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Formulation of a tempeh and mocaf flour-based analog nugget with the addition of red spinach

[Formulasi dan karakterisasi fisikokimia serta sensori nugget analog berbasis tempe dan tepung mocaf dengan penambahan bayam merah]

Yanti Meldasari Lubis[1*], Asmawati[1], Yuliani Aisyah[1], dan Maharani Putri[1]

[1]Departemen Teknologi Hasil Pertanian, Fakultas Pertanian, Universitas Syiah Kuala, Jl. Tgk. Krueng Kalee No. 3, Aceh

*Correspondence email: yantimeldasari@usk.ac.id

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ABSTRACT

Tempeh, a protein-rich ingredient, and mocaf flour and red spinach, which are high in dietary fiber, have potential as functional food ingredients. This study aimed to determine the optimal ratio of tempeh to mocaf flour and the appropriate concentration of red spinach to produce an analog nugget with desirable chemical, physical, and sensory properties. A factorial Randomized Block Design (RBD) was applied, with two factors: the tempeh-to-mocaf flour ratio (2:1, 3:1, and 4:1) and red spinach concentration (10%, 15%, and 20% per 300 g of dough). Analyses included moisture, fat, fiber, protein, and cooking loss. Sensory attributes (color, taste, aroma, and texture) and color value (L) were also evaluated. Ash and carbohydrate contents were determined for the best treatment. The results demonstrated that tempeh and mocaf flour can substitute chicken meat and wheat flour in nugget production. The optimal formulation consisted of a tempeh-to-mocaf flour ratio of 4:1 with 20% red spinach, yielding an analog nugget with 60.67% moisture, 2.93% fat, 14.96% fiber, 32.81% protein, 1.30% ash, 2.29% carbohydrate, 19% cooking loss, and neutral sensory acceptance for color, aroma, texture, and taste.*

Keywords: nugget, analog, tempeh, mocaf, red spinach

ABSTRAK

Tempe yang kaya protein, tepung mocaf, dan bayam merah kaya serat, berpotensi menjadi bahan pangan fungsional. Penelitian ini bertujuan untuk menentukan perbandingan tempe dan tepung mocaf serta konsentrasi bayam merah untuk menghasilkan *nugget* analog yang memiliki karakteristik kimia, fisik dan sensori, terbaik. Penelitian menggunakan Rancangan Acak Kelompok (RAK) faktorial, yaitu perbandingan tempe dan tepung mocaf (2:1, 3:1, 4:1), dan konsentrasi bayam merah (10%, 15%, 20% per 300 gram adonan). Analisis yang dilakukan meliputi kadar air, lemak, serat, protein, susut masak, sensori (warna, rasa, aroma, tekstur), dan warna (nilai L*). Untuk perlakuan terbaik dilakukan analisis kadar abu, dan kadar karbohidrat. Hasil penelitian menunjukkan bahwa tempe dan tepung mocaf dapat menggantikan ayam dan tepung terigu sebagai bahan baku dalam pembuatan *nugget*. Perlakuan terbaik diperoleh pada *nugget* analog dengan perbandingan tempe dan tepung mocaf 4:1 dengan konsentrasi bayam merah 20%. Nugget terbaik mempunyai kandungan abu 60.67%, lemak 2.93%, serat 14.96%, protein 32.81%, kadar abu 1.3%, dan kadar karbohidrat sebesar 2.29%. dengan susut masak 19%, warna 2.95 (netral), aroma 3.22 (netral), tekstur 3.13 (netral), rasa 3.37 (netral),

Kata Kunci: *nugget*, analog, tempe, mocaf, bayam merah

Introduction

The development of plant-based food innovations has accelerated in line with increasing public awareness of the importance of consuming healthy, nutritious, and environmentally friendly foods. One promising product is the analog nugget, a processed food that resembles meat nuggets but is made from plant-based protein sources. This product not only serves as an alternative for vegetarian consumers but also supports food diversification by utilizing local raw materials such as tempeh and red spinach. Tempeh is a fermented soybean-based food that serves as a source of protein, vitamin B12, antioxidants,

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phytochemicals, and bioactive compounds such as isoflavones. Tempeh contains 8.7 mg/g of soluble protein (Astuti et al., 2020). Its high protein content makes tempeh highly suitable as a base ingredient for analog nugget production. However, several studies have reported that the use of tempeh often results in products with less compact texture and a tendency to crumble due to its low starch and binding fiber content. (Indriani et al., 2022) reported that substituting tempeh in plant-based nuggets significantly reduced nugget hardness. Similarly, Abubakar et al. (2022) found that higher levels of tempeh flour addition resulted in a coarser texture and lower sensory scores. Meanwhile, Zivanovic (2000) stated that texture is closely related to the degradation of proteins and polysaccharides. Therefore, the addition of texture-forming ingredients is necessary to improve the physical characteristics of the product.

