Effect of Sweet Potato Flour Pretreatment on the Physicochemical and Sensory Properties of Wheat-Sweet Potato Composite Bread

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Abstract:

This research work studied the effect of different pre-treatment methods used on sweet potato flour and different substitution levels on the quality characteristics of wheat-sweet potato composite bread. Sweet potato tubes passed through three pre-treatment methods: Chipping (sample A), blanching (sample B) and citric acid steeping (sample C). The Composite bread samples were initially formulated at 20% sweet potato flour substitution and evaluated for specific loaf volume and sensory qualities. The pre-treatment method with the best performance was used to produce bread at varying substitution levels of 10%, 20%, 30%, and 40%. Standard baking procedures were employed, while specific volume was determined using the millet seed displacement method. Sensory evaluation was conducted using a 9-point hedonic scale with fifteen trained panelists, and statistical analysis was carried out using the SciPy and NumPy libraries in python and the results were considered statistically significant at p ≤ 0.05. The Results showed that blanching significantly improved the specific volume of the composite bread when compared to other treatment methods. Sensory evaluation results also revealed that bread produced with blanched sweet potato flour recorded the highest scores in appearance, texture, taste, and overall acceptability among the composite samples. At increasing substitution levels, bread containing 10% and 20% blanched sweet potato flour maintained sensory qualities and loaf volumes comparable to the wheat control, while 30% and 40% substitutions resulted in significant reductions in loaf volume, texture quality, and consumer acceptability. Proximate analysis indicated a gradual decrease in protein and fat contents with increased sweet potato substitution, whereas fibre, ash, and moisture contents increased. The study concluded that blanching is the most suitable pre-treatment method for sweet potato flour in composite bread production, and up to 20% substitution of wheat flour with blanched sweet potato flour can produce acceptable bread with improved nutritional quality and reduced dependence on imported wheat flour.

Keywords: *Blanching, composite bread, loaf volume, sensory evaluation, sweet potato flour, wheat substitution.*

1. Introduction

The application of composite flour technology in commercial bread production is a resourceful way for the utilization of sweet potato flour particularly in relation to socio-economic development and agricultural sustainability. Bread remains a major staple food across urban and rural populations in West Africa and it is traditionally produced from wheat flour, yeast, salt, and water. However, wheat cultivation is poorly suited to tropical regions because of their climates condition when compared to the temperate climate which is more favorable for wheat farming. Composite flour technology which has been recommended by the Food and Agricultural Organization (FAO), has increasingly promoted the partial substitution of imported wheat with locally available crops such as sweet potato, cassava, and yam (Shittu et al., 2007; Jisha et al., 2008). In Nigeria, government policies have also encouraged the utilization of indigenous agricultural flours in bakery products to reduce dependence on imported wheat and stimulate local agricultural production (FAO, 2013; CBN, 2022).

Despite these economic and nutritional advantages, the formulation of wheat-sweet potato composite bread presents notable rheological and sensory challenges. Previous studies have consistently reported that increasing sweet potato flour substitution levels tends to reduce loaf volume, increase crumb density, alter crust and crumb color, and negatively affect sensory acceptability due to gluten dilution and changes in dough structure (Edun *et al.,* 2018; Oyinloye *et al.,* 2022; Machine *et al.,* 2020). Although recent studies have explored substitution ratios and the use of hydrocolloids or improvers to enhance composite bread quality (Chikpah *et al.,* 2021; Agbara *et al.,* 2022), limited attention has been given to the influence of flour pre-treatment methods on the quality characteristics of wheat-sweet potato composite bread. Therefore, this study investigates the effects of different sweet potato flour pre-treatment methods; Chipping, Citric Acid Steeping, and Blanching, on the specific volume and sensory quality of composite bread, with the aim of identifying the optimum pre-treatment and substitution ratio for producing highly acceptable bread.

2.0 Materials and Methods

2.1 Baking Procedure

The primary baking ingredients comprises of wheat flour, sugar, refined iodized salt, instant dry active yeast, nutmeg, commercial margarine, liquid milk, and standard baking flavor. These were procured from specialized baking suppliers, ensuring strict batch consistency across all experimental phases. The sweet potato was passed through three pre-treatment procedure; blanching, Steeping in Citric acid and chipping before it was dried and milling into sweet potatoes flour.

