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Development of Soft Lactation Cookies with *Katuk*, Moringa, and Sweet Potato: Nutritional Enhancement and Sensory Acceptability for Breastfeeding Mothers

Olivia Anggraeny*, **Adelya Desi Kurniawati, Clarista Aurelia Saputri, Fania Nur Aini, Helena Christiani Putri, Octaviana Anisatul and Sabila Dwi Masita Febriani**

Department of Nutrition, Faculty of Health Sciences, Brawijaya University, Malang, Indonesia

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Abstract

Breastfeeding plays a crucial role in maternal and infant health, yet many mothers face challenges such as insufficient milk supply and inadequate micronutrient intake. This study aimed to develop and assess soft lactation cookies enriched with locally available galactagogues, specifically *katuk* leaves (*Sauropus androgynus*), moringa leaves (*Moringa oleifera*), and Cilembu sweet potatoes (*Ipomoea batatas*). Four cookie formulations were tested, including a control (P0) and three treatment groups (P1, P2, P3). These formulations were evaluated through nutritional analysis, physical quality tests, and sensory evaluation. The P3 formulation, containing 6.6% *katuk* leaves, demonstrated the highest concentrations of micronutrients, including iron (3.32 mg 100 g^{-1}) and zinc (0.168 mg 100 g^{-1}), and exhibited the softest texture with enhanced yellowness. Hedonic testing revealed that P3 had significantly higher taste and overall acceptability scores compared to the other formulations. This formulation provides a culturally relevant, nutrient-dense alternative for lactating mothers, addressing common micronutrient deficiencies. The results suggest that soft lactation cookies, particularly P3, may serve as an effective dietary intervention to support maternal nutrition and exclusive breastfeeding. Future studies should focus on the bioavailability and clinical impact of these cookies.

Keywords: breastfeeding support; functional foods; galactagogues; maternal nutrition; nutritional enhancement

INTRODUCTION

Breast milk is a critical source of nutrition during the first 1,000 days of life, a period often referred to as the golden window for child growth and development. The World Health Organization (WHO) recommends exclusive breastfeeding for the first six months of life, emphasizing its role in reducing infant mortality and promoting health. However, in Indonesia, challenges to breastfeeding, such as low milk supply and inadequate maternal nutrition, persist. Data from the Ministry of Health of Indonesia in 2020 shows that exclusive breastfeeding rates reached only 66.1%, indicating significant room for improvement (Ministry of Health of Indonesia, 2021). The quality and quantity of breast milk are influenced by maternal diet and nutritional status, making dietary interventions a promising strategy for enhancing lactation outcomes (McBride et al., 2021).

Galactagogues, substances that stimulate or increase breast milk production, have been traditionally used to address lactation insufficiency. Foods rich in vitamins and minerals, such as *katuk* leaves (*Sauropus*

* **Corresponding author**: olivia.fk@ub.ac.id

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androgynus), moringa leaves (*Moringa oleifera*), and sweet potatoes (*Ipomoea batatas*), are considered potent natural galactagogues. Studies show that *katuk* leaves contain essential micronutrients, such as iron and zinc, alongside bioactive compounds like saponins and flavonoids, which support milk production and maternal health (Sampurno, 2007; Singh et al., 2011). Similarly, moringa leaves are known for their high iron content and lactation-enhancing properties, as evidenced by increases in serum prolactin levels (Shoffiyah et al., 2021). Sweet potatoes, particularly the local variety Cilembu, are rich in beta-carotene, a precursor of vitamin A, which has been linked to improved lactation outcomes (Chahyanto and Roosita, 2013). Despite the recognized potential of these ingredients, there is a lack of evidence-based formulations integrating these local foods into functional products for breastfeeding mothers.

Iron, beta-carotene, and zinc are critical micronutrients that influence both maternal health and breast milk composition. Iron deficiency in lactating mothers has been linked to low birth weight and developmental issues in infants, while maternal iron supplementation has been shown to increase breast milk iron content (Black et al., 2011; Kutty, 2021). Beta-carotene is essential for vitamin A production, supporting the immune function and visual development of infants (Schaefer et al., 2020; Lu et al., 2022). Zinc plays a crucial role in immune function and growth, and its levels in breast milk are closely tied to maternal dietary intake (Donangelo and King, 2012; Aumeistere et al., 2018). However, most interventions use single galactagogues in isolation. Emerging evidence suggests that combining multiple galactagogues may result in synergistic effects, enhancing lactation more effectively than individual use (Buntuchai et al., 2017; Ranjani et al., 2021; Jain et al., 2024). Such multi-ingredient strategies also reflect cultural practices in postpartum diets (Shawahna et al., 2018; Arogundade et al., 2022).

