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Sensory Profiling of Mocaf (*Modified Cassava Flour)* Cookies with Substitution of *Gomphrena globosa L.* Powder Using the RATA (Rate-All-That-Apply) Method

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A B S T R A C T

Gomphrena globosa L. flowers are edible flowers containing betacyanin and bioactive compounds that can contribute to the sensory attributes of food products, such as purple color and floral aroma. This study aimed to describe the sensory profile of mocaf-based cookies with *Gomphrena globosa L.* flower powder substitution (0%, 5%, 10%, 15%, and 20%) using the Rate-All-That-Apply (RATA) method. The evaluation was conducted by 70 untrained panelists using 22 sensory attributes, which were analyzed through the Kruskal-Wallis test and Principal Component Analysis (PCA). PCA results showed that sample F0 (100% mocaf) was dominant in sweet, caramel, fatty, and yellow color attributes; F1 (5%) in savory, crispy, light, and gritty attributes; F2 and F4 (10% and 20%) in firm, dry, bitter, burnt, throat irritation, and floral aroma attributes; whereas F3 (15%) was associated with floral, green noteid, ashy, roasted, purple, and brown color attributes.

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero hunger
SDG 3: Good Health and Well-being
SDG 12: Responsible Consumption and Production
SDG 13: Climate Action

1. INTRODUCTION

1.1. Research Background

Consumer awareness of healthy foods continues to increase, driving a preference for natural food products that are not only nutritious but also maintain desirable sensory qualities [1]. This trend is reflected in the growing consumption of cookies, which increased from 1.9 kg in 2016 to 2.2 kg in 2020, with an average annual growth of 4.25%. In Indonesia, cookies are generally made from wheat flour derived from imported wheat, with a yearly import volume reaching 5 million tons This situation not only creates dependency on imports but also limits consumers with gluten intolerance [2]. Therefore, alternative local raw materials are needed, one of which is mocaf (Modified Cassava Flour), which has characteristics similar to wheat flour. Mocaf contains 87.3% starch, 0.4% fat, 1.2% protein, and 3.4% fiber [3]. Using mocaf as a base ingredient for cookies opens opportunities for developing new products by adding ingredients that are rarely used in similar products. One potential ingredient is *Gomphrena globosa L.* flower. The combination of mocaf with *Gomphrena globosa L.*flower introduces novelty in cookie development, as it utilizes local ingredients while producing sensory characteristics that have not been extensively studied.

Gomphrena globosa L. is an edible flower commonly found in home gardens. It is rich in betacyanin (92.4–166.62 mg/100 g) and contains protein (13.45%), crude fiber (13.39%), ash (15.58%), and antioxidant activity of up to 48.01% [4]. Additionally, *Gomphrena globosa L.*flowers contain volatile compounds such as (E)-β-ocimene and 3-hexen-1-ol acetate, which provide a characteristic sweet aroma, as well as nonanal,

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decanal, and geranyl acetone, which enrich the aroma profile [5]. The utilisation of Gomphrena globosa L. flowers has been widely applied in herbal teas [6] and as natural betacyanin-based colouring in cookies [7]. However, studies on their effect on the sensory profile of cookies remain limited. Therefore, consumer preference assessment becomes essential to ensure the product meets market expectations.

Consumer preference is usually measured through hedonic tests, which evaluate overall liking, including color, aroma, texture, and taste. This study employed the Rate-All-That-Apply (RATA) method, a consumer-based sensory profiling technique. RATA is a descriptive test designed to obtain quantitative data on the intensity of various sensory attributes, such as taste, aroma, texture, colour, and mouthfeel, perceived by panellists [8]. Data obtained from this method can serve as a basis for product development with optimal sensory quality aligned with consumer preferences [9].

The RATA procedure begins with a Focus Group Discussion (FGD), followed by RATA and hedonic testing. The resulting data were analyzed using XLSTAT 2024 and visualized in a Principal Component Analysis (PCA) table. PCA is used to simplify complex data into a biplot visualization, illustrating relationships among sensory attributes and the distribution of samples. In this study, sensory profiling of mocaf cookies with *Gomphrena globosa L.* flower powder substitution was conducted using the RATA method. The findings are expected to contribute to the development of natural food products based on local ingredients, with distinctive taste and aroma that enhance market appeal.

