such as cysteine and methionine and exhibits lower diastatic activity (Dudu et al., 2020; Zambelli et al., 2018).

Modified Cassava Flour (MOCAF), a cassava derivative, is produced through fermentation involving lactic acid bacteria (LAB). This process enhances the nutritional and functional properties of cassava flour, making it a viable alternative to wheat flour while promoting the utilization of Indonesia's local food resources (Hanifa, 2013). Additionally, the fermentation process contributes to gut health by alleviating constipation. MOCAF contains high carbohydrate content and demonstrates superior functional properties compared to wheat flour, such as improved viscosity, gelation ability, rehydration capacity, and solubility (Yustisia, 2013)

In addition to cassava-based alternatives, rice flour has also gained attention as a gluten-free substitute for wheat flour. Rice flour is particularly beneficial for individuals with celiac disease or gluten intolerance and has been used to create various gluten-free food products, including bread (Qian & Zhang, 2013). Derived from *Oryza sativa L.*, rice is a staple energy source due to its high starch content and abundance of minerals, proteins, and vitamins (Patria et al., 2020). Its hypoallergenic nature and flavor-enhancing properties make rice flour suitable for diverse applications, including gluten-free bread, tortillas, low-fat sauces, and processed meats (Wang et al., 2013). Recent research has focused on developing gluten-free cookies by substituting wheat flour with alternative flour (Olaweye et al., 2017; Santos et al., 2020). This study used a combination of rice flour and MOCAF as a wheat flour replacement to produce gluten-free cookies. These flours were selected for their gluten-free status and high mineral content, offering an improved nutritional profile and functional benefits.

MATERIALS AND METHODSMATERIALS

The ingredients used in cookie preparation included mocaf flour (Malang, Indonesia), japonica rice flour (Taiwan), sugar, milk, eggs, salt, margarine, butter, and baking powder. All raw materials were sourced from a local market in Pingtung, Taiwan.

COOKIES PREPARATION

Cookie dough was prepared by creaming margarine, butter, sugar, milk, eggs, and salt using a mixer for 5 minutes. Baking powder (0.25 g), rice flour, and mocaf flour were then gradually added to the mixture. Cookies were formulated with mocaf flour concentrations of 30%, 50%, and 70%, combined with rice flour. The dough was mixed until uniform and refrigerated for 2 hours. The chilled dough was shaped into 6 mm thick sheets with a diameter of 3.4 cm using a noodle machine. The cookies were arranged on baking trays and baked at three different temperatures (150°C, 160°C, and 170°C) for 15 minutes. Control samples were prepared using 100% rice flour. The ingredient composition is detailed in **Table 1.**

Table 1. Ingredients of cookies for 100 g flour

No	Ingredients	Amount
1	Margarine	40 g
2	Butter	15 g
3	Sugar	35 g
4	Raw Milk	4 g
5	Egg	1
6	Salt	1 g
7	Baking powder	0.25 g

METHODS ANALYSIS

HARDNESS

Texture profile (hardness) analysis of cookies was modified based on Inglett et al. (2015) using the Texture Profile Analyzer (5564, Instron Co., USA). The diameter of the cookies was 3.4 cm, and the thickness was 10 mm. The cookie sample was compressed to 50% deformation. The plunger was withdrawn to the original height, and the sample was stopped for 5 s, followed by the compression-withdraw cycle at 50% deformation. The speed of the compression head was adjusted to 30 mm/min, and the diameter probe was 6.34 mm. The hardness value was the maximum peak force during the first compression.

COLOR

Color of the cookies was measured using a calibrated color meter (Color Quest XE, Hunter Lab, Inc., USA). Prior to measurement, the cookies were crushed, and 50 grams of the sample were placed in the machine. The L* (lightness), a* (redness), and b* (yellowness) color parameters were recorded. The instrument was calibrated with a standard white plate before testing. These parameters were used to evaluate the overall color profile of the samples.

