Physicochemical and sensory characteristics of corn silk enriched bread prepared using sponge dough method

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ABSTRACT With growing demand for healthier food options, recent research has focused on enriching bread with functional ingredients to improve its nutritional value, particularly dietary fiber content. However, most of these studies have used only the straight dough method, limiting understanding of how different breadmaking techniques affect product quality. This study aimed to assess the physicochemical and sensory properties of bread enriched with corn silk powder (CSP) at varying substitution levels (2 %, 4 % and 6 %) using the sponge dough method. These were compared with two control breads prepared without CSP, using both the straight and sponge dough methods. Results showed that breads with 4 % and 6 % CSP had significantly lower volume ($p < 0.05$) than the straight dough control, although specific volume did not differ significantly ($p > 0.05$) among all samples. Increasing CSP levels also resulted in darker crumb color and greater hardness. However, the texture remained comparable to the straight dough control. CSP-enriched breads at 4 % and 6 % contained significantly higher dietary fiber ($p < 0.05$) than controls. Sensory evaluation indicated moderate liking for CSP bread. Overall, the findings demonstrate that CSP enhances the dietary fiber content of bread and that the sponge dough method improves baking quality, making it a promising approach for developing high-fiber, value-added bread.

KEYWORDS: Bread; Corn silk; Physicochemical; Sensory; Sponge dough.
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INTRODUCTION

Bread is a globally consumed staple food, traditionally made from wheat flour, water and yeast. Fermentation plays a crucial role in breadmaking, significantly influencing the texture, volume and flavour of the final product. Among the commonly used dough preparation methods are straight dough, sponge dough, and no-time dough, each varying in its fermentation process and affecting the final bread quality in different ways. The straight dough method involves a single stage mixing process and is widely applied due to its simplicity and efficiency (Zhou & Hui, 2014). In contrast, the sponge dough method consists of a two-step fermentation process, which, although more time-consuming, tends to produce bread with improved sensory attributes and processing tolerance (Luiz & Vanin, 2022).

In Malaysia, white bread ranks among the top ten most consumed foods weekly according to the Malaysian Adults Nutrition Survey (MANS) by the Institute for Public Health (2014). Given its high consumption, the nutritional composition of bread is particularly important. In response to growing consumer awareness of health and diet, bread is increasingly being fortified with functional ingredients such as whole grains, soy flour, herbs, spices, and plant-based by-products to enhance fibre content, lower caloric value, and reduce reliance on artificial additives (Ibrahim *et al*., 2015; Ni *et al*., 2020). Corn silk (*Stigma maydis*), a shiny, thread-like structure found atop each corn ear, is an agricultural by-product generated during corn harvesting. Corn is the world's third most cultivated crop after wheat and rice (Klein & Luna, 2022). Although often discarded, corn silk is rich in nutrients, dietary fibres, and bioactive compounds, making it a valuable functional ingredient in food applications (Ning *et al*., 2022; Mihali *et al*., 2024).

Several studies have attempted to enrich bread with fibre by substituting conventional ingredients with various fibrous materials such as tea fibre, lemon pomace and broad bean hull, primarily using the straight dough method (Akın *et al*., 2021; Ni *et al*., 2020). The sensory characteristics of fibre-enriched bread may differ significantly from those of traditional bread. Consumers often report that these products can taste drier or have an altered mouthfeel, which poses challenges in consumer acceptance (Curutchet *et al*., 2021). This finding consistently aligns with studies that have found lower substitution levels of fibre result in better bread texture and higher sensory acceptance (Akın *et al*., 2021; Ni *et al*., 2020). This is because high-fibre ingredients tend to bind water, reducing the water available for gluten development, making the bread denser and crumblier, affecting perceived freshness and moistness (Bilgic & Sensoy, 2023). Nonetheless, the market perception of fibre-enriched bread appears favourable, with studies indicating that these products often elicit a positive perception of health benefits and wellness (Claudia *et al*., 2023). Despite promising findings on fibre-enriched bread, there is a lack of studies evaluating the use of corn silk powder (CSP) in bread produced via the sponge dough method. Studies on fibre-rich byproducts show that a 2-6 % substitution range balances dietary fibre enrichment and technological feasibility. Exploring this approach could offer more favourable physicochemical properties and improve the sensory profile, potentially making corn silk-enriched bread an alternative to conventional white bread. Moreover, utilising corn silk in food production adds value to an underutilised agricultural by-product, contributing to sustainability and waste reduction in the food industry.