Despite this, there remains limited research evaluating the combined nutritional and sensory impact of multiple galactagogues in one functional food product. Furthermore, available lactation supplements often lack affordability, convenience, and cultural relevance. It highlights the need for accessible alternatives using local foods.

Soft cookies were selected as the delivery medium due to their convenience, portion control, and long shelf life, making them ideal for regular consumption (Dewi, 2016). This study introduces a new formulation of soft lactation cookies that incorporates fresh *katuk* and moringa leaves, along with Cilembu sweet potatoes, to preserve their nutrient quality. Unlike previous studies that used powdered ingredients, this research utilizes whole leaves to preserve polyphenols and flavonoids better (Roosita et al., 2022). Although high baking temperatures can degrade heat-sensitive nutrients such as beta-carotene, baking is more effective in retaining these nutrients than drying. For example, baking resulted in moderate retention of beta-carotene (56 to 78%), compared to drying, which resulted in the lowest retention rates (44 to 67%) (Rayamajhi and Mishra, 2020). Similarly, Shin et al. (2016) observed that while the beta-carotene content in yellow-fleshed sweet potatoes decreased with baking, the retention was still higher than with drying, indicating that baking is a more effective method for preserving bioactive compounds. The goal of this study is to evaluate the nutritional composition, physical properties, and sensory acceptability of the cookies, with a focus on the micronutrients crucial for lactation, while also contributing to the development of culturally appropriate functional foods for breastfeeding mothers.

MATERIALS AND METHOD

Experimental design and treatments

This experimental study was conducted using a completely randomized design (CRD) with a single factor: the ratio of moringa and *katuk* leaves incorporated into the formulations. Four formulations were developed: one control (P0), which did not include moringa or *katuk* leaves, and three experimental formulations: P1 (6.6% moringa leaves), P2 (3.3% moringa + 3.3% *katuk* leaves), and P3 (6.6% *katuk* leaves). Each formulation was replicated three times, yielding a total of 12 experimental units. The formulation has been submitted for patent protection under patent submission number: S00202406464 to the Directorate General of Intellectual Property, Indonesia.

Raw materials and chemicals

The materials used in this study were carefully selected based on their nutritional value, safety, and galactagogue properties. The primary ingredients included fresh *katuk* leaves, moringa leaves, and Cilembu sweet potatoes, all sourced locally to ensure quality. Supporting ingredients consisted of brown rice flour, cornstarch, coconut oil, coconut sugar, eggs, dates, peanut butter, and skim milk. Selection criteria for the ingredients required Cilembu sweet potatoes with a yellow-brown color, fresh moringa and *katuk* leaves that were green and free from wilting, and dates that were brownish and fresh. Exclusion criteria involved moringa and *katuk* leaves with holes, Cilembu sweet potatoes with mold growth, and any ingredients past their expiration date. The proportion of Cilembu sweet potato was kept constant across all formulations as the base carbohydrate source. At the same time, only the content of *katuk* and moringa leaves was varied among the treatment groups. All laboratory chemicals, including sulfuric acid, sodium hydroxide, boric acid, petroleum ether, and solvents for spectroscopic analyses, were of analytical grade and sourced from certified suppliers.

Sample preparation

Fresh *katuk* and moringa leaves were thoroughly washed and finely chopped without undergoing drying or powdering to retain their bioactive compounds. This approach was adapted from prior research by Ansharullah et al. (2019). The dough was prepared by combining dry and wet ingredients, then shaped into 25 g portions and baked at 160 °C for 25 minutes. A detailed flow of the preparation process is shown in Figure 1 (with modifications from the original recipe).