MOISTURE CONTENT

The moisture content was determined using AOAC (2000). The average moisture content was found in the cookies after baking and cooling. The weight of the cookies was recorded before and after the cookies were placed in a drying cabinet at 105°C for 24 h (or until no further changes were registered in the weight). The mass loss during drying is assumed to be equal to the total water content in the baked cookie before drying. The final weight is seen as the dry matter content of the cookie. The value of moisture content can be calculated using this formula:

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$$Moisture\ Content\ (\%) = \frac{(Wo - Wd)}{Wo} x100\%$$

Wo: weight of cookies after drying Wd: weight of cookies before drying

SIZE

The thickness (T) and diameter (D) of the biscuits were determined using Digital Caliper (TESA Technology Co., Ltd., Renens, Switzerland).

RESTRUCTURED COOKIES SURFACE

The surface morphology of the cookies was analyzed using a Laser Microscope (VK-X series, Keyence, USA) to evaluate structural differences between control and experimental samples.

STATISTICAL ANALYSIS

The experimental data were analyzed using analysis of variance (ANOVA) with Minitab software (version 17). Significant differences between treatments were determined at a 95% confidence level ($p < 0.05$).

RESULTS AND DISCUSSIONS

The expansion of dough during baking is limited by water evaporation, which occurs due to the presence of pores in mocaf flour created by its modified starch structure. These pores contribute to increased porosity in the final cookies as the proportion of mocaf flour in the formulation rises. As illustrated in Figure 1, the control sample exhibits a smooth, non-porous texture, while samples containing a blend of rice flour and mocaf flour display noticeable pores.

Figure 1. Cookies after baking 15 minutes (a) control 150℃ (b) control 160℃ (c) control 170℃ (d) mocaf 30% 150℃ (e) mocaf 30% 160℃ (f) mocaf 30 170℃ (g) mocaf 50% 150℃ (h) mocaf 50% 160℃ (i) mocaf 50 170℃ (j)mocaf 70% 150℃ (k) mocaf 70% 160℃ (l) mocaf 70% 170℃

A. Hardness

The hardness of cookies formulated with a mixture of rice flour and mocaf flour is generally higher compared to the control. The results indicate significant variations in hardness across treatments, attributable to differences in mocaf flour concentration and baking temperature. These findings are consistent with previous studies, which reported that increased hardness in cookies results from hydrogen bonding between protein and starch molecules (Inglett et al., 2015). As shown in **Figure 2**, the baking temperature notably influences the final hardness value. At 170°C, the highest hardness value, 3.08 kgf, was recorded for cookies containing 50% mocaf flour. Conversely, the control sample displayed the lowest hardness value, 1.15 kgf, when baked at 150°C.

B. Color

The color characteristics of the cookies after baking are depicted in **Figures 3–5**, using the L*, a*, and b* parameters. The L* value represents lightness, ranging from 0 (black) to 100 (white) (Culetu et al., 2021). A positive a* value indicates redness, while a negative value signifies greenness. Similarly, a positive b* value represents yellowness, whereas a negative value suggests blueness.

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An increase in baking temperature resulted in a decrease in the L* value, indicating that the cookies became darker. Conversely**,** both the a* and b* values increased with higher baking temperatures, reflecting enhanced redness and yellowness, respectively. The decrease in lightness (L*) is linked to a reduction in the whiteness of the cookies, influenced by protein content. The Maillard reaction, driven by the interaction between reducing sugars and amino acids, plays a critical role in the browning process duringbaking (Usman et al., 2020; Yang et al., 2020). A negative correlation between protein content and cookie lightness suggests that Maillard browning is a primary contributor to color development (Chauhan, 2015). Additionally, caramelization and the Maillard reaction during baking are believed to generate brown pigments, further influencing the cookie's appearance.

