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Sensory Properties of Gluten-Free Biscuits Formulated with Cassava-Jicama Combined Flour and Various Fats

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ABSTRACT

Biscuits, a popular bakery item, usually contain wheat flour as a main ingredient, making them unavailable for gluten-sensitive consumers. This research aims to determine the effect of different formulations on the sensory characteristics of gluten-free biscuits. The research followed a randomized block design. The factor in this study was biscuit formulations (100:0, 90:10, 80:20, 70:30, 60:40,50:50). Determination of preferred formulation was done using the De Garmo method. The selected formulation was a gluten-free biscuit made with 90:10 cassava and jicama flour with shortening, namely F4. Panelists perceived F4 had no foreign aroma (2.20±1.18), no foreign taste (2.37±1.14), and no bitter aftertaste (2.57±1.17). The biscuit also does not have a hard texture (2.31±1.02) with a slightly not brown color (3.29±1.36). From the hedonic results, the panelists were slightly like the acceptance of foreign aroma (5.29±1.13), foreign taste (5.00±0.94), foreign aftertaste (5.00±1.19), color (5.20±1.28), and overall acceptance (5.06±1.11). Meanwhile, the panelist was neutral to accepting the biscuit's hardness (4.71±1.93). Moreover, the result of the present study also aligned with the previous research, which conducted the objective measurement of the biscuits.

Keywords: combined flour; gluten-free biscuit; hedonic; sensory; scoring

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INTRODUCTION

Biscuits are highly popular among consumers due to their affordability, simplicity, and easily accessible ingredients. Commonly, wheat flour, fats, and sugar are utilized as ingredients in the making of biscuits. Biscuits typically have a crunchy texture due to the higher fat (13.17±0.04%) and sugar content (30.00±1.9%) (Da *et al*., 2019; Hashem *et al*., 2018). However, biscuits generally contain low fiber content (1.17±0.04%), thus limiting their nutritional value.

Wheat flour contains gluten protein, imparting the dough's viscosity, elasticity, and cohesiveness, providing a soft yet firm texture. However, gluten protein can trigger celiac disease. Celiac disease leads to autoimmune reactions, resulting in diarrhea, bloating, and abdominal pain (Caio *et al*., 2019). Furthermore, health issues, including concerns such as constipation and obesity, are linked to the consumption of wheat flour and fats (Klunklin & Savage, 2018). Consequently, there is a rising awareness of the importance of health-promoting bakery products, which drives the substitution and fortification of ingredients with higher nutritional value, such as the development of non-gluten flours (Klunklin & Savage, 2018). Flour can be claimed as gluten-free products if they contain gluten less than 20 ppm (Verma *et al*., 2017).

Various ingredients make gluten-free flour, including rice, millet, potato, corn, and cassava. These constituents produce sensory attributes like bakery products made with wheat flour (Quinones *et al.*, 2015).

Cassava is one of the staple crops in many countries. Laswai *et al. (*2017) also stated that cassava helped the African micronutrient intervention. The protein, fat, and dietary fiber content of cassava is 1.36, 0.28, and 1.8%, respectively. The cassava roots are containing amylopectin (83%) and amylose (17%), making them a versatile ingredient for food products (Salvador *et al.*, 2014). Cassava flour is also commonly used as a substitute flour due to the high number of starches (67.92%-88.11%) (Mughal, 2019). Cassava flour retains the high starch content of the root and is commonly used as a gluten-free alternative in various baked goods, including biscuits. However, its low protein and fiber content can result in biscuits with a crumbly texture and limited structural integrity compared to wheat-based products (Cock and Connor, 2021; Aruna *et al*., 2021). They can have a slightly grainy texture, which can be minimized by combining them with other ingredients that provide better cohesion

Despite these limitations, cassava flour is valued for its affordability, higher yield, and suitability for creating gluten-free based products. Cassava flour does have neutral flavor makes it a versatile base for combining with other nutrient-dense ingredients such as jicama flour to enhance the nutritional profile of biscuits (Lu *et al*., 2020).

Jicama or locally known as *bengkuang* is a vegetable crop that is generally produced in Indonesia. It contains carbohydrate (8.82%), protein (0.72%), and fat (0.09%) but is considered to contain much dietary fiber (4.9%) in tubers compared with cassava (1.8%), potato (2.4%), tube sweet potato (3%), and taro (4.1%). Jicama tuber contains many different bioactive compounds, such as flavonoids, ascorbic acids, riboflavin, and inulin. Jicama contains higher inulin than bananas and wheat. It contains 14% inulin. Inulin is a soluble fiber that can slow gastric emptying, the nutrient absorption will slow down, and therefore, it can prevent blood glucose level rise (Santoso *et al.*, 2019; Santoso *et al*., 2020).