METHODOLOGY

Raw Materials

The raw materials used in this study included corn silk, high-protein bread flour, sugar, salt, vegetable oil, and instant dry yeast. Fresh corn silk was collected from a corn seller at Tanjung Lipat, Kota Kinabalu. Bread flour was sourced from Peanuts Bakery Supply. Refined sugar (CSR), salt (Double Swallow), vegetable oil (Daisy) and yeast (Bunga Raya) were all purchased from a local store (Bataras), Kota Kinabalu.

Corn Silk Powder Preparation

The obtained corn silk was thoroughly washed and blanched in boiling water at 100 °C for 60 sec (Singh *et al*., 2022). After blanching, the corn silks were cut into short strands and dried in a drying cabinet oven (Termoline, TD-78T-SD) at 75 °C for 24 h until a final moisture content of approximately 10 % was achieved. The dried corn silks were ground into a fine powder using an electrical grinder (Waring 7010S). The resulting powder was sieved through a 120 mesh screen (W.S. Tyler) to remove coarse particles. The prepared CSP was stored in an airtight container at room temperature until further use.

Bread Formulations and Preparation

Three bread formulations were prepared with the addition of CSP at 2 % (SP2), 4 % (SP4) and 6 % (SP6) based on the baker's percentage. In this method, bread flour was set at 100 %, serving as the reference for other ingredients. The addition of CSP partially replaced the flour in each formulation. The other ingredients remained constant across all samples: yeast 2 %, salt 1 %, sugar 5%, oil 5% and water 62 %. All corn silk bread samples were prepared using the sponge dough method. Additionally, two control samples were prepared without the addition of corn silk, one using the sponge dough method (SPCT) and the other using the straight dough method (STCT).

The sponge-dough method was followed according to AACC Method 10-11.01 (AACC, 2000a). For sponge preparation, 70 % of the flour, water, and yeast were mixed until smooth, then left to ferment at 35 °C for 3 h. To prepare the final dough, the remaining ingredients were combined at low speed, and the fermented sponge was added in three portions at 15, 25, and 35 sec of mixing. The dough was then mixed at high speed until smooth, rounded, and allowed to ferment for 45 min. After fermentation, the dough was divided, moulded into baking trays, and proofed at 35 °C for 20 min. The straight dough method was followed according to AACC Method 10-10.03 (AACC, 2000b). All dry ingredients were first weighed and added to the mixer, followed by the addition of the wet ingredients. The mixture was initially mixed at low speed until a dough ball formed, then mixed at high speed until smooth. The dough was rounded, fermented for 45 min, punched down and left to ferment for another 45 min. After fermentation, the dough was divided, shaped, and proofed at 35 °C for 20 min.

All dough samples were baked in a preheated baking oven at 180 °C for 25 min. Baked loaves were then cooled at room temperature and stored in zip-lock bags under ambient conditions.

Physicochemical Analysis

Volume, specific volume and density

Bread volume was measured using the seed displacement method, with green beans as the displacement material (AACC, 2000c). The weight of each bread loaf was recorded to calculate the specific volume (volume-to-weight ratio) and density.

Color of bread crumb

The colour of the bread crumb was measured on the mid-section of the baked loaves using a colourimeter (Hunter Lab, ColorFlex EZ). Measurements were recorded in terms of L*, a*, and b* values (Alcântara *et al*., 2020).

Texture profile analysis

Bread texture attributes, including hardness, cohesiveness and chewiness, were measured using a TA.XT2 Texture Analyser. Bread samples were cut from the centre of each loaf into 2.0 cm x 2.0 cm cubes. A cylindrical probe (75.0 mm diameter) was used under the following settings: 5 kg load cell, 45 % compression, pre-test and post-test speed of 1.0 mm/s, test speed of 1.7 mm/s, a 5 g trigger force and a 5 s interval between compression (Feili *et al*., 2013).

Total dietary fiber content

Total dietary fibre (TDF) content was determined using the enzymatic-gravimetric method with a Fibretec 1023 system (FOSS), following standard procedures. Briefly, samples were sequentially digested with α-amylase, protease and amyloglucosidase, and the resulting residue was precipitated with ethanol, filtered, dried, ashed and corrected for protein to obtain TDF content.