Nutritional analysis

Macronutrient and micronutrient contents were determined using standard methods from the Association of Official Analytical Chemistry International (Horwitz and Latimer, 2006). Protein content was measured using the Kjeldahl method (AOAC 992.23), total fat via Soxhlet extraction (AOAC 948.15), and carbohydrates were quantified using the Luff-Schoorl method (AOAC 995.13). Iron and zinc levels were

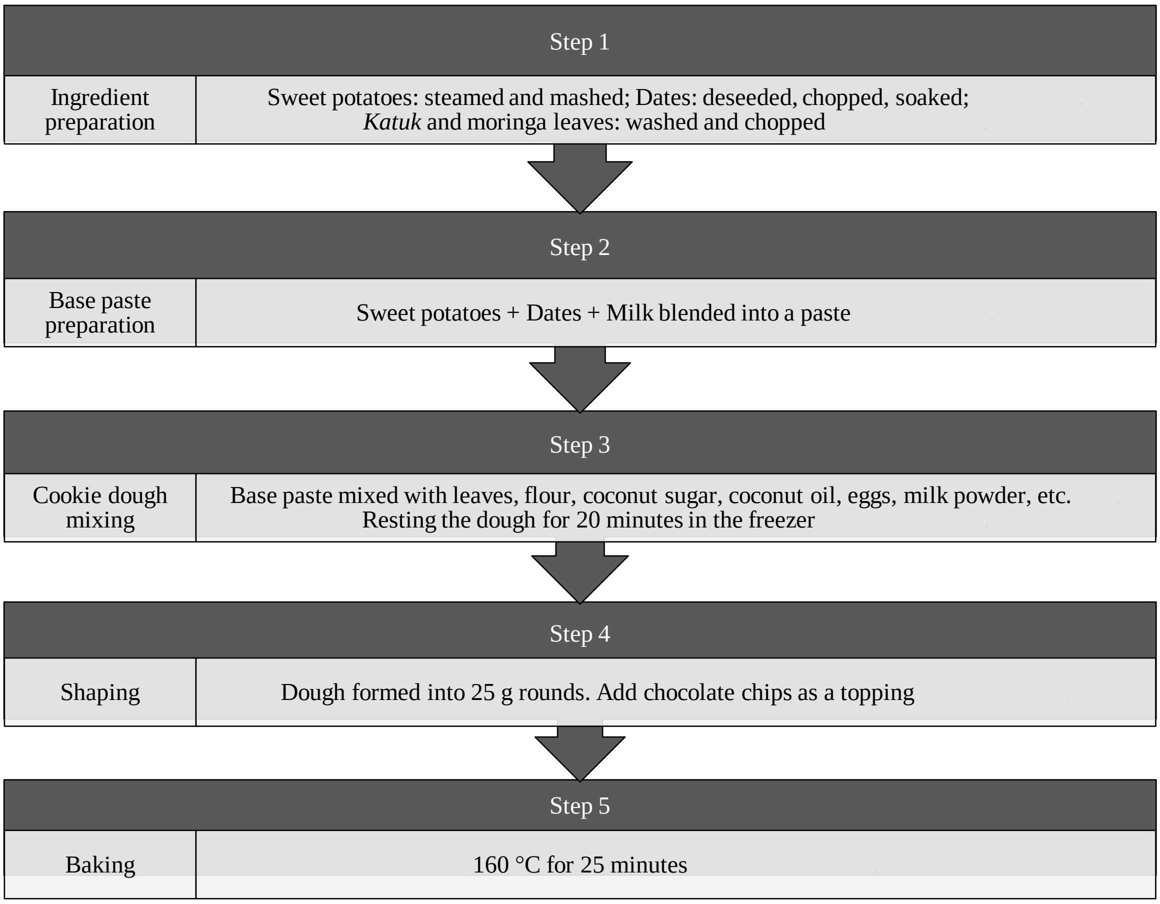

Figure 1. Flowchart of soft lactation cookie preparation using *katuk* leaves, moringa leaves, and Cilembu sweet potatoes

analyzed using atomic absorption spectroscopy (AAS) (Khoirunnisa et al., 2023), while beta-carotene was assessed using UV-Vis spectrophotometry (Herawati et al., 2015; Hagos et al., 2022). Results were reported per 100 g of cookies.

Physical properties

Cookie texture was assessed using a texture analyzer LLOYD with a cylindrical probe to measure hardness and fracture strength in Newtons (N) (Ashwath Kumar and Sudha, 2021). Color parameters (lightness/L*, hue/a*, and chroma/b*) were measured using a chromameter after conditioning the cookies at 25 °C for 24 hours. Color intensity (E) was calculated by combining the L*, a*, and b* values from the chromameter measurements, which provided an overall assessment of the cookies' color characteristics (Konzen and Tsai, 2014).