Biscuits made from combined flours of cassava and cowpea within a ratio of 70:30 gave the highest dietary fiber content (20.54±0.32%). The panelists slightly liked the overall acceptance within the value of 5.01±0.97 (Soedirga *et al*., 2021). Another utilization of cassava flour was done with the incorporation of jicama flour by Richirose & Soedirga (2023), in which flour ratios were varied from 100:0 down to 50:50. Diverse fat varieties such as margarine and shortening were applied in making the biscuits. This research aimed to continue Richirose & Soedirga (2023), who analyzed the physicochemical characteristics of biscuits. Gluten-free biscuits have improved significantly in quality over the years; however, some consumers may still perceive them as less appealing due to the textural and flavor differences compared to wheat-based products. Therefore, this research aimed to determine the effect of different formulations on the sensory characteristics of gluten-free biscuits.

MATERIALS AND METHOD

Materials

Materials used in this research were cassava and jicama flour obtained from Richirose & Soedirga (2023), free-range chicken egg (Organic Plus Selenium), sugar (Gulaku), salt (Dolphin), margarine (Blue band), shortening (Menara), skim milk powder (IndoPrima), baking powder (Koepoe-Koepoe), vanilla essence (Koepoe-Koepoe), and aquadest (Amidis).

Equipment

Equipment that was used in this research were a knife (Oxone), baking oven (Bakbar), table balance (Tanika), hand mixer (Phillips), spatula, biscuit molder, plastic wrap (Klin pak), non-stick baking paper (Best Fresh), plastic plates.

Method

Production of Gluten-Free Biscuit

Production of gluten-free biscuits was based on Richirose & Soedirga (2023). Cassava and jicama flour were combined into 6 ratios, namely 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50. The fats incorporated were margarine and shortening. There will be 12 formulations, namely F1 (100:0, margarine), F2 (100:0, shortening), F3 (90:10, margarine), F4 (90:10, shortening), F5 (80:20, margarine), F6 (80:20, shortening), F7 (70:30, margarine), F8 (70:30, shortening), F9 (60:40, margarine), F10 (60:40, shortening), F11 (50:50, margarine), F12 (50:50, shortening). This study applied two replications, and each was performed in two repetitions. The making of gluten-free biscuits begun with combined cassava and jicama flour according to the predetermined ratio followed by other dry ingredients such as sugar, salt, skim milk powder, baking powder, and vanilla essence using a wire whisk. An egg, sugar, and fat were homogenized using a hand mixer. The combined flours and fat used were prepared according to the formulations shown in Table 1.

The dry and wet ingredients were blended until homogeneous using a spatula and left to rest at room temperature (30°C) for 10 minutes. The dough was cut using a ring cutter into round-shaped doughs with a 4.7 cm diameter and 2 mm thickness.

Table 1. Formulations of gluten-free biscuits

Ingredients	Amount of ingredients (g)
Combined flours*	47.78
Fat (margarine/shortening)	17.20
Sugar	16.24
Egg	15.29
Skim milk powder	2.87
Baking powder	0.24
Vanilla’s essence	0.24
Salt	0.14
Total weight	100.0

Source: Richirose & Soedirga (2023)
Note: *) cassava and jicama flour

Table 2. Scoring parameters and scale

Score	Parameter				
	Aroma	Taste	Aftertaste	Hardness	Color
1	Extremely not foreign aroma	Extremely not foreign taste	Extremely has no bitter aftertaste	Extremely not hard	Extremely not brown
2	Not foreign aroma	Not foreign taste	No bitter aftertaste	Not hard	Not brown
3	Slightly not foreign aroma	Slightly not foreign taste	Slightly has no bitter aftertaste	Slightly not hard	Slightly not brown
4	Slightly foreign aroma	Slightly foreign taste	Slightly has bitter aftertaste	Slightly hard	Slightly brown
5	Foreign aroma	Foreign taste	Has bitter aftertaste	Hard	Brown
6	Extremely foreign aroma	Extremely foreign taste	Extremely has bitter aftertaste	Extremely hard	Extremely brown

Source: Meilgaard *et al*. (2016)

The round-shaped doughs were spread on a baking tray and baked in an oven at 150°C for 20 minutes. The resulting gluten-free biscuits were analyzed for their sensory properties, including the scoring and hedonic tests, to a total of 35 untrained panelists from Universitas Pelita Harapan with the age range of 17-21.

The scoring test aimed to assess the intensity level of aroma, taste, aftertaste, hardness, and color toward the formulations of gluten-free biscuits. Table 2 illustrates the scoring test scale. Meanwhile, the objective of the hedonic test was to evaluate how well the panelists accepted the aroma, taste, aftertaste, hardness, color, and overall acceptance of gluten-free biscuits. The acceptance scales range from 1 (extremely-dislike) to 7 (extremely-like) (Meilgaard *et al*., 2016).

Data Analysis

This research used a randomized block design. The factor in this study was gluten-free biscuit formulations. Data was analyzed using a non-parametric (Kruskal-Wallis) test at the 5% significance level. A further Dunn-Bonferroni test was performed on the results of the significant Kruskal-Wallis test. Statistical software SPSS version 25 was used. Determination of the preferred formulation was done using De Garmo method by determining the weight for each sensory parameter (BN). Afterwards, the value of effectiveness (NE) was calculated using the following equation:

$$NE = \frac{treatment\ value - worst\ value}{best\ value - worst\ value}$$

The obtained NE was then used to calculate the highest result value (NH), which was obtained by multiplying the NE with the weight value (BN). Formulation with the highest NH was selected as the preferred formulation (Linangsari *et al*., 2022).

