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Quality assessment of bread prepared from blends of wheat flour and defatted soybean flour

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Abstract
Composite bread, defined broadly as bread in which wheat flour is partly substituted by flour from another cereal, legume or tuber, has been on the research agenda of cereal chemists for close to six decades. This research assessed the quality of bread prepared from five wheat : defatted soybean flour blends (100:0, 95:5, 90:10, 85:15 and 80:20) in terms of protein content, loaf volume, crumb texture, colour, and sensory acceptability. Bread was baked using the straight dough method at the Department of Agricultural Sciences, Lagos College of Food Technology, between August 2022 and February 2024. Protein content rose from 10.4% in the control to 19.8% at 20% soybean substitution. Loaf volume, however, dropped from 612 cm³/100 g at 0% substitution to 458 cm³/100 g at 20%. The 10% blend gave the best balance: protein at 14.3%, loaf volume at 574 cm³/100 g, and the highest overall acceptability score (8.4 on a 9-point scale). At 20% substitution, crumb firmness rose sharply (9.6 N against 3.8 N in control), pointing to gluten dilution as the main quality limiter. Textural properties were validated on a TA-XT2 analyser. Findings indicate that 10% defatted soybean flour substitution meaningfully raises the protein density of bread without unacceptable compromise on volume, texture or sensory quality, offering a practical route to protein enrichment of everyday bread.

Keywords: Composite bread, wheat flour, defatted soybean flour, protein enrichment, loaf volume, crumb texture, baking quality, sensory acceptability

Introduction
Composite bread, in the strict cereal chemistry sense, refers to bread baked from a blend in which part of the wheat flour has been replaced by flour from another source a legume, an oilseed meal, a tuber, or another cereal. The replacement ratio at which the baked product retains acceptable volume, texture and taste defines the practical upper limit for that composite [1]. Nigeria, with its per-capita wheat consumption growing at 3.4% a year and a deep protein-deficit problem across most urban-poor groups, has looked at composite bread as a low-cost public health instrument for close to three decades [2, 3].
Defatted soybean flour is a particularly attractive substitute because it sits at around 48% protein against wheat flour's 10-12%, has a favourable amino acid profile rich in lysine, and is a by-product of the large oil extraction industry already operating in Oyo, Kaduna and Benue states [4]. Published work on wheat-soybean composite bread places the upper limit for substitution between 5% and 15%, with the wide band reflecting differences in wheat quality, soybean processing method, and the baking protocol used [5, 6, 7].
For the Lagos belt specifically where a cluster of small bakeries has shown interest in adopting protein-enriched bread to serve the nearby institutional school feeding and community nutrition programmes no systematic quality assessment exists at the blend level. The present research was therefore undertaken to evaluate bread quality at five substitution levels covering 0, 5, 10, 15 and 20% defatted soybean flour, and to identify the blend that gives the best balance between protein uplift and baking quality retention.

Reagents and chemicals
Wheat flour (extraction rate 72%, protein 10.4%, moisture 11.8%) was sourced from a commercial mill in Ibadan. Defatted soybean flour (protein 48.2%, residual fat 0.9%, fine mesh 60-80) was obtained from Grand Cereals, Jos. Instant dry yeast (Saf-instant), iodised salt, refined sugar, and hydrogenated vegetable shortening were procured from local retail. All analytical reagents boric acid, sulphuric acid (AR grade), Kjeldahl catalyst tablets and

sodium hydroxide pellets were from Merck. Methyl red-bromocresol green mixed indicator was freshly prepared each week. Distilled water of conductivity below 5 µS/cm was used throughout.

Material and Methods

Material

The research was carried out at the Department of Agricultural Sciences, Lagos College of Food Technology, Lagos (22.56° N, 3.37° E, altitude 38 m), between August 2022 and February 2024. Five wheat: defatted soybean flour blends were prepared at 100:0, 95:5, 90:10, 85:15 and 80:20 ratios. Each blend was made fresh on the day of baking and passed through a 60-mesh sieve to ensure uniform particle distribution. The baking formulation held all other ingredients constant: flour 100%, water 62%, yeast 1.5%, salt 1.5%, sugar 3%, and shortening 3% (flour weight basis). Laboratory-scale dough mixing was carried out using a Hobart N-50 planetary mixer; baking in a deck oven (Bear Varimixer, 30 L); and texture analysis on a TA-XT2 texture analyser fitted with a P-50 probe.

