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Formulation and Organoleptic Evaluation of Moringa Leaf (*Moringa oleifera*) Crackers as an Innovative Nutritious Snack

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Abstract: This study aimed to analyze the effect of moringa leaf flour addition at concentrations of 0%, 5%, 10%, and 15% on the sensory quality of crackers and to identify the most acceptable formulation based on consumer preference. The study employed a Completely Randomized Design (CRD) with three replications. Organoleptic evaluation was conducted with 30 untrained panelists using a 5-point hedonic scale to assess color, aroma, taste, and texture. The data were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's HSD test at a significance level of $\alpha = 0.05$. The results showed that moringa leaf flour addition had a significant effect on all organoleptic attributes ($p < 0.05$). The formulation containing 10% moringa leaf flour showed the most balanced sensory profile, with mean hedonic scores of 3.60 for aroma, 3.47 for texture, 3.10 for taste, and 3.03 for color. These scores ranged from neutral to approaching like, indicating that the 10% formulation was relatively the most acceptable formulation compared with the other treatments.
Keywords: Moringa leaves; food formulation; crackers; organoleptic characteristics; hedonic test

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INTRODUCTION

Malnutrition remains a major global health challenge, particularly in low- and middle-income countries, including Indonesia. Malnutrition includes undernutrition, micronutrient deficiencies, overweight, obesity, and diet-related noncommunicable diseases; however, undernutrition remains closely associated with child morbidity and mortality in many developing regions (World Health Organization, 2024). According to the Ministry of Health of the Republic of Indonesia (2013), the minimum energy requirement for emergency food provision is 2,100 kcal/day for adults and 1,125–1,250 kcal/day for children aged 1–6 years. This condition highlights the need for food diversification based on local resources as a strategy to improve community nutritional status and strengthen household food resilience. One local plant with high nutritional potential is moringa (*Moringa oleifera*). This plant is widely known as the "miracle tree" because of its exceptional nutrient content, including protein at 6.7 g/100 g, which is approximately twice that of yogurt; vitamin A at 6.8 mg/100 g, which is approximately four times that of carrots; and vitamin C at 220 mg/100 g, which is approximately seven times that of oranges (Krisnadi, 2015). Previous reviews have also reported that moringa leaves are rich in minerals, vitamins, essential phytochemicals, and antioxidant compounds, making them a promising ingredient for nutrition-oriented food development (Gopalakrishnan et al., 2016; Saini et al., 2016). All parts of the moringa plant, including its leaves, flowers, and seeds, can be utilized to support health and improve household nutritional quality (Suaib, 2015).

Despite its high nutritional value, the utilization of moringa leaves in Indonesia remains limited and is generally restricted to traditional vegetable dishes. In Central Sulawesi, particularly among the Kaili ethnic community, moringa leaves are commonly known as the main ingredient of *uta kelor*, a traditional moringa-based vegetable dish, and have not been widely developed into modern food products. The limited variety of moringa-based processed foods may reduce consumer interest, especially among children, who are generally less inclined to consume vegetables. Therefore, innovative food products are needed to improve consumer acceptability while maintaining nutritional value (Dima & Waja, 2022). Developing familiar snack products enriched with nutrient-dense local ingredients is one practical approach to increasing the consumption of plant-based functional foods, particularly when the product remains acceptable in terms of taste, aroma, color, and texture (Lawless & Heymann, 2010; Oyeyinka & Oyeyinka, 2018).

Kerupuk is one of the most popular snack products in Indonesia. It has a relatively long shelf life, is easy to consume across different age groups, and can be produced using either traditional or modern processing methods. From a food technology perspective, starch-based *kerupuk* has the potential to serve as a carrier or vehicle for nutrient fortification. The starch matrix structure of *kerupuk* allows the incorporation of functional ingredients, such as moringa leaf flour, without substantially altering the basic characteristics of the product when properly formulated. In starch-based products, the balance between starch gelatinization, moisture removal, and expansion during frying plays an important role in determining the final texture and crispness of the product (Fellows, 2017). The processing stages of *kerupuk*, including mixing, molding, steaming, and drying, also provide an opportunity for relatively uniform ingredient distribution in the final product. According to the Indonesian National Standard (BSN, 2013), *kerupuk* is defined as a dry food product made from tapioca or sago flour that must be fried before consumption. Thus, the selection of *kerupuk* as a product development model is based not only on its popularity but also on its technological characteristics, which support fortification and its broad potential consumer acceptance. Fortifying *kerupuk* with moringa leaves may therefore offer a promising alternative for developing a healthier snack that can be accepted by the wider community (Noflidaputri & Lestari, 2022). However, the incorporation of moringa leaf flour must be optimized because excessive addition may alter sensory attributes, including color, aroma, taste, and texture, which are critical determinants of consumer acceptance (Lawless & Heymann, 2010; Oyeyinka & Oyeyinka, 2018).

