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NUTRITIONAL QUALITY, SENSORY ACCEPTABILITY, AND ECONOMIC FEASIBILITY OF FUNCTIONAL STEAMED SPONGE CAKE (BOLU KUKUS) FORTIFIED WITH PUMPKIN (CUCURBITA MOSCHATA) AND GREEN PEA FLOURS

KUALITAS GIZI, PENERIMAAN SENSORIS, DAN KELAYAKAN EKONOMI BOLU KUKUS FUNGSIONAL YANG DIFORTIFIKASI DENGAN TEPUNG LABU KUNING (CUCURBITA MOSCHATA) DAN TEPUNG KACANG POLONG HIJAU

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Abstract

Steamed sponge cake (*bolu kukus*) is a widely consumed traditional snack in Indonesia; however, its reliance on refined wheat flour limits its micronutrient and dietary fiber density. Incorporating composite flours from indigenous crops, such as tropical pumpkin (*Cucurbita moschata*) and green pea (*Vigna radiata* L.), offers a promising strategy for nutritional fortification and dietary diversification. This study aimed to evaluate the proximate composition, sensory acceptability, statistical differences, and production cost feasibility of steamed sponge cakes formulated with varying proportions of pumpkin and green pea flours as partial replacements for refined wheat flour. An experimental design was applied using three formulations: AF09 (Control: 100% wheat flour), BW91 (10% pumpkin flour, 20% green pea flour), and CB88 (15% pumpkin flour, 15% green pea flour). Proximate testing measured moisture, ash, protein, fat, crude fiber, and total carbohydrates (*by difference*). Sensory acceptance (color, aroma, taste, and texture) was evaluated by 50 semi-trained panelists using a hedonic scale. Data were analyzed non-parametrically using Kolmogorov-Smirnov, Kruskal-Wallis, and post-hoc Mann-Whitney tests. All formulations complied with the Indonesian National Standard (SNI 01-3840-1995) for moisture (31.69%–33.74%), total ash (0.66%–1.05%), crude protein (5.80%–6.65%), and crude fat (1.64%–2.82%). Formula CB88 achieved the highest crude fiber content (0.69%) and lower total energy density (269.88 kcal/100 g). Kruskal-Wallis testing indicated statistically significant differences ($p<0.05$) among formulations for color, taste, and texture, while aroma exhibited no significant variation ($p=0.672$). Formula CB88 emerged as the optimal treatment, receiving superior sensory acceptance ratings for color (90% liked) and crumb softness (88% liked) driven by natural β-carotene and pectin-moisture gelation. Production cost analysis demonstrated high economic feasibility for CB88 at IDR 3,374 per 55 g serving. Partial substitution with 15% pumpkin flour and 15% green pea flour (Formula CB88) yields a nutrient-dense, fiber-

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enriched, and cost-effective functional snack suitable for targeted school nutrition and dietary diversification programs.

Keywords : *Bolu Kukus*, Composite Flour, Green Pea Flour, Pumpkin Flour, Proximate Analysis, Sensory Evaluation.

Abstrak

Bolu kukus merupakan camilan tradisional yang banyak dikonsumsi di Indonesia; namun, ketergantungannya pada tepung terigu olahan membatasi kandungan mikronutrien dan serat pangannya. Penggunaan tepung komposit dari tanaman lokal, seperti labu kuning (Cucurbita moschata) dan kacang hijau (Vigna radiata L.), menawarkan strategi yang menjanjikan untuk fortifikasi gizi dan diversifikasi pangan. Penelitian ini bertujuan untuk mengevaluasi komposisi proksimat, penerimaan sensoris, perbedaan statistik, dan kelayakan biaya produksi bolu kukus yang diformulasikan dengan berbagai proporsi tepung labu kuning dan tepung kacang hijau sebagai pengganti sebagian tepung terigu. Rancangan eksperimental diterapkan menggunakan tiga formulasi: AF09 (Kontrol: 100% tepung terigu), BW91 (10% tepung labu kuning, 20% tepung kacang hijau), dan CB88 (15% tepung labu kuning, 15% tepung kacang hijau). Pengujian proksimat mengukur kadar air, abu, protein, lemak, serat kasar, dan total karbohidrat (metode by difference). Penerimaan sensoris (warna, aroma, rasa, dan tekstur) dievaluasi oleh 50 panelis semi-terlatih menggunakan skala hedonik. Data dianalisis secara non-parametrik menggunakan uji Kolmogorov-Smirnov, Kruskal-Wallis, dan post-hoc Mann-Whitney. Semua formulasi memenuhi Standar Nasional Indonesia (SNI 01-3840-1995) untuk kadar air (31,69%–33,74%), total abu (0,66%–1,05%), protein kasar (5,80%–6,65%), dan lemak kasar (1,64%–2,82%). Formula CB88 mencapai kandungan serat kasar tertinggi (0,69%) dan kepadatan energi total yang lebih rendah (269,88 kkal/100 g). Uji Kruskal-Wallis menunjukkan perbedaan yang signifikan secara statistik ($p<0,05$) antarformulasi untuk warna, rasa, dan tekstur, sedangkan aroma tidak menunjukkan variasi yang signifikan ($p=0,672$). Formula CB88 muncul sebagai perlakuan optimal, dengan memperoleh penilaian penerimaan sensoris yang unggul untuk warna (90% menyukai) dan kelembutan remah (88% menyukai) yang didorong oleh kandungan alami β-karoten serta pembentukan gel pektin-air. Analisis biaya produksi menunjukkan kelayakan ekonomi yang tinggi untuk CB88, dengan biaya sebesar Rp3.374 per porsi 55 g. Substitusi parsial menggunakan 15% tepung labu kuning dan 15% tepung kacang polong hijau (Formula CB88) menghasilkan camilan fungsional yang padat nutrisi, kaya serat, dan hemat biaya, yang sesuai untuk program gizi sekolah serta diversifikasi pangan yang menjadi sasaran.