One natural binding agent that can be used is modified cassava flour (mocaf). Mocaf flour has good gelatinization properties and water-binding capacity, which can support structure and texture formation in nuggets. According to Jayanti et al. (2023), mocaf flour can be used as a filler and binder in fish nugget production. However, a higher mocaf-to-cassava flour ratio (80:20) was reported to reduce fish nugget hardness due to the lower amylose content of mocaf compared to cassava flour. Excessively high ratios of mocaf to chicken meat (80:20) were also shown to reduce organoleptic texture scores in chicken nuggets (Abdi et al., 2025), as well as high tempeh-to-kapok banana blossom ratios (100:0) in tempeh–banana blossom-based nuggets (Agustin et al., 2023). Thus, variations in the ratio of tempeh and mocaf flour are required to obtain an optimal formulation balancing nutritional value, texture, and sensory attributes of analog nuggets. Variation in the ratio of these two ingredients is crucial because a higher proportion of tempeh is expected to increase protein content and provide a more pronounced soybean flavor. However, excessively high tempeh levels may result in fragile or less cohesive nuggets due to insufficient carbohydrate-based binding agents. A higher proportion of mocaf flour has the potential to produce a more elastic, dense, and cohesive texture because of its high amylopectin content. Nevertheless, excessive mocaf levels may reduce protein content and diminish the characteristic flavor of tempeh, which may ultimately decrease consumer sensory acceptance.

Red spinach (*Amaranthus tricolor* L.) is incorporated into the formulation as a functional nutritional enhancer (rich in dietary fiber and antioxidants such as anthocyanins) and as a natural colorant. The concentration of red spinach in the batter strongly influences the physicochemical and sensory properties of the final product. Increasing red spinach concentration is expected to correlate positively with higher crude fiber content and antioxidant activity. Concentrations that are too low may not provide sufficiently intense red coloration or significant functional nutritional benefits. Conversely, excessively high concentrations may result in a vegetal aftertaste and lower color brightness (darker appearance) (Aprilia, 2021), which may reduce sensory acceptance. To date, no studies have reported variations in the ratio of tempeh flour to mocaf flour combined with the addition of red spinach in the production of analog nuggets (Abdi et al., 2025; Agustin et al., 2023; Fitriyani et al., 2024; Jayanti et al., 2023). Therefore, the objective of this study was to determine the optimal formulation and to evaluate the physicochemical and sensory characteristics of analog nuggets by varying the ratio of tempeh flour to mocaf flour and the concentration of red spinach used.

Materials and methods

Materials and equipment

The materials used in this study included tempeh, mocaf flour, red spinach, eggs, garlic, onion, ground white pepper, salt, sugar, mushroom seasoning, and water. The chemical reagents used for analysis consisted of NaOH (Merck), H_2SO_4 (Merck), HCl (Merck), ethanol (Merck), boric acid (Merck), distilled water, and DPPH (Sigma-Aldrich). The equipment used in this study included a food chopper (Panasonic),

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steamer, molds (5 × 20 cm, 5.5 cm thickness), analytical balance (Fujitsu), oven (EYELA WFO-450D), desiccator (OSK 1 3235A), Kjeldahl flasks (OPSIS), Soxhlet apparatus (GERHARDT EV16), UV–Vis spectrophotometer (Shimadzu UV-1900i), colorimeter (LS175 45/0), and hedonic evaluation forms.

Research methodology

This study employed a 3 × 3 factorial Randomized Block Design (RBD) with three replications. The factors investigated were the ratio of tempeh flour to mocaf flour (2:1, 3:1, and 4:1) and the concentration of red spinach (10%, 15%, and 20%). The obtained data were analyzed using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level.

Experimental procedure

(1) Preparation of red spinach purée (modified from Aprita et al., 2023; Rahmah & Mustika, 2018).

Fresh red spinach leaves were sorted, thoroughly washed, and drained. The leaves were then blanched using a hot water blanching method at 92 °C for 2 minutes. After blanching, the red spinach leaves were homogenized using a chopper for 5 minutes to obtain a red spinach purée. The amount of red spinach used was adjusted according to the formulation table, namely 25, 37.5, and 50 g.

Table 1. Composition of raw materials per 300 g

Ingredients	Composition (%)	Composition (g)	P1 (2:1) (10%)	P2 (3:1) (10%)	P3 (4:1) (10%)	P1 (2:1) (15%)	P2 (3:1) (15%)	P3 (4:1) (15%)	P1 (2:1) (20%)	P2 (3:1) (20%)	P3 (4:1) (20%)
Tempeh	55.55	166.65	150.00	168.7	180.00	141.6	159.3	170.0	133.3	150.0	160.0
Mocaf Flour	27.78	83.34	75.00	56.25	45.00	70.83	53.13	42.5	66.66	50.0	40.0
Red spinach purée	-	-	25.00	25.00	25.00	37.5	37.5	37.5	50.00	50.00	50.00
Garlic	3.33	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Onion	3.33	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Ground pepper	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	1.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Sugar	1.67	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Mushroom seasoning	2.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Egg	5.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Total	100.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00

Notes : P1 (tempeh-to-mocaf flour ratio, 2:1), P2 (tempeh-to-mocaf flour ratio, 3:1), P3 (tempeh-to-mocaf flour ratio, 4:1).

(2) Preparation of analog nuggets (modified from Rahmah & Mustika, 2018).

