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Utilization of Cassava-Jicama Composite Flour in Making Gluten-Free Biscuits with Different Types of Fats

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Abstract

Biscuits are a commonly consumed bakery product typically using wheat flour as a primary ingredient, rendering them unsuitable for gluten-intolerant consumers. Using cassava as a gluten-free alternative for composite flour in bakery products has been proven effective. Furthermore, jicama, which has high total dietary fiber contents, including inulin, can enhance total dietary fiber content. However, high-fiber ingredients can often produce a tough texture. To address this, fats such as butter and margarine are typically used to enhance the texture of baked products, although the use of shortening still needs to be explored. Both margarine and shortening are vegetable-based, making them more widely consumable. The production of jicama flour and gluten-free biscuits was the focus of this study. This study uses a completely randomized design with two factors: the ratio of composite flour (100:0, 90:10, 80:20, 70:30, 60:40) and the type of fat (margarine and shortening). Analyses were performed on the gluten-free biscuits to determine the total dietary fiber, inulin, fat, moisture, spread ratio, color and hardness. Results indicated that biscuits made with shortening with a flour ratio of 90:10 of cassava to jicama flour are the best formulation, yielding 2.54±0.00% inulin, 6.50±0.10% total dietary fiber, 19.88±0.17% fat, 2.20±0.10% moisture content, 10.03±0.20 spread ratio, lightness (L*) value of 52.53±0.37, °Hue value of 66.78±0.51, and 869.88±16.07 g hardness. This study shows that jicama flour can be an alternative to producing composite flour for gluten-free products. Shortening, which is not commonly used in biscuit making, may be considered an alternative fat source.

Keywords: bakery product; dietary fiber; inulin; shortening; spread ratio

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INTRODUCTION

Biscuit is the most widely consumed bakery product because of its simplicity and affordability, as well as the availability of raw materials. People prefer biscuits considering their long shelf life and acceptable taste. Biscuits comprise 65.90±0.08% carbohydrates, 13.17±0.04% fats and 1.17±0.04% fiber (Ighere et al., 2018). Wheat flour, fats and sugar are commonly used ingredients in the production of bakery products. Wheat flour contains gluten protein, which provides the dough's cohesiveness, viscosity, and elasticity. However, gluten can cause celiac disease, leading to the exploration of non-gluten flours (Klunklin and Savage, 2018). Caio et al. (2019) stated celiac disease causes a person to have an autoimmune with symptoms, such as bloating, diarrhea and abdominal pain. Moreover, consuming wheat flour and fat is linked to health issues, such as obesity and constipation (Klunklin and Savage, 2018). As a result, there is

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an increasing awareness of the need for health-promoting bakery products, leading to substituting and fortifying more nutritious ingredients (Klunklin and Savage, 2018). Cassava, a staple crop with high carbohydrate content, grows in subtropical and tropical areas where nutritional deficiencies are common (Bayata, 2019). According to Oduro-Yeboah et al. (2010) and Pornpraipech et al. (2017), cassava is an important tropical crop with potential applications in the food, feed and industrial sectors. Small-scale farmers and business owners widely cultivate cassava, which contains 0.28% fat and 1.8% dietary fiber (Onodu et al., 2017). Studies have shown that cassava flour can successfully replace wheat flour in the production of bakery products (Bayata, 2019). A study conducted by Nwanekezi (2013) showed cassava flour is used as a composite flour with soybean, which produces good quality bread, with a cassava and soybean flour ratio of 4:1.

Jicama, or yam bean (*Pachyrhizus erosus* (L.) Urban), is a widely produced crop in Indonesia (Santoso et al., 2020). It can be integrated into marginal farming systems in drought-prone locations, such as Sub-Saharan Africa (Buckman et al., 2018). Jicama is a cheap source of carbohydrates for food and feeds with good nutritional value. It has the highest production capacity among tuber-bearing legumes and contains 0.09 to 4.9% dietary fiber (Rana and Mamatha, 2017; González-Vázquez et al., 2022). Jicama has a crispy and fruity flavor and can be eaten fresh, processed into dishes or canned (Sharma et al., 2016).

Research conducted by Violalita et al. (2019) showed that jicama flour could replace wheat flour at 0%, 20%, 30% and 50% in cookies. Higher substitutions of jicama flour resulted in higher fiber content in the cookies. Jicama contains many bioactive compounds, such as ascorbic acid, riboflavin, flavonoids and inulin. Inulin is a soluble dietary fiber with a linear β-(2-1) bond between fructose units that slows gastric emptying (Sutikno et al., 2020). Inulin is present in Jerusalem artichoke, yacon and jicama plants, and it benefits the human body by aiding mineral absorption and easing defecation. Inulin also preserves moisture in the dough, improving its texture (Shoaib et al., 2016).

In making biscuits, fat contributes to a higher spread rate and a softer texture. Fat also gives mouthfeel and helps the mixing process, improving mobility. Fat helps to prevent gluten network formation. When fat attends, fat surrounds starch granules and protein that isolates them from water, preventing the protein and starch structure from breaking (Mamat and Hill, 2014; Rios et al., 2014; Davidson, 2016). Bakers commonly use butter and margarine in bakery products, but butter derived from animal-based milk is not suitable for vegetarians. While margarine and shortening are vegetable-based fat. Margarine contains a minimum of 80% fat, flavoring, coloring, stabilizer, and other food additives. Shortening, however, contains 100% fat and no flavoring. It has monounsaturated and polyunsaturated fats as well as saturated fats. Food manufacturers often fortify margarine with omega-6 and omega-3 fatty acids, and they can make it from sunflower or corn. Manufacturers can produce shortening through hydrogenation or solidifying processes. Although shortening has a higher fat content, it lacks the flavor of margarine. Therefore, vegetarians often add ground nuts to enhance the flavor of bakery products (Marcus, 2013). However, food companies have been seeking alternatives to replace it due to the hydrogenation process of margarine that results in trans-fat.

This study aimed to investigate the potential of using composite flour of cassava and jicama to substitute wheat flour and to evaluate the effects of different types of fats, such as margarine and shortening, on the properties of gluten-free biscuits. The physicochemical properties of cassava and jicama flour was also determined. The findings demonstrated that using cassava and jicama flour, combined with margarine, or shortening, resulted in gluten-free biscuits with improved physicochemical properties and higher dietary fiber content. Therefore, replacing wheat flour with cassava flour, which is both cost-effective and lower in fat content, could provide a sustainable alternative for biscuit production (Lu et al., 2020).