Sensory Analysis

Sensory analysis was conducted with 50 untrained panelists using a 9-point hedonic scale, where 9 represented "like extremely" and 1 "dislike extremely". Panelists evaluated the bread samples based on color, aroma, texture, taste, and overall acceptance.

Statistical Analysis

Data was analysed using one-way analysis of variance (ANOVA) with IBM SPSS Statistics ver. 28. Tukey's post-hoc test was applied to determine significant differences between sample means at a confidence level of $p < 0.05$.

RESULT AND DISCUSSION

The sponge dough corn silk bread volume ranges from 1730 cm³ to 1745 cm³ (Table 1). As the percentage of the corn silk powder substitution increased, the bread volume decreased insignificantly ($p > 0.05$), and SP4 (sponge dough bread 4 % corn silk powder) and SP6 (sponge dough bread 6 % corn silk powder) were significantly lower ($p < 0.05$) compared to the STCT (control straight dough bread).

Table 1. Volume, specific volume and density of corn silk bread made using the sponge dough method.

Formulation	Volume (cm³)	Specific volume (cm³/g)	Density (g/cm³)
STCT	1760.00 ± 10.00^{c}	11.76 ± 0.16^{a}	0.09 ± 0.00^{a}
SPCT	1745.00 ± 5.00^{abc}	11.83 ± 0.06^{a}	0.08 ± 0.00^{a}
SP2	1745.00 ± 5.00^{abc}	11.89 ± 0.06^{a}	0.08 ± 0.00^{a}
SP4	1743.33 ± 2.89^{ab}	11.67 ± 0.06^{a}	0.09 ± 0.00^{a}
SP6	1730.00 ± 5.00^{a}	11.75 ± 0.03^{a}	0.09 ± 0.00^{a}

Results are shown in mean ± standard deviation.
Difference in superscripts (a-b) of the same column indicates there is a significant difference ($p < 0.05$) between different formulations.
STCT, SPCT - Control bread with 0 % corn silk powder using straight dough and sponge dough method, respectively.
SP2, SP4, SP6 - Sponge dough bread with 2 %, 4 % and 6 % corn silk powder, respectively.

However, there were no differences in specific volume and density between the corn silk breads and controls. The slightly lower loaf volume observed in bread made with the sponge dough method may be attributed to the fibre addition, which can lead to partial gluten weakening and some air loss during sponge incorporation (Luiz & Vanin, 2022). This method also results in reduced final loaf weight due to lower moisture retention after baking, which balances the volume-to-weight ratio. As a result, the specific volume of sponge dough bread remains comparable to that of control straight dough bread.

The lightness of breadcrumbs decreased significantly ($p < 0.05$) with 6 % corn silk powder substitution, showing the darkest colour, whereas control samples showed the lightest colour (Table 2). Both redness and yellowness increase with the increase of corn silk powder substitution. This could be due to corn silk powder showing a yellow-brownish colour naturally, which imparts and changes the colour of the bread and the Maillard reaction products during baking (Alcântara et al., 2020).

Table 2. The crumb color of corn silk bread made using the sponge dough method.

Formulation	Crumb color		
	L*	a*	b*
STCT	77.32 ± 0.95^{d}	1.61 ± 0.07^{a}	19.67 ± 0.70^{a}
SPCT	76.81 ± 0.08^{d}	1.54 ± 0.27^{a}	20.02 ± 0.69^{a}
SP2	70.39 ± 0.12^{c}	2.51 ± 0.02^{b}	22.04 ± 0.07^{b}
SP4	65.37 ± 0.32^{b}	3.31 ± 0.05^{c}	23.30 ± 0.31^{bc}
SP6	63.35 ± 0.23^{a}	3.89 ± 0.07^{d}	24.08 ± 0.45^{cd}

Results are shown in mean ± standard deviation.
Difference in superscripts (a-b) of the same column indicates there is a significant difference ($p < 0.05$) between different formulations.
STCT, SPCT - Control bread with 0 % corn silk powder using straight dough and sponge dough method, respectively.
SP2, SP4, SP6 - Sponge dough bread with 2 %, 4 % and 6 % corn silk powder, respectively.