Tempeh was steamed for 30 minutes, cooled, and then mashed. All ingredients, including tempeh, mocaf flour, garlic, onion, ground white pepper, salt, sugar, mushroom seasoning, eggs, and red spinach purée, were mixed according to the predetermined formulation (Table 1). The batter was molded in trays and steamed for 45 minutes. After steaming, the nuggets were cooled at room temperature for 10 minutes, followed by cooling at 10 °C for 15 minutes. The solidified nuggets were then cut into 2 × 1 cm pieces and stored in a freezer at –20 °C for 24 hours. The final step was deep frying in hot oil for 2–3 minutes until the surface color turned golden brown.

Chemical analysis

The proximate chemical analysis of analog nuggets was conducted according to AOAC (2005) methods, including moisture content (method no. 925.10), ash content (method no. 942.05), protein content using the micro-Kjeldahl method (method no. 954.01), fat content using the Soxhlet method (method no. 996.06), and carbohydrate content determined by the by-difference method. Crude fiber analysis was performed following the method described by Irshad et al. (2023).

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Cooking loss

Cooking loss analysis was conducted following Houten (1976). Nugget samples (10 g) were weighed and then deep-fried for 5 minutes. After frying, the samples were drained and reweighed. Cooking loss was calculated using the following formula:

$$\text{Cooking loss (\%)} = \frac{x-y}{x} \text{ x } 100,$$

x = weight of the sample before cooking,
y = weight of the sample after cooking

Color measurement

Color measurement (L* value) was performed using a Linshang LS173 colorimeter. Samples were placed on a white background. The colorimeter was turned on, the sensor was directed toward the sample surface, and the start button was pressed. The displayed L* value represents lightness.

Sensory analysis

Sensory evaluation was carried out using a hedonic scoring method involving 45 untrained panelists. Sensory attributes evaluated included color, aroma, taste, and texture. A five-point hedonic scale was used: 1 = strongly dislike, 2 = dislike, 3 = neutral, 4 = like, and 5 = strongly like (Hamundu & Herdhiansyah, 2023).

Results and discussion

Moisture content

According to SNI 01-6683-2014, the maximum moisture content of nuggets is 50%. In this study, the moisture content of analog nuggets ranged from 60.00% ± 0.86 to 65.73% ± 0.25, with an average value of 62.61% ± 0.54. Analysis of variance showed that the ratio of tempeh to mocaf flour (P) and the concentration of red spinach (K) had a significant effect (P ≤ 0.01) on the moisture content of analog nuggets, whereas the interaction between the tempeh–mocaf flour ratio and red spinach concentration (PK) had no significant effect (P > 0.05). The effects of the tempeh-to-mocaf flour ratio (P) and red spinach concentration (K) on the moisture content of analog nuggets are presented in Figures 1 and 2.

Based on Figure 1, an increase in the proportion of tempeh and a decrease in mocaf flour resulted in a decreasing trend in the moisture content of analog nuggets. The lowest moisture content was observed in treatment P3 (4:1), at 61.11% ± 1.39, which was significantly different from treatments P2 and P1. This finding is consistent with the study by (Fitriyani et al., 2023), which reported that higher levels of tempeh addition in nugget formulations led to increased water binding, with moisture contents ranging from 57.03% to 62.06%.

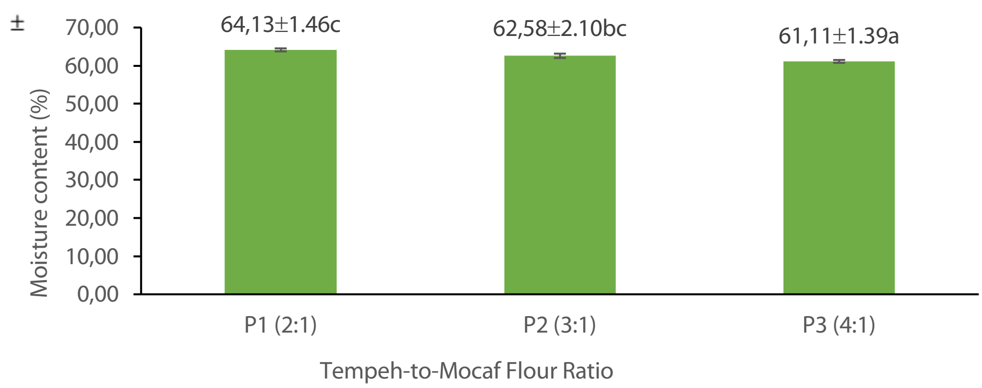

Figure 1. Effect of the tempeh-to-mocaf flour ratio (P) on the moisture content of analog nuggets (the same letter indicates no significant difference based on DMRT at α = 0.05).

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This phenomenon can be attributed to the protein content in tempeh, which contains hydrophilic groups capable of absorbing and binding water, thereby reducing the availability of free water in the matrix. Increased tempeh incorporation results in more bound water, consequently lowering the measurable moisture content of the product (Rahmah & Mustika, 2018). According to Afriliyanti et al. (2023), mocaf flour contains approximately 23.3% amylose. Amylose possesses numerous hydroxyl groups that readily interact with water molecules. Therefore, an increase in amylose content in a food system is positively correlated with its water absorption capacity. In this study, analog nuggets under treatment P3 (4:1) contained the lowest proportion of mocaf flour; thus, reduced mocaf addition resulted in less amylose available to absorb water, leading to a lower overall moisture content in the product.