MATERIALS AND METHOD

Field materials

This study aims to produce cassava-jicama composite flour using cassava roots and jicama tubers sourced from Bogor, Indonesia. This study used an experimental method to determine the best ratio of cassava-jicama composite flour and the best type of fat to gluten-free biscuits' physical and chemical characteristics. The fats used were margarine and shortening. This study was conducted at Universitas Pelita Harapan, Tangerang, Indonesia in 2022.

Cassava flour making

Cassava flour production followed the method described by Sobhan et al. (2014) with some modifications. The cassava roots were washed, peeled, and sliced into approximately 2 mm thickness, followed by blanching in 90 ºC water for 7 minutes. The blanched cassava slices were drained, spread over trays, and dried using an oven dryer (Memmert UNB 500) at 60 ºC for 24 hours. To obtain cassava flour the dried cassava was cooled at room temperature, milled with a dry blender (Phillips) and sifted through an 80-mesh sieve (Retsch). Cassava flour underwent analysis to determine its yield, moisture content, total dietary fiber and inulin content. The yield analysis was performed based on Pezzali et al. (2020). In addition, determining moisture content and total dietary fiber involved using the oven method (AOAC, 2005) and multienzyme method (AOAC, 1995) respectively. The inulin content was analyzed using Dische's Carbazole method (Frier et al., 1969). Inulin content analysis was started with the dilution of a 5 g sample with aquadest. The solution was filtered, and 1 ml of clear solution was added with 0.2 ml 1.5% L-Cysteine followed by 6 ml 70% H_2SO_4 solution and 0.2 ml 0.12% Carbazole. The solution was mixed by using a vortex (Dlab Type Mx-S) and heated at 60 °C for 30 minutes inside a water bath (Memmert WNB14). The solution was cooled and added with 50% ethanol. The solution was mixed by using vortex (Dlab Type MX-S) and measured by spectrophotometer (Genesys 20 VIS) with 630 nm wavelength. The yield, moisture content, total dietary fiber (TDF), and inulin content of cassava flour are determined using Equations 1 to 4.

The present study analyzed the gluten-free biscuits' lightness (L*) and °Hue values using a chromameter (Konica Minolta CR-400) with granular-materials attachment (Konica Minolta CR-A50) following the method described by Soedirga et al. (2021). The L* value was calculated, signifying the degree of lightness on a scale of 0 to 100 (0 = black; 100 = white). To determine the °Hue value (Equation 5), the chromameter readings of a* and b* values were utilized, whereby +a* and -a* denoted red and green colors, respectively, while +b* and -b* represented yellow and blue colors, respectively.

Jicama flour making

Jicama flour preparation followed Sutikno et al. (2020) method with modifications. Jicama tubers were washed, peeled and sliced into approximately 2 mm thickness, followed by blanching in water at 90 °C for 1 minute, draining and drying in an oven (Memmert UNB 500) at 65 °C for 24 hours after being spread over trays. The resulting dried jicama flour was then milled by a dry blender (Phillips) and sieved through

$$\text{Yield (\%)} = \frac{\text{weight of cassava flour (g)}}{\text{weight of cassava after cutting and slicing (g)}} \times 100\% \quad (1)$$

$$\text{Moisture content (\%, wb)} = \frac{\text{initial sample weight (g) - final sample weight (g)}}{\text{initial sample weight (g)}} \times 100\% \quad (2)$$

$$\text{TDF (\%)} = \text{soluble dietary fiber (\%)} + \text{insoluble dietary fiber (\%)} \quad (3)$$

$$\text{Inulin content (\%)} = \frac{\text{X} \times \text{dilution factor}}{\text{sample weight (mg)}} \times 100\% \quad (4)$$

Where, $X = \frac{y - a}{b} \times 100\%$, and y, a, and b values were obtained from the inulin standard curve

$$°\text{Hue} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (5)$$

$$\text{Yield (\%)} = \frac{\text{weight of jicama flour (g)}}{\text{weight of jicama after cutting and slicing (g)}} \times 100\% \quad (6)$$

$$\text{Spread ratio of gluten-free biscuits} = \frac{\text{average of biscuit diameter}}{\text{average of biscuit thickness}} \quad (7)$$

an 80-mesh sieve (Retsch). Using the same methods and formulas in making cassava flour, the analysis of jicama flour for moisture (Equation 2), TDF (Equation 3) and inulin content (Equation 4), as well as the determination of its yield (Equation 6), was conducted based on the formula provided by Pezzali et al. (2020).

Gluten-free biscuit making

Modified methods from Widodo and Sirajuddin (2019) and Lu et al. (2020) were used to produce gluten-free biscuits. Cassava and jicama flour were mixed into six ratio levels, namely 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50. The fat was used as margarine and shortening. This research used two replications; each replication was performed in two repetitions. Table 1 displays the formulation of gluten-free biscuits. Dry ingredients, including cassava-jicama composite flours, salt, sugar, skim milk powder, vanilla essence and baking powder, were mixed using a wire whisk. The composite flour was prepared by blending cassava and jicama flour in various ratios (100:0, 90:10, 80:20, 70:30, 60:40, and 50:50). Using a hand mixer (Phillips), the fat, egg and sugar were homogenized. The dry and wet ingredients were combined using a spatula until the dough reached a homogeneous texture. The dough was allowed to cool at room temperature for 10 minutes, then cut into round shapes with a diameter of 4.7 cm and a thickness of 2 mm using a ring cutter. Subsequently, the biscuits were placed on a greased baking tray and baked in an oven (Bakbar) at 150 °C for 20 minutes.

After reaching room temperature, physical analyses such as color, texture, and spread ratio were conducted on the gluten-free biscuits. Later, gluten-free biscuits were stored and examined for chemical analysis that includes moisture, fat, TDF and inulin content on the next day. Calculation of moisture (Equation 2), TDF (Equation 3) and inulin content (Equation 4) was performed using the same method and formula for cassava flour. The fat content of gluten-free biscuits was analyzed using the Soxhlet method, according to AOAC (2005).