Sensory evaluation

The sensory evaluation followed the Indonesian National Standard (SNI 01-2346-2006), with 25 panelists assessing sensory attributes such as appearance, texture, taste, aroma, and overall acceptability on a 7-point hedonic scale (Indonesian National Standard, 2006). Scores ranged from 1 (dislike very much) to 7 (like very much). Cookies were anonymized and served in random order.

Statistical analysis and ethics

All data were collected in triplicate. Statistical analysis was performed using SPSS version 25.0 with significance set at $p < 0.05$. One-way ANOVA and Tukey's honestly significant difference (HSD) tests were applied to identify differences between formulations. Ethical approval was granted by the Ethics Committee of Politeknik Kesehatan Kemenkes Malang (registration number: 377/KEPK-POLKESMA/ 2022). Panelists provided informed consent, and all ingredients were approved for use in humans.

RESULTS AND DISCUSSION

This study evaluated the nutritional composition, physical characteristics, and sensory acceptability of four soft cookie formulations containing local galactagogues. The formulations included a control (P0) and three variations: one incorporating moringa leaves (P1), another incorporating *katuk* leaves (P3), and a third combining both (P2) (Figure 2).

Nutritional composition

Despite the incorporation of diverse galactagogue-rich ingredients in the formulations, no statistically significant differences were observed in the energy, protein, fat, and carbohydrate content across all cookie samples (Table 1). This similarity is likely due to the controlled proportions of base ingredients such as sweet potatoes, dates, and milk, which contribute predominantly to the macronutrient profile. As a result, the overall energy density remained consistent among formulations. These findings suggest that the nutritional variations among the samples are mainly attributable to differences in micronutrient content rather than macronutrient composition.

The micronutrient profiles of fresh moringa and *katuk* leaves are well-established in the literature. Fresh moringa leaves are rich in essential micronutrients, including iron, zinc, and beta-carotene. The iron content in moringa leaves is approximately 9.99 mg 100 g^{-1}, a significant amount for a leafy vegetable (Wardhani et al., 2024). The zinc content is 2.32 mg 100 g^{-1}, and moringa leaves are also an excellent source of

a. b. c. d.

Figure 2. Appearance of lactation cookies formulation

Note: a = P0 (control), b = P1 (6.6% moringa leaves), c = P2 (3.3% moringa + 3.3% *katuk* leaves), d = P3 (6.6% *katuk* leaves)

Table 1. Macronutrient and micronutrient composition of lactation cookies (per 100 g)

Nutrient	P0 (Control)	P1 (Moringa)	P2 (Moringa+*Katuk*)	P3 (*Katuk*)	*p*-value
Energy (kcal)	229.5±11.57	219.7±15.86	234.9±16.48	231.9±13.19	0.546
Carbohydrate (%)	38.92±2.15	38.08±1.53	40.17±2.76	39.39±2.15	0.621
Protein (%)	5.24±0.25	4.91±0.13	5.71±0.75	5.43±0.55	0.347
Fat (%)	5.87±0.23	5.31±0.34	5.71±0.27	5.85±0.35	0.797
Iron (mg 100 g^{-1})	1.60±0.06[a]	1.84±0.05[b]	3.11±0.05[c]	3.32±0.006[d]	0.016*
Zinc (mg 100 g^{-1})	0.118±0.0002[a]	0.122±0.0008[b]	0.142±0.0008[c]	0.168±0.0007[d]	0.000*
Beta-carotene (mg)	3.10±0.42	2.95±0.37	3.22±0.58	3.14±0.50	0.863

Note: Different superscript letters ([abcd]) in the same row indicate statistically significant differences ($p < 0.05$; Tukey's HSD test)

beta-carotene, with levels reaching up to 5,791.64 µg 100 g^{-1} (Issa et al., 2022; Wardhani et al., 2024). Similarly, fresh *katuk* leaves are a valuable source of micronutrients, particularly iron, zinc, and beta-carotene. The iron content of *katuk* leaves is approximately 7.30 mg 100 g^{-1}, which is relatively high compared to other leafy vegetables, making it a beneficial dietary source, especially in areas with a prevalence of iron deficiency (Bhavithra et al., 2021). *Katuk* leaves also contain zinc up to 0.66 mg 100 g^{-1} and are rich in beta-carotene, with concentrations as high as 2,586 µg 100 g^{-1} (Purba and Paengkoum, 2022; Kurniawan et al., 2024). These levels justify their selection as potential galactagogues and nutrient sources in the formulation of cookies. The observed nutrient content in the final cookie products may reflect the retention of these native values, subject to degradation from processing, particularly for thermolabile nutrients such as beta-carotene.