1.2. Literature Review

Cookies are one of the widely consumed food products as instant and convenient snacks because they can be eaten anytime. Well-packaged cookies can have a relatively long shelf life. Cookies can be regarded as a type of food that meets consumer needs. They are made from a mixture of wheat flour and other flours, combined with sugar, butter, and various ingredients, processed through baking [10]

Mocaf (modified cassava flour) is a flour made from cassava processed through fermentation using lactic acid bacteria, which produce pectinolytic and cellulolytic enzymes as well as lactic acid, resulting in flour with characteristics and quality similar to wheat flour. The development of local Indonesian food products can be supported by using mocaf as a new alternative to wheat flour [11]. Mocaf contains more carbohydrates than wheat flour but exhibits lower gelation properties. Its characteristics, such as gelation ability, adhesiveness (viscosity), solubility, and superior rehydration capacity, make it suitable for partial or complete substitution of wheat flour.

Gomphrena globosa L. or globe amaranth, is a perennial plant growing 30–60 cm tall, with opposite, elongated leaves 10–15 cm long. Its flower head resembles a clover, about 3.8 cm in size, consisting of inconspicuous small flowers. Gomphrena globosa is often used as an ornamental plant. Biochemical analysis of ethanol extracts from Gomphrena globosa L. flowers reveals bioactive compounds like sterols, triterpenoids, tannins, phenols, and flavonoids, which exhibit potential pharmacological activities, including antioxidant, anti-inflammatory, anticancer, and antibacterial effects. Seven identified phytochemicals show anti-inflammatory activity [12]. These compounds can contribute to sensory profiles when applied in food, adding uniqueness and complexity to flavors. Furthermore, natural pigments in *Gomphrena globosa L.*flowers can provide attractive color to cookies, enhancing the visual appeal of the final product

The Rate-All-That-Apply (RATA) method is an extension of the Check-All-That-Apply (CATA) method, allowing panelists not only to identify attributes but also to rate their intensity. This approach produces a more comprehensive sensory profile RATA testing is often combined with hedonic evaluation to link attribute intensity with consumer acceptance levels [13].

1.3. Research Objective

This study aims to describe the sensory profile of mocaf-based cookies substituted with *Gomphrena globosa L.*flower (Gomphrena globosa) powder at different levels using the Rate-All-that-Apply (RATA) method, as well as to identify the most preferred formulation to obtain the desired product quality..

2. MATERIALS AND METHODS

2.1. Research Materials

The ingredients used in this study included mocaf flour, Gomphrena globosa L. flower powder purchased from e-commerce platforms, margarine, eggs, granulated sugar, and baking powder, all obtained from a baking supply store in Surabaya. The equipment used in this research consisted of a digital scale, mixing bowls, a mixer, baking trays, an oven, spatulas, a sifter, a whisk, measuring spoons, a dough roller, and cookie molds. Additional tools included plates, prepared sensory evaluation questionnaires, and XLSTAT and SPSS software for data analysis.

2.2. Method

2.2.1. Experimental Design

The research methodology was carried out in several sequential stages, beginning with sample preparation, followed by texture and color analysis. A Focus Group Discussion (FGD) was conducted to identify relevant sensory attributes, which were then evaluated using the Rate-All-That-Apply (RATA) test with selected panellists. The final stage involved statistical data analysis to interpret the results. The product formulations tested included five variations: F0 (100% mocaf), F1 (95% mocaf: 5% *Gomphrena globosa L.* flower powder), F2 (90% mocaf: 10% *Gomphrena globosa L.* flower powder), F3 (85% mocaf: 15% *Gomphrena globosa L.* flower powder), and F4 (80% mocaf: 20% *Gomphrena globosa L.* flower powder), all prepared using the same procedures to ensure consistency across samples. The visual appearance of the five product formulations is presented in Figure 1. From left to right, the cookies exhibit a gradual change in color intensity corresponding to the increasing levels of *Gomphrena globosa L***.** flower powder substitution. The control sample F0 (100% mocaf) displays a bright yellowish tone characteristic of mocaf-based products without additional pigments, whereas samples F1 through F4 progressively develop darker brownish-red hues in line with the higher concentrations of flower powder

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Fig 1. Visual appearance of mocaf cookies with varying levels of Gomphrena globosa L. flower powder substitution