Based on Figure 2, the moisture content of analog nuggets with a red spinach concentration of 15% (K2) was 61.11% ± 1.54, which was significantly different from analog nuggets with a red spinach concentration of 10% (K1), but not substantially different from analog nuggets with a red spinach concentration of 10% (K1). The moisture content obtained in this study was higher than that reported by Widyasmara et al. (2021) for anchovy fish stick nuggets substituted with red spinach, which ranged from 42.36% to 42.99%.

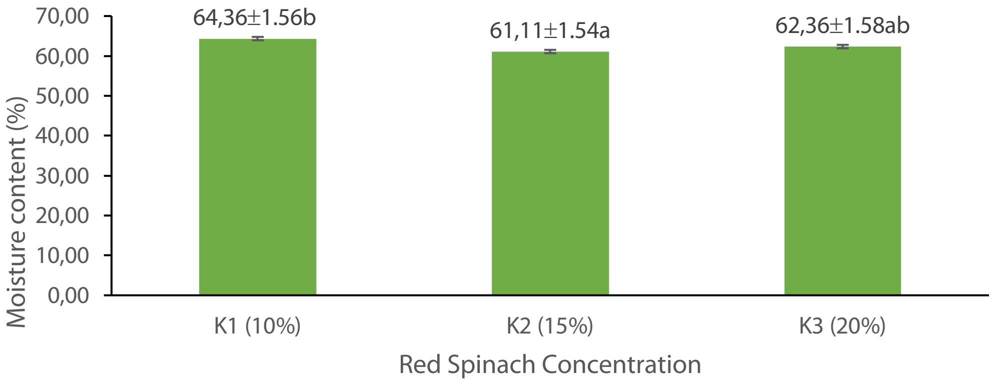

Figure 2. Effect of red spinach concentration (K) on the moisture content of analog nuggets (the same letter indicates no significant difference based on DMRT at α = 0.05).

The increase in red spinach concentration is presumed to provide a higher fiber content, which effectively binds free water by enhancing the water-holding capacity (WHC) and forming a denser matrix with proteins and starches. As a result, more water becomes entrapped within the structure of the analog nuggets, leading to a lower final moisture content (Khan et al., 2013). However, the moisture content of the analog nuggets in this study still did not meet the nugget moisture requirement according to SNI 01-6683-2014, which specifies a maximum moisture content of 60%. This may be attributed to the main ingredients used in the analog nuggets: tempeh, mocaf flour, and red spinach, each of which has a relatively high moisture content. The simultaneous use of these ingredients likely increased the overall moisture content of the analog nuggets. Tempeh contains approximately 68.3% moisture (Pujilestari et al., 2020), mocaf flour 11.9% (Kemenkes RI, 2019), and red spinach 88.5 g per 100 g of fresh material (Widyasmara et al., 2021).

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Fat content

The fat content of analog nuggets ranged from 2.93% ± 0.17 to 3.35% ± 0.11, with an average value of 3.07% ± 0.23, which is well below the maximum limit specified by the Indonesian National Standard (SNI) for chicken nuggets (20%). Analysis of variance indicated that the tempeh-to-mocaf flour ratio (P), red spinach concentration (K), and their interaction (PK) had no significant effect ($P > 0.05$) on fat content, despite tempeh having a relatively high fat content (8.8 g/100 g). This suggests that variations in the proportion of tempeh and mocaf flour used in the formulation did not influence the fat content of the analog nuggets. The fat content obtained in this study was considerably lower than that reported by Fitriyani et al. (2023), who observed fat contents of 16.08%–21.27% in tempeh nuggets supplemented with wood ear mushrooms and carrots.

Crude fiber content

The crude fiber content of analog nuggets ranged from 10.09% ± 0.09 to 14.96% ± 0.09, with an average value of 12.41% ± 0.15. Analysis of variance showed that the tempeh-to-mocaf flour ratio (P) and red spinach concentration (K) had a significant effect ($P \leq 0.01$) on the crude fiber content of analog nuggets, while their interaction (PK) had no significant effect ($P > 0.05$). The effects of the tempeh-to-mocaf flour ratio (P) and red spinach concentration (K) on crude fiber content are presented in Figures 3 and 4.

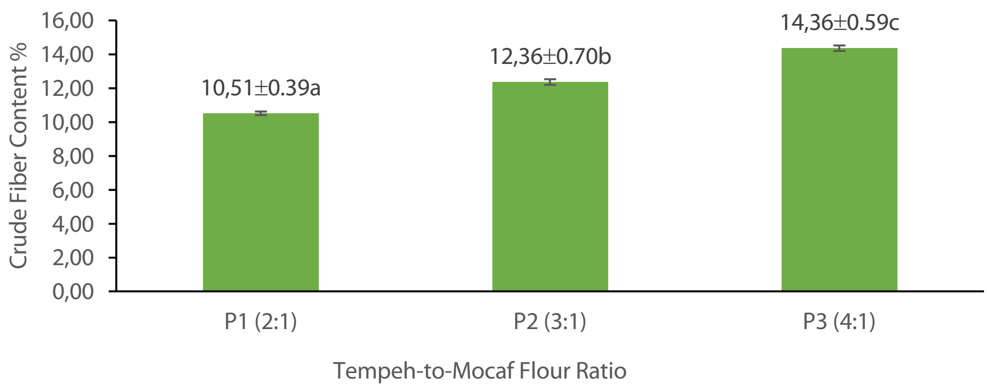

Figure 3. Effect of the tempeh-to-mocaf flour ratio (P) on the crude fiber content of analog nuggets (values followed by the same letter indicate no significant difference based on DMRT at α = 0.05).