The addition of moringa and *katuk* leaves had a significant influence on the micronutrient profile of the cookies. P3, containing only *katuk* leaves, had the highest levels of iron, zinc, and beta-carotene. The control formulation (P0) exhibited the lowest concentrations of these micronutrients. These results suggest that *katuk* leaves provide superior micronutrient fortification compared to moringa or a combination of the two. The detailed nutritional composition of each cookie formulation, per 100 g, is presented in Table 1.

To better illustrate the contribution of each cookie to daily nutritional requirements, Figures 3 and 4 present the percentage of daily nutrient requirements fulfilled for lactating women aged 19 to 29 years, based on one serving (100 g or 4 cookies).

The bar chart (Figure 3) illustrates the content of energy, carbohydrates, protein, and fat per serving of the P3 cookie formulation, while the line graph represents the percentage of daily nutritional requirements met for lactating mothers aged 19 to 29 years, based on the Indonesian Recommended Dietary Allowances (RDA). These percentages were calculated using the measured nutrient contents of the cookies and the RDA values for lactating mothers, as provided by the Ministry of Health (Regulation of the Minister of Health, 2019).

The micronutrient composition plays a vital role in maternal health and breast milk quality. This study showed that the P3 formulation yielded the highest concentrations of iron (3.32 mg 100 g^{-1}), zinc (0.168 mg 100 g^{-1}), and beta-carotene (3.14 mg 100 g^{-1}) (Figure 4). The significance of these findings lies in their implications for maternal and infant health. For instance, iron is critical for maintaining maternal hemoglobin levels and supporting postpartum recovery. Although breastmilk contains highly bioavailable iron, the quantity is low, highlighting the importance of maternal dietary iron intake in preventing deficiencies and supporting infant development (Black, 2008; Kutty, 2021).

The iron contribution from P3 (18.4% RDA for lactating women aged 19 to 29) was the highest among all formulations. The soft cookie matrix likely helped preserve the mineral integrity during processing (Negu et al., 2020). Furthermore, baking can reduce the phytic acid content due to heat degradation, which may enhance iron bioavailability (Lubaale et al., 2023). It suggests that baking not only preserves the iron content but also improves its absorption, further supporting the nutritional value of the cookies.

Zinc is another essential trace element required for immune function and the development of infants. While maternal dietary zinc does not always directly correlate with breastmilk zinc concentration, sufficient intake helps sustain maternal stores and supports optimal lactation outcomes (Donangelo and King, 2012; Han et al., 2023). The inclusion of *katuk* leaves in P3 increased the zinc content more than in other formulations, aligning with the literature indicating the efficacy of zinc-rich foods in maternal nutrition strategies (Aumeistere et al., 2018).

Beta-carotene, a provitamin A compound, also showed elevated levels in P3. The synergy of sweet potatoes and *katuk* leaves contributed to a richer carotenoid profile, which is crucial for visual development and immune protection in infants. Beta-carotene in breast milk has been associated with higher serum retinol levels in infants, directly impacting their vitamin A status and reducing the risk of deficiency-related complications (Nishiyama et al., 2010; Gannon et al., 2020). Furthermore, the antioxidant properties of beta-carotene enhance maternal and neonatal defense against oxidative stress (Zielinska-Pukos et al., 2019).

Physical properties

The physical properties of the cookies were evaluated based on hardness, fracture force, and color intensity as shown in Figure 5. P0 demonstrated the highest fracture force, while P3 exhibited the lowest. The hardness of the cookies decreased with increasing leaf content,

