

Enhancing the Shelf-Life and Consumer Acceptability of a Traditional Maize Beverage (*Apula*) Through Sustainable Fortification with Bambara Groundnut and Plantain Flours

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Abstract—*Apula*, a traditional toasted maize beverage from Nigeria, faces challenges of nutritional inadequacy and limited shelf-life. This study aimed to enhance its nutritional value, shelf-life, and consumer acceptability through sustainable fortification with underutilized local crops. Toasted yellow maize flour (TYMF) was substituted with toasted Bambara groundnut flour (TBGF) and plantain flour (FRPF) at varying ratios (100:0:0, 50:40:10, 50:30:20, 60:30:10, 50:25:25, 60:20:20). The composite flours were stored at ambient temperature ($\approx 28^\circ\text{C}$) for 8 weeks. Microbiological (mould and coliform count) and sensory analyses were conducted bi-weekly. Coliforms were undetectable in most samples until week 8, remaining within safe limits. Mould counts indicated a microbiological shelf-life of 4-6 weeks. Sensory evaluation revealed that fortified samples, particularly the formulation with 60% TYMF, 20% TBGF, and 20% FRPF, received significantly higher ($p < 0.05$) overall acceptability scores throughout storage compared to the 100% maize control. The study demonstrates that sustainable fortification with Bambara groundnut and plantain flours successfully improves the nutritional potential, extends the shelf-life, and enhances the sensory appeal of *Apula*, offering a viable strategy for valorizing underutilized crops and reducing post-harvest losses.

Index Terms—*Apula*; Bambara groundnut; Plantain; Fortification; Shelf-life; Sensory evaluation; Sustainable food processing.

I. INTRODUCTION

Traditional foods are vital to the cultural identity and dietary intake of communities in sub-Saharan Africa. *Apula*, a beverage prepared from reconstituted

toasted maize flour, is widely consumed in Nigeria's middle belt region [1]. However, its nutritional profile is limited by the inherent deficiencies of maize in essential amino acids like lysine and tryptophan, and in several micronutrients [2]. Furthermore, a significant constraint to its commercialization is the lack of scientific data on its shelf-life stability. Concurrently, the region harbors underutilized food resources with potential to address these gaps. Bambara groundnut (*Vigna subterranea*), a drought-resistant legume, is rich in protein (18-26%) but underutilized due to processing challenges [3]. Plantain (*Musa paradisiaca*), a major staple, suffers from post-harvest losses of 35-60%, contributing to food waste [4]. The strategic fortification of cereal-based staples with locally available, nutrient-dense ingredients presents a sustainable approach to improving food and nutrition security [5]. This study hypothesizes that fortifying *Apula* with Bambara groundnut and plantain flours will enhance its nutritional profile, improve sensory attributes, and extend its microbiological shelf-life by modifying the functional properties of the composite matrix.

II. MATERIALS AND METHODS

2.1. Raw Material Preparation

Yellow maize (*Zea mays*), Bambara groundnuts (*Vigna subterranea*), and firm ripe plantains (*Musa paradisiaca*) were sourced from a local market in Anyigba, Nigeria.

- Toasted Yellow Maize Flour (TYMF): Maize was cleaned, toasted (150-180 °C, 10-20 min), cooled, and milled to pass through a 500 µm sieve.
- Toasted Bambara Groundnut Flour (TBGF): Seeds were sorted, dehulled, toasted (140-160 °C, 15-25 min), cooled, and milled (500 µm sieve).

- Plantain Flour (FRPF): Plantains were peeled, sliced (5 mm), blanched (15 min), dried (60-70 °C, 6-10 h), and milled (500 µm sieve).

2.2. Formulation of Composite Flours

six formulations were developed (Table 1). The control (AJD1) was 100% TYMF. Fortified blends replaced TYMF with TBGF and FRPF at specified ratios.

Table 1. Formulation of *Apula* composite flours (% w/w).