3. RESULT AND DISCUSSION

3.1. Focus Group Discussion (FGD)

Focus Group Discussion (FGD) is a guided discussion technique used to understand panelists perceptions and experiences regarding the sensory characteristics of a food product. The FGD in this study involved untrained panellists experienced in consuming similar products, particularly cookies. This experience enabled them to provide relevant responses regarding differences in sensory characteristics arising from the substitution of *Gomphrena globosa L*. flower powder in mocaf cookies. Additionally, panelists were selected based on good sensory health, particularly unimpaired taste and smell, to ensure the accuracy of their evaluations. The FGD was conducted using five mocaf cookie samples with varying levels of *Gomphrena globosa L*. flower powder substitution. Following the FGD, 22 RATA sensory attributes considered most relevant were identified. These agreed-upon attributes were then used for sensory evaluation using the RATA method with 70 untrained panelists. These attributes were grouped into five main categories: color (brown, yellow, purple), aroma (roasted, ashy, sweet, burnt, caramel, floral, green note), texture (firm, light, gritty), taste (savory, fatty, sweet, floral, bitter), and mouthfeel (crispy, gritty, throat irritation, dry).

Table 1. Results of attribute selection from the Focus Group Discussion

Attribute		Description
Color	Brown	The sample appears brown in color
	Yellow	The sample appears yellow in color
	Purple	The sample appears purple in color
Aroma	Roasted	Aroma impression of baked products at high temperature
	Ashy	Dry, dusty, smoky aroma associated with burnt residues
	Sweet	Aroma associated with sweetness
	Burnt	Aroma associated with baked products at high temperature
	Caramel	Aroma associated with caramelized sugar
	Floral	Floral aroma (*Gomphrena globosa L.* flower-like)
	Green note	Fresh, raw aroma associated with plant material, with a green note
Texture	Firm	Sample feels firm when broken
	Light	Texture feels light when broken
	Gritty	Presence of small, hard, sandy particles when broken
Flavor	Savory	Savory taste
	Fatty	Fat-associated taste
	Sweet	Sweet taste stimulated by sucrose
	Floral	Floral taste lingering after consumption
	Bitter	Taste associated with bitterness
Mouthfeel	Renyah	Crispy or easily crumbling sensation in the mouth
	Gritty	Gritty sensation in the mouth
	Throat Irritation	Coarse or rough sensation when swallowing
	Dry	Dry impression during consumption

3.2 Attribute Profiling of Cookies Using the Rate-All-That-Apply (RATA) Method

Analysis of data obtained from the Focus Group Discussion (FGD) identified p-values for 22 sensory attributes, which were subsequently assessed using the RATA (Rate-All-That-Apply) method.

To be included in Table 2. the analysis results showed that sample F0 (control without *Gomphrena globosa L*. flower) was characterized by a dominant yellow color and a more pronounced savory taste. This is consistent with the basic characteristics of mocaf, which are off-white to yellowish, and the absence of betacyanin pigments from Gomphrena globosa L. flowers. The savoury taste arises from Maillard reaction compounds formed during baking [14]. In F1, a color shift toward purple was observed, likely due to the contribution of betacyanin pigments [15].

In F2, floral characteristics in both aroma and taste became more evident, accompanied by the emergence of a gritty texture. The floral aroma is likely triggered by volatile compounds such as nonanal and hexanal from *Gomphrena globosa L*. flowers [16], while the gritty texture originates from fibers that were not fully dispersed [17]. Furthermore, F3 exhibited increased roasted and sweet aromas along with a firm texture. This indicates an intensification of the Maillard reaction with the addition of *Gomphrena globosa L*. flowers. The increased density is related to the higher fibre content in the cookie formulation [18].

Table 2. Analysis results of p-values for sensory attributes of mocaf cookies with *Gomphrena globosa L.* flower powder substitution