Several previous studies have explored the use of moringa leaves in food products, including fish meatballs (Indraswari et al., 2022), nuggets (Amelia et al., 2023), and animal-protein-based *kerupuk* (Aprillia, 2023; Muchsiri et al., 2019). Indraswari et al. (2022) reported that 5% substitution with moringa leaf flour in mackerel fish meatballs produced the best organoleptic characteristics, with a protein content of 11.71%, iron content of 15.5 mg/100 g, and calcium content of 480.9 mg/100 g. Meanwhile, Muchsiri et al. (2019) found that the addition of up to 10% moringa leaf flour to snakeskin gourami fish *kerupuk* remained organoleptically acceptable. These findings indicate that moringa leaf flour has potential as a fortifying ingredient, but its concentration should be carefully controlled to maintain product palatability and consumer preference. However, these studies generally used animal protein as the main ingredient and therefore do not fully represent the development of entirely plant-based products. Studies on moringa leaf flour-based *kerupuk* without the addition of animal-derived ingredients remain limited, and systematic evaluation of different concentrations to determine the optimal formulation has not been widely conducted.

This research gap is important because plant-based *kerupuk* may provide a more accessible and culturally acceptable snack innovation while supporting the use of local food resources.

Based on this background, this study aimed to: (1) analyze the effect of adding moringa leaf flour at concentrations of 0%, 5%, 10%, and 15% on the sensory quality of *kerupuk*, including color, aroma, taste, and texture; and (2) determine the best formulation based on consumer preference through a hedonic test. The findings of this study are expected to provide a practical contribution to the development of local food-based snack products with the potential to improve community nutritional quality. In addition, this study may provide preliminary information for further research on the nutritional composition, shelf life, and consumer acceptance of plant-based *kerupuk* fortified with moringa leaf flour.

METHOD

This study was conducted as an experimental study using a Completely Randomized Design (CRD) with four treatment levels of moringa (*Moringa oleifera*) leaf flour substitution, namely F0 (0%), F1 (5%), F2 (10%), and F3 (15%). The percentage of moringa leaf flour was calculated based on the total dry flour mixture of 500 g. Each treatment was replicated three times, resulting in 12 experimental units. The materials used in this study consisted of tapioca flour as the main ingredient, moringa leaf flour, garlic, salt, and water. The equipment used included a digital scale, mixing bowls, sieves, stove, steamer, knives, cutting board, drying trays, and frying equipment.

The main ingredient formulation for each treatment was prepared by substituting tapioca flour with moringa leaf flour according to the specified treatment level. The formulations were as follows:

- F0 consisted of 500 g tapioca flour and 0 g moringa leaf flour
- F1 consisted of 475 g tapioca flour and 25 g moringa leaf flour
- F2 consisted of 450 g tapioca flour and 50 g moringa leaf flour
- F3 consisted of 425 g tapioca flour and 75 g moringa leaf flour.

The seasoning ingredients, consisting of 10 g garlic and 5 g salt, were added in equal amounts to all treatments to minimize their influence on the experimental variables. A total of 250 mL of water was added to each formulation to obtain a homogeneous dough with a consistency suitable for shaping.

The cracker production process began by mixing tapioca flour and moringa leaf flour according to the formulation of each treatment. Garlic, salt, and water were then added gradually, and the mixture was kneaded until a uniform and homogeneous dough was obtained. The dough was shaped into cylinders and steamed at approximately 100°C for 30-45 minutes until fully cooked. After steaming, the dough was cooled at room temperature for approximately 12 hours until it hardened and could be sliced easily. The dough was then sliced into thin pieces with a thickness of approximately 2-3 mm using a cutting tool to obtain uniform size and thickness. The cracker slices were dried under direct sunlight for 1-3 days until they became sufficiently dry and brittle. The dried crackers were then fried in hot oil at 170-180°C for approximately 10-15 seconds until fully expanded. The fried crackers were subsequently used for organoleptic evaluation.

The organoleptic evaluation was conducted by 30 untrained panelists. The number of panelists was selected based on the recommended range for consumer hedonic testing, which generally involves 20-30 panelists. Sensory assessment was performed using a five-point hedonic scale, where 1 = strongly dislike, 2 = dislike, 3 =

neutral, 4 = like, and 5 = strongly like. The evaluated sensory attributes included color, aroma, taste, and texture.