The Initial dough matrices were formulated using a 20% substitution threshold. The standardized recipe consisted of 480 g hard wheat flour, 120 g of the designated pre-treated sweet potato flour, 100 g margarine, 40 g sugar, 4 g yeast, 3 g salt, 1 g nutmeg, 30 ml milk, and 2.5 ml flavor. To counteract the varying water absorption capacities inherent to the different pre-treated flours and guarantee a uniform rheological consistency across all batches, the hydration volume was carefully modulated between 320 ml and 360 ml. The ingredients were homogenized in a mechanical dough mixer for 10 minutes, followed by manual kneading. The dough was then portioned into exact 350g masses, placed in greased baking pans, covered with a sterile kitchen cloth, and subjected to a two hour proofing phase within a climate-controlled chamber at 35°C. Following volumetric expansion, the proofed samples were transferred to a preheated oven and baked at 190°C for exactly 25 minutes. The resulting loaves were cooled at ambient temperature for one hour before being sealed in cellophane for subsequent evaluation. A 100% wheat flour control was formulated and baked simultaneously under identical thermodynamic conditions.

2.2 Evaluation of Specific Volume of the Bread Samples

The specific volume of the baked loaves was quantified utilizing a modified seed displacement methodology, substituting the conventional rapeseed with millet grains. Initially, the absolute mass of the cooled loaf was recorded utilizing a precision analytical balance, designated as Wb. A standardized metallic calibration box was placed on a containment tray, slightly overfilled with millet, and leveled using a rigid straight-edge to establish a baseline volume. These baseline grains were then decanted into a holding vessel. The weighed bread sample was subsequently positioned inside the empty metallic box, and the previously decanted grains were poured back over the loaf until the box was refilled and perfectly leveled. The volume of the displaced millet which directly corresponds to the volumetric displacement of the bread was collected in a graduated cylinder and recorded as Vb. The final specific volume was mathematically derived using Equation 1:

$$Sv\ (\text{cm}^3/\text{g}) = \frac{V_b}{W_b} \qquad (1)$$

Where;
Sv = specific volume (cm^3/g)
Vb = Volume of the bread displaced by the millet (cm^3)
Wb = Weight of the bread sample (g)

2.3 Sensory Evaluation

Organoleptic acceptability was assessed using a carefully selected panel of fifteen trained evaluators, all intimately familiar with the sensory profiles of local commercial bread. The evaluation exclusively utilized mini-loaves baked from the specific pre-treatment combination that yielded the most optimal specific volume. To prevent bias, all samples were anonymized using randomly generated 3-digit codes. The evaluators independently analyzed the samples in isolated booths, utilizing unsalted crackers and water between tastings to cleanse their palates and eliminate residual flavor crossover. Scoring was executed on a standard 9-point hedonic scale ranging from 1 ("disliked extremely") to 9 ("liked extremely") assessing key quality parameters including appearance, color, aroma, taste, crust integrity, crumb texture, mouthfeel, and overall acceptability.

2.4 Evaluation of Substitution Levels on Bread Quality

Following the initial trials, the pre-treatment methodology that yielded the highest specific volume was selected for a progressive substitution analysis. Utilizing the identical base recipe outlined, the hard wheat flour was systematically displaced by the optimized sweet potato flour at escalating intervals of 10%, 20%, 30%, and 40%, while maintaining a constant ratio for all secondary ingredients. A 100% pure wheat loaf served as the definitive control. To ensure statistical reliability, all baking formulations were executed in triplicate.

2.5 Statistical Analysis

All empirical data generated during the baking and sensory evaluations were rigorously analyzed utilizing the Python programming language (Version 3.10), specifically leveraging the computational power of the SciPy and NumPy libraries. This computational framework evaluated the variances in specific volume, proximate composition, and hedonic sensory scores across both the pre-treatment types and the escalating substitution thresholds. Mean separation was achieved through the application of Duncan's Multiple Range Test, with statistical significance strictly defined at a probability level of $p \leq 0.05$.

3.0 Results and Discussion

3.1 Pre-Treatment of Specific Volume of Composite Bread

The statistical analysis confirms that the specific volume of the 20% substitution composite loaves was significantly influenced ($p \leq 0.05$) by the upstream flour pre-treatment methodology, as detailed in Table 1.0.