Based on Figure 3, an increase in the ratio of tempeh to mocaf flour resulted in a corresponding increase in the crude fiber content of the analog nuggets. Both tempeh and mocaf flour contain appreciable amounts of dietary fiber, which contributed to the crude fiber content of the final product. Tempeh contains approximately 1.4% fiber, while mocaf flour contains around 6.0% fiber. Variations in the ratio of these two ingredients led to significant differences in the final crude fiber content of the analog nuggets.

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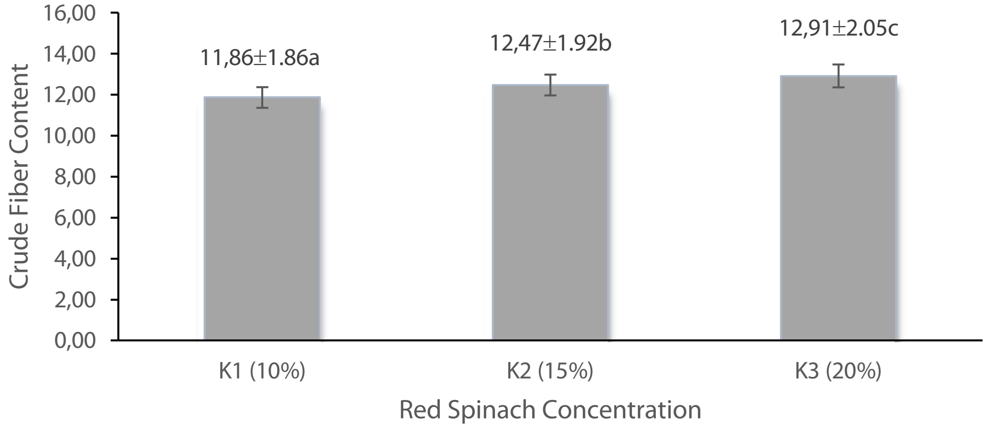

Figure 4. Effect of red spinach concentration (K) on the crude fiber content of analog nuggets (the same letter indicates no significant difference based on DMRT at α = 0.05).

Based on Figure 4, the crude fiber content of analog nuggets increased with higher concentrations of red spinach. The highest fiber content was obtained at a red spinach concentration of 20% (K3), with a value of 12.91% ± 2.05, which was significantly different from treatments with 15% and 10% red spinach. Increasing the concentration of red spinach adds more dietary fiber to the product, as supported by (Lacobellis et al., 2024), who reported a positive correlation between the addition of green vegetables and increased fiber content in food products. Red spinach is a rich source of dietary fiber, including cellulose, hemicellulose, and lignin, with a fiber content of 2.2% per 100 g (Maqbool et al., 2022). These results are consistent with those of Agustin et al. (2023), who found that increasing the amount of banana blossom in tempeh nuggets led to higher fiber content. According to Kemenkes (2019), children require approximately 20 g of fiber per day. Based on the crude fiber content of the analog nuggets (ranging from 10.09% to 14.96%) and a nugget weight of 10–15 g, approximately 16 to 22 nuggets per day would be needed to meet the daily fiber requirement of 19–23 g.

Protein content

The protein content of analog nuggets ranged from 20.54% ± 0.44 to 32.81% ± 0.71, with an average value of 24.47% ± 0.55, which meets the minimum SNI standard of 12%. Compared to tempeh nuggets supplemented with banana blossom, which have protein contents ranging from 6.03% to 9.22%, the analog nuggets in this study have substantially higher protein levels. Analysis of variance showed that the tempeh-to-mocaf flour ratio (P) and red spinach concentration (K) had no significant effect ($P > 0.05$) on protein content, whereas the interaction between these factors (PK) had a significant effect ($P \leq 0.01$), as shown in Figure 5. Based on Figure 5, increasing the percentage of tempeh and decreasing the percentage of mocaf flour resulted in analog nuggets with higher protein content. Although increasing the red spinach concentration also led to higher protein levels, the differences were not statistically significant. Treatments P3K3 (4:1, 20%) and P3K2 (4:1, 15%) produced the highest protein contents, which were significantly different from the other treatments. This indicates that the main raw materials, especially tempeh, mocaf flour, and red spinach, contribute substantially to the protein content. The complete combination of essential amino acids in tempeh makes this product a potential source of high-quality protein with good nutritional value.