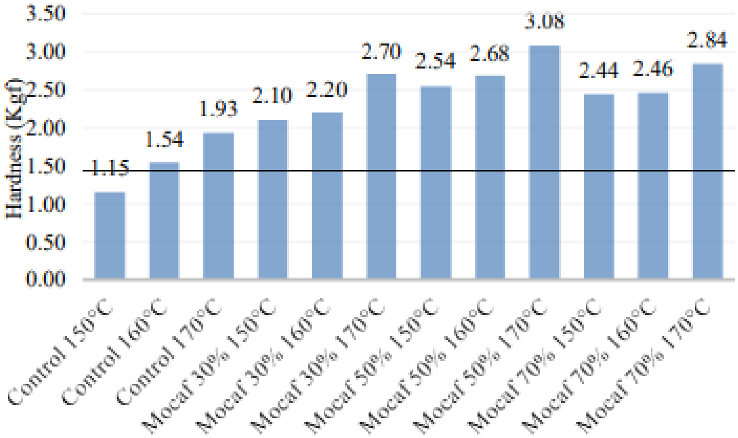

Figure 2. Hardness of Cookie

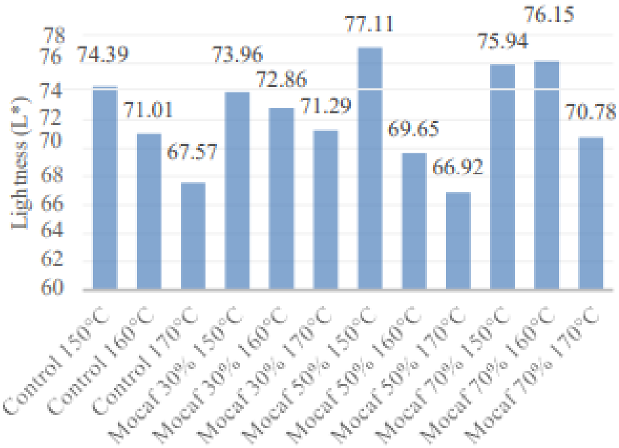

Figure 3. Lightness of Cookies

C. Moisture Content

The moisture content of baked goods varies significantly, depending on the product type. While bread typically contains 35–45% moisture and cakes range between 15–30%, biscuits have a much lower moisture content of 1–5% (Sani et al., 2014). Biscuits, cookies, and crackers are widely consumed globally, with consumer preferences often guided by taste and appearance (Zydenboz, 2003). However, distinguishing between these baked goods can be challenging for bakers, with moisture content serving as a key differentiating factor. A moisture level below 5% is the primary characteristic that separates biscuits, cookies, and crackers from other baked products like bread and cake. In this study, cookies made with a 70% mocaf flour formulation baked at 170°C exhibited the lowest moisture content (4.53%). By comparison, cookies made with 50% mocaf flour baked at 150°C had a moisture content of 8.07%. Generally, cookies formulated with a combination of mocaf and rice flour retained less moisture compared to the control sample. As illustrated in **Figure 6**, higher baking temperatures resulted in lower water content, underscoring the impact of temperature on moisture retention in cookies.

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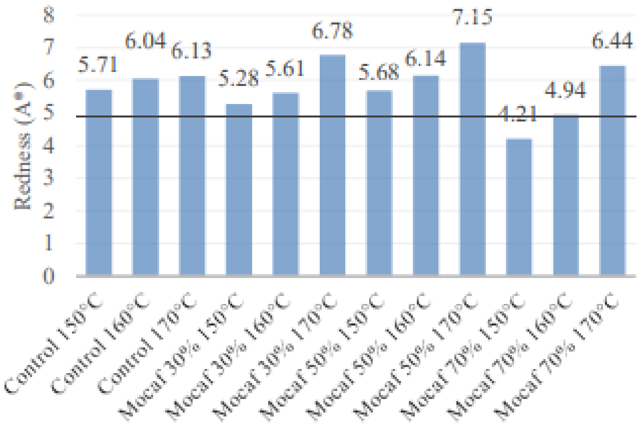