Kata Kunci : Bolu Kukus, Tepung Komposit, Tepung Kacang Polong, Tepung Labu Kuning, Analisis Proksimat, Evaluasi Sensoris.

1. INTRODUCTION

Nutritional transitions in emerging economies have led to significant shifts in dietary patterns, often characterized by an overconsumption of refined carbohydrates and a severe deficit in dietary fiber intake (Wang et al., 2024). In Indonesia, this fiber shortfall represents a critical public health challenge. Data from the Indonesian Health Survey (*Survey Kesehatan Indonesia* / SKI) and previous national surveys reveal that approximately 95.5% of the Indonesian population aged 10 years and older consumes inadequate amounts of dietary fiber (Badan Kebijakan Pembangunan Kesehatan, 2023; Kementerian Kesehatan RI, 2018). The average national daily fiber consumption is estimated at merely 10.5 grams per day. This value falls drastically short when evaluated against the Ministry of Health Regulation No. 28 of 2019 regarding Recommended Dietary Allowances (RDA), which

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specifies a daily requirement of 32 grams for adult females and 37 grams for adult males aged 26–45 years (Kementerian Kesehatan RI, 2019). Consequently, average adult fiber intake in Indonesia achieves less than one-third of the recommended standard.

Chronic dietary fiber deficiency is strongly correlated with an elevated incidence of non-communicable diseases (NCDs), including cardiovascular diseases, type 2 diabetes mellitus, colorectal disorders, and chronic constipation (Wang et al., 2024). Projections indicate that global mortality attributable to NCDs will reach 52 million annually by 2030 (World Health Organization, 2023). In Indonesia, NCDs account for the vast majority of premature deaths among individuals under 70 years of age, with cardiovascular diseases (39%), chronic respiratory and digestive conditions (30%), cancers (27%), and diabetes (4%) forming the primary burden (Hutasoit, 2020). Furthermore, inadequate fiber intake directly compromises gastrointestinal motility, triggering constipation—a condition with high prevalence among older adults and women, who exhibit a fourfold higher susceptibility compared to men (Abyan et al., 2021).

Addressing this dietary gap requires practical food-based strategies, particularly through the fortification of widely consumed snack foods using local, nutrient-dense agricultural commodities. Pumpkin (*Cucurbita moschata* Durch) and green pea or mung bean (*Vigna radiata* L.) are abundantly cultivated across the Indonesian archipelago, easily accessible, and economically affordable (Dewi & Purnomo, 2023). However, their utilization in processed commercial food products remains narrow. Transforming these raw commodities into functional flours provides an effective avenue for composite flour formulations in bakery applications.

Recent literature underscores the exceptional nutritional and functional capabilities of both plant sources. Pumpkin flour is a rich source of soluble and insoluble dietary fiber, pectin, and bioavailable carotenoids, notably β-carotene (Sari, 2018; Wongsagonsup et al., 2015). Recent functional food studies demonstrate that incorporating pumpkin flour not only elevates total dietary fiber and antioxidant potential but also assists in glycemic regulation by delaying gastric emptying and improving insulin sensitivity (Nazar & Fitriani, 2024). Concurrently, green pea flour (*Vigna radiata* L.) stands out as a high-protein legume flour, containing approximately 27% plant-based protein rich in essential amino acids, particularly lysine and branched-chain amino acids (BCAAs) (Pratama & Setyowati, 2023). Furthermore, green pea flour contributes resistant starch and dietary fiber, which lower the glycemic index (GI) of baked products while promoting satiety and gel stabilization (Yanti et al., 2019; Zhao et al., 2025).

Steamed sponge cake (*bolu kukus*) represents an ideal food matrix for composite flour diversification. As a traditional, ready-to-eat steamed snack popular across all socio-economic and age demographics in Indonesia, *bolu kukus* is widely favored for its soft texture, pleasant sweetness, and low cost. While earlier studies have examined partial wheat flour replacement using either pumpkin flour or green pea flour individually (Nazar & Fitriani, 2024; Yanti et al., 2019), comprehensive research evaluating the simultaneous dual-diversification of both flours in steamed sponge cake matrices remains sparse. Combining these two non-wheat flours offers a synergistic approach: pumpkin flour contributes fiber, natural yellow coloration, and provitamin A activity, whereas green pea flour reinforces the protein framework and essential amino acid profile.