Atribut	Sampel				
	F0	F1	F2	F3	F4
Color					
Brown	0.31[a]	1.21[a]	3.28[b]	3.84[b]	4.22[c]
Yellow	4.78[d]	3.10[c]	1.38[b]	2.07[ab]	0.62[a]
Purple	0.07[a]	1.15[b]	2.21[c]	3.84[cd]	2.97[d]
Aroma					
Roasted	1.90[a]	2.42[ab]	2.92[bc]	3.10[c]	3.28[c]
Ashy	0.87[a]	1.24[ab]	1.64[bc]	2.08[c]	2.12[c]
Sweet	2.51[b]	1.54[a]	1.31[a]	1.28[a]	1.21[a]
Burnt	1.44[a]	1.72[a]	2.77[b]	2.55[bb]	2.5[b]
Floral	0.55[a]	1.02[ab]	2.20[bc]	1.68[cd]	2.32[d]
Green note	0.51[a]	1.04[ab]	1.77[b]	1.44[bc]	2.27[c]
Caramel	1.41[a]	1.21[a]	1.25[a]	1.31[a]	1.27[a]
Texture					
Firm	1.95[ab]	1.62[a]	2.94[c]	2.62[bc]	3[c]
Light	3.31[c]	3.21[bc]	2.21[a]	2.52[ab]	2.2[a]
Gritty	2.51[a]	2.7[a]	2.18[a]	2.5[a]	2.34[a]
Flavor					
Savory	3.25[c]	3.15[bc]	2.57[ab]	2.41[a]	2.22[a]
Fatty	2.42[b]	1.61[a]	2.1[ab]	1.74[ab]	1.78[ab]
Sweet	3.28[c]	2.44[b]	1.97[ab]	1.87[ab]	1.41[a]
Floral	0.62[a]	1.12[a]	2.48[b]	2.18[b]	2.34[b]
Bitter	0.12[a]	0.24[a]	1.6[b]	2.12[bc]	2.88[c]
Mouthfeel					
Crispy	3.14[bc]	3.24[c]	2.77[bc]	2.5[ab]	2.22[a]
Throat Irritation	1.41[ab]	1.24[a]	2.11[b]	1.8[ab]	2.15[b]
Gritty	2.87[a]	3.20[a]	2.84[a]	3.08[a]	2.84[a]
Dry	2.28[a]	2.30[a]	2.71[a]	2.70[a]	2.84[a]

Description: Mean values followed by different letters indicate significant differences between rows ($p < 0.05$). Scale criteria: 1 (low), 2 (slightly low), 3 (medium), 4 (slightly high), 5 (high).

In F4, roasted and floral aromas became more dominant compared to the other samples, accompanied by a more pronounced gritty texture. The color changes were also consistent, with reduced yellow dominance and increased purple coloration due to betacyanin pigments. Overall, the substitution of *Gomphrena globosa L.* flower powder had a significant effect on the sensory profile of the cookies, particularly in terms of aroma, color, and texture, with a tendency for increased floral and roasted notes as the *Gomphrena globosa L.* concentration increased, albeit with the trade-off of a stronger gritty texture.

3.3. Principal Componen Analysis (PCA)

Principal Component Analysis (PCA) aims to summarize as much variability in the original data as possible using a smaller number of principal components, also referred to as factors. This method works by linearly transforming the original variables into a new coordinate system, so that the greatest variance is captured by the first principal component, followed by the subsequent components. This process facilitates more efficient interpretation and visualization of the data without substantially losing important information.

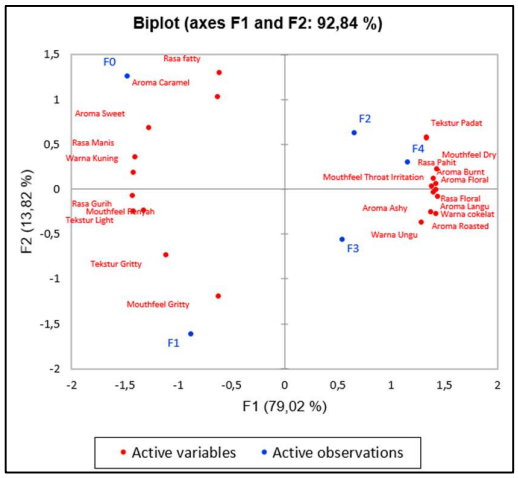

Fig 2. Results of Principal Component Analysis (PCA) Of cookies

Figure 2. illustrates the mapping of sensory attributes for each mocaf cookie sample with *Gomphrena globosa L.* flower powder substitution. Sample F0 was associated with sweet aroma, caramel aroma, sweet taste, savory taste, yellow color, and light mouthfeel. Sample F1 was related to gritty texture and gritty mouthfeel, reflecting a less smooth character. Sample F2 occupied a neutral position, with relatively few associated attributes. Sample F3 was associated with purple color and ashy aroma. Meanwhile, sample F4 was linked to bitter taste, firm texture, dry mouthfeel, burnt, roasted, floral, and green note aromas, as well as brown color, representing a dominant and intense sensory profile.

3.4. Preference Mapping Sensory Attributes

The objective of Preference Mapping is to identify the sensory attributes associated with panelists' liking of mocaf cookies with *Gomphrena globosa L.* flower powder substitution. Preference mapping was obtained through cluster analysis using the Agglomerative Hierarchical Clustering (AHC) method and principal component analysis (PCA) [19]. The red area indicates that 80–100% of panelists rated the preference above average or high, the yellow area 60–80%, the green area 40–60%, the light blue area 20–40%, and the dark blue area 0–20%. The results of the preference mapping are presented in Figure 3.