The collected data were first tested for statistical assumptions using the Shapiro–Wilk test for normality and Levene's test for homogeneity of variance. Data that met these assumptions were analyzed using one-way analysis of variance (One-Way ANOVA) at a significance level of $\alpha = 0.05$. When significant differences were detected (Sig. < 0.05), Tukey's honestly significant difference (HSD) test was performed to identify differences among treatments and to determine the best cracker formulation based on overall sensory acceptability.

RESULTS AND DISCUSSION

The results showed that variations in the concentration of Moringa leaf flour in the cracker formulation produced differences in sensory characteristics among treatments. These differences were evaluated through organoleptic testing based on four sensory attributes: color, aroma, taste, and texture. Sensory evaluation is an important approach in food product development because attributes such as color, aroma, taste, and texture strongly influence consumer acceptance of new food products (Lawless & Heymann, 2010). The mean hedonic scores for the four sensory attributes are presented in Table 1.

Table 1. Mean hedonic scores of Moringa leaf crackers under different treatments

Parameter	F0 (0%)	F1 (5%)	F2 (10%)	F3 (15%)
Color	3.27	2.65	3.03	2.45
Aroma	3.38	2.65	3.60	2.54
Taste	3.01	3.74	3.10	2.76
Texture	3.45	2.68	3.47	2.95

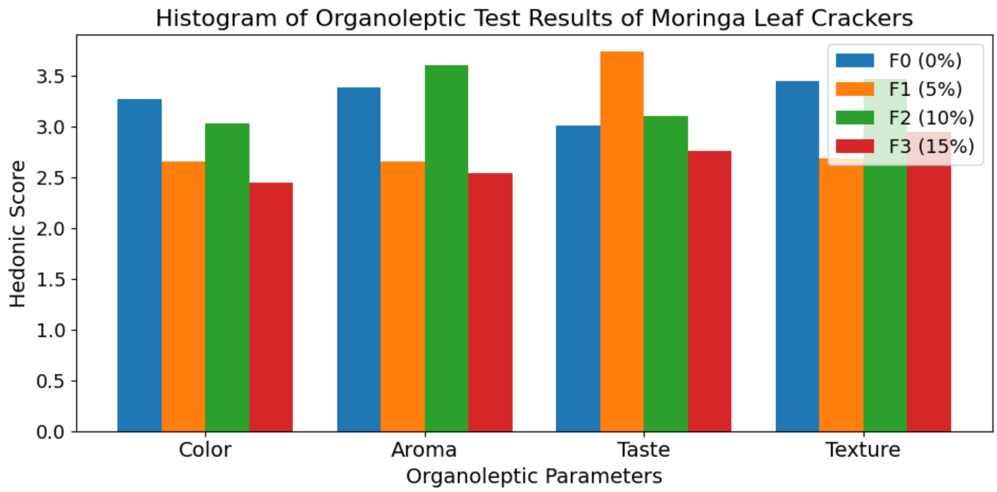

Figure 1. Mean hedonic scores of moringa leaf crackers based on organoleptic parameters

Color

The organoleptic evaluation of color, as shown in Table 1, indicated that different concentrations of Moringa leaf flour significantly affected panelists' acceptance of the product ($p < 0.05$). The F0 treatment, without Moringa leaf flour, produced a bright yellowish-white color and obtained the highest mean score of 3.27. This result indicates that crackers without Moringa leaf flour substitution were the most preferred in terms of color. The F1 treatment, containing 5% Moringa leaf flour, produced a pale greenish color and obtained a mean score of 2.65. The F2 treatment, containing 10% Moringa leaf flour, obtained a mean score of 3.03, with a more uniform and clearly visible green color that remained acceptable to the panelists. In contrast, the F3 treatment, containing 15% Moringa leaf flour, received the lowest mean score of 2.45 because it produced a darker green color than the other treatments.

The color change was primarily associated with the chlorophyll content of Moringa leaves. During heating, chlorophyll may degrade and be converted into pheophytin, which produces a darker green color (Marhaeni, 2021). In general, chlorophyll pigments in green plant-based foods are sensitive to heat, pH, and oxidation. During thermal processing, the loss of magnesium ions from the chlorophyll structure can lead to pheophytin formation, causing the green color to become duller or darker (Damodaran & Parkin, 2017). Therefore, the higher the concentration of Moringa leaf flour added to the formulation, the more intense the color change became.