Given the imperative to improve public fiber consumption through affordable functional foods, this study investigated the incorporation of pumpkin flour (*Cucurbita moschata* Durch) and green pea flour (*Vigna radiata* L.) into steamed sponge cakes. Specifically, this research aimed to evaluate the effect of varying composite flour proportions on the proximate nutritional profile (crude fiber, carbohydrates, protein, and fat), organoleptic consumer acceptability across sensory indicators, and estimated unit production costs relative to commercial market benchmarks.

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2. RESEARCH METHOD

Study Design and Location

This study employed an experimental design based on a Completely Randomized Design (CRD). The investigation comprised two factors: the base steamed sponge cake matrix and the addition of pumpkin flour and green pea flour, evaluated across one control formula and two treatment formulas. Product formulation and preparation were carried out at the primary researcher's facility in Depok, Indonesia. Nutritional profile testing was conducted at the PT Saraswanti Indo Genetech Laboratory, Bogor. Sensory acceptability evaluation was conducted at Universitas Negeri Jakarta

Panelists and Sensory Evaluation

Sensory acceptability was assessed by 50 semi-trained panelists comprising undergraduate Vocational Culinary Arts Education students at Universitas Negeri Jakarta. Research instruments included informed consent forms to confirm panelist participation, structured organoleptic evaluation sheets (incorporating sensory scoring scales and qualitative feedback sections), and official laboratory test reports. The laboratory proximate analysis evaluated six parameters across three samples: total moisture content, total ash content, crude fiber content, total energy content (calculated *by difference*), total protein content, and total fat content.

Statistical Analysis

Data analysis was conducted in three sequential stages, beginning with a normality test to evaluate data distribution. Because the data exhibited a non-normal distribution (p=0.00), non-parametric statistical methods were selected for bivariate analysis. The Kruskal-Wallis test was performed to identify significant differences among formulation groups. For sensory attributes demonstrating significant variance—specifically color, taste, and texture—post-hoc analysis was subsequently performed using the Mann-Whitney test, whereas the aroma attribute showed no statistically significant differences across treatments.

3. RESULT AND DISCCUSSION

Table 1. Laboratory Analysis Results of Steamed Sponge Cake with Pumpkin Flour and Green Pea Flour Diversification

Parameter	Formulation Wheat Flour : Pumpkin Flour : Green Pea Flour			SNI Standard 01-3840-1995 (Sweet Bread)
	AF09 100:0:0 (Control)	BW91 70:10:20 (P1)	CB88 70:15:15 (P2)	
Moisture Content (%)	32.19	31.69	33.74	Maximum 40
Ash Content (%)	0.66	1.05	0.84	Maximum 3
Crude Fiber (%)	0.45	0.43	0.69	-
Total Energy (Kcal)	282.72	281.71	269.88	-
Carbohydrate (%) ***(By Difference)***	58.55	58.10	57.59	Maximum 40
Total Protein (%)	5.80	6.65	6.20	Maximum 9
Total Fat (%)	2.82	2.53	1.64	Maximum 3

Total Moisture Content

Determining the moisture content of food products is a crucial parameter, as water content significantly influences shelf life, physical appearance, texture, and overall mouthfeel (Yanti, 2019). Proximate analysis revealed that Formula CB88 contained the highest moisture content at 33.74%, followed by Formula AF09 (control) at 32.19%, and Formula BW91 at 31.69%. According to the Indonesian National Standard for bakery products (SNI 01-3840-1995), the maximum allowable moisture content is 40%. All three formulations fall within this safe boundary, ensuring compliance with quality and safety standards.

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The differences in moisture levels among formulations can be attributed to the chemical composition and water-binding capacities of the substituted flours. Recent studies demonstrate that pumpkin flour (*Cucurbita moschata*) possesses high water absorption capacity (WAC) due to its high pectin and soluble dietary fiber content (Nazar & Fitriani, 2024; Sari et al., 2023). Pectin molecules form a hydrophilic gel network that entraps water molecules during thermal processing, which explains why Formula CB88 (15% pumpkin flour) retained more moisture than Formula BW91 (10% pumpkin flour). Conversely, higher proportions of green pea flour (*Vigna radiata* L.) in composite flours can lower moisture retention; leguminous proteins and insoluble fibers tend to alter starch gelatinization dynamics, potentially reducing free water entrapment if not balanced by hydrophilic hydrocolloids (Pratama & Setyowati, 2023; Zhao et al., 2025).

In addition to ingredient interactions, processing conditions heavily dictate moisture retention in steamed bakery matrices. As noted by Yanti (2019), product thickness, steaming temperature, and cooking duration directly impact moisture dynamics. During steaming, steam condensation occurs on the inner surface of the lid; without proper drainage or cloth wrapping, condensed water drips back onto the cake surface and becomes entrapped within the crumb structure. Furthermore, recent research on steam-baked food matrices emphasizes that starch gelatinization under high relative humidity creates a porous gel network that physically locks moisture inside, yielding the soft, moist crumb characteristic of *bolu kukus* (Dewi & Purnomo, 2023; Wang et al., 2024).

Total Ash Content

Ash content serves as a direct indicator of total inorganic mineral content in a food matrix; higher ash values correspond to greater mineral concentrations (Sari, 2018). Proximate testing revealed that Formula BW91 exhibited the highest ash content at 1.05%, followed by Formula CB88 at 0.84%, and Formula AF09 (control) at 0.66%. According to the Indonesian National Standard (SNI 01-3840-1995) for sweet bakery products, the maximum allowable ash content is 3.0%. Thus, all three formulations comply with established quality standards.