Table 1. Formulation of gluten-free biscuits

Ingredient	Amount of ingredient (g)
Composite flour*	47.78
Sugar	16.24
Fat (margarine/shortening)	17.20
Skim milk powder	2.87
Egg	15.29
Salt	0.14
Baking powder	0.24
Vanilla essence	0.24
Total weight	100.00

Source: Soedirga et al. (2021) with modification

Note: *) Cassava:jicama flour ratio = 100:0, 90:10, 80:20, 70:30, 60:40, 50:50

A texture analysis of the biscuits was conducted using a texture analyzer (TA.XT Plus) to evaluate their hardness attributes, following the method of Li et al. (2020) with some modifications. It used a cylindrical probe with a 2 mm thickness. The pre-test, test, and post-test speeds were 2.0, 0.5, and 1.0 mm s^{-1}, respectively. The compression distance was set to 1.8 mm while applying 25 g of trigger force during the texture analysis. The spread ratio of the biscuits (Equation 7) was determined using a Vanier caliper (Taffware) following the method described by Adeola and Ohizua (2018). Four biscuits were placed edge to edge and recorded for their length. The biscuits were turned and measured six times again. The average of six measurements was later divided by four to obtain the average of a single biscuit. The biscuit thickness was obtained by stacking four biscuits and recording the heights. The measurement was also done six times and obtained its average. Then, it was divided by four to obtain the average thickness of a single biscuit.

Data analysis

This study used a completely randomized design with two factors: the ratio of cassava-jicama composite flour and types of fat. The data were tested and analyzed by SPSS version 25 using Two-Way ANOVA and Duncan post-hoc test.

RESULTS AND DISCUSSION

Characteristics of cassava and jicama flour

As can be seen from Table 2, the moisture content of cassava flour is 5.88±0.05%, which is slightly higher than that reported by Soedirga et al. (2018) of 4.72±0.22%. Both studies used the same drying method, time, and temperature. However, Soedirga et al. (2018) did not perform a blanching process on the cassava roots, which resulted in a lower moisture content and quicker drying time for the cassava flour.

Furthermore, Table 2 shows that the moisture content of jicama flour is 8.87±0.08%, which is higher than the moisture content reported by Buckman et al. (2018) of 5.79±0.04%. Buckman et al. (2018) dried the jicama tubers immediately at 55 °C for 5.5 hours using a mechanical dryer without any blanching process. Szymanek et al. (2020) suggested that blanching can increase the sample's moisture content, thereby increasing the drying time required.

Gulati and Datta (2015) suggested that higher moisture content in dried materials can lead to lower yields due to the materials' rigid texture, complicating the crushing and milling process. This finding is consistent with the results presented in Table 2, which show that jicama flour, with a higher moisture content than cassava flour, resulted in a lower yield (7.73±0.16%) than cassava flour (34.66±0.05%). Eke et al. (2009) reported that the blanching process could cause the starch to leach out from plants, and the longer the blanching process, the higher the presence of starch, which can improve the L* and °Hue of the materials. In this study, cassava flour was blanched for 7 minutes, while the jicama flour was subjected to blanched for 1 minute at the same temperature. As a result, cassava flour exhibited higher values of L* and °Hue than jicama flour, indicating that cassava flour has lighter a color than jicama flour. Kortei and Akonor (2015) suggested that the range of yellow color is 90° to 126°. Both cassava and jicama flour fall within this range, denoting that they are yellow in color.

The inulin content of jicama flour was found to be higher (9.79±0.03) than cassava flour (1.14±0.02) due to the inherent properties of jicama, which contains approximately 14% inulin (Sutikno et al., 2020). However, contrary to the findings of González-Vázquez et al. (2022), the jicama flour obtained, without blanching, exhibited inulin content ranging from 3.1±0.09 to 13.4±0.69%. In the present study, blanching and drying processes resulted in lower inulin content due to the solubility of inulin, which is soluble in water and has increased solubility at higher temperatures (Naskar et al., 2010).

The TDF content of cassava flour obtained in this study was 2.60±0.12%. Soedirga et al. (2018) reported a higher dietary fiber content of 13.72±0.53%, attributed to the blanching process that reduced starch and resistant starch. The TDF content of jicama flour obtained in the current study was 10.94±0.01%. According to Nursandi et al. (2017), higher moisture content of jicama flour results in higher dietary fiber content. Moreover, the inulin content is proportional to the flour's TDF content.

Chemical characteristics of gluten-free biscuits

Inulin content

Two types of dietary fibers, water-soluble and water-insoluble, are widely recognized for their numerous health benefits for humans. Inulin, which belongs to the category of soluble dietary fiber, is a fructan that consists of a linear chain. It can pass through the colon and be digested by colon bacteria, making it a crucial diet component (Dhingra et al., 2012; Shoaib et al., 2016).

The statistical analysis revealed an interaction ($p < 0.05$) between the ratio of cassava to jicama flour and the types of fat used in the inulin content of biscuits. Table 2 shows that jicama flour had a higher inulin content (9.79±0.03%) than cassava flour (1.14±0.02%). Consequently, using a higher ratio of jicama flour resulted in a higher inulin content in the biscuits. Biscuits made from 100% cassava flour with margarine (2.01±0.01%) and shortening (2.50±0.00%) exhibited lower inulin content compared to biscuits made from a 50:50 flour ratio of cassava and jicama flours with margarine (3.40±0.01%) and shortening (3.83±0.01%).

Biscuits manufactured using shortening exhibited a significantly higher inulin content than those prepared using margarine in every ratio tested (Figure 1). Biscuits with a flour ratio of 100:0 made by shortening exhibited a higher inulin content (2.50±0.00%) than those prepared using margarine (2.01±0.01%). Moreover, biscuits prepared using shortening and a flour ratio of 50:50 showed a higher inulin content (3.83±0.01%) than those made with margarine

Table 2. Physicochemical characteristics of cassava and jicama flour

Parameter	Cassava flour	Jicama flour
Moisture (%)	5.88±0.05	8.87±0.08
Yield (%)	34.66±0.05	7.73±0.16
L* value	75.23±0.11	70.79±0.08
°Hue value	99.09±0.09 (yellow)	90.93±0.10 (yellow)
Inulin (%)	1.14±0.02	9.79±0.03
TDF (%)	2.60±0.12	10.94±0.01

Note: Values are presented as mean±SD

(3.40±0.01%). Inulin and lipids can interact, resulting in stability in an abiotic environment (Vereyken et al., 2003). This study subjected inulin to high heat treatment (drying at 65 ºC for 24 hours and baking at 150 ºC). Inulin is a fructan that can interact with lipid membranes and thus can create stability. Fructans move towards the lipid membrane and approach the lipid headgroups, allowing fructans to insert their body into the lipid headgroups through hydrogen bonds, creating a sheet-like structure that can prevent leakage and preserve membrane stability. Marcus (2013) stated that margarine and shortening contain 80% and 100% fat, respectively. Due to the interaction of inulin and fat, biscuits made using shortening exhibited higher inulin content than those made using margarine.