This finding is consistent with Aprillia (2023), who reported that the addition of 8–12% Moringa leaves to shrimp-head skin crackers produced the most acceptable color, with hedonic scores ranging from 3.8 to 4.2 on a five-point scale. From a consumer preference perspective, an excessively dark or intense color is often associated with reduced product quality and an undesirable taste expectation, which may influence sensory perception before consumption. This is in line with the principle of sensory evaluation, which states that color is the first visual attribute assessed by consumers and can influence their initial perception of product quality, freshness, and flavor (Lawless & Heymann, 2010).

Aroma

The organoleptic evaluation of aroma showed significant differences among treatments ($p < 0.05$). The F0 treatment obtained a mean score of 3.38 and was characterized by the typical neutral aroma of tapioca-based crackers. The F1 treatment obtained a mean score of 2.65, indicating that the aroma of Moringa leaves began to emerge but remained mild and blended with the tapioca aroma. The F2 treatment produced the highest mean score of 3.60, indicating that at this concentration, the aroma of Moringa leaves was better balanced and more preferred by the panelists. In contrast, the F3 treatment obtained a mean score of 2.54 because the Moringa aroma became more dominant and intense, thereby reducing panelist preference.

The decline in aroma acceptance at concentrations above 10% is consistent with the findings of Indraswari et al. (2022) in fish balls substituted with Moringa leaf flour, in which the aroma score decreased from 4.2 to 3.5 at a concentration of 15%. This result indicates that the acceptance threshold for Moringa aroma in processed food products occurs within a certain concentration range; therefore, excessive addition should be carefully controlled. Moringa leaves contain various bioactive compounds, including phenolic compounds, flavonoids, and glucosinolates, which may contribute to their characteristic aroma, green or leafy notes, and bitter taste in fortified food products (Saini et al., 2016; Oyeyinka & Oyeyinka, 2018).

In sensory perception, aroma and taste are closely related in forming the overall flavor of a product. Thus, a dominant Moringa aroma at higher concentrations may mask the original flavor profile of the crackers and reduce consumer acceptance. Therefore, maintaining a balance between the characteristic aroma of the fortifying ingredient and the basic sensory properties of the product is essential for the successful formulation of plant-based functional foods (Lawless & Heymann, 2010).

Taste

The organoleptic evaluation of taste showed significant differences among treatments ($p < 0.05$). The F0 treatment obtained a mean score of 3.01 and was characterized by the relatively neutral taste of tapioca crackers. The F1 treatment produced the highest mean score of 3.74, indicating that the mild taste of Moringa leaves blended harmoniously with the tapioca base and was the most preferred formulation for the taste attribute. The F2 treatment obtained a mean score of 3.10, showing that the Moringa taste was more noticeable but still balanced with the tapioca flavor. Meanwhile, the F3 treatment received the lowest mean score of 2.76 because the stronger Moringa taste reduced panelist preference.

Muchsiri et al. (2019) stated that the addition of up to 10% Moringa leaf flour to snakeskin gourami crackers remained organoleptically acceptable without significantly reducing the sensory quality of the product. However, concentrations above 12% began to produce off-flavors that were not preferred by consumers. This phenomenon confirms that a 10% concentration represents a relatively optimal point for balancing fortification value and palatability. Moringa leaves are widely recognized as a food ingredient rich in protein, minerals, vitamins, and antioxidant compounds and have therefore been used as a fortifying ingredient in various food products. However, excessive addition may negatively affect sensory characteristics because of the distinctive leafy, bitter, or astringent taste of Moringa leaves (Gopalakrishnan et al., 2016; Oyeyinka & Oyeyinka, 2018).

At a concentration of 10%, the bioactive compounds in Moringa leaves were likely still within an acceptable sensory range and did not produce excessive bitterness or astringency. The initial steaming process may also help reduce the raw or grassy flavor of plant-based ingredients and may partially reduce antinutritional compounds, such as tannins and phytates, which can contribute to an astringent taste (Ramdhani et al., 2024). Therefore, the lower taste score observed in the F3 treatment indicates that increasing the concentration of Moringa leaf flour does not necessarily improve sensory acceptance, particularly for the taste attribute.

Texture

The organoleptic evaluation of texture also showed significant differences among treatments ($p < 0.05$). The F0 treatment obtained a mean score of 3.45, reflecting the typical crispy texture of tapioca-based crackers. The F1 treatment obtained a mean score of 2.68 and was perceived as relatively less crispy. The F2 treatment produced the highest mean score of 3.47, indicating the crispiest texture among all treatments. In contrast, the F3 treatment obtained a mean score of 2.95 and tended to produce a harder texture than the other formulations.