RESULTS AND DISCUSSIONS

Aroma of Gluten-Free Biscuits

The Kruskal-Wallis test showed that there was a significant difference between the categories of the independent variable (Formulation) and the dependent variable (scoring and hedonic aroma), as the p-value is <.001, which is less than 0.05. The scoring aroma values of F1 (1.86±1.03) and F2 (1.94±1.03) indicate the absence of a foreign aroma in these formulations. The values suggest that these formulations, containing no jicama flour, were perceived to have a neutral aroma without a pronounced off-flavor.

Table 3. Scoring and hedonic value of biscuits' aroma with different formulations

Formulation	Scoring Aroma	Hedonic Aroma
F1 (100:0, margarine)	1.86±1.03	5.40±1.09
F2 (100:0, shortening)	1.94±1.03	5.51±1.01
F3 (90:10, margarine)	2.23±0.97	4.97±1.10
F4 (90:10, shortening)	2.60±1.14	4.94±1.16
F5 (80:20, margarine)	3.00±1.19	4.46±1.09
F6 (80:20, shortening)	3.77±1.24	3.89±1.21
F7 (70:30, margarine)	2.06±1.21	5.69±0.99
F8 (70:30, shortening)	2.20±1.18	5.86±0.77
F9 (60:40, margarine)	2.46±1.20	4.83±1.34
F10 (60:40, shortening)	3.00±1.21	4.43±1.20
F11 (50:50, margarine)	3.34±1.28	4.11±1.02
F12 (50:50, shortening)	3.40±1.42	3.89±1.41

Notes: Means±SD. in the same column indicate significant differences based on the Kruskal-Wallis test followed by Dunn-Bonferroni. The Dunn-Bonferroni test has an adjusted p-value less than 0.05, it can be assumed that these groups are significantly different in each significantly different in pairs. Scoring scale: 1 (Extremely not foreign aroma)-6 (Extremely foreign aroma). Hedonic scale 1 (extremely dislike) – 7 (extremely like)

Meanwhile, F3 to F12 shows an increasing presence of foreign aroma due to the higher proportion of jicama flour compared to F1 and F2, indicating the presence of jicama flour led to the presence of foreign aroma. The result aligns with the findings of Faizal and Syarif (2021), who noted that jicama flour is associated with an unpleasant aroma. Meanwhile, fats, skim milk powder, and vanilla essence in this study contributed to a sweet aroma in the biscuits. However, as the proportion of jicama flour increased in the formulations, it introduced a more pronounced off-notes aroma, even though the other aroma-balancing ingredients remained consistent. Consequently, a higher proportion of jicama flour in the formulation resulted in a more pronounced foreign aroma in the biscuits,. likely due to the higher content of triterpenes (such as saponins) and phenolic compounds (like aldehydes), which are volatile and contribute to undesirable aromas. Saponin, commonly found in legumes and root vegetables such as jicama, contributes to bitter, soapy, and astringent flavor; thus, it can produce off notes or undesirable aromas in food products. In addition, phenolic compounds such as aldehyde and other secondary metabolites that are present in jicama can generate an earthy aroma, potentially affecting the sensory properties, thus leading to the production of foreign aroma (Salsabila & Wikandari, 2024; Wigati *et al*., 2022).

Both margarine and shortening share similar aroma profiles. However, the higher fat content of shortening affects both aroma scores and overall acceptance. This is evident in the higher aroma scores of biscuits made with shortening, as observed in F4 (2.60±1.14), F6 (3.77±1.24), F8 (2.20±1.18), F10 (3.00±1.21), and F12 (3.40±1.42), compared to those made with margarine. Additionally, biscuits made with shortening without jicama flour (F2) also exhibited an increase in foreign aroma (1.94±1.03) compared to those made with margarine (F1:1.86±1.03). These findings align with Marcus (2013), which noted the similarities in aroma profiles between margarine and shortening despite the latter's higher fat content that margarine and shortening, both vegetable-based fats, share similar aroma profiles despite shortening having a higher fat content than margarine. This observation also corresponds with research by Richirose and Soedirga (2023), which indicated that biscuits made with shortening contained higher fat levels and exhibited increased total dietary fiber content. Consequently, biscuits made with shortening yield higher aroma scores, suggesting a heightened detection of foreign aromas thus lowering the acceptance score of biscuits.

Table 3 demonstrates an inverse correlation between the presence of jicama flour and the panelist's acceptance. As the substitution of jicama flour increased, the panelists also reduced their acceptance. The panelists neither liked nor disliked the aroma of biscuits with the highest jicama flour substitution ratio, such as in F11 (4.11±1.02) and F12 (3.89±1.41). The results presented in this study correspond with Violalita *et al*. (2019), who reported that cookies with higher levels of jicama flour substitution also yielded lower acceptance scores for aroma due to the unpleasant aroma of jicama flour (Faizal & Syarif, 2021). Consequently, the hedonic test results proportionally correlated with the scoring test, suggesting that higher levels of jicama flour substitution result in a more unfavorable aroma profile, thus yielding lower aroma scores in the hedonic test.