TDF content

Dietary fiber is present in plant components and is resistant to digestion and absorption in the small intestine while undergoing fermentation in the large intestine. The appropriate classification of dietary fiber based on its solubility in the gastrointestinal tract is determined, namely water-soluble or well-fermented fiber and water-insoluble or less-fermented fiber. Soluble dietary fiber has higher fermentability, leading to more significant health-promoting effects on the human body, and serves as a potential prebiotic due to its ability to maintain the viscosity of food products, which is attributed to its low molecular weight and highly fermentable characteristics. The characteristic allows carbohydrate fermentation in the large intestine and makes soluble dietary fiber favorable for consumption. Fruits and vegetables are rich sources of soluble dietary fiber (Williams et al., 2019). Gut bacteria can ferment insoluble dietary fiber, even though it is resistant to degradation by digestive enzymes in the human body. As the name itself, it is not soluble in water and hence does not form a gel structure in food products. Insoluble dietary fiber has low density, which helps to bulk feces that helps with the defecation process. Insoluble dietary fiber is available in vegetables, grains and woody plants (Dhingra et al., 2012; Mudgil, 2017; Williams et al., 2019).

There was an interaction ($p < 0.05$) between the ratio of cassava to jicama flour and the type of fat used in the preparation of biscuits, as illustrated in Figure 2. Biscuits prepared with margarine and a flour ratio of 50:50 displayed higher TDF content (7.21±0.13%) than those prepared with a flour ratio of 100:0 (3.07±0.01%). Similarly, biscuits made with shortening and a flour ratio of 50:50 exhibited higher TDF content (9.54±0.12%) than those made with a flour ratio of 100:0 (4.88±0.14%). Table 2 indicated that jicama flour contained higher TDF content (10.94±0.01%) than cassava flour (2.60±0.12%), leading to a higher TDF content in biscuits with a higher ratio of jicama flour. Additionally, the TDF content was influenced by

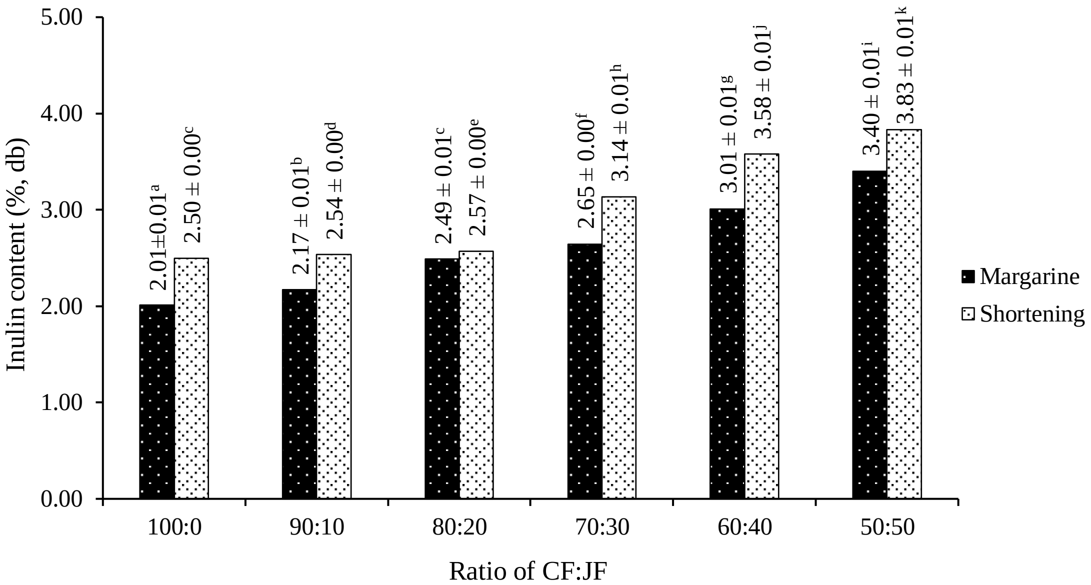

Figure 1. Inulin content of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Bars with different superscript letters indicate significant differences ($p < 0.05$)

inulin, a soluble dietary fiber, as evidenced by the higher inulin content observed in biscuits with a higher flour ratio (Figure 1), which explains the higher TDF content in biscuits with a higher flour ratio.

The result shown in Figure 2 stated that biscuits made by shortening have higher TDF than the ones made with margarine. Although the TDF of biscuits made with margarine with a flour ratio of 60:40 (6.61±0.14%) and that of biscuits made by shortening with a flour ratio of 90:10 (6.50±0.10%) are not significant towards each other, the flour ratio and types of fat remain significantly increasing the TDF of biscuits. Biscuits with a flour ratio of 100:0 made with shortening have higher TDF (4.88±0.14%) than the biscuits made with margarine (3.07±0.01%). This pattern continues with a higher flour ratio. As shown in Figure 2, a biscuit with a flour ratio of 70:30 made by shortening contains higher TDF (8.01±0.09%) than the one made by margarine (5.11±0.04%). As shown in Figure 1, the inulin content of biscuits is also higher in biscuits made by shortening. The higher fat content of shortening gives higher inulin content, leading to the higher TDF content of biscuits. According to van der Kamp and Lupton (2013), solid food that has above 3% and 6% dietary fiber has been claimed as food with a source of dietary fiber and high dietary fiber food, respectively. The statistical analysis in Figure 2 indicates that all flour ratios with both types of fats can be considered dietary fiber sources.

Fat content

The statistical analysis has shown that the fat content of biscuits was significantly influenced ($p < 0.05$) by the ratio of cassava to jicama flour with different types of fat, as illustrated in Figure 3. Biscuits made from margarine with a flour ratio ranging from 90:10 (16.46±0.26%) to 50:50 (16.42±0.54%) showed no significant difference.