Muchsiri et al. (2019) also reported that snakeskin gourami crackers with 10% Moringa leaf flour had the best texture, with crispness that remained acceptable to most panelists, whereas the 15% concentration produced a significantly harder and less crispy texture. The reduction in crispness at concentrations above 10% may be attributed to the protein and fiber content of Moringa leaf flour, which can interfere with starch gelatinization and the formation of an optimal porous structure (Yuliyanti & Arifin, 2020). In starch-based products such as crackers, starch gelatinization during heating and dough expansion during frying are essential processes that determine air-cell formation, expansion volume, and the crispness of the final product (Fellows, 2017).

Increased fiber content may also bind water molecules more strongly, thereby reducing dough expansion during frying and producing a denser texture. In addition, substituting part of the tapioca flour with Moringa leaf flour may reduce the proportion of starch responsible for cracker expansion. As a result, higher concentrations of

Moringa leaf flour may produce a more compact structure and reduce crispness. Therefore, the 10% concentration in the F2 treatment appeared to maintain an appropriate balance between the addition of the fortifying ingredient and the formation of the characteristic crispy texture of crackers.

Determination of the Best Formulation

Based on the overall organoleptic evaluation of the four sensory attributes—color, aroma, taste, and texture—the F2 formulation, containing 10% Moringa leaf flour, equivalent to 450 g of tapioca flour and 50 g of Moringa leaf flour, was identified as the best formulation relative to the other treatments. Although F1 (5%) produced the highest score for taste and F0 (0%) produced the highest score for color, F2 demonstrated a more balanced sensory profile across all attributes, with scores of 3.60 for aroma, 3.47 for texture, 3.03 for color, and 3.10 for taste. The selection of the best formulation in food product development should not be based on a single sensory attribute but rather on the overall balance of attributes that determine consumer acceptance (Lawless & Heymann, 2010).

In addition to sensory considerations, the addition of 10% Moringa leaf flour may provide greater nutritional fortification potential than lower concentrations, considering that Moringa leaves contain relatively high levels of protein, vitamins, minerals, and antioxidant compounds (Krisnadi, 2015; Gopalakrishnan et al., 2016; Oyeyinka & Oyeyinka, 2018). However, because this study focused on organoleptic evaluation, the nutritional benefits of the product still need to be confirmed through proximate analysis and assessment of mineral, vitamin, and bioactive compound contents in the final product. Therefore, the F2 formulation can be considered the best formulation from a sensory perspective and has potential for further development as a local food-based cracker product with improved nutritional value.

Overall, color, aroma, taste, and texture interacted in determining product acceptance. An imbalance in one sensory attribute may reduce the overall sensory quality of the product. The F2 formulation, containing 10% Moringa leaf flour, successfully maintained a balance between the effect of Moringa leaf addition and the basic characteristics of crackers preferred by consumers. Therefore, this formulation is suitable for further development as a local food-based snack. Further studies should include nutritional analysis, shelf-life evaluation, food safety assessment, and consumer acceptance testing with a larger number of panelists to support the claim of Moringa leaf crackers as a nutritious snack with more comprehensive chemical and sensory data.

CONCLUSION

The addition of Moringa leaf flour (Moringa oleifera) significantly affected all sensory attributes of the crackers, including color, aroma, taste, and texture ($p < 0.05$). Among the tested formulations, the 10% Moringa leaf flour formulation (F2), consisting of 450 g tapioca flour and 50 g Moringa leaf flour, showed the most balanced sensory acceptance. This formulation produced mean hedonic scores of 3.03 for color, 3.60 for aroma, 3.10 for taste, and 3.47 for texture. Although these scores were generally within the neutral to nearly liked category, F2 demonstrated better overall acceptability than the other Moringa-enriched formulations. Therefore, the 10% formulation has potential for further development as a local food-based snack product with added Moringa leaf flour. Further nutritional and shelf-life analyses are needed to confirm its functional value and feasibility for broader application.

RECOMMENDATION

Further research is recommended to examine the nutritional composition of Moringa leaf crackers, including protein, fiber, vitamin, and mineral contents, as well as their shelf-life stability. Sensory evaluation involving a larger and more demographically diverse panel should also be conducted to obtain more representative data on consumer acceptance. In addition, economic feasibility analysis and proximate testing of the best formulation are needed to support the development of this product at the household industry scale.

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