Taste of Gluten-Free Biscuits

There was a significant difference between formulations toward the scoring and hedonic taste, as the p-value resulted from the Kruskal-Wallis test is <.001. The Dunn-Bonferroni test has an adjusted p-value of less than 0.05, so it can be assumed that these groups are significantly different. Table 4 demonstrates that a higher ratio of jicama in biscuits' formulation leads to a higher intensity of foreign taste perceived by the panelists. According to

Violalita *et al*. (2019), egg, fat, skim milk powder, and sugar can also mask the jicama flour taste. However, as the ratio of jicama flour increased, the flavor from those masking ingredients overpowered the taste of jicama flour, resulting in higher detection of foreign tastes by panelists. Faizal and Syarif (2021) also support that jicama flour has a more pungent taste than sugar, eventually overpowering sugar's sweet taste. In addition, jicama consists of saponin, phenolic compounds, and other secondary metabolites, which contribute to the presence of an unpleasant aroma, thus forming a foreign taste.

The scoring test results were based on the hedonic test results. There was a decrease in likeness as the higher level of jicama flour substitution was applied, as shown in Table 4. F3 and F4, which contain only a low ratio of jicama flour, already exhibited an increase in the scoring of foreign aroma compared to F1 and F2, thus influencing their hedonic values. Panelists still preferred the taste of the biscuits in F1 and F2, which did not include jicama flour. However, when jicama flour was added in F3 and F4, panelist acceptance decreased to a neutral level. Furthermore, as the substitution level of jicama flour increased in the formulations (e.g., F11 and F12), the intensity of foreign aroma detected by panelists also increased, leading to even lower acceptance scores for F11 and F12, at 3.57± 1.12 and 3.40±1.31, respectively

According to Table 4, the biscuits made with shortening had a higher taste score such as in F2 (2.34±1.03), F4 (2.80±1.11), F6 (4.00±1.21), F8 (2.37±1.14), and F12(3.97±1.27). Klunklin and Savage (2018) noted lipid oxidation could occur in biscuits before baking and during storage, producing off-flavors. Shortening, being 100% fat, contains a higher fat content than margarine, composed of 80% fat. As a result, biscuits made with shortening are more susceptible to lipid oxidation, leading to more pronounced off-flavors. This is reflected in the sensory results, where biscuits made with margarine had a higher hedonic taste score compared to those made with shortening. Panelists slightly liked the biscuits made with margarine. In contrast, those made with shortening received a more neutral or slightly negative score due to the off flavors associated with higher fat content and lipid oxidation.

Table 4. Scoring and hedonic value of biscuit’ taste with different formulations

Formulation	Scoring Taste	Hedonic Taste
F1 (100:0, margarine)	2.06±0.87	5.37±1.19
F2 (100:0, shortening)	2.34±1.03	5.31±1.13
F3 (90:10, margarine)	2.60±0.95	4.77±1.21
F4 (90:10, shortening)	2.80±1.11	4.60±1.24
F5 (80:20, margarine)	3.37±1.19	4.00±1.14
F6 (80:20, shortening)	4.00±1.21	3.91±1.12
F7 (70:30, margarine)	2.03±1.10	5.29±1.36
F8 (70:30, shortening)	2.37±1.14	5.37±0.91
F9 (60:40, margarine)	3.34±1.24	4.14±1.38
F10 (60:40, shortening)	3.34±1.00	3.80±1.13
F11 (50:50, margarine)	3.63±1.17	3.57± 1.12
F12 (50:50, shortening)	3.97±1.27	3.40±1.31

Notes: Means±SD. in the same column indicate significant differences based on the Kruskal-Wallis test followed by Dunn-Bonferroni. The Dunn-Bonferroni test has an adjusted p-value less than 0.05, it can be assumed that these groups are significantly different in each significantly different in pairs. Scoring scale: 1 (Extremely not foreign taste)-6 (Extremely foreign taste). Hedonic scale 1 (extremely dislike) – 7 (extremely like)

Aftertaste of Gluten-Free Biscuits

The Kruskal-Wallis test showed that there was a significant difference between the categories of the independent variable (Formulation) to the dependent variable (scoring and hedonic aroma), as the p-value is <.001, which is less than 0.05. The Dunn-Bonferroni test has an adjusted p-value of less than 0.05, so it can be assumed that these groups are significantly different. The panelist did not detect the aftertaste of both biscuits made with F1 (2.63±1.55) and F2 (2.09±1.20). In contrast, the biscuit with the highest substitution of jicama flour, such as at F11 (4.00±1.16) and F12 (4.43±1.20), was detected as having foreign aftertaste. This circumstance could occur due to the triterpenes contained in jicama. Rivera *et al*. (2010) stated that jicama has triterpenes, specifically saponins (Santoso *et al*., 2019) and phenolic compounds. As Alexander *et al*. (2019) emphasized, phenolic acids also contribute to a foreign aftertaste in food products, which may not be limited to bitterness alone. Liu *et al*. (2020) point out that saponins can impart a foreign aftertaste, such as bitter. Hence, a higher ratio of jicama flour in biscuit formulations can give higher detection of a foreign aftertaste. The findings from the scoring test correlate with the outcomes of the hedonic test.