Meanwhile, biscuits made from shortening with a flour ratio ranging from 90:10 to 70:30 showed no significant difference towards each other but had significantly higher fat content (19.88±0.17%; 20.23±0.17%) compared to those with a flour ratio of 100:0. Moreover, biscuits with a flour ratio ranging from 60:40 to 50:50 had significantly higher fat content (21.32±0.06%; 21.38±0.09%) compared to the former type. It is noteworthy that raw cassava and jicama have a fat content of 0.28% and 0.09%, respectively, according to González-Vázquez et al. (2022). Soedirga et al. (2018) reported that the fat content of cassava flour made by drying at 60 °C for 24 hours using an oven was 0.86±0.04%, while Nursandi et al. (2017) reported that the fat content of jicama varied within the range of 0.29 to 0.45%. Therefore, it is evident that cassava has a higher fat content than jicama.

On the other hand, as illustrated in Figure 1, it is observed that the inulin content increased with the higher flour ratio. Inulin has been recognized for its ability to interact with the headgroup of the lipid membrane, leading to

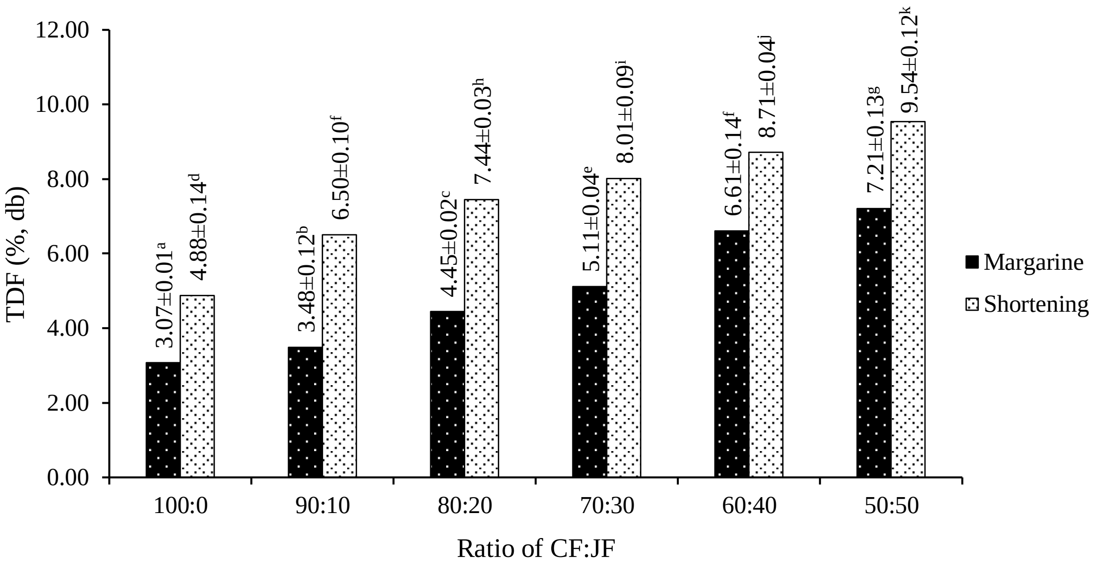

Figure 2. TDF content of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Bars with different superscript letters indicate significant differences ($p < 0.05$)

a more stable membrane. Therefore, the higher substitution of jicama flour resulted in a higher fat content due to the increased inulin content. A previous study by Violalita et al. (2019) also reported that biscuits with 20% and 50% jicama flour substitution had a fat content of 22.5% and 25%, respectively. Biscuits made with shortening contain significantly higher fat levels than those made with margarine. Biscuits made with shortening and a flour ratio of 100:0 exhibit a fat content of 19.19±0.13%, which surpasses the fat content of biscuits made with margarine (17.12±0.14%). This trend continued until the flour ratio was 50:50, where biscuits made with shortening had a higher fat content (21.38±0.09%) than those made with margarine (16.42±0.54%). Shortening and margarine have 100% and 80% fat content, respectively. These findings indicate that a higher fat content in the raw materials results in a higher fat content in the resulting biscuits. Additionally, the interaction between inulin and lipid headgroups, which promotes membrane stability, may contribute to the higher fat content observed in biscuits with higher inulin content.

Moisture content

The result showed that the ratio of cassava to jicama flour with different types of fat has significant interaction ($p < 0.05$) towards the moisture content of the biscuit. Regardless of the flour ratio, biscuits made with shortening exhibited lower moisture content than those made with margarine, potentially attributable to the higher fat content of shortening (100%) compared to margarine (80%). Figure 4 further illustrates a significant increase in moisture content of biscuits made with shortening as the proportion of jicama flour was increased, particularly for flour ratios exceeding 90:10, starting from a flour ratio of 80:20 (2.04±0.14%) to 60:40 (3.85±0.16%). However, moisture content did not significantly increase when the flour ratio was 60:40 (3.85±0.16%) or 50:50 (3.97±0.34%). Similarly, the moisture content of biscuits made with margarine significantly increased from a flour ratio of 90:10 (2.96±0.02%) to 60:40 (5.16±0.08%) before decreasing significantly to 4.71±0.06% at a flour ratio of 50:50.

The study of Paramita and Putri (2015) demonstrated that a higher substitution of jicama flour in flakes resulted in higher moisture content. As per Table 2, the jicama flour used in the study also exhibited higher moisture content (8.87±0.08%), indicating that increasing the jicama flour substitution in biscuits also led to higher moisture content. The presence of carbohydrates and protein may account for the decrease in moisture content observed in biscuits made with shortening at the flour ratio of 100:0 (3.37±0.15%) to 80:20 (2.04±0.14%) and in biscuits made with margarine at the flour ratio of 60:40 (3.85±0.16%) to 50:50 (3.97±0.34%). Carbohydrates, like starch and sugar, have better water-binding capabilities at higher temperatures (Utama et al., 2017). Cassava, for instance, contains higher carbohydrates (38.1%) than jicama (8.82%). Meanwhile, protein creates dough viscosity (Blanco Canalis et al., 2017a).