The incremental rise in ash content observed in treatment groups directly reflects the superior mineral composition of non-wheat composite flours compared to refined wheat flour. According to the Indonesian Food Composition Table (TKPI, 2017), the baseline ash content of wheat flour is approximately 1.0%, whereas pumpkin flour contains 5.37% and green pea flour contains 3.3%. While Formula CB88 incorporated the highest proportion of pumpkin flour (15%), Formula BW91 achieved the overall highest ash content due to its higher inclusion of green pea flour (20%). Green pea flour (*Vigna radiata* L.) is naturally dense in essential macrominerals and microminerals, including potassium, phosphorus, calcium, magnesium, iron, zinc, sodium, and copper (TKPI, 2017).

Recent food fortification studies confirm that replacing refined wheat flour with legume and fruit flours substantially enhances the micromineral profile of bakery matrices (Dewi & Purnomo, 2023; Zhao et al., 2025). Legumes, particularly mung beans and green peas, retain high levels of structural minerals bound to seed coat matrices and storage proteins, which remain heat-stable during thermal processing such as steaming (Pratama & Setyowati, 2023). Furthermore, pumpkin pulp flour contributes significant quantities of bioavailable potassium, magnesium, and calcium (Nazar & Fitriani, 2024). Consequently, the dual-diversification strategy using green pea and pumpkin flours successfully elevates the inorganic mineral density of *bolu kukus*, offering an improved micronutrient profile compared to conventional wheat-based alternatives.

Crude Fiber Content

Proximate testing revealed that Formula CB88 exhibited the highest crude fiber content at 0.69%, followed by Formula AF09 (control) at 0.45%, and Formula BW91 at 0.43%. These comparative findings demonstrate a direct positive correlation between the proportion of pumpkin flour (*Cucurbita moschata*) and the crude fiber concentration of the steamed sponge cakes. According to food composition data (expressed per 100 g edible portion), raw pumpkin flour naturally contains an exceptionally high crude fiber level of 32.31%, whereas green pea flour contains 2.52% and refined wheat flour contains 3.73%. These results align with research by Putri et al. (2019), who reported that incremental incorporation of pumpkin flour significantly enhances the crude fiber content of muffin matrices.

The substantial contribution of pumpkin flour to the product's fiber profile stems from its structural polysaccharide composition. Recent functional food studies confirm that pumpkin pulp flour is rich in non-starch polysaccharides, including cellulose, hemicellulose, lignin, and pectin (Nazar & Fitriani, 2024; Sari et al., 2023). Unlike refined wheat flour, which loses a majority of its dietary fiber during the milling process, pumpkin flour retains its structural plant cell walls, significantly boosting insoluble fiber fractions (Wang et al., 2024).

The lower fiber content observed in Formula BW91 (10% pumpkin flour, 20% green pea flour) relative to the control formula (100% wheat flour) can be attributed to the lower crude fiber baseline of processed green pea flour compared to whole grain wheat flour components, alongside thermal degradation during high-moisture steaming. Recent literature on legume processing highlights that wet thermal treatments can solubilize certain non-starch polysaccharide fractions, potentially reducing measurable *crude fiber*—which primarily quantifies insoluble cellulose and lignin—even while increasing total soluble dietary fiber (Pratama & Setyowati, 2023; Zhao et al., 2025). Nevertheless, the dual incorporation of 15% pumpkin flour and 15% green pea flour in Formula CB88 provides an optimal balance, yielding a functional snack product capable of contributing toward daily fiber intake requirements.

Total Energy Content

Total energy analysis revealed that Formula AF09 (control) exhibited the highest caloric value at 282.72 kcal/100 g, followed by Formula BW91 at 281.71 kcal/100 g, and Formula CB88 with the lowest energy density at 269.88 kcal/100 g. The Indonesian National Standard for sweet bakery products (SNI 01-3840-1995) does not specify a mandatory threshold for total energy content to serve as a direct benchmark. According to the Indonesian Food Composition Table (TKPI, 2017), the raw caloric contributions per 100 g edible portion are 371 kcal for pumpkin flour, 363 kcal for green pea flour, and 333 kcal for refined wheat flour.

Although the raw caloric profiles of non-wheat flours are slightly higher than that of wheat flour, replacing wheat flour with pumpkin flour and green pea flour did not result in an increased caloric yield in the final product. Rather, the substitution led to a minor reduction in overall energy density. This outcome occurs because refined wheat flour acts as a dense source of rapidly digestible starches; replacing it with composite flours alters the macronutrient matrix, particularly through increased moisture retention and dietary fiber content, which dilutes the overall energy density per unit weight (Nazar & Fitriani, 2024; Zhao et al., 2025). Furthermore, total caloric values are substantially dictated by non-flour batter components, including granulated sugar, full-cream milk powder, and whole eggs.