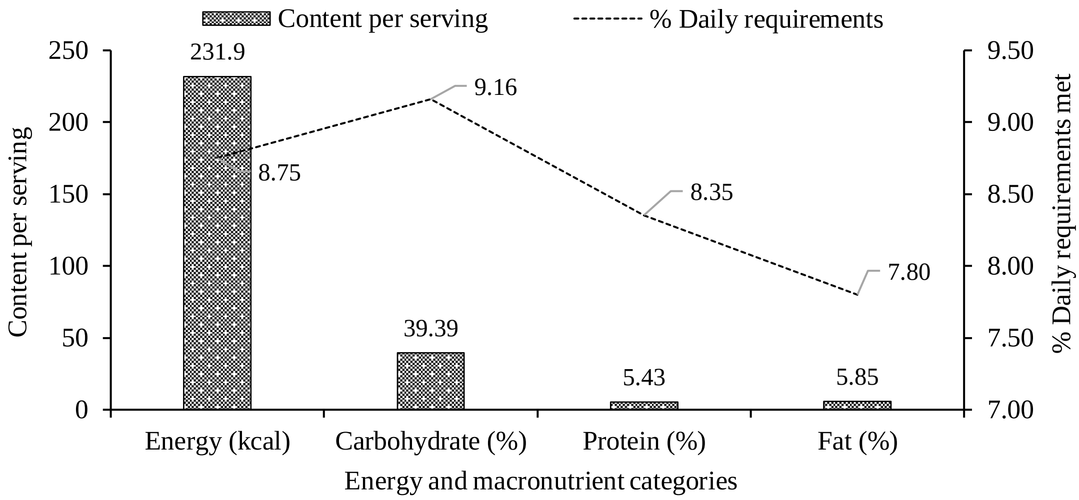

Figure 3. Macronutrient content and percentage of daily requirements met by lactation cookies (P3, 6.6% *katuk* leaves)

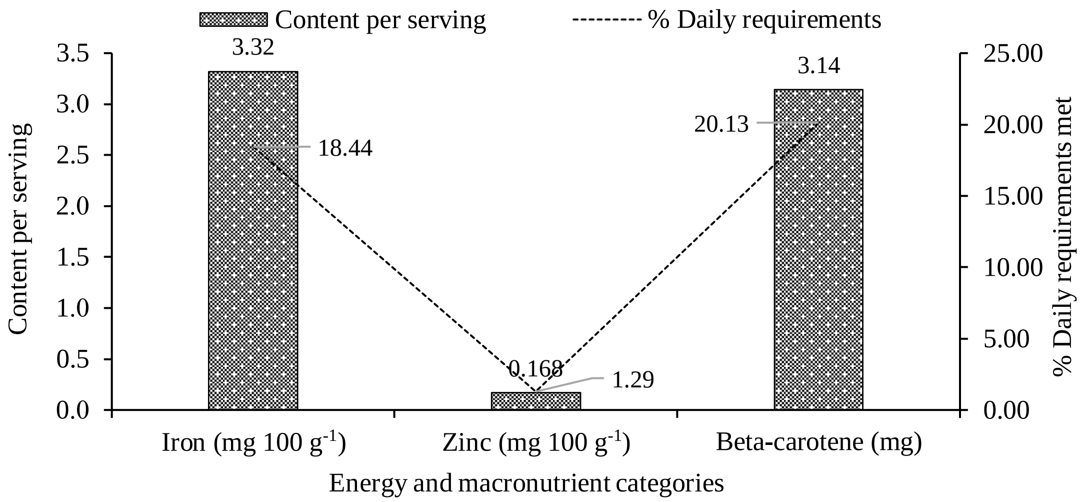

Figure 4. Micronutrient content and percentage of daily requirements met by lactation cookies (P3, 6.6% *katuk* leaves)

particularly in the P3 formulation. In terms of color, the control cookies (P0) had the highest L* values, whereas P3 cookies appeared the darkest, which is attributed to the natural pigmentation of *katuk* leaves.

The physical quality evaluation of the lactation cookie formulations (Figure 5) shows a decreasing trend in hardness and fracture force with the addition of moringa and *katuk* leaves, with P3 (100% *katuk*) exhibiting the lowest values. It suggests a softer texture, which aligns with the intended soft cookie characteristics. Additionally, color intensity values also declined across the treatments, indicating visual changes due to the incorporation of green leafy ingredients. The combination of reduced hardness and moderate color intensity supports the sensory preference observed in the study.

From a physical perspective, although P3 had slightly reduced fracture force and hardness compared to P1, its texture was consistent with the desired softness of this cookie type. This characteristic not only meets consumer expectations but also reflects an appropriate formulation design that utilizes steamed sweet potatoes, which naturally impart moisture and tenderness. The color profile of P3, characterized by darker tones and higher yellowness (b*, 0.59), supports its carotenoid content, thereby enhancing its visual appeal. Such color characteristics are favorable in functional foods, as noted by Wijayanti et al. (2019) and Haron and Yusof (2021).