Figure 4. Redness of Cookies

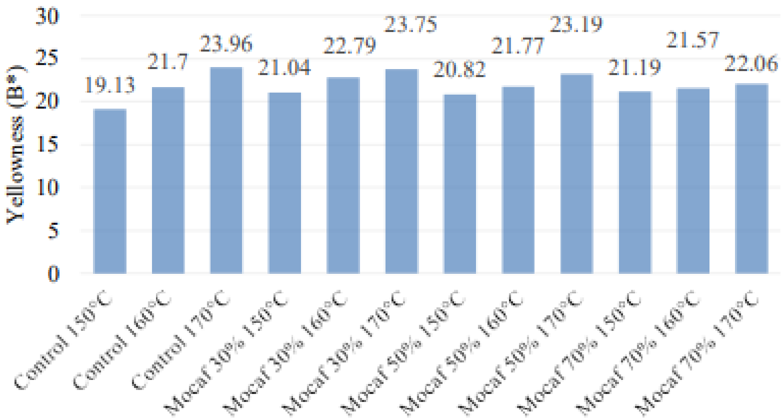

Figure 5. Yellowness of Cookies

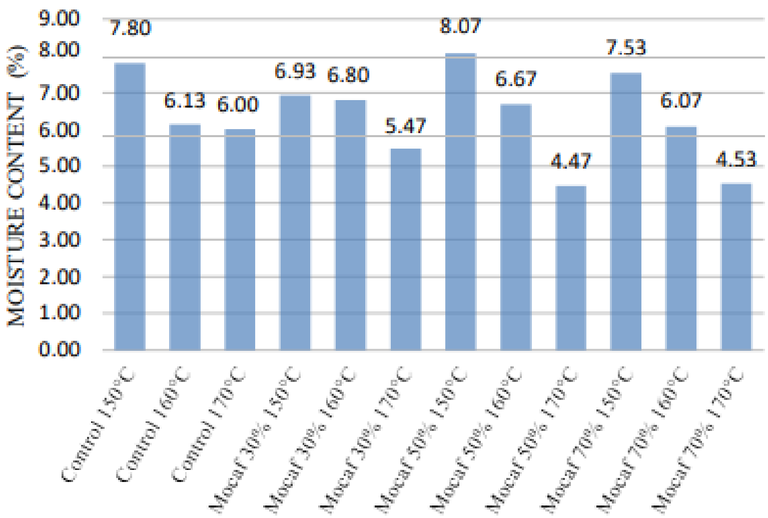

Figure 6. Moisture Content

D. Cookies Dimension

The influence of mocaf flour on cookie dimensions is summarized in **Table 2**. Prior to baking, the cookies measured 6 cm in thickness and 3.4 cm in diameter. As the concentration of mocaf flour increased, the cookies displayed reduced development in both thickness and diameter. Across all formulations, the dough exhibited minimal expansion during baking. The limited development

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can be attributed to the properties of mocaf flour, which is derived from cassava. Mocaf flour is characterized by its low protein content and absence of gluten, both of which are critical for dough elasticity and expansion. Additionally, mocaf flour contains a high carbohydrate concentration, including over 25% amylose. Elevated amylose levels result in stiff, less elastic dough that is prone to breaking and does not rise significantly during baking. The low protein content further limits the dough's baking performance, making mocaf flour particularly suitable for products that do not rely on extensive baking development (Raharja, 2017).

Table 2. Dimension of Cookies after Baking

Samples	Thickness (cm)	Diameter (cm)
Control 150°C	8.36	36
Control 160°C	8.28	35.35
Control 170°C	8.49	35.64
Mocaf 30% 150°C	8.20	37.15
Mocaf 30% 160°C	8.26	36.22
Mocaf 30% 170°C	8.43	36.28
Mocaf 50% 150°C	7.48	35.98
Mocaf 50% 160°C	7.77	35.21
Mocaf 50% 170°C	8.09	35.39
Mocaf 70% 150°C	7.40	34.93
Mocaf 70% 160°C	7.83	34.76
Mocaf 70% 170°C	8.19	34.63

E. Restructured Cookies surface

The surface characteristics of cookies were analyzed using a laser microscope, as shown in **Figures 7 and 8**. This tool provides 3D surface topography by analyzing height variations on the sample's surface. The color mapping (often red for high points and blue for low points) emphasizes roughness, with mocaf-rich cookies showing more pronounced peaks and valleys compared to rice-flour cookies. Control cookies exhibited a smooth surface, whereas cookies formulated with a combination of mocaf flour and rice flour displayed a slightly rougher surface texture. This difference in texture can be attributed to the coarser granulation of mocaf flour compared to rice flour. Mocaf, being derived from cassava and fermented, tends to have a coarser texture and higher porosity due to its fiber content and starch retrogradation properties during baking (Putri et al., 2023). The roughness is reflected in the contrasting surface colors observed in the microscopic images, with the blended formulations showing uneven patterns. These structural variations are likely influenced by the physical properties of mocaf flour, which contribute to the distinct surface features of the cookies.