F1 and F2, which are biscuits with no substitution for jicama flour and with the lowest substitution ratio of jicama flour (F3 and F4), indicated that panelists slightly liked and had neutral acceptance toward the aftertaste of the biscuits. The lowest acceptance was recorded for F12 (3.40±1.31), where the proportion of jicama flour was the highest, combined with the usage of shortening. This combination likely contributed to the pronounced off-notes aftertaste, such as bitter or rancid, as both jicama and shortening play roles in imparting this undesirable flavor. Rivera *et al*. (2010) stated that jicama contains saponin and phenols, contributing to off-notes aftertaste such as bitter aftertaste. Both saponin and phenols can bind with lipids. Kregiel *et al*. (2017) explain that saponin is amphiphilic in water-soluble and lipid-soluble. Roby (2017) also elaborates that phenolic compounds can bind with lipids. Moreover, shortening is made 100% and can lead to lipid oxidation, especially in baked products. Hence, biscuits with shortening that have higher fat content also contain higher saponin and phenolic compounds, with a higher off-notes aftertaste in the biscuits, such as a bitter or rancid aftertaste.

Table 5. Scoring and hedonic value of biscuit' aftertaste with different formulations

Formulation	Scoring Aftertaste	Hedonic Aftertaste
F1 (100:0, margarine)	2.63±1.55	5.37±1.19
F2 (100:0, shortening)	2.09±1.20	5.31±1.13
F3 (90:10, margarine)	2.91±1.36	4.77±1.21
F4 (90:10, shortening)	3.46±1.15	4.60±1.24
F5 (80:20, margarine)	3.91±1.15	4.00±1.14
F6 (80:20, shortening)	3.74±1.31	3.91±1.12
F7 (70:30, margarine)	2.20±1.23	5.29±1.36
F8 (70:30, shortening)	2.57±1.17	5.37±0.91
F9 (60:40, margarine)	3.60±1.17	4.14±1.38
F10 (60:40, shortening)	3.57±1.22	3.80±1.13
F11 (50:50, margarine)	4.00±1.16	3.57±1.12
F12 (50:50, shortening)	4.43±1.20	3.40±1.31

Notes: Values are presented as mean±SD. A Kruskal-Wallis test showed that there is a significant difference between the categories of the independent variable (Formulations) with respect to the dependent variable (scoring aftertaste and hedonic aftertaste) (p=<.001). Scoring scale: 1 (Extremely not foreign aftertaste)-6 (Extremely foreign aftertaste). Hedonic scale 1 (extremely dislike) – 7 (extremely like)

Hardness of Gluten-Free Biscuits

Table 6 displays a significant difference between the categories of the independent variable (Formulation) and the dependent variable (scoring and hedonic hardness),as the p-value is <.001 from the Kruskal-Wallis test. As the proportion of jicama flour increases in the biscuit formulations, the scoring hardness generally increases. This trend is particularly notable in the formulations with higher jicama flour substitution. For example, F5 achieved the highest scoring hardness of 4.83±1.10, indicating a significant increase in texture firmness compared to F1, which scored 2.54±1.42. This value suggests that adding jicama flour contributes to a denser and firmer structure, likely due to its higher fiber content, which enhances the biscuit's rigidity.

However, this increase in hardness did not correspond with a similar increase in hedonic hardness. On the contrary, a higher jicama substitution ratio decreased the hedonic scores, indicating that panelists preferred softer rather than harder biscuits. For example, F5 with a high scoring hardness of 4.83±1.10 had a significantly lower hedonic score (3.60±1.38), reflecting the decreased acceptance of the firmer texture.

As a result of the hedonic taste, varying in fat type did not affect the acceptance of panelists toward the hardness of biscuits. However, different fat types did influence the intensity level of biscuits' hardness. Biscuits made with margarine have a higher intensity of hardness detected by the panelists than the ones made with shortening. According to Richirose & Soedirga (2023), biscuits made with margarine have a more rigid texture than those made with shortening. Margarine contains around 15%-20% water. Thus, it can absorb the flour, causing more moisture to evaporate during baking, resulting in a drier texture and making the biscuits harder. In contrast, shortening is 100% fat and does not add extra water, which helps retain more tender crumbs. In addition, margarine mainly contains a higher proportion of saturated fats, which may form more extensive or more structured crystals, contributing to a more rigid texture. On the other hand, shortening tends to form finer, more stable fat crystals, which can promote tenderness, as highlighted by Dadali and Elmaci (2020) and Moriya et al. (2020).