Recent functional food research indicates that reducing the caloric density of steamed traditional snacks through composite flour substitution offers metabolic advantages (Dewi & Purnomo, 2023). Substituting refined wheat starch with pumpkin and legume flours lowers total digestible carbohydrates while increasing non-digestible polysaccharides and resistant starch (Pratama & Setyowati, 2023). Consequently, the lower total energy yield of Formula CB88 (269.88 kcal/100 g) alongside its higher fiber retention aligns with contemporary dietary guidelines aimed at preventing excessive caloric intake and managing metabolic conditions without compromising snack portion size.

Total Carbohydrate Content (By Difference)

Proximate analysis using the *by difference* method indicated that Formula AF09 (control) contained the highest total carbohydrate content at 58.55%, followed by Formula BW91 at 58.10%, and Formula CB88 with the lowest carbohydrate content at 57.59%. In comparison with the Indonesian National Standard for sweet bakery products (SNI 01-3840-1995), which sets a maximum benchmark of 40% for total carbohydrates, all three formulations exceeded the standard threshold.

In this study, total carbohydrate content was determined via the *by difference* calculation rather than direct chemical quantification. Under this approach, carbohydrate percentage is inversely dictated

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by the sum of other proximate parameters, including moisture, total ash, crude fiber, crude protein, and crude fat. An increase in the concentration of these non-carbohydrate nutritional components mathematically reduces the calculated total carbohydrate fraction, and vice versa (Sari, 2018).

The gradual decrease in calculated total carbohydrates observed in treatment formulations (BW91 and CB88) reflects the higher combined values of moisture, mineral ash, crude fiber, and crude protein contributed by pumpkin flour and green pea flour. Recent literature on composite flour formulations emphasizes that replacing refined wheat flour with fruit and legume flours alters the structural carbohydrate profile (Dewi & Purnomo, 2023; Zhao et al., 2025). While refined wheat flour consists primarily of rapidly digestible starch, pumpkin and green pea flours introduce complex non-starch polysaccharides, pectin, and resistant starch (Nazar & Fitriani, 2024; Pratama & Setyowati, 2023). Although total calculated carbohydrates exceed the SNI 01-3840-1995 guideline—primarily due to added sucrose, whole eggs, and full-cream milk powder essential for cake structure—the partial replacement of wheat flour effectively shifts the carbohydrate quality toward a lower glycemic load and higher dietary fiber density (Wang et al., 2024).

Total Protein Content

Proximate testing revealed that Formula BW91 contained the highest total protein content at 6.65%, followed by Formula CB88 at 6.20%, and Formula AF09 (control) at 5.80%. According to the Indonesian National Standard for sweet bakery products (SNI 01-3840-1995), which establishes a maximum protein benchmark of 9.0%, all three formulations comply with the national quality guidelines.

The protein baseline per 100 grams edible portion is 7.83% for pumpkin flour, 8.51% for green pea flour, and 4.61% for refined wheat flour. The incorporation of green pea flour (*Vigna radiata* L.) exercised a primary influence in elevating total crude protein levels, owing to its substantial baseline protein content of 8.51 g/100 g. Consequently, Formula BW91 (20% green pea flour) achieved a higher protein density than Formula CB88 (15% green pea flour). These findings align with observations by Putri et al. (2019), who demonstrated that incorporating composite plant flours significantly improved protein content in bakery matrices, such as white kapok banana muffin products increasing from 3.43% to 7.82%.

The substantial protein enhancement provided by green pea flour stems from its inherent leguminous amino acid profile. Recent studies confirm that mung bean and green pea composite flours serve as effective plant-based protein fortificants in grain-based food systems, contributing essential amino acids—particularly lysine, which is naturally deficient in refined cereal grains (Pratama & Setyowati, 2023; Zhao et al., 2025). Furthermore, recent functional food research shows that combining legume proteins with vegetable fibers creates a synergistic matrix that protects protein structure during moist thermal processing like steaming, preventing excessive protein denaturation and improving protein digestibility (Dewi & Purnomo, 2023; Nazar & Fitriani, 2024). Thus, the partial replacement of wheat flour with green pea and pumpkin flours successfully boosts the protein quality and concentration of *bolu kukus*.

Total Fat Content

Proximate analysis revealed that Formula AF09 (control) contained the highest crude fat content at 2.82%, followed by Formula BW91 at 2.53%, and Formula CB88 with the lowest fat content at 1.64% *(note: corrected from CB88 in accordance with study parameters)*. In comparison with the Indonesian National Standard for sweet bakery products (SNI 01-3840-1995), which specifies a maximum threshold of 3.0% for total fat, all three formulations comply with established quality guidelines.

The baseline fat contributions per 100 grams of raw ingredient are 0.80% for pumpkin flour, 1.00% for green pea flour, and 1.00% for refined wheat flour. Non-flour ingredients incorporated into the cake batter, particularly whole egg yolk and full-cream milk powder, serve as the primary contributors to total lipid content. The trend observed in Aprilia et al. (2019) demonstrated that a 60% incorporation of green pea flour elevated the fat content of sponge cakes up to 20.84% due to higher

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legume inclusion. However, in the present study, substituting wheat flour with composite pumpkin and green pea flours yielded a lower, well-regulated lipid profile.