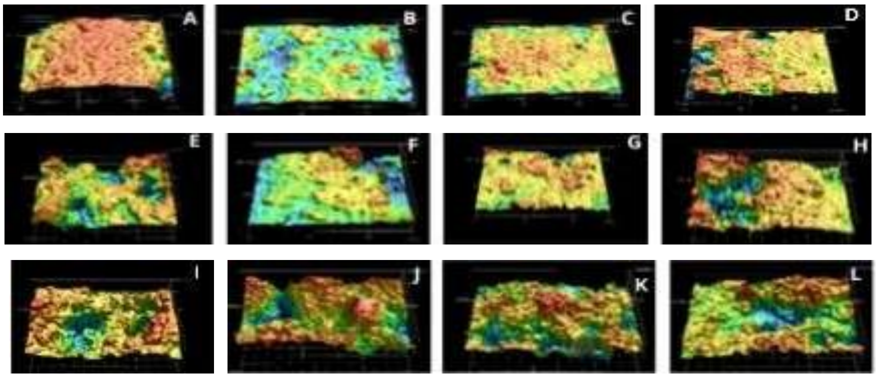

Figure 7. Cookies after baking 15 minutes (a) control 150℃ (b) control 160℃ (c) control 170℃ (d) mocaf 30% 150℃ (e) mocaf 30% 160℃ (f) mocaf 30 170℃ (g) mocaf 50% 150℃ (h) mocaf 50% 160℃ (i) mocaf 50 170℃ (j) mocaf 70% 150℃ (k) mocaf 70% 160℃ (l) mocaf 70% 170℃

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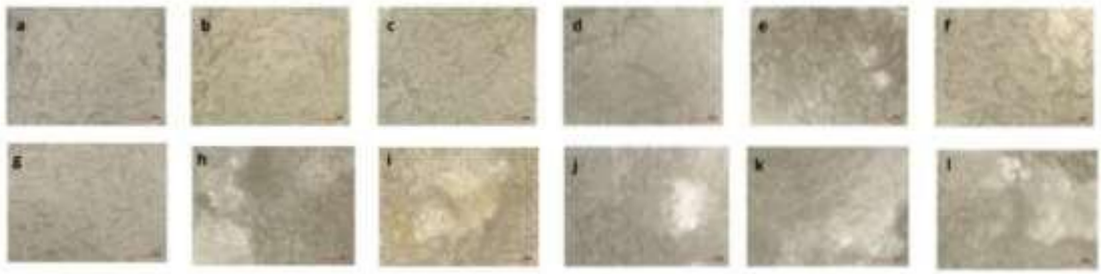

Figure 8. Cookies after baking 15 minutes (a) control 150℃ (b) control 160℃ (c) control 170℃ (d) mocaf 30% 150℃ (e) mocaf 30% 160℃ (f) mocaf 30 170℃ (g) mocaf 50% 150℃ (h) mocaf 50% 160℃ (i) mocaf 50 170℃ (j) mocaf 70% 150℃ (k) mocaf 70% 160℃ (l) mocaf 70% 170℃

CONCLUSIONS

This study demonstrates the effects of mocaf flour incorporation on the functional and sensory properties of gluten-free cookies, including moisture content, hardness, color, and surface structure. Cookies made with higher concentrations of mocaf flour showed significantly lower moisture content, particularly at higher baking temperatures, making them more shelf-stable. The hardness of cookies also increased with the addition of mocaf flour, attributed to its high amylose content and lack of gluten, which limited dough elasticity and expansion. Baking temperature further amplified this effect, with the highest hardness value recorded in cookies containing 50% mocaf flour baked at 170°C.

In terms of color, the use of mocaf flour and increased baking temperatures led to a darker appearance, evidenced by a decrease in the lightness (L*) value and an increase in redness (a*) and yellowness (b*). These changes were primarily due to the Maillard reaction and caramelization during baking, enhancing the visual appeal of the cookies. Additionally, the surface structure analysis revealed that cookies with mocaf flour had a rougher texture compared to the smooth surface of control cookies. This roughness was attributed to the coarser granulation of mocaf flour, providing a unique textural characteristic.

Overall, the findings highlight the potential of mocaf flour as a viable alternative to wheat flour in gluten-free cookie production. Its ability to reduce moisture content, increase firmness, and impart distinct color and texture makes it a promising ingredient for innovative baked products. Future studies should focus on optimizing mocaf flour formulations to further enhance the sensory and nutritional qualities of gluten-free products while meeting consumer demands.

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