Sensory acceptability

Hedonic testing revealed differences in consumer preferences across the formulations. P0 scored the highest in all attributes, while P3 cookies, containing only *katuk* leaves, received the highest ratings for taste. The P1 cookies, which contained only moringa leaves, received the lowest scores across all sensory parameters. Statistical analysis confirmed that P3 exhibited significantly greater acceptability than the other variants, indicating that *katuk* contributes positively to sensory characteristics (Figure 6).

The sensory evaluation further affirmed P3 as the most accepted formulation. The naturally sweet and earthy flavor from sweet potatoes was well-balanced, with the *katuk* leaves contributing a noticeable leafy taste. Unlike P1, which had higher fracture strength but lower flavor scores, P3 achieved a favorable equilibrium between nutrient density and consumer palatability. This highlights a key challenge in functional food development: the need to balance bioactive content with sensory characteristics to ensure acceptability.

The qualitative taste evaluation revealed distinct flavor characteristics among the cookie formulations. The control cookies (P0) were described as having a pleasant sweet flavor from the cookie base and chocolate chips, complemented by a strong nutty taste derived from the peanuts. Cookies containing only moringa leaves (P1) maintained the overall sweetness of the cookie and chocolate chips, with panelists noting a slight herbal note attributed to the moringa. In the P2 formulation, which included both moringa and *katuk* leaves, the sweet and chocolaty base remained dominant, but a mild combined taste of the two leaves was perceptible. Meanwhile, cookies in the P3 group, formulated solely with *katuk* leaves, were described as sweet and chocolaty but with a noticeably stronger leafy flavor, indicating a more pronounced presence of *katuk*.

This study contributes to existing literature by demonstrating the synergistic effect of combining multiple galactagogue ingredients into a single food product. While previous studies focused on isolated components, such as moringa or papaya leaves, the current formulation integrates multiple ingredients (Wijayanti et al., 2019; Mogaka et al., 2022). This formulation integrates three potent local ingredients, enhancing nutritional value while maintaining sensory acceptability. Such integration addresses multiple micronutrient gaps commonly observed among lactating mothers, especially in low-resource settings.

Additionally, this research addresses the accessibility and cultural compatibility of maternal nutritional interventions. Using fresh, whole *katuk* and moringa leaves rather than commercial powders ensures higher phytochemical integrity and aligns with local dietary traditions. It distinguishes the study from others employing processed or imported materials, offering a model for culturally grounded, sustainable food innovation.

The implications of this work extend to public health nutrition and maternal wellness programs. Functional snacks, such as the P3 cookies, offer a convenient and culturally acceptable strategy for enhancing maternal dietary quality,

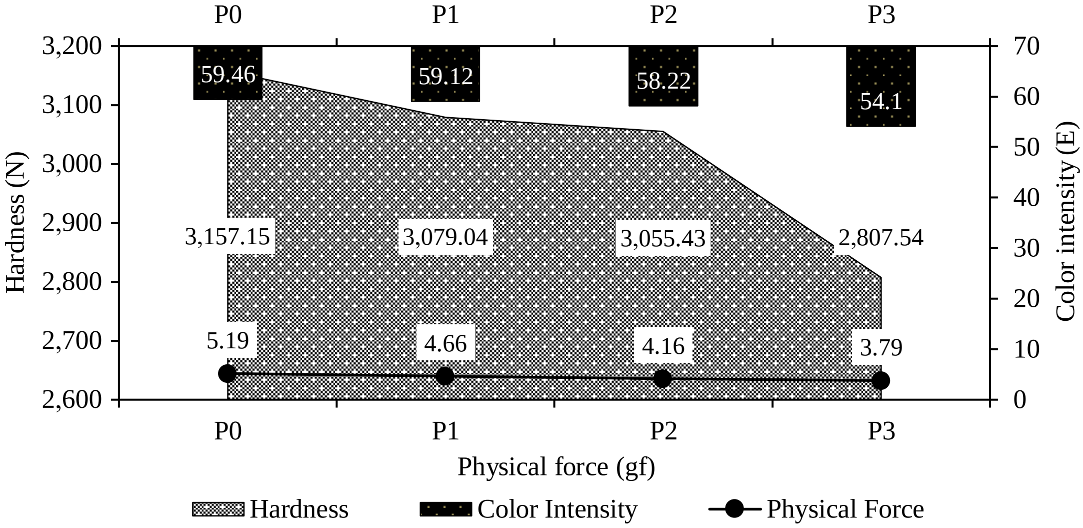

Figure 5. Comparison of texture (hardness in Newtons), fracture force (gf), and color intensity (E) for lactation cookie formulations