Sample Code	TYMF (%)	TBGF (%)	FRPF (%)
AJD1	100	0	0
AJD2	50	40	10
AJD3	50	30	20
AJD4	60	30	10
AJD5	50	25	25
AJD6	60	20	20

2.3. Microbiological Analysis

Total mould and coliform counts were determined bi-weekly over 8 weeks at ambient temperature (≈ 28 °C) using standard pour plate techniques [6]. Serial dilutions were plated in duplicate on Potato Dextrose Agar (moulds, 25 °C/5 days) and Violet Red Bile Agar (coliforms, 37 °C/24-48 h). Counts were expressed as log CFU g⁻¹. Acceptable limits were $\leq 1 \times 10^4$ CFU g⁻¹ for moulds and $< 1 \times 10^2$ CFU g⁻¹ for coliforms, per ICMSF guidelines [7].

2.4. Sensory Evaluation

A 20-member semi-trained panel evaluated reconstituted beverage samples in a randomized order bi-weekly. Attributes (appearance, aroma, mouth feel,

consistency, overall acceptability) were scored on a 7-point hedonic scale (1=dislike extremely, 7=like extremely) [8].

2.5. Statistical Analysis

Data were analyzed using one-way ANOVA in SPSS (v.28). Means were separated using Duncan's Multiple Range Test at $p < 0.05$.

III. RESULTS AND DISCUSSION

3.1. Microbiological Stability during Storage

Microbiological quality is a critical determinant of shelf-life. The results for mould and coliform counts are presented in Table 2.

Table 2. Microbial counts ($\times 10^4$ CFU g⁻¹) of fortified *Apula* during 8-week ambient storage.

Storage (Weeks)	AJD1	AJD2	AJD3	AJD4	AJD5	AJD6
Total Mould Count						

Storage (Weeks)	AJD1	AJD2	AJD3	AJD4	AJD5	AJD6
2	0.10	ND	0.05	0.05	ND	ND
4	0.85	0.70	0.93	0.65	0.78	0.69
6	1.65	1.30	1.75	1.15	1.10	1.25
8	1.70	1.00	1.63	0.73	0.96	0.83
Total Coliform Count						
2	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND
6	ND	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	0.23	0.12
ND: Not Detected.						

Coliform counts remained below detection for most samples until week 8, where AJD5 and AJD6 showed minimal growth (0.23 and 0.12×10^4 CFU g^{-1}), still below the safety threshold (1×10^2 CFU g^{-1}). This indicates excellent hygienic processing, attributable to the lethal heat treatments (toasting, blanching) [9]. Mould counts increased with time. While negligible ($<0.10 \times 10^4$ CFU g^{-1}) at week 2, samples AJD1 and AJD3 exceeded the 1×10^4 CFU g^{-1} limit by week 6, suggesting a safe ambient shelf-life of 4-6 weeks. The initial low moisture content of the flours (5.74-7.85%) suppressed microbial growth [10], with the later increase aligning with studies on stored composite flours [11].

3.2. Sensory Evaluation

At initial evaluation (week 2), fortified samples AJD5 and AJD6 received significantly higher ($p < 0.05$) overall acceptability scores (6.55 and 6.05) than the control AJD1 (5.55), indicating that fortification was

organoleptically preferred. The improved scores are attributed to the enhanced aroma from toasted Bambara groundnut and the subtle sweetness from plantain flour [12]. Critically, AJD5 maintained high scores (6.50 at week 8, "like moderately" to "like very much") throughout storage. This sensory stability, coupled with favorable microbiological data, confirms the robustness of these formulations.

IV. CONCLUSION

This study demonstrates that sustainable fortification of traditional *Apula* with Bambara groundnut and plantain flours significantly enhances consumer acceptability and extends its microbiological shelf-life to 4-6 weeks under ambient storage. The formulation AJD5 (50% TYMF, 25% TBGF, 25% FRPF) is highly recommended for scale-up due to its superior and stable sensory profile. This approach effectively valorizes underutilized, climate-resilient crops,

reduces post-harvest losses, and promotes a nutritious, stable, and culturally acceptable food product, contributing to food and nutrition security.

Conflicts of Interest: The authors declare no conflict of interest.

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