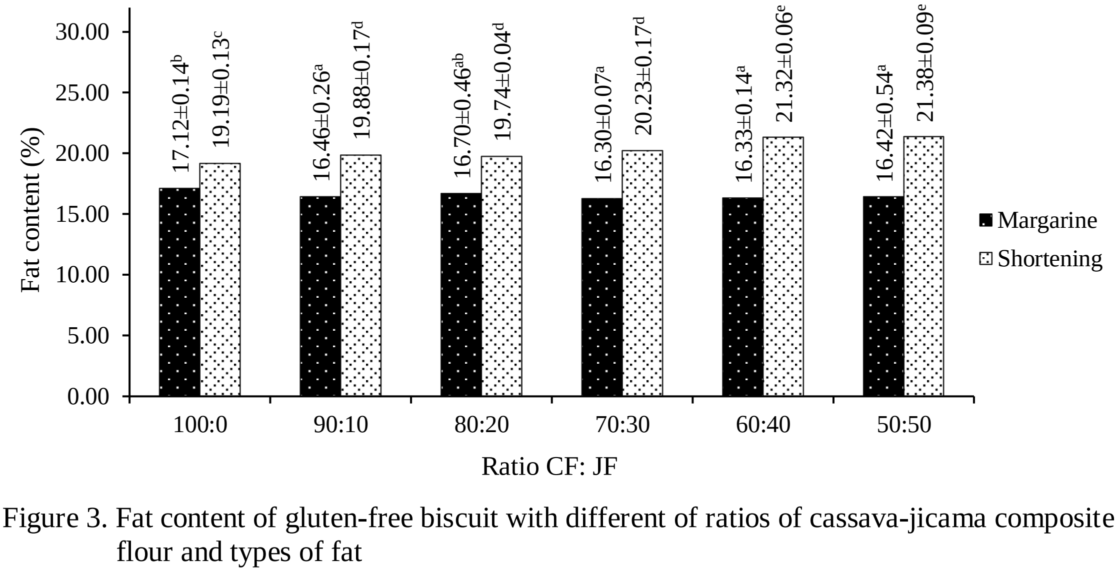

Figure 3. Fat content of gluten-free biscuit with different of ratios of cassava-jicama composite flour and types of fat

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Bars with different superscript letters indicate significant differences ($p < 0.05$)

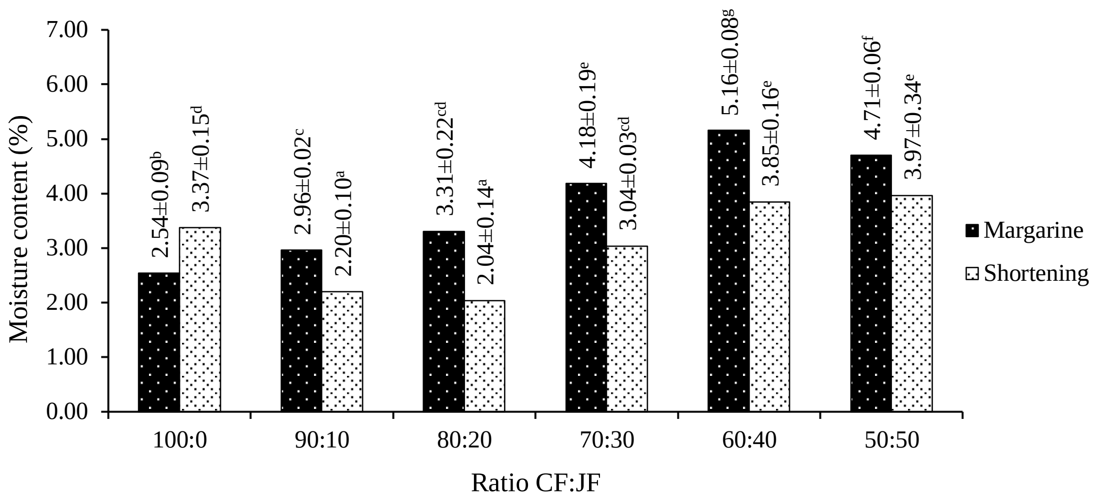

Figure 4. The moisture content of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Bars with different superscript letters indicate significant differences ($p < 0.05$)

According to Rana and Mamatha (2017), jicama has a lower protein content (0.72%) than cassava (1.36%). Notably, all biscuit formulations complied with the moisture content standard set by Indonesian National Standard (INS 2973-2018), except for biscuits made with margarine at the flour ratio of 60:40 (5.16±0.08%).

Physical characteristics of gluten-free biscuits

Spread ratio

Adeola and Ohizua (2018) analyzed the spread ratio to determine the quality of flour used in making biscuits, which measures their rising ability. A higher spread ratio is considered more desirable. The results of the statistical analysis in Table 3 present that the ratio of cassava flour did not significantly influence the spread ratio of biscuits to jicama flour with different types of fat ($p > 0.05$). Additionally, the ratio of cassava to jicama flour and the type of fat used did not significantly affect ($p > 0.05$) the spread ratio of the biscuits. Biscuits made with shortening, and a flour ratio of 100:0 (9.68±0.68) and 90:10 (10.03±0.20) showed a higher spread ratio compared to those made with margarine and a flour ratio of 100:0 (8.70±0.19) and 90:10 (9.31±0.42). Moreover, biscuits made with shortening and flour ratios of 80:20 (9.73±0.14) to 50:50 (9.18±0.16) had a lower spread ratio than those made with margarine and flour ratios of 80:20 (9.86±0.72) and 50:50 (10.11±0.74).

Table 3. Spread ratio of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

CF:JF ratio	Types of fat	Spread ratio
100:0	Margarine	8.70±0.19
90:10		9.31±0.42
80:20		9.86±0.72
70:30		9.83±0.95
60:40		10.12±0.15
50:50		10.11±0.74
100:0	Shortening	9.68±0.68
90:10		10.03±0.20
80:20		9.73±0.14
70:30		9.66±0.83
60:40		9.09±0.56
50:50		9.20±0.14

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD

According to Blanco Canalis et al. (2017b), the melting process of fat contributes to a higher spread ratio in biscuits. As shortening contains higher fat than margarine, biscuits with a flour ratio of 100:0 made by shortening exhibited a higher spread ratio (9.68±0.68) than those made by margarine (8.70±0.19). Conversely, biscuits made with margarine with lower flour ratios resulted in a higher spread ratio than those made by shortening. Higher substitution of jicama flour increased insoluble dietary fiber content (Mancebo et al., 2018). Notably, the flour ratio did not significantly affect the spread ratio of biscuits. In biscuits made with margarine, the increasing substitution of jicama flour increased the spread ratio, whereas those made by shortening displayed a decrease. Blanco Canalis et al. (2017b) suggested that higher amounts of inulin added to biscuits can contribute to a higher spread ratio due to increased dough viscosity. The dough's viscosity increases until it suddenly spreads, thereby influencing the spreading of biscuits. Protein is a hydrophilic-like substance that binds with water and is responsible for increasing the viscosity of dough (Agrahar-Murugkar et al., 2015; Blanco Canalis et al., 2017a). Research by Nogueira and Steel (2018) shows that higher protein content leads to a lower spread ratio of biscuits. Therefore, a higher substitution of jicama flour resulted in lower protein content and a higher spread ratio of biscuits.