Color of Gluten-Free Biscuits

Table 7 displays a significant difference between the categories of the independent variable (Formulation) for the dependent variable (scoring and hedonic hardness), as the p-value is <.001 from the Kruskal-Wallis test. Table 7 shows that the intensity of the biscuit's color varied across formulations, with higher jicama flour substitution generally leading to an increased color, having to be browner, for example, in F11 and F12, which received the highest scoring color value of 4.46±1.50 and 4.77±1.19, respectively. The highest score suggests that jicama flour contributes to a darker or more intense biscuit color. This finding is aligned with Richirose & Soedirga (2023) that the higher the jicama flour in the biscuit's formulation, the lower the lightness value of the biscuits, indicating a darker color. Specifically, jicama flour itself has a lower lightness value (70.79±0.08) than cassava flour (75.23±0.11); thus, higher jicama flour substitution contributed to the darker color of biscuits. In addition, the darker color is also possibly due to Maillard reaction products formed between reducing sugars and amino acids during baking.

Regarding fat type, biscuits made with shortening tended to have slightly higher scoring color Regarding the fat type, biscuits made with shortening tended to have slightly higher scoring color values compared to their margarine-based counterparts at the same jicama flour ratio (e.g., F6: 4.34±1.45 vs F5: 3.80±1.64 and F12: 4.77±1.19 vs F11: 4.46±1.50). The color difference might have happened due to the difference in water content between the margarine and the shortening.

Table 6. Scoring and hedonic value of biscuit' hardness with different formulations

Formulation	Scoring Hardness	Hedonic Hardness
F1 (100:0, margarine)	2.54±1.42	5.23±1.24
F2 (100:0, shortening)	3.60±1.65	5.31±1.23
F3 (90:10, margarine)	3.09±1.25	5.03±1.27
F4 (90:10, shortening)	3.74±1.17	4.51±1.36
F5 (80:20, margarine)	4.83±1.10	3.60±1.38
F6 (80:20, shortening)	3.80±1.05	4.14±1.40
F7 (70:30, margarine)	2.43±1.20	5.17±1.67
F8 (70:30, shortening)	2.31±1.02	4.89±1.45
F9 (60:40, margarine)	2.37±0.84	4.66±1.30
F10 (60:40, shortening)	2.89±1.05	4.54±1.15
F11 (50:50, margarine)	3.46±1.24	4.37±1.24
F12 (50:50, shortening)	3.40±1.06	4.11±1.55

Notes: Values are presented as mean±SD. A Kruskal-Wallis test showed that there is a significant difference between the categories of the independent variable (Formulations) with respect to the dependent variable (scoring hardness and hedonic hardness) (p=<.001). Scoring scale: 1 (Extremely not hard)-6 (Extremely hard). Hedonic scale 1 (extremely dislike) – 7 (extremely like)

Table 7. Scoring and hedonic value of biscuit color with different formulations

Formulation	Scoring Color	Hedonic Color
F1 (100:0, margarine)	3.80± 1.57	5.63±0.97
F2 (100:0, shortening)	3.34±1.49	5.29±1.27
F3 (90:10, margarine)	3.80±1.37	4.66±1.28
F4 (90:10, shortening)	3.91±1.40	4.29±1.10
F5 (80:20, margarine)	3.80±1.64	4.17±1.36
F6 (80:20, shortening)	4.34±1.45	4.06±1.06
F7 (70:30, margarine)	3.97±1.54	5.94±1.00
F8 (70:30, shortening)	3.31±1.32	5.91±0.98
F9 (60:40, margarine)	3.89±1.47	4.63±1.09
F10 (60:40, shortening)	4.20±1.26	4.40±1.38
F11 (50:50, margarine)	4.46±1.50	4.06±1.35
F12 (50:50, shortening)	4.77±1.19	4.14±1.42

Notes: Values are presented as mean±SD. A Kruskal-Wallis test showed that there is a significant difference between the categories of the independent variable (Formulations) with respect to the dependent variable (scoring color and hedonic color) (p=<.001). Scoring scale: 1 (Extremely brown)-6 (Extremely brown). Hedonic scale 1 (extremely dislike) – 7 (extremely like)

Margarine contains around 15-20% water, which may influence the hydration of flour and affect browning reactions, while shortening, being 100% fat, allows for more uniform heat transfer and potential color development during baking (Dadali & Elmaci, 2020; Moriya *et al*., 2020).

The hedonic color values reveal that panelists preferred the appearance of biscuits with a lower jicama flour substitution. The highest hedonic color scores were observed in F7 (5.94±1.00) and F8 (5.91±0.98), indicating that formulations with a 70:30 wheat-to-jicama flour ratio had the most appealing color to panelists. However, as the jicama flour substitution increased, hedonic color scores tended to decrease, with F12 (4.14±1.42) and F11 (4.06±1.35) receiving the lowest scores. The difference in panelist acceptance suggests that while a certain degree of browning is desirable, excessive darkening due to high jicama flour content might negatively impact consumer preference.

Biscuits formulated with higher levels of jicama flour exhibited a darker color, likely contributing to lower color acceptance scores, implying that panelists prefer the lighter color of biscuits due to the perception of burnt and bitter taste acquired from darker-colored biscuits. The browning of biscuits can be attributed primarily to the Maillard reaction, which typically occurs between 140°C and 165°C. The baking process in this study was conducted at 150°C; it is likely that Maillard browning significantly contributed to the biscuit's darker appearance. (Lukinac *et al*., 2022).