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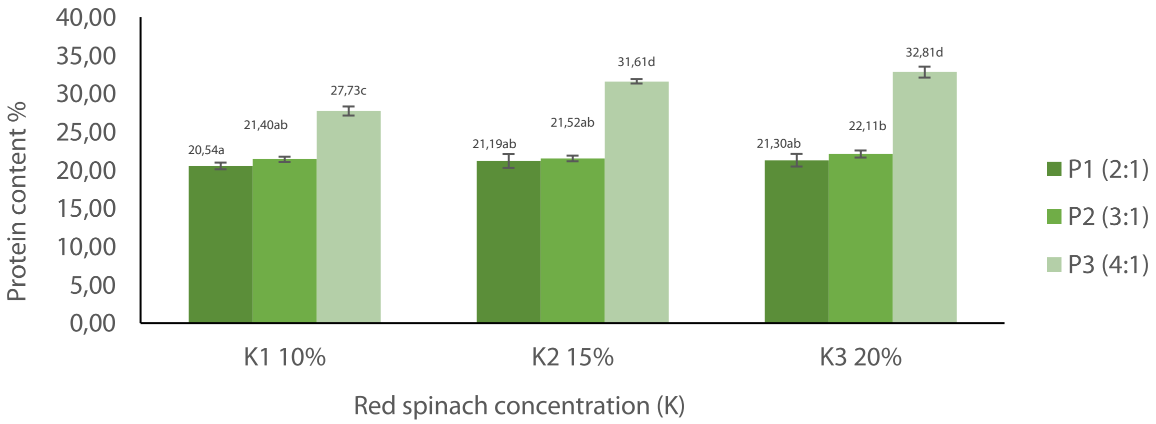

Figure 5. Effect of the interaction between the tempeh-to-mocaf flour ratio and red spinach concentration (K) on the protein content of analog nuggets (values followed by the same letter indicate no significant difference based on DMRT at α = 0.05).

Increasing the proportion of tempeh relative to mocaf flour tends to increase the protein content of analog nuggets. This is because tempeh has a higher protein content compared to mocaf flour, with tempeh containing approximately 14.87% protein (Agustin et al., 2023). The more tempeh incorporated into the formulation, the greater its contribution to the protein content of the final product (Pujilestari et al., 2020). In addition to the effect of the tempeh-to-mocaf flour ratio, the concentration of red spinach also significantly influenced protein content. Higher concentrations of red spinach contributed to an increase in protein content, indicating that red spinach provides a significant protein contribution to the analog nuggets. Protein content in analog nuggets is closely related to the composition of the raw materials. Ingredients such as tempeh and red spinach, which are high in protein, play a major role in determining the protein content of the nuggets. Therefore, increasing the proportion of tempeh and the concentration of red spinach tends to enhance the protein content of the analog nuggets. This demonstrates that the ratio of raw materials directly affects the final protein content of the product.

Cooking loss

Cooking loss indicates the amount of water and nutrients lost during heating, serving as an important indicator of product quality. Cooking loss of analog nuggets ranged from 18.00% ± 0.10 to 20.67% ± 0.94, with an average of 19.63% ± 0.72. Analysis of variance showed that the tempeh-to-mocaf flour ratio (P) and red spinach concentration (K) had no significant effect ($p > 0.05$) on cooking loss, while the interaction between these factors (PK) had a significant effect ($p \leq 0.05$), as shown in Figure 6.

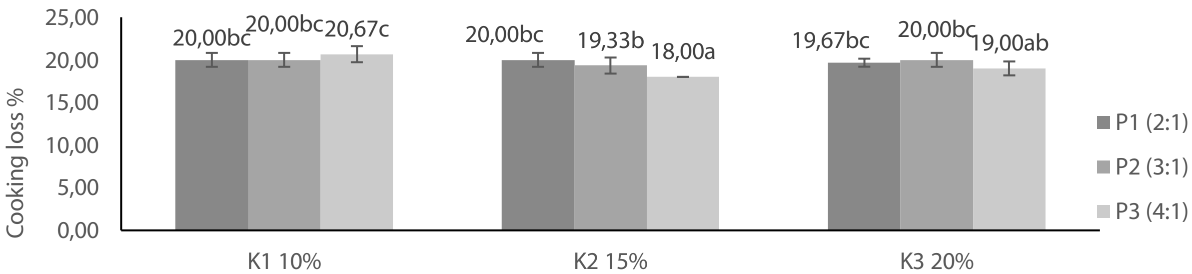

Figure 6. Effect of the interaction between the tempeh-to-mocaf flour ratio and red spinach concentration (PK) on the cooking loss of analog nuggets (values followed by the same letter indicate no significant difference based on DMRT at α = 0.05).

Based on Figure 6, the cooking loss of analog nuggets ranged from 18.00% to 20.67%, with an average of 19.63%. The lowest cooking loss was observed in treatments P3 (4:1) K2 (15%) and P3 (4:1) K3 (20%). This is attributed to the optimal balance of ingredient composition in these treatments. A higher proportion of tempeh can form a stronger protein network, minimizing water release during heating (Ratulangi & Rimbing, 2021). Meanwhile, the red spinach concentration is presumed to contribute positively through its fiber content and hydrophilic compounds, which help retain water (Michelle et al., 2023). The cooking loss observed in this study was higher than that reported for chicken nuggets with added sweet potato flour, which ranged from 1.50% to 1.62% (Ratulangi & Rimbing, 2021).