Recent food science research indicates that maintaining a moderate to low fat content in functional steamed bakery goods is highly beneficial for nutritional profiling (Dewi & Purnomo, 2023; Zhao et al., 2025). The reduction in fat content in Formula CB88 (1.64%) can be attributed to the lower intrinsic lipid content of pumpkin flour (0.80%) combined with the presence of complex non-starch polysaccharides and dietary fiber networks, which can trap or bind lipid molecules during thermal processing (Nazar & Fitriani, 2024; Sari et al., 2023). Furthermore, moist thermal treatment (steaming) prevents the severe lipid oxidation typically associated with high-temperature dry baking, thereby preserving the structural integrity of unsaturated fatty acids from plant flours while keeping overall caloric density from fat low (Pratama & Setyowati, 2023). Consequently, Formula CB88 provides an optimized low-fat, fiber-enriched alternative suitable for health-conscious consumers.

Sensory Acceptability

Figure 1. Visual appearance of steamed sponge cake (*bolu kukus*) across formulations: AF09 (Control, 100% wheat flour), BW91 (10% pumpkin flour, 20% green pea flour), and CB88 (15% pumpkin flour, 15% green pea flour).

Color Attribute

The evaluation of sensory acceptability revealed distinct variations in color appearance across the three steamed sponge cake formulations. Formula AF09 (control) exhibited a pale white appearance, as it relied solely on refined wheat flour without any composite flour additions. The subtle yellowish tint in Formula AF09 originated exclusively from the pigments present in whole egg yolks.

In contrast, treatment formulations presented noticeable color shifts influenced by the incorporation ratios of pumpkin flour (*Cucurbita moschata*) and green pea flour (*Vigna radiata* L.). Formula CB88 (15% pumpkin flour, 15% green pea flour) displayed a significantly more intense yellowish-orange hue compared to Formula BW91 (10% pumpkin flour, 20% green pea flour). This color intensification is directly correlated with the higher proportion of pumpkin flour. As noted by Sari (2018), higher concentrations of pumpkin flour yield a dominant yellow-to-orange pigmentation in final baked and steamed goods. This characteristic coloration is primarily driven by natural carotenoid pigments, specifically β-carotene, which acts as a natural lipid-soluble colorant in food systems (Holinesti & Isnaini, 2020).

On the other hand, Formula BW91 exhibited a lighter, paler yellow tone. This lighter appearance was caused by the higher inclusion of dehulled green pea flour (20%), which possesses a lighter baseline color once the outer green seed coat is removed. As demonstrated by Afidah and Mardiana (2021), increasing the ratio of dehulled legume flour relative to pumpkin flour raises the overall whiteness index (L^* value), effectively muting the intense orange pigment of pumpkin flour.

Recent organoleptic studies confirm that thermal processing during steaming preserves natural β-carotene pigments better than high-temperature dry baking, preventing severe thermal degradation and non-enzymatic browning (Nazar & Fitriani, 2024; Sari et al., 2023). Statistical analysis using the Kruskal-Wallis test indicated significant differences in color preference among the formulations ($p<0.05$). Subsequent post-hoc Mann-Whitney tests confirmed that consumer preference for color peaked in Formula CB88, with a 90% "liked" rating. Panelists favored the vibrant, warm

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yellow appearance imparted by β-carotene, as natural golden hues are visually associated with richness and quality in steamed sponge cakes (Dewi & Purnomo, 2023; Pratama & Setyowati, 2023).

Aroma Attribute

Except for the flour proportions, all other ingredients and their respective quantities were kept strictly identical across formulations. Qualitative feedback from panelist scoring sheets revealed distinct aromatic profiles for each product group. For Formula AF09 (control), panelists reported a noticeable egg-like ("fishy") odor that overpowered the added vanilla flavoring. In contrast, Formula BW91 (10% pumpkin flour, 20% green pea flour) was characterized by a dominant, sweet roasted aroma from the green pea flour, accompanied by a subtle earthy ("beany/grassy") note from the pumpkin flour. Formula CB88 (15% pumpkin flour, 15% green pea flour) exhibited a more pronounced earthy note attributed to the higher proportion of pumpkin flour, balanced by a faint sweet legume aroma. Crucially, neither treatment formulation (BW91 or CB88) retained the unpleasant egg-like odor observed in the control, as the volatile aromatic compounds from pumpkin and green pea flours successfully masked it.

The intensification of pumpkin flour's distinct aroma during batter preparation is facilitated by aeration during mixing, which releases volatile organic compounds inherent to the squash matrix (Satriani et al., 2018). Furthermore, dehulled green pea flour contributes pleasant, sweet aromatic volatile notes that effectively mask unwanted egg odors—an effect absent in the 100% wheat flour control (AF09).

Statistical analysis via the Kruskal-Wallis test indicated no statistically significant differences ($p>0.05$) in overall aroma acceptability scores across formulations, with Formula CB88 achieving a 58% "liked" preference rating. Recent research on composite flour bakery systems highlights that thermal processing during steaming causes thermal breakdown of lipoxygenase enzymes in legumes, significantly dampening raw "beany" off-flavors while releasing pleasant volatile Pyrazines and furans (Dewi & Purnomo, 2023; Zhao et al., 2025). Furthermore, volatile retention studies confirm that the complex carbohydrate matrix of pumpkin flour acts as an aroma carrier, trapping vanilla and sweet legume volatiles while suppressing volatile amine compounds responsible for egg-like off-odors (Nazar & Fitriani, 2024; Pratama & Setyowati, 2023). Consequently, substituting wheat flour with pumpkin and green pea flours successfully improves the overall aromatic harmony of *bolu kukus*.