Hardness

The hardness of biscuits is an important parameter that reflects the force required to achieve a certain deformation (Wang et al., 2014). Statistical analysis indicated that the ratio of cassava to jicama flour, in conjunction with different types of fat, has a significant interaction ($p < 0.05$) with the hardness of the biscuit. Biscuits made with margarine displayed a significant increase in hardness from a flour ratio of 100:0 (927.81±49.36 g) to 50:50 (3415.86±134.37 g). Biscuits made with shortening, with a flour ratio of 90:10 (869.88±16.07 g) to 70:30 (1115.35±39.54 g), also significantly increased. However, there was no significant increase in hardness from a flour ratio of 70:30 to 50:50 (1247.43±28.54 g). Blanco Canalis et al. (2017b) asserted that inulin might result in lower hardness due to the interaction of fat and inulin. Although higher substitution of jicama flour yields a higher soluble dietary fiber and inulin, the increase in insoluble dietary fiber contributes significantly to the hardness of the biscuit. Mancebo et al. (2018) suggested that insoluble dietary fiber imparts a more rigid texture to cookies, which is consistent with the results obtained in this study.

Upon analysis of Figure 5, shortening resulted in a lower hardness or a tougher biscuit. Specifically, the biscuit made with a 100:0 flour ratio using shortening has a lower hardness value (782.97±25.25 g) than the one made with margarine (927.81±49.36 g). This trend continues until the 50:50 flour ratio, where the biscuit made with shortening (1247.43±28.54 g) still has a lower hardness value than the one made with margarine (3415.86±134.37 g). It is noteworthy that shortening has a higher fat content than margarine, and as a result, the fat acts as a lubricant and reduces the hardness of the biscuit (Kouhsari et al., 2022). Consequently, biscuits with higher fat content are associated with lower hardness values. Blanco Canalis et al. (2017a) stated the presence of inulin content could give a lower hardness value which is due to the interaction of fat and inulin. Statistical analysis showed biscuit made by shortening has significantly ($p < 0.05$) higher inulin content

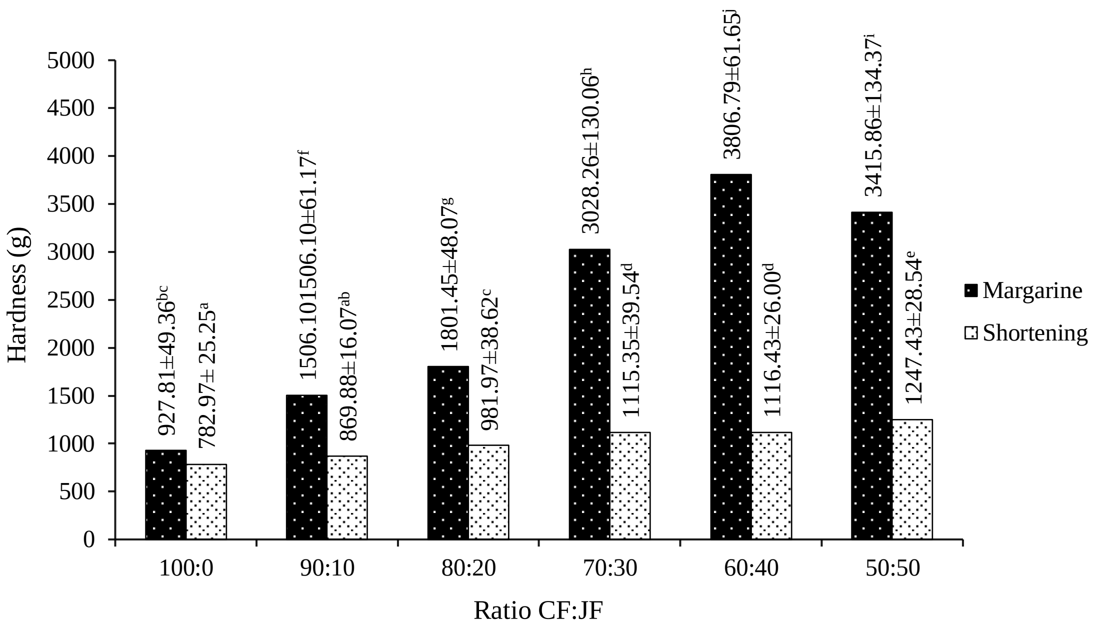

Figure 5. Hardness of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Bars with different superscript letters indicate significant differences ($p < 0.05$)

than biscuit made with margarine. In addition, Mancebo et al. (2018) stated higher insoluble dietary fiber gives a harder texture. Therefore, shortening adds higher fat content to biscuits and it results in lower hardness.

Color

The color of the biscuits was analyzed based on two parameters, namely L* and °Hue values. The statistical analysis revealed that the interaction between the ratio of cassava to jicama flour with different types of fat was significant ($p < 0.05$) towards the L* value of biscuits as shown in Figure 6. Higher substitution of jicama flour resulted in a lower L* value, indicating a darker color. For both margarine and shortening biscuits, a flour ratio of 100:0 exhibited a higher L* value than a flour ratio of 50:50. The findings in Table 2 were consistent with the result that jicama flour had a lower L* value (70.79±0.12) than cassava flour (72.23±0.11). Thus, a higher substitution of jicama flour led to a darker color of biscuits.