Table 1: Pre-treatment of Specific Volume of wheat-sweet potato composite bread at 20% substitution

	Control (100% Wheat)	**Pre-treatment**			**CV (%)**
		Sample A (Chipping)	Sample C (Citric Acid)	Sample B (Blanching)	
Sv (cm^3/g)	3.24	2.68	2.85	3.12	4.2

Source; Compiled by Author

Evaluating the structural dynamics reveals that flour derived from the blanched sweet potato (sample B) generated a highly improved specific volume (3.12 cm^3/g). This metric was significantly superior ($p \leq 0.05$) to both sample A and C. Notably, it did not demonstrate a statistically significant variance from the 100% pure wheat (3.24 cm^3/g). Interestingly, the acidulated sample C flour outperformed sample A. These physical outcomes strongly corroborate the mechanical theories proposed by Dereje *et al.* (2020) and Wibowo *et al.* (2019), who assert that the thermal shock of blanching induces partial starch gelatinization and elevates solubility. This preliminary gelatinization acts as a structural reinforcement mechanism, partially offsetting the absence of gluten by improving the gas-holding capacity of the expanding dough cells during thermal baking.

3.2 Sensory Qualities of Composite Bread Samples from Different Pre-Treatments

The hedonic evaluations for the 20% substitution loaves across the distinct pre-treatment protocols are categorized in Table 2.

Table 2: Mean score for hedonic sensory attributes of wheat-sweet potato composite bread samples from different pre-treatments

Sample code	**Appearance**	**Aroma**	**Colour**	**Crust**	**Texture**	**Mouth feel**	**Taste**	**Overall acceptability**
Control	7.53	7.40	7.67	7.33	7.60	7.47	7.80	7.67
A	6.47	6.60	6.40	6.53	6.13	6.27	6.87	6.40
C	6.80	6.40	6.93	6.80	6.67	6.73	6.53	6.73

B	7.33	7.13	7.40	7.13	7.20	7.27	7.47	7.40
Lsd	0.85	0.82	0.9	0.88	0.79	0.84	0.92	0.86
CV (%)	15.2	16.4	14.8	16.5	17.1	18.2	15.6	15.5

Source; Compiled by Author

The organoleptic analysis confirms the superiority of the thermal pre-treatment. The visual appearance scores ranged from a baseline of 6.47 to a peak of 7.53. The blanched composite (B) achieved an appearance score of 7.33, statistically matching the pure wheat control while significantly outperforming both A and C. Furthermore, the critical metrics of taste and overall acceptability for the B loaf proved significantly higher ($p \leq 0.05$) than those recorded for the Chipped and acid-steeped variations. The depressed taste score associated with the C formulation is directly attributable to the residual sourness imparted by the citric acid retention, an organoleptic limitation previously documented by Owuamanam *et al.* (2007) in their evaluation of chemically treated tubers. Because the Blanched (B) matrix achieved unparalleled success in both physical volume expansion and consumer sensory acceptance, it was definitively selected as the base material for the subsequent progressive substitution trials.

4.0 Sensory Qualities of Composite Bread at different Substitution Ratios

Utilizing the blanched flour, the structural and sensory impacts of progressive wheat displacement (10%, 20%, 30%, and 40%) were evaluated. The resulting hedonic data is presented in Table 3.

Table 3: Qualities of composite bread from blanched sweet potato flour (B) at different levels of substitution

Percentage of SPF	Appearance	Aroma	Colour	Crust	Texture	Mouth feel	Taste	O/A
Control	7.67	7.53	7.73	7.40	7.67	7.60	7.87	7.73
10%	7.53	7.40	7.60	7.27	7.40	7.47	7.67	7.60
20%	7.27	7.13	7.33	7.07	7.13	7.20	7.40	7.33
30%	6.60	6.53	6.80	6.47	6.20	6.33	6.67	6.53
40%	5.40	5.80	5.53	5.33	4.87	5.13	5.47	5.27

Lsd	0.81	0.76	0.88	0.82	0.91	0.85	0.8	0.84
CV (%)	14.5	15.2	16.1	15.8	18.4	17.6	14.9	15

Source; Compiled by Author
O/A = Overall Acceptability

As detailed in Table 3, the composite bread successfully maintained high commercial viability at lower substitution thresholds. Specifically, none of the sensory qualities at the 10% and 20% integration levels demonstrated a statistically significant deviation ($p \leq 0.05$) from the 100% wheat control. However, a distinct structural and organoleptic degradation occurred at the 30% and 40% levels. At 40% substitution, overall acceptability plummeted, with the crumb texture recording the absolute lowest score (4.87), indicating severe dough densification. This behavioral trend perfectly mirrors the conclusions drawn by Oluwalana *et al.* (2012) and Machine *et al.* (2020), who reported that while composite formulations remain highly consumer-acceptable up to a 20-30% inclusion limit, pushing beyond this threshold inevitably results in detrimental crust darkening and excessive crumb firmness.