Note: P0 = Control, P1 = 6.6% moringa leaves, P2 = 3.3% moringa + 3.3% *katuk* leaves, P3 = 6.6% *katuk* leaves

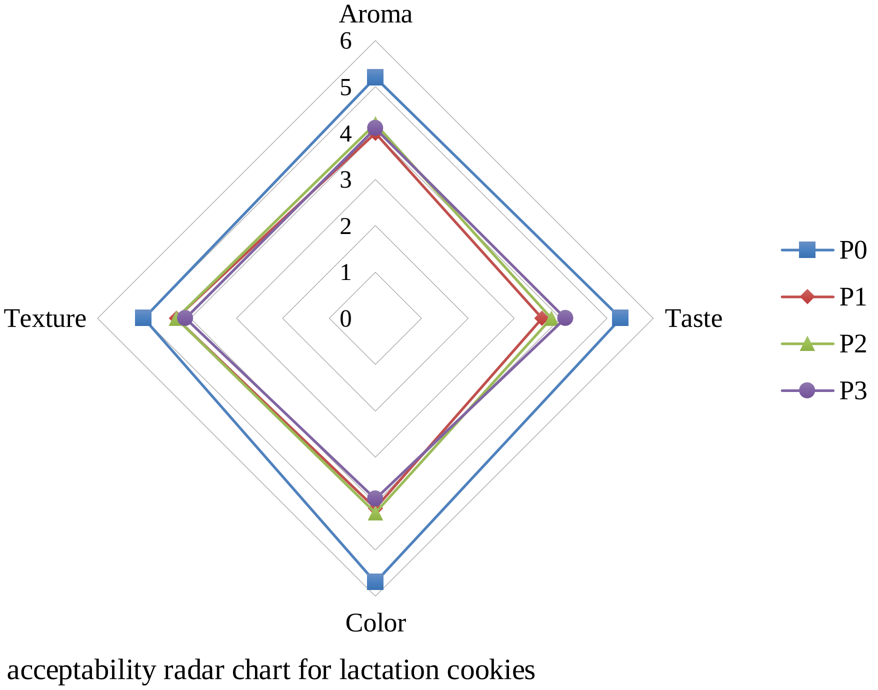

Figure 6. Sensory acceptability radar chart for lactation cookies

Note: P0 = Control, P1 = 6.6% moringa leaves, P2 = 3.3% moringa + 3.3% *katuk* leaves, P3 = 6.6% *katuk* leaves

especially during the postpartum period. Their shelf stability and palatability facilitate regular consumption, improving dietary adherence without altering routine eating habits.

However, despite its promising outcomes, the study has limitations. It did not assess the bioavailability or direct impact of cookie consumption on breastmilk composition or infant outcomes. While the nutrient content is supportive, future clinical studies are necessary to confirm efficacy through lactation biomarkers or milk yield measurements. Furthermore, exploring variations in preparation methods, portion sizes, or consumer groups could provide deeper insights into the scalability and applicability of these approaches.

CONCLUSIONS

This study successfully developed a soft lactation cookie using *katuk* leaves, moringa leaves, and Cilembu sweet potatoes, with the P3 formulation (6.6% *katuk* leaves) demonstrating superior micronutrient content, including iron (3.32 mg 100 g^{-1}), zinc (0.168 mg 100 g^{-1}), and beta-carotene (3.14 mg 100 g^{-1}). The P3 formulation also exhibited favorable physical characteristics, including a soft texture, moderate color intensity, and a well-balanced sensory profile. The P3 cookies achieved the highest sensory acceptability among all formulations, making them an optimal choice for lactating mothers seeking a nutrient-dense, convenient, and culturally appropriate snack. The results underline the value of incorporating local, galactagogue-rich ingredients into functional food products to support maternal nutrition. Further studies are recommended to investigate the clinical efficacy and bioavailability of these cookies, thereby enhancing their potential for broader use in maternal nutrition programs.

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