Previous research by Paramita and Putri (2015) showed that a higher substitution of jicama flour resulted in a darker color of flakes. The color of biscuits is also affected by the inulin content. Longoria-García et al. (2020) reported that cassava-based biscuits added with up to 50% inulin had an L* value ranging from 55.96±3.92 to 73.92±3.88% with no significant difference. Adding higher inulin content to the biscuit resulted in a darker color or lower L* value. Furthermore, the L* value increased when the jicama flour substitution was higher, such as in biscuits with a flour ratio of 70:30 (49.68±1.72) made by shortening and a flour ratio of 50:50 (48.89±1.28) made by margarine. This phenomenon could be attributed to carbohydrates' caramelization and Maillard reaction, resulting in a darker color (Zamora and Hidalgo, 2011; Maire et al., 2013).

The statistical analysis showed a significant interaction ($p < 0.05$) between the ratio of cassava to jicama flour and the type of fat to the L* value of biscuits. Specifically, a higher substitution of jicama flour led to a lower L* value, indicating a darker color. Biscuits made with a flour ratio of 100:0 had a higher L* value than those made with a ratio of 50:50, regardless of the type of fat used. The research findings were consistent with those presented in Table 2 that jicama flour had a lower L* value (70.79±0.12) than cassava flour (72.23±0.11), indicating that a higher substitution of jicama flour led to a darker biscuit color. Paramita and Putri (2015) reported similar results, demonstrating that a higher substitution of jicama flour produced a darker color of flakes. The color of biscuits is significantly affected by their inulin content. Longoria-García et al. (2020) found that the L* value of cassava-based biscuits increased with higher inulin content, resulting in a darker color. A similar trend was observed in this study, where biscuits made with a higher substitution of jicama flour exhibited a darker color due to the caramelization and Maillard reaction of carbohydrates (Zamora and Hidalgo, 2011; Maire et al., 2013). The statistical analysis also showed that the biscuits made with shortening have lower L* values indicating the darker color of biscuits than that of biscuits

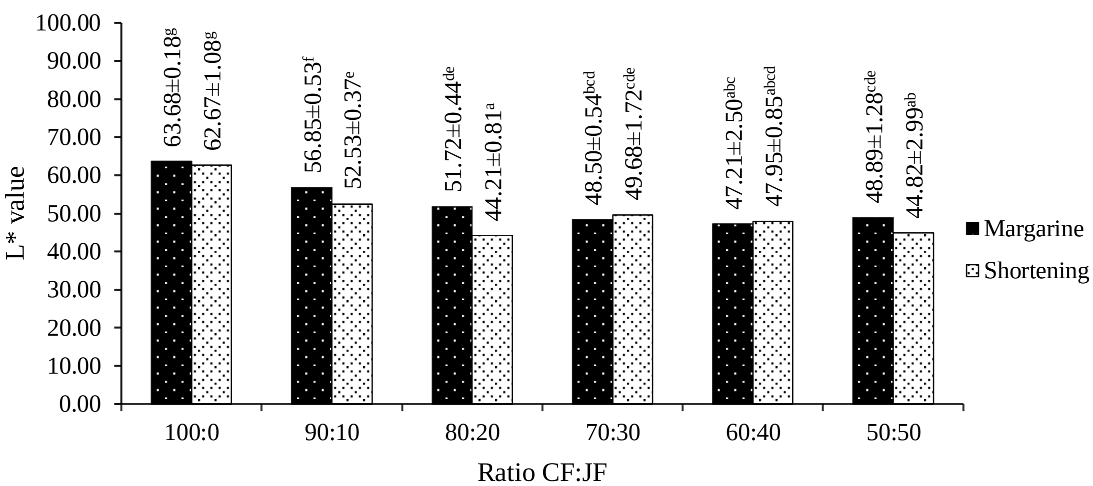

Figure 6. L* value of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Bars with different superscript letters indicate significant differences ($p < 0.05$)

Table 4. Hue values of gluten-free biscuits with different of ratios of cassava-jicama composite flour and types of fat

CF:JF ratio	Types of fat	ºHue	Color
100:0	Margarine	72.20±0.40[f]	Yellow-red
90:10		69.33±0.33[e]	
80:20		66.30±0.10[cd]	
70:30		64.86±0.39[cd]	
60:40		63.45±1.93[bc]	
50:50		64.75±1.53[cd]	
100:0	Shortening	73.14±0.92[f]	
90:10		66.78±0.51[de]	
80:20		61.23±0.68[ab]	
70:30		64.67±0.13[cd]	
60:40		63.75±1.65[bcd]	
50:50		59.72±2.15[a]	

Note: CF = cassava flour; JF = jicama flour. Values are presented as mean±SD. Different superscript letters indicate significant differences ($p < 0.05$)

made with margarine. Zamora and Hidalgo (2011) and Maire et al. (2013) stated that lipids could undergo lipid oxidation that gives darker color to biscuits.

The type of fat and flour ratio also significantly affected the ºHue value of biscuits, although not all values were significantly different as shown in Table 4. Biscuits made with shortening had a lower ºHue value, indicating a reddish color and a higher substitution of jicama flour led to a lower ºHue value. Overall, biscuits with a higher substitution of jicama flour had a darker color in the yellow-red region when associated with the L* values. The higher ºHue value of biscuits made with margarine indicates that the biscuits lie more in yellow color, which is lighter than the biscuits made with shortening. It is aligned with the statistical analysis that showed biscuits made with margarine have a higher L* value, which also implies the biscuit has a lighter color (Figure 6).

CONCLUSIONS

Among cassava-jicama flour biscuits made with shortening and margarine, biscuits with 90:10 ratio combined with shortening are chosen to be the biscuits with the best formulation. It was chosen due to considerations from some factors. In the matter of total dietary fiber content, the biscuits are considered to have high dietary fiber (6.36±0.092%). The biscuit with a 90:10 ratio of cassava-jicama flour combined with shortening has an inulin content of 2.48±0.003%. Moreover, the fat content of the biscuits is 19.88±0.17%, which is the lowest aside from the one with no jicama flour substitution and has no significant difference from other substitution flour ratio biscuits. In terms of hardness, the biscuit has the lowest hardness value (869.88±16.07 g) among other flour ratio biscuits. The moisture content of the chosen formulation (2.20±0.10%) also meets INS 2973-2018. Furthermore, the spread ratios of L* value and ºHue value are 10.03±0.20; 52.53±0.37 and 66.78±0.51, respectively. Further fat content analysis of each composite flour should be performed to strengthen the analysis results. Additional sensory analyses, such as scoring and hedonic tests, are recommended to evaluate the acceptability of the various biscuit formulations among panelists. The sensory analyses will also enable the identification of the correlation between objective and subjective analyses.

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