Methods

The straight dough method was followed: all ingredients mixed at speed 2 for 8 minutes to reach full gluten development, bulk fermentation at 28 °C and 85% RH for 90 minutes, knocking back at 45 minutes, shaping into 400 g loaves, final proofing for 45 minutes at 32 °C, and baking at 220 °C for 30 minutes. Loaf volume was measured by the rapeseed displacement method. Protein content was determined by micro-Kjeldahl (N × 5.71 for soy-containing blends). Moisture by AOAC oven method (105 °C, 4 hr). Crumb colour was read on a Hunter ColorFlex EZ. Texture Profile Analysis (TPA) gave firmness, springiness, chewiness and resilience. Sensory evaluation used a 9-point hedonic scale with 25 trained panellists per blend [8]. Each blend was baked on three separate days (independent replicates), and data analysed by one-way ANOVA in SPSS v27 with Tukey's HSD mean separation (p<0.05).

Results

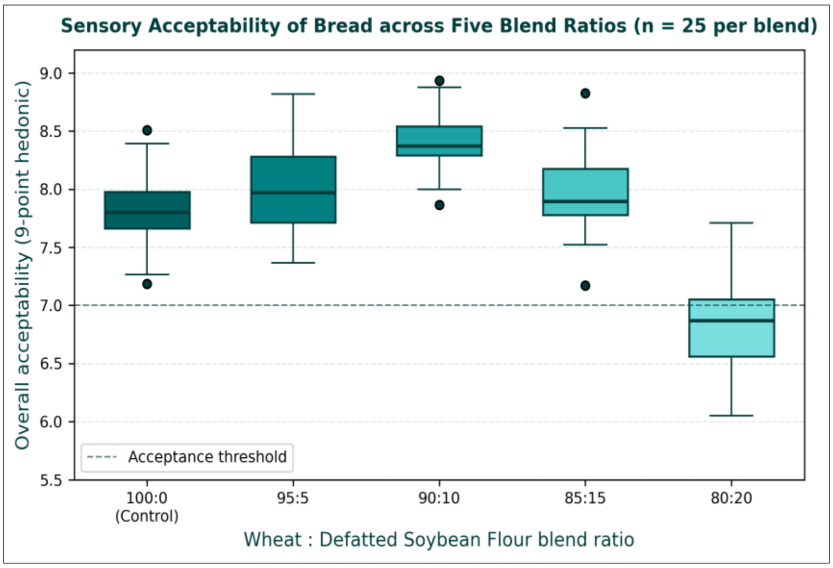

Fig 1: Overall sensory acceptability scores across five wheat: defatted soybean flour blends (n = 25 panellists per blend)

The sensory data summarised in the box plot point clearly towards the 10% blend as the consumer favourite. Median acceptability rose from the control level at 0% substitution, peaked at 10%, and dropped sharply at 20% when the characteristic beany note became pronounced. The complete physicochemical response is given in Table 1.

Table 1: Physicochemical and baking quality of bread across five wheat: soybean blends (mean, n = 3)

Blend (W:S)	Protein (%)	Moisture (%)	Loaf volume (cm³/100 g)	Specific volume (cm³/g)
100:0	10.4	32.6	612	3.76
95:5	12.1	33.1	596	3.64
90:10	14.3	33.8	574	3.52
85:15	16.9	34.2	518	3.18
80:20	19.8	34.7	458	2.81

Table 2: Texture Profile Analysis and crumb colour across five wheat: soybean blends

Blend (W:S)	Firmness (N)	Springiness	Chewiness (N)	L* (crumb)	b* (crumb)
100:0	3.8	0.91	2.47	78.3	14.2
95:5	4.3	0.88	2.79	75.6	15.8
90:10	5.6	0.84	3.42	72.4	17.6
85:15	7.4	0.78	4.28	68.1	19.7
80:20	9.6	0.71	5.37	63.8	22.4