In addition to the Maillard reaction, caramelization may have played a role in darkening the biscuits. Caramelization occurs when sugars undergo thermal decomposition at higher temperatures, typically above 160°C, producing deep brown pigments and characteristic flavors. The presence of sugars in jicama flour could enhance this effect, further darkening color and possibly altering the overall flavor profile. Maillard reaction and caramelization are key processes in baked goods, contributing to complex flavor development. However, these reactions can produce bitter and undesirable flavors at excessive levels, which could explain the lower hedonic color scores observed in biscuits with higher jicama flour content (Lukinac *et al*., 2022; Sukhla *et al*., 2022).

Overall, these findings highlight that both fat type and jicama flour substitution influence biscuits' color attributes. Shortening promotes a more intense color while increasing jicama flour levels results in darker biscuits, which may reduce the visual appeal and lower consumer acceptance.

Overall Acceptance of Gluten-Free Biscuits

Table 8 demonstrates a significant difference between the categories of the independent variable (Formulation) for the dependent variable (scoring and hedonic hardness), as the p-value is <.001 from the Kruskal-Wallis test. The overall acceptance scores indicate panelists preferred biscuits with lower jicama flour substitution. The highest acceptance was observed in F8 (5.69±0.96) and F1 (5.57±1.07), suggesting that biscuits made entirely from wheat flour or with a moderate substitution level (70:30 wheat-to-jicama flour ratio) were the most well-received. In contrast, biscuits with the highest jicama flour substitution (F11 and F12) had the lowest acceptance scores, 3.74±1.04 and 3.57±1.29, respectively.

This trend suggests that increasing jicama flour substitution negatively impacted the overall acceptance of the biscuits. One possible explanation is the intensified presence of foreign aromas and flavors associated with jicama flour, which became more pronounced at higher substitution levels. The sensory attributes of biscuits, including texture and color, may also have influenced panelist preferences.

Table 8. Overall acceptance of biscuit with different formulations

Formulation	Overall Acceptance
F1 (100:0, margarine)	5.57±1.07
F2 (100:0, shortening)	5.31±1.23
F3 (90:10, margarine)	4.77±1.26
F4 (90:10, shortening)	4.71±1.20
F5 (80:20, margarine)	4.09±1.17
F6 (80:20, shortening)	3.69±0.87
F7 (70:30, margarine)	5.54±1.12
F8 (70:30, shortening)	5.69±0.96
F9 (60:40, margarine)	4.37±1.06
F10 (60:40, shortening)	3.94±1.11
F11 (50:50, margarine)	3.74±1.04
F12 (50:50, shortening)	3.57±1.29

Notes: Values are presented as mean±SD. A Kruskal-Wallis test showed that there is a significant difference between the categories of the independent variable (Formulations) with respect to the dependent variable (overall acceptance). Scale 1 (extremely dislike) – 7 (extremely like)

As previously discussed, excessive browning due to the Maillard reaction and caramelization at higher jicama flour levels may have contributed to a less desirable appearance and potential bitter notes, reducing acceptance (Lukinac *et al*., 2022; Sukhla *et al*., 2022).

The highest overall acceptance was observed in F8 (5.69±0.96) and F7 (5.54±1.12), formulated with a 70:30 wheat-to-jicama flour ratio, suggesting that the biscuits maintained a desirable flavor, texture, and color balance at this substitution level. Interestingly, formulations with no jicama flour (F1 and F2) had slightly lower acceptance scores (5.57±1.07 and 5.31±1.23, respectively) than F7 and F8. The higher acceptance at F7 and F8 indicates that a moderate addition of jicama flour may have contributed positively to the sensory properties due to its mild sweetness and moisture-retaining properties, which could enhance the overall mouthfeel and texture.

As the proportion of jicama flour increased beyond moderate substitution (70:30), particularly in formulations with an 80:20 ratio (F5 and F6), the overall acceptance decreased ($p<0.05$) with acceptance scores of 4.09±1.17 and 3.69±0.87, respectively. These scores indicate that the panelists were generally neutral or slightly disliked the biscuits. The trend continued with higher levels of jicama flour, where F11 and F12 had lower acceptance scores of 3.74±1.04 and 3.57±1.29, respectively, suggesting that panelists slightly disliked these formulations. These findings might arise from several factors shown in the parameters tested in a hedonic test, such as aroma, taste, aftertaste, taste, and color of biscuits illustrated in Table 3-Table 7, respectively. The higher jicama flour content likely influenced the lower acceptance scores, which likely introduced more pronounced undesirable characteristics, such as an off-putting aroma and aftertaste, as well as textural changes that negatively impacted the biscuits' overall appeal. A higher proportion of jicama flour likely introduced more pronounced undesirable characteristics, such as an off-putting aroma, a lingering aftertaste, and a change in texture that negatively impacted the biscuits' overall appeal. The increased presence of jicama flour may have intensified these negative attributes, leading to lower acceptability.