4.1 Specific Volume of Composite Bread at Different Substitution Ratios

The corresponding physical expansion metrics for the escalating substitution levels are shown in Table 4.

Table 4: Specific volume of composite bread produced from blanched sweet potato flour at different substitution levels

Sample code	Percentage of sweet potato flour	Specific Volume (cm3/g)
Ctr	0% (Control)	3.25
B_{P10}	10%	3.21
B_{P20}	20%	3.10
B_{P30}	30%	2.75
B_{P40}	40%	2.24
Lsd		0.18
CV (%)		3.6

Source; Compiled by Author

The empirical data demonstrates a strict inverse relationship between sweet potato flour concentration and specific loaf volume. While the 10% and 20%

formulations maintained a volumetric expansion that did not significantly differ *($p \leq 0.05$)* from the pure wheat control, structural collapse became evident at 30% and 40%. This progressive loss of specific volume is a well-documented rheological phenomenon, previously observed by *Edun et al.* (2018) and *Chikpah et al.* (2021). Because sweet potato flour lacks native gluten forming proteins, escalating its inclusion artificially dilutes the total functional gluten network within the dough. Consequently, the weakened viscoelastic matrix loses its capacity to entrap the carbon dioxide generated during yeast fermentation, leading to poor gas retention and a dense, heavy loaf (Nemar *et al.,* 2015).

4.2 Proximate Composition of Composite Bread at Escalating Substitution Ratios

The final nutritional architecture of the baked composite loaves across the varying substitution thresholds is detailed in Table 5.

Table 5: Proximate compositions of Composite Bread Samples from blanched sweet potato flour at different substitution levels

Subst.	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Moist. (%)	CHO (%)
Control	12.14	2.10	0.85	1.25	24.30	59.36
10%	11.20	1.95	1.15	1.42	25.80	58.48
20%	10.35	1.82	1.45	1.65	27.45	57.28
30%	8.90	1.65	1.85	1.90	29.60	56.10
40%	7.45	1.50	2.15	2.20	31.80	54.90
CV	4.2	5.1	18.4	12.6	6.5	2.8

Source; Compiled by Author

Subst. = % of sweet potato flour in the composite bread, CHO = carbohydrate, Moist. = Moisture content; Control = 100% wheat flour; CV = coefficient of variation.

The biochemical analysis reveals clear nutritional trade-offs driven by the substitution mechanics. The pure wheat control retained the maximum protein (12.14%) and fat (2.10%) concentrations. Predictably, as the sweet potato ratio increased from 10% to 40%, the total protein fraction experienced a significant, linear decline *($p \leq 0.05$)*. Conversely, this integration drove a highly beneficial surge in dietary fiber, mineral ash, and moisture retention. This simultaneous reduction in protein and elevation in structural fiber aligns perfectly with the research of Oyinloye *et al.* (2022) and Babarinsa *et al.* (2025). Their work establishes that while tuber substitution inherently dilutes the wheat's protein density, it successfully bio fortifies the bread with critical micronutrients and gut-supporting fibers. Furthermore, the progressive increase in loaf moisture is directly linked to the enhanced water absorption capacity characteristic of the blanched starch matrix.

5.0 Conclusions

The application of a blanching pre-treatment (sample B) on sweet potato flour produces a significantly superior ($p \leq 0.05$) specific loaf volume at 20% substitution when compared to both chipping (sample A) and citric acid steeping (sample C). Impressively, this optimized 20% blanched formulation generated a specific volume statistically indistinguishable from a 100% pure wheat loaf.

The sensory evaluation panels confirmed that bread produced with 10% and 20% blanched sweet potato flour competes exceptionally well with bread made with 100% wheat flour hence, securing high scores across all acceptability metrics. However, extending the substitution threshold to 30% and 40% induces critical gluten dilution, triggering a failure in the dough's viscoelastic network that results in reduced volumetric expansion, darkened crusts, and an unpleasantly dense crumb. Ultimately, this research confirms that up to 20% of imported wheat flour can be successfully replaced with domestically sourced, blanched sweet potato flour. This specific formulation matrix provides a commercially viable, consumer-acceptable product that heavily mitigates wheat dependency while simultaneously ensuring the production of bread with enhanced dietary fiber and essential minerals.

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