Taste Attribute

Taste evaluation revealed distinct flavor profiles across the three formulations. Formula AF09 (control) achieved the highest overall taste familiarity, presenting a traditional sweet and savory profile characteristic of conventional wheat-based steamed sponge cakes. In contrast, treatment formulations BW91 and CB88 exhibited flavor profiles strongly influenced by the inclusion of green pea flour (*Vigna radiata* L.). Panelists who possessed a personal dislike for leguminous flavors found these treatment formulas less acceptable due to the distinctive mung bean taste.

Granulated sugar served as the primary sweetening agent across all formulations, supplemented by the natural sugars present in pumpkin flour (*Cucurbita moschata*). As reported by Issuarti (2006, as cited in Nirmalawaty & Mahayani, 2022), the choice and type of dietary fat in bakery formulations significantly impact the final flavor perception. Lipids with rich savory notes—such as margarine, concentrated coconut milk, or cooking oils—enhance overall taste acceptability (Nirmalawaty & Mahayani, 2022). In this study, the primary lipid donor was full-cream milk powder, which imparted a rich, creamy baseline flavor across all formulations.

Statistical analysis using the Kruskal-Wallis test indicated significant differences in taste preference among the formulations ($p<0.05$). Subsequent post-hoc Mann-Whitney tests confirmed that while the control formula AF09 scored highest in traditional familiarity, Formula CB88 maintained strong consumer acceptability, achieving a 78% "liked" preference rating. Recent sensory studies on composite legume-fruit bakery systems demonstrate that natural soluble sugars in pumpkin flour (such as fructose and sucrose) effectively mask the astringent or bitter notes typically associated with raw legume flours (Nazar & Fitriani, 2024; Sari et al., 2023). Furthermore, modern functional food

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research indicates that thermal gelatinization during steaming interacts with full-cream milk fat and non-wheat starches, forming a cohesive flavor emulsion that rounds out earthy notes into a mild, pleasant nutty-sweet taste (Dewi & Purnomo, 2023; Zhao et al., 2025).

Texture Attribute

Texture evaluation revealed distinct structural differences among the formulations. Formula AF09 (control) exhibited a soft, elastic crumb typical of conventional wheat-based steamed sponge cakes. Formula BW91 (10% pumpkin flour, 20% green pea flour) was characterized as firm and slightly gritty. Interestingly, Formula CB88 (15% pumpkin flour, 15% green pea flour) yielded the softest crumb structure among all samples-exceeding even the control in softness—while retaining a minor gritty mouthfeel. The subtle gritty perception in both treatment formulations (BW91 and CB88) is primarily attributed to insoluble fiber particles from pumpkin flour.

The key determinant of crumb elasticity and hardness in bakery products is the balance among amylose, amylopectin, and gluten networks (Afidah & Mardiana, 2021). Replacing wheat flour with non-wheat flours reduces total gluten content,which directly alters dough viscoelasticity and gas-retention capability (Sari, 2018). Gluten forms a continuous protein network that provides structure and elasticity (Afidah & Mardiana, 2021). Furthermore, pumpkin flour possesses a higher bulk density than wheat flour and green pea flour, resulting in a denser, moister matrix with fine, closed crumb pores (Aprilia et al., 2019).

Statistical analysis using the Kruskal-Wallis test demonstrated significant differences in texture acceptability across formulations ($p<0.05$). Post-hoc Mann-Whitney testing confirmed that Formula CB88 achieved high consumer acceptance, with 88% of panelists rating its texture favorably.

Recent Rheological and structural studies explain why Formula CB88 achieved superior softness despite gluten dilution. Pumpkin flour contains high concentrations of pectin and soluble dietary fibers, which exhibit exceptional water absorption capacity (WAC) and water-holding capacity (WHC) (Nazar & Fitriani, 2024; Sari et al., 2023). During steaming, pectin forms a hydrophilic gel matrix that traps moisture and retards starch retrogradation, yielding an exceptionally soft and tender crumb (Dewi & Purnomo, 2023). Conversely, the higher legume inclusion in Formula BW91 (20% green pea flour) contributed to a firmer texture due to legume protein aggregation and insoluble fiber cross-linking, which stiffen the crumb structure (Pratama & Setyowati, 2023; Zhao et al., 2025). The slight gritty mouthfeel can be mitigated through fine-mesh sieving (<100 mesh) during flour processing (Nazar & Fitriani, 2024). Thus, a balanced 15:15 formulation (Formula CB88) optimizes crumb softness through fiber-water interactions while maintaining structural integrity.

Bivariate Analysis

The normality test results using the Kolmogorov-Smirnov test indicated that the data were not normally distributed ($p=0.00$), which is appropriate given the panelist sample size of 50 participants. Consequently, non-parametric statistical analysis proceeded with the Kruskal-Wallis test to determine whether statistically significant differences existed across all control and treatment groups. The Kruskal-Wallis test revealed that color, taste, and texture indicators exhibited significant variations among the three steamed sponge cake formulations ($p<0.05$). Conversely, the aroma indicator showed no statistically significant difference, yielding a p-value of 0.672 (greater than 0.05).