Samples F0 and F1 were located in the green zone (40–60%), indicating a moderate level of liking. Sample F0 was positioned close to positive sensory attributes such as sweet aroma, sweet taste, caramel aroma, fatty aroma, and yellow color, which are generally associated with conventional cookie characteristics preferred by consumers. This aligns with [20]. who reported that sweet taste and caramel aroma contribute significantly to increasing consumer liking of cookies. Conversely, although sample F1 was also in the green zone, it was positioned near attributes related to gritty texture and gritty mouthfeel.

Meanwhile, samples F2, F3, and F4 occupied the light blue area (20–40%), indicating a low level of liking. These three samples were located near attributes associated with less preferred perceptions, such as firm texture, dry mouthfeel, throat irritation, burnt aroma, floral aroma, floral taste, green note aroma, ashy aroma, brown color, roasted aroma, and purple color. The presence of these attributes is due to the higher substitution

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levels of *Gomphrena globosa L*. flower powder, which affected the resulting cookie characteristics and introduced less favored sensory traits. The firm cookie texture is attributed to the fiber content in the flower powder [21]. Reported that higher levels of *Gomphrena globosa L*. substitution produce a firmr and drier structure. The green note aroma and bitter taste are influenced by bioactive compounds naturally present in the flowers. At the substitution levels used in this study, these compounds resulted in characteristic bitter taste, floral aroma, and green note aroma, affecting consumer perception and acceptance. Specifically, sample F4 was positioned closest to these less-preferred attributes, indicating a dominance of unbalanced sensory characteristics due to the high level of *Gomphrena globosa L*. substitution.

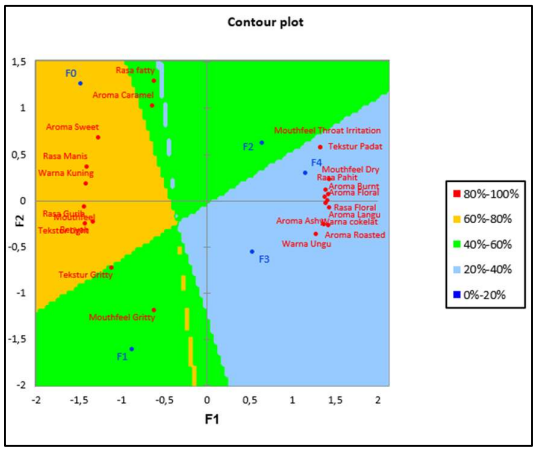

Fig 3. Preference Mapping of Sensory Attributes mocaf cookies substitute for *Gomphrena globosa L.* flower powder

The preference mapping results indicate that panellist acceptance was higher for mocaf cookie formulations substituted with Gomphrena globosa L. flower powder, which retained sensory characteristics similar to conventional cookies. The dominance of Gomphrena globosa L.'s specific attributes, such as bitter, green note, dry, and firm, reduced the liking. In contrast, samples F1 (5% *Gomphrena globosa L*.) and F0 (100% mocaf) were the most preferred, associated with a caramel aroma, sweet and savoury taste, yellow colour, light texture, and crisp mouthfeel. Therefore, F1 is recommended as the base formulation for developing mocaf cookies with *Gomphrena globosa L*. flower powder substitution.

4. CONCLUSION

Panelists' perceptions of mocaf cookies with *Gomphrena globosa L*. flower powder substitution revealed distinct sensory attribute characteristics for each product. A sweet aroma, sweet taste, yellow colour, caramel aroma, and fatty taste characterised the product without substitution (F0). The 5% substitution product (F1) was associated with gritty texture and gritty mouthfeel. Products with 10%, 15%, and 20% substitution (F2, F3, F4) were linked to firm texture, dry mouthfeel, throat irritation, bitter taste, burnt aroma, floral aroma, green note aroma, ashy aroma, brown color, purple color, and roasted aroma. Panelists showed the highest preference (around 60–80%) for the non-substituted product, followed by the 5% substitution. In contrast, products with 10%, 15%, and 20% substitution received preference scores below 40%. Overall, panelists tended to avoid attributes such as bitter taste, burnt, throat irritation, ashy, and dry mouthfeel, which were associated with the least-liked products. Conversely, attributes like a sweet aroma, sweet taste, and caramel aroma dominated the most-preferred products.

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