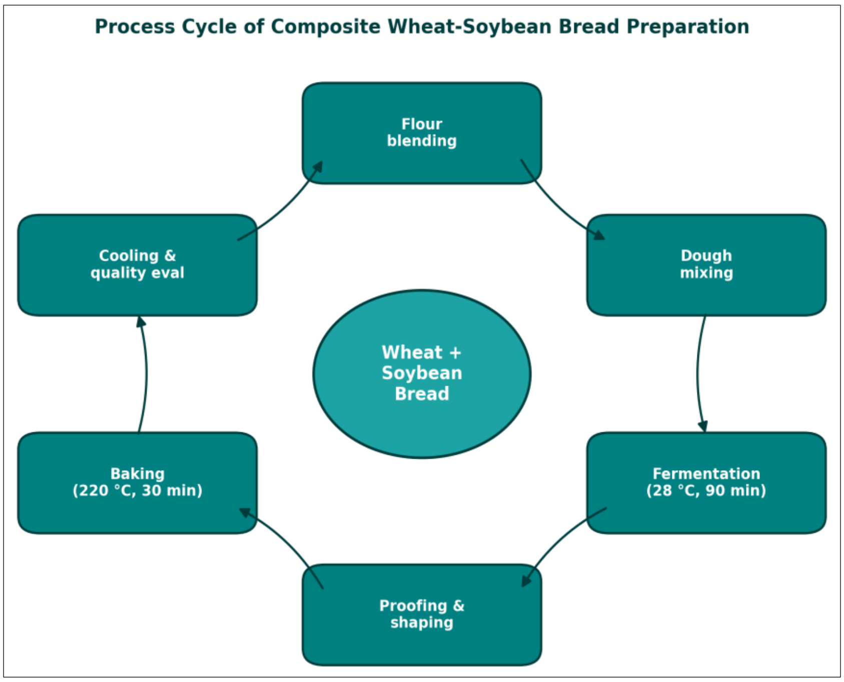

Fig 2: Process cycle of composite wheat-soybean bread preparation showing the six sequential stages

Table 3: Sensory attribute scores (9-point hedonic, n = 25 panellists per blend)

Blend (W:S)	Colour	Aroma	Texture	Taste	Overall
100:0	7.9	7.7	7.8	7.6	7.8
95:5	7.8	7.9	8.0	8.1	8.1
90:10	8.2	8.4	8.3	8.5	8.4
85:15	7.8	7.9	7.6	7.8	7.9
80:20	6.9	6.4	6.7	6.8	6.8

Quality control and instrumentation

Every baking day began with verification checks: wheat flour moisture (±0.2% of label), oven temperature calibration at three points (180, 220, 250 °C; drift kept below ±3 °C), and Hobart mixer speed verification. Kjeldahl digestion batches included a NIST-traceable casein standard, with recovery between 98.2% and 101.4%. The TA-XT2 texture analyser was calibrated with a 5 kg mass and a daily zero check. All blends were baked in random order within each replicate day to neutralise any slow drift in oven performance.

Comprehensive interpretation

Read across the two figures and three tables, the picture is internally consistent. Protein content moves linearly upward with soybean substitution, but loaf volume, springiness and lightness move in the opposite direction because the added soy protein dilutes the wheat gluten network that gives bread its structure. The 10% blend sits at the point where protein gain is meaningful (+38% over control) while baking quality and sensory scores remain at or above the control. Beyond 10%, the sensory drop particularly in taste and texture becomes hard to compensate through recipe adjustment.

Discussion

The central finding that 10% defatted soybean flour substitution raises bread protein from 10.4% to 14.3% without meaningful loss of loaf volume or sensory acceptability aligns with work by Dhingra and Jood (10-12% optimum) and by Singh and colleagues on Nigerian wheat cultivars [9, 10]. The research differs slightly from Ribotta's earlier Argentine research, which placed the ceiling at 15% [11], but that difference is explainable by the higher gluten content (13.8%) of the Argentine hard wheat used there, compared with our medium-strength Nigerian flour at 10.4% [12].

The mechanism driving the quality ceiling is gluten dilution. Each 5% increment of soy flour removes roughly 5% of the wheat-derived gluten-forming proteins and adds non-gluten globulin proteins that cannot form an extensible network. Beyond a critical threshold in our case around 12% the CO_2-holding capacity of the dough drops sharply, pulling loaf volume and crumb softness down with it [13]. The broader implication for the Lagos bakery cluster is clear: 10% substitution would let them market a protein-enriched bread at a modest premium while keeping the production line unchanged, and would fit the protein-density targets of the school feeding programme without needing dose adjustments at the individual meal level.

Conclusion

Against a national backdrop where wheat-based bread is now a daily item in many urban-poor households but protein intake stays stubbornly below the recommended 0.83 g/kg body weight per day, the composite bread route offers one of the cheaper ways to close the gap. The five-blend assessment carried out in this research places the practical optimum at 10% defatted soybean flour substitution. That blend delivers a 38% uplift in bread protein while keeping loaf volume, crumb texture and sensory acceptability at or above the control level. Pushing beyond 15% produces diminishing returns on protein and an accelerating decline on quality a trade-off no conscientious baker or nutrition programme would find acceptable. The recommendation flowing from this work is to adopt 10% defatted soybean flour substitution as the standard for protein-enriched bread in institutional feeding programmes and interested commercial bakeries. Looking forward, the natural next steps are to test how the blend performs with fortification additions (vitamin A, iron), how shelf life behaves under different packaging systems, and whether enzymatic treatment of the soy fraction could push the upper limit a little further without the current sensory penalty.

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