Color (value L)*

In this study, color analysis (L* value) of analog nuggets was conducted using a colorimeter to measure sample lightness. The L* value represents the amount of reflected light that produces achromatic colors such as white, gray, and black (Spetriani & Fathurahmi, 2019). L* values describe the brightness of a sample, ranging from 0 (dark) to 100 (bright) (Tamura et al., 2020). The results showed that L* values of analog nuggets ranged from 59.64 to 73.72, with an average of 65.92. This indicates that all samples had similar color characteristics, likely due to the yellowish color of tempeh and mocaf flour. Compared to commercial nuggets, (Kim et al., 2015) reported L* values of 68–74, which are slightly brighter. This difference is attributed to the use of raw materials tempeh, mocaf flour, and red spinach, whose lighter colors tend toward white.

Hedonic evaluation

Color plays an important role in influencing consumer preference and acceptance of food products (Rahmah & Mustika, 2018). Based on sensory evaluation results, the color scores of the analog nuggets ranged from 2.76 ± 0.12 (neutral) to 3.30 ± 0.15 (neutral), with an average score of 3.02 ± 0.12 (neutral). Analysis of variance showed that red spinach concentration (K) had a significant effect ($P \leq 0.01$) on nugget color, whereas the tempeh-to-mocaf flour ratio (P) and the interaction between the tempeh-to-mocaf flour ratio and red spinach concentration (PK) had no significant effect ($p > 0.05$). The effect of red spinach concentration on the color of analog nuggets is presented in Figure 7. In this study, the use of tempeh and red spinach as raw materials imparted a distinctive aroma that contributed to the unique characteristics of the product. Analysis of variance showed that red spinach concentration (K) had a significant effect ($p< 0.05$) on the aroma of analog nuggets, whereas the tempeh-to-mocaf flour ratio (P) and the interaction between the tempeh-to-mocaf flour ratio and red spinach concentration (PK) had no significant effect ($p> 0.05$). Based on Figure 7, it can be observed that panelists preferred the color of analog nuggets with red spinach concentrations of 10% (K1) and 15% (K2), with color scores of 3.21 (neutral) and 2.95 (neutral), respectively. However, the color scores for K2 (15%) and K3 (20%) showed no significant difference in the perceived color of the analog nuggets. These results indicate that panelists tended to rate the color of nuggets with lower red spinach concentrations more favorably. This is likely because the color produced at a 10% concentration appeared brighter and more appealing to the panelists. Panelists tended to rate the color less favorably at higher red spinach concentrations. The stronger color intensity or unfamiliar color changes associated with higher red spinach levels may be the cause (Erliani et al., 2020). Additionally, during processing, particularly frying, natural pigments in red spinach can interact with other components, such as proteins, through Maillard reactions. These reactions can produce darker brown compounds, resulting in a final nugget color that appears less attractive or even dull to panelists (Azzahra, 2024). The color produced at the 10% concentration was considered preferable, appearing as a bright brown, whereas

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at 20% concentration, the nuggets had a darker brown hue. Therefore, the results indicate that using excessively high concentrations of red spinach may reduce the visual appeal of analog nuggets.

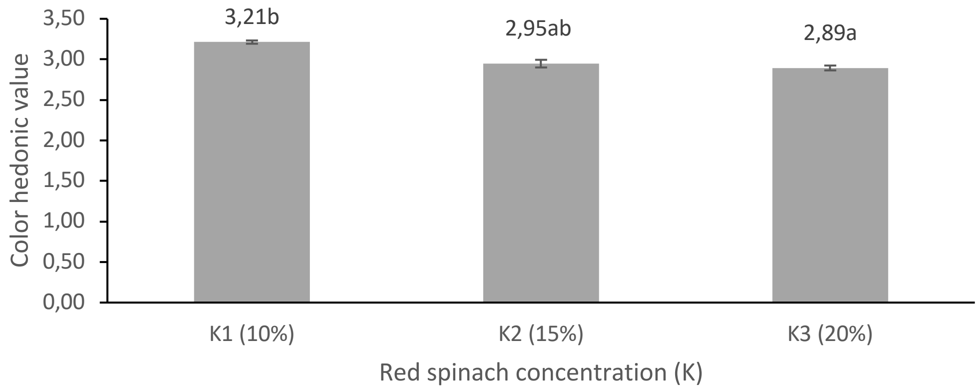

Figure 7. Effect of red spinach concentration (K) on the sensory evaluation of color in analog nuggets (values followed by the same letter indicate no significant difference based on DMRT at α = 0.05. CV = 5.86%).

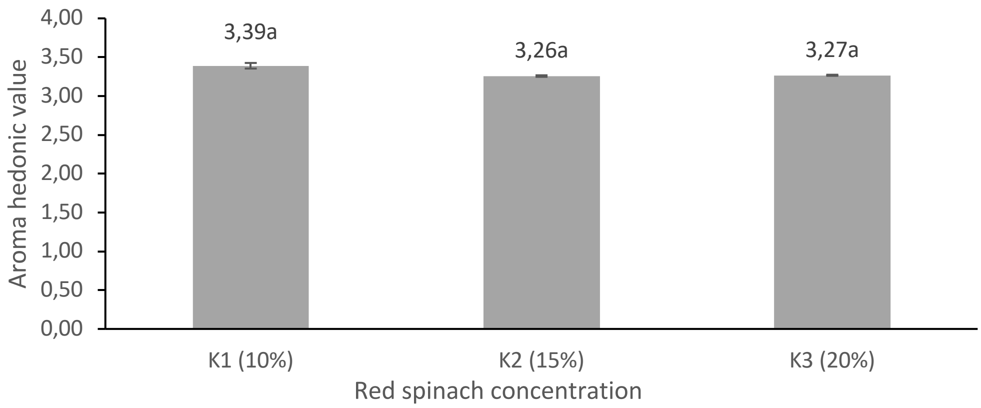

Figure 8. Effect of red spinach concentration (K) on the sensory evaluation of aroma in analog nuggets (values followed by the same letter indicate no significant difference based on DMRT at α = 0.05. CV = 2.94%).