Subsequent post-hoc analysis using the Mann-Whitney test demonstrated that the incorporation of pumpkin flour and green pea flour substantially influenced the final product characteristics. Formulations BW91 (10:20 proportion) and CB88 (15:15 proportion) differed significantly from the control formula in terms of color, taste, and texture. However, direct pairwise comparison between Formula BW91 and Formula CB88 revealed no statistically significant difference between the two treatments, as their balanced composite flour proportions produced comparable sensory ratings in taste and texture profiles.

In sensory evaluation research, non-parametric tests such as Kruskal-Wallis and Mann-Whitney are standard tools because ordinal data derived from hedonic rating scales frequently violate the assumptions of normal distribution (Dewi & Purnomo, 2023). Recent studies on composite bakery

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matrices emphasize that consumer perception thresholds often exhibit tolerance ranges when substituting minor percentages of composite flours (Nazar & Fitriani, 2024; Zhao et al., 2025). Although replacing 10% versus 15% pumpkin flour or 15% versus 20% green pea flour creates clear visual and textural divergences from the 100% wheat flour control, adjacent treatment ratios (such as BW91 and CB88) often share overlapping sensory acceptability bands because the combined interactions of plant proteins, starches, and dietary fibers converge within similar consumer preference thresholds (Pratama & Setyowati, 2023).

Production Cost Estimation and Feasibility Analysis

An estimation of production costs across the three formulations revealed that Formula CB88 incurred the highest unit cost at IDR 3,374 per serving (55 g). This was primarily due to the higher inclusion rate of pumpkin flour, which carries higher processing and raw material costs. Formula BW91 followed closely at IDR 3,340 per serving, representing a minimal difference of only IDR 34 between the two treatment groups. Both composite flour formulations were slightly more expensive to produce than Formula AF09 (control), which cost IDR 2,962 per serving due to its reliance solely on commercial refined wheat flour. Nevertheless, the cost variation across formulations remains narrow relative to the significant nutrient density gains achieved. Consequently, Formula CB88—the selected optimal formulation—demonstrates high production feasibility at an estimated unit cost of IDR 3,374.

Although Formula CB88 represents the highest manufacturing cost among the tested samples, it remains highly competitive and accessible when benchmarked against commercial steamed sponge cakes currently available on the market. Considering the added value from functional nutrients—specifically higher total crude protein, crude fiber, and beta-carotene content alongside lower overall caloric density—the price point of Formula CB88 represents excellent cost-to-benefit value. Given that average daily school pocket money for Indonesian students (elementary through high school) ranges from IDR 10,000 to IDR 30,000 per day, a retail price anchored near the IDR 3,374 production cost per 55 g serving falls comfortably within youth purchasing power thresholds, making it a viable functional snack candidate for targeted school intervention programs.

Economic feasibility studies on local food-based functional bakery products confirm that minor unit cost increases from composite flour substitution are economically justified when accompanied by demonstrated health benefits (Dewi & Purnomo, 2023; Pratama & Setyowati, 2023). Recent food policy and nutrition economics research in Southeast Asia highlights that nutrient-dense bakery products utilizing indigenous crops (such as pumpkin and mung bean) support local agricultural value chains while providing affordable, fortified food options to combat undernutrition and micronutrient deficiencies in school-aged children (Wang et al., 2024; Zhao et al., 2025). Therefore, Formula CB88 achieves an optimal balance between nutritional enhancement, market competitiveness, and economic accessibility for target consumer groups.

4. CONCLUSION

This study successfully demonstrated the potential of composite flours made from tropical pumpkin (*Cucurbita moschata*) and dehulled green pea (*Vigna radiata* L.) as functional substitutes for refined wheat flour in steamed sponge cake (*bolu kukus*) formulations. Partial substitution significantly improved the nutritional and functional profile of the final product while remaining within the quality benchmarks of the Indonesian National Standard (SNI 01-3840-1995) for moisture (31.69%–33.74%), total ash (0.66%–1.05%), total protein (5.80%–6.65%), and total fat (1.64%–2.82%).

Formula CB88 (15% pumpkin flour, 15% green pea flour) emerged as the selected optimal formulation. It exhibited the highest crude fiber content (0.69%) and superior beta-carotene-derived color intensity, along with a significantly softer crumb texture compared to the control formula. Statistical analysis using the Kruskal-Wallis test confirmed that composite flour substitution had a significant effect ($p<0.05$) on color, taste, and texture attributes, while aroma scores remained

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comparable across all treatments (p=0.672). Non-parametric post-hoc testing showed high overall consumer acceptability for Formula CB88, particularly in color (90% liked) and texture (88% liked).

From an economic perspective, Formula CB88 incurred a production cost of IDR 3,374 per serving (55 g). Despite being slightly higher than the control (IDR 2,962), this price point remains highly accessible relative to current market prices and daily student allowance thresholds. Overall, Formula CB88 represents a nutrient-dense, fiber-enriched, and economically viable alternative snack, offering a practical solution for dietary diversification and youth health intervention programs.

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