The increase in corn silk powder (CSP) levels resulted in higher bread hardness ($p < 0.05$) due to the reduced gluten-forming proteins and the strong water-binding capacity of dietary fibre, which reduced gluten hydration and gas retention (Table 3). This resulted in a firmer crumb structure, similar to that observed in the study conducted by Marinho *et al.* (2025) on pearl millet bread. Thus, the softening advantage of sponge dough was offset by the inclusion of high levels of CSP. However, the hardness of CSP-enriched sponge dough bread was lower (SP2) or remained comparable (SP4 and SP6) to the control bread prepared by the straight dough method. Straight dough bread typically exhibits a firmer texture due to its shorter fermentation and less-developed gluten network (Luiz & Vanin, 2022). The cohesiveness and chewiness of all breadcrumbs with corn silk powder were not significantly different ($p > 0.05$) from controls.

Table 3. The texture profile analysis of corn silk bread made using the sponge dough method.

Formulation	Hardness (g)	Cohesiveness	Chewiness (g.mm)
STCT	1067.52 ± 113.67^{bc}	0.79 ± 0.05^{bc}	1.27 ± 0.06^{a}
SPCT	603.04 ± 39.32^{a}	0.78 ± 0.06^{bc}	1.31 ± 0.11^{a}
SP2	587.20 ± 27.90^{a}	0.81 ± 0.03^{c}	1.30 ± 0.09^{a}
SP4	828.64 ± 57.73^{ab}	0.75 ± 0.04^{abc}	1.53 ± 0.48^{a}
SP6	971.15 ± 85.00^{bc}	0.78 ± 0.06^{bc}	1.61 ± 0.59^{a}

Results are shown in mean ± standard deviation.
Difference in superscripts (a-b) of the same column indicates there is a significant difference ($p < 0.05$) between different formulations.
STCT, SPCT - Control bread with 0 % corn silk powder using straight dough and sponge dough method, respectively.
SP2, SP4, SP6 - Sponge dough bread with 2 %, 4 % and 6 % corn silk powder, respectively.

Corn silk is a natural source of dietary fiber. Dietary fiber analysis showed that CSP-enriched breads of at least 4 % were significantly higher (3.11 % ± 0.06; $p<0.05$) than the control (2.54 % ± 0.31) and met the food regulations threshold (≥ 3 g/100 g) to be considered a source of dietary fiber (Malaysia, 2023). Studies by Asiri *et al*. (2024) and Ning *et al*. (2022) also demonstrated that the incorporation of corn silk into cookies and noodles, respectively, showed a significant increase in total dietary fiber.

Table 4. Sensory analysis of cornsilk bread made using the sponge dough method.

Formulation	Color	Aroma	Texture	Taste	Aftertaste	Overall Acceptance
SP2	7.44 ± 1.22^{b}	6.64 ± 1.29^{a}	6.88 ± 1.27^{a}	7.08 ± 0.94^{a}	7.06 ± 1.06^{b}	7.20 ± 1.03^{b}
SP4	6.76 ± 1.41^{ab}	6.78 ± 1.27^{a}	6.64 ± 1.55^{a}	6.52 ± 1.30^{a}	6.56 ± 1.11^{ab}	6.62 ± 1.26^{ab}
SP6	6.46 ± 1.43^{a}	6.44 ± 1.66^{a}	6.38 ± 1.65^{a}	6.46 ± 1.45^{a}	6.36 ± 1.55^{a}	6.54 ± 1.39^{a}

Results are shown in mean ± standard deviation.
Difference in superscripts (a-b) of the same column indicates there is a significant difference ($p < 0.05$) between different formulations.
SP2, SP4, SP6 - Sponge dough bread with 2 %, 4 % and 6 % corn silk powder, respectively.

Most of the panelists have a preference towards bread which was lighter in color with a lower concentration of corn silk powder (Table 4). Although pre-treatment was done before drying, corn silk powder still shows an astringent aftertaste when incorporated into a food product. A low percentage of corn silk powder gives a milder aftertaste compared to a higher percentage, which is more preferred by the panelists. Overall, sensory evaluation indicated moderate liking for CSP bread. These findings align with a previous study by Asiri *et al*. (2024), which indicated that increasing CSP in cookies had significantly reduced sensory quality but remained within an acceptable liking.

CONCLUSION

The sponge dough method demonstrates potential as an effective strategy for developing composite breads. In this study, incorporating corn silk powder (CSP) into bread using the sponge dough method resulted in a more desirable hardness level, an important physical attribute in bread. CSP also proved to be an excellent natural source of dietary fiber, and inclusion levels of up to 6 % CSP successfully increased fiber content with acceptable sensory attributes that align with consumer demand for healthier baked products.

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