Additionally, the type of fat used influenced the overall acceptance of the biscuits. Table 8 shows that formulations containing margarine have higher overall acceptance than those made with shortening. For instance, in F1 and F2, where no jicama flour was used, the acceptance scores for margarine-based biscuits (5.57±1.07) were slightly higher than for shortening-based biscuits (5.31±1.23). A similar trend was observed in F3 and F4 (90:10 wheat-to-jicama ratio), where margarine-based biscuits scored 4.77±1.26, slightly higher than their shortening-based biscuits at 4.71±1.20. The flavor-enhancing properties of margarine can explain this difference. Unlike shortening, which is flavor-neutral, margarine contains added butter-like notes that may contribute to a more favorable sensory perception (Dadali & Elmaci, 2020; Moriya *et al*., 2020). Margarine also has a higher water content (15–20%), affecting the texture by producing a firmer and slightly crispier bite, preferred in biscuits. On the other hand, shortening, which is 100% fat, leads to a more tender texture but lacks the additional flavor of margarine.

However, as the proportion of jicama flour increased (F9-F12), both margarine and shortening formulations experienced a decline in overall acceptance, though margarine formulations consistently received slightly higher scores. At higher jicama flour levels (F11 and F12), the undesirable foreign aroma and taste from the jicama flour became more prominent, which neither margarine nor shortening could effectively mask. Additionally, as discussed in the hedonic color evaluations, excessive darkening due to Maillard reaction and caramelization may have led to a perception of burnt or bitter flavors, further contributing to lower acceptance scores (Lukinac *et al*., 2022; Sukhla *et al*., 2022).

These findings suggest that moderate jicama flour substitution (ratio 70:30) enhances overall acceptability, but higher levels negatively affect sensory perception. Margarine-based formulations have a slight advantage in consumer preference due to their enhanced flavor contribution. However, this advantage diminishes at higher jicama flour ratios, where negative sensory attributes dominate.

Preferred Formulation of Gluten-Free Biscuit

The objective of effectiveness test is to determine the preferred formulation of biscuit in this study. Table 9 shows the F4 exhibits the highest NH value, which are 0.735 and 0.553, respectively compared to other formulations. These NH values were derived using the De Garmo method, commonly applied to evaluate overall effectiveness or preference based on various attributes. Based on these NH values, the preferred formulation chosen by the panelists was F4, which is a gluten-free biscuit made with a 90:10 ratio of cassava flour to jicama flour and shortening.

In contrast, formulations with higher ratios of jicama flour, such as F5 (80:20, margarine) and F6 (80:20, shortening), exhibited lower NH values (0.586 and 0.475 for the scoring test and 0.434 and 0.341 for the hedonic test, respectively), indicating reduced preference by the panelists. The decrease in NH values suggests that the higher proportion of jicama flour negatively impacted the overall acceptance of the biscuits, particularly in sensory attributes like aroma and taste, which are more affected by the increased presence of jicama flour.

Formulations F9 (60:40, margarine) and F10 (60:40, shortening) displayed even lower NH values (0.251 and 0.195 for the scoring test and 0.414 and 0.405 for the hedonic test), indicating a marked decline in preference. The decrease in NH values is likely due to the more presence foreign aftertaste and foreign aroma such as bitter and earthy which became more prominent as the jicama flour ratio increased.

Additionally, formulations with a 50:50 cassava: jicama flour ratio, such as F11 (margarine) and F12 (shortening), exhibited NH values of 0.209 and 0.095 (scoring test) and 0.373 and 0.444 (hedonic test), respectively. Although these formulations showed a slight improvement in the hedonic test, their overall acceptance was still lower compared to F4, suggesting that the panelists did not favor the high jicama flour content, possibly due to the undesirable sensory characteristics it introduced.

Table 9. NH value for each biscuit's formulation

Formulation	NH Value (scoring test)	NH value (hedonic test)
F1 (100:0, margarine)	0.729	0.457
F2 (100:0, shortening)	0.732	0.532
F3 (90:10, margarine)	0.723	0.454
F4 (90:10, shortening)	0.735	0.533
F5 (80:20, margarine)	0.586	0.434
F6 (80:20, shortening)	0.475	0.341
F7 (70:30, margarine)	0.434	0.372
F8 (70:30, shortening)	0.354	0.359
F9 (60:40, margarine)	0.251	0.414
F10 (60:40, shortening)	0.195	0.405
F11 (50:50, margarine)	0.209	0.373
F12 (50:50, shortening)	0.095	0.444

Overall, the results from both the scoring and hedonic tests show a clear trend: the formulation with a 90:10 ratio of cassava flour to jicama flour, combined with shortening (F4), was the most preferred formulation with the highest NH values. This formulation was perceived as having a balanced aroma, taste, texture, and color and was chosen as the preferred biscuit formulation.

CONCLUSIONS

Different formulations show a significant effect on the sensory properties of gluten-free biscuits. F4 was selected as the preferred formulation in this study. This formulation, consists of cassava flour and jicama flour within a ratio of 90:10 with shortening, was chosen to be the preferred formulation of gluten-free biscuits due to the closer sensory characteristics to the control than other formulations. Moreover, the preferred formulation in this study also aligns with the best formulation obtained based on the physicochemical characteristics in previous studies.

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