The effect of red spinach concentration on the aroma of analog nuggets is presented in Figure 8. Based on the hedonic evaluation, the aroma scores of the analog nuggets ranged from 3.23 (neutral) to 3.52 (like), with an average score of 3.30 (neutral). Based on Figure 8, the analog nuggets at each red spinach concentration (K) showed no significant differences, as indicated by the same letter notation. This suggests that panelists tended to give similar ratings for the aroma of analog nuggets across all red spinach concentrations used. The aroma was generally rated as neutral, indicating that the intensity of red spinach aroma at all concentrations was not very strong or interacted with other components in the nuggets, resulting in a relatively uniform perception of aroma. According to Hidayati et al. (2022), red spinach has a "green" or slightly earthy aroma.

Texture is a physical property of food related to its shape and structure, perceived through touch and taste. It is experienced through sensory responses to physical stimuli in the oral cavity during chewing. Analysis of variance showed that the tempeh-to-mocaf flour ratio (P), red spinach concentration (K), and their interaction (PK) had no significant effect ($p>0.05$) on the texture of analog nuggets. Hedonic evaluation results indicated that texture scores ranged from 3.02 (neutral) to 3.20 (neutral), with an average of 3.12 (neutral). The ratio of tempeh to mocaf flour and the addition of red spinach in each formulation were not found to significantly affect nugget texture. Panelists tended to perceive the texture as uniformly

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soft across all samples, despite differences in nugget formulations. These findings align with Rahmah & Handayani (2018), who reported that plant-based nuggets exhibit a soft texture.

Taste refers to the sensation perceived by the taste buds when consuming food. Based on hedonic evaluation, taste scores of the analog nuggets ranged from 3.16 (neutral) to 3.43 (neutral), with an average of 3.32 (neutral). Analysis of variance showed that the tempeh-to-mocaf flour ratio (P), red spinach concentration (K), and their interaction (PK) had no significant effect ($P > 0.05$) on nugget taste. This indicates that panelists perceived the taste as relatively similar across all formulations of analog nuggets.

Best treatment

The analog nugget formulation P3K3 (tempeh-to-mocaf flour ratio 4:1 with 20% red spinach) was selected as the best treatment because it had the lowest moisture content (60.67%), highest fiber content (14.96%), highest protein content (32.81%), and lowest fat content (2.93%) compared to the other formulations. This P3K3 formulation was subsequently analyzed for ash content, carbohydrate content by difference, and total plate count (TPC) (Table 2). Based on Table 2, the ash content of the best-performing analog nugget in this study was 1.3%, which varies compared to other studies. According to Pujilestari et al. (2020), ash represents the inorganic residue reflecting the mineral content in food. The addition of mocaf flour can increase ash content due to its mineral content of approximately 0.28% (Novian, 2021). Besides mocaf flour, other raw materials, such as tempeh, also contribute to the ash content of analog nuggets, with tempeh minerals ranging from 0.8% to 1.79%. The carbohydrate content of the best analog nugget formulation was 2.29%. Carbohydrates play an important role not only as a primary energy source but also in determining sensory characteristics such as taste, color, and texture of food products (Rahmah & Mustika, 2018). This carbohydrate level meets the SNI standard for chicken nuggets, which sets a maximum limit of 25%. The relatively low carbohydrate content in this study is likely due to the unique formulation of the analog nugget, which differs from conventional chicken nuggets (which use wheat flour without tempeh or red spinach). Although mocaf flour is one of the main ingredients and has a starch content of around 85% (Kemenkes, 2019), its proportion in the nugget formulation is not dominant. Furthermore, the fermentation process in mocaf production, which may enhance starch availability through cellulolytic and pectinolytic enzyme activity, does not automatically yield a final product with high carbohydrate content. The proportions of other ingredients, such as protein sources and water, can influence the final carbohydrate content of the product.

Table 2. Ash and carbohydrate content of nuggets

Ash content (%)	Carbohydrate content (%)
1.3±0.2 (research results)	2.29±0.39 (research results)
1.23 *	20.05*
1.73 **	8.78 **

*Fitriyani et al. (2024), ** Pujilestari et al. (2020)

Conclusion

The results of this study indicate that tempeh and mocaf flour can replace chicken and wheat flour as raw materials for nugget production. The best analog nugget formulation was obtained with a tempeh to mocaf flour ratio of 4:1 and 20% red spinach, which resulted in the following characteristics: moisture content 60.67%, fat 2.93%, fiber 14.96%, protein 32.81%, cooking loss 19%, color 2.95 (neutral), aroma 3.22 (neutral), texture 3.13 (neutral), taste 3.37 (neutral), ash content 1.3%, and carbohydrate content 2.29%.

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