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Sustainable Utilisation of Local Agro-Resources: Development and Evaluation of Nutrient-Enriched Kunun Zaki Using Groundnut Tigernut and Dates

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Abstract
This study investigated the production and quality evaluation of kunun zaki, a traditional Nigerian non-alcoholic beverage made from sorghum (Sorghum bicolor) and fortified with groundnut (Arachis hypogaea), tigernut (Cyperus esculentus), and dates (Phoenix dactylifera). Two formulations were compared: the traditional method (TKZ) and an improved formulation (IKZ) containing the additional ingredients. Chemical analyses were conducted to determine pH, Brix, and total titratable acidity (TTA), while sensory evaluation assessed taste, colour, texture, flavour, and overall acceptability. Results revealed that the improved kunun zaki (pH 3.50, Brix 12.81, TTA 0.68%) exhibited lower acidity and higher sweetness compared to the traditional version (pH 3.10, Brix 12.70, TTA 0.73%). Sensory analysis showed significant differences ($p < 0.05$) between both samples, with the improved formulation scoring higher across all attributes. The findings demonstrate that fortification with locally sourced ingredients significantly enhanced the beverage's nutritional quality and consumer acceptability. The improved Kunun Zaki offers a sustainable, low-cost approach to developing functional beverages, promoting food security, and adding economic value to indigenous crops.

Keywords: Kunun Zaki, Fortification, Sorghum-Based Beverage, Sensory Evaluation, Functional Foods

Introduction

Traditional cereal-based beverages such as *Kunun Zaki* remain integral to the diet and culture of many West African communities, particularly in Nigeria, where they serve as affordable, energy-dense, and refreshing drinks (Adesulu-Dahunsi et al., 2025; Ashaolu & Adeyeye, 2024; Ratau et al., 2025). Typically prepared from fermented sorghum, millet, or maize, *Kunun Zaki* is appreciated for its unique flavour, cooling effect, and moderate nutritional content. However, conventional formulations often exhibit low protein and fat contents and are susceptible to microbial spoilage due to their high moisture and carbohydrate levels (Adejumo et al., 2023; Egbere et al., 2021; Ndukwe et al., 2023). This nutritional and safety limitation underscores the need for innovative fortification strategies using locally available plant-based materials that enhance the beverage's nutritional and sensory qualities without compromising its traditional appeal.

Recent studies have explored the use of functional ingredients such as legumes, nuts, and natural sweeteners to enhance the quality of fermented cereal beverages (Adebayo & Oladunjoye, 2026; Amissah et al., 2025; Chandrasekaran & Shanmugham, 2025; Jolayemi et al., 2023; Sadiq & Atteh, 2023). Groundnuts (Arachis hypogaea) are rich in plant protein, healthy fats, and essential amino acids (Syed et al., 2022; Tiwari et al., 2025); tigernuts (Cyperus esculentus) provide fibre, minerals, and a creamy texture (Edo et al., 2024); while dates (Phoenix dactylifera) offer natural sweetness and antioxidants that may improve flavour and extend shelf life Al-Habsi, 2025; Alu'datt et al., 2025). The combination of these additives with sorghum is expected to create a nutritionally enriched *Kunun Zaki* with improved taste, texture, and consumer acceptability. Such fortification not only addresses malnutrition challenges but also promotes value addition to indigenous crops, aligning with global sustainable food system goals (Burki, 2022).

This study aimed to produce and evaluate *Kunun Zaki* formulated from sorghum, groundnut, tigernut, and dates, and to assess its physicochemical and sensory properties in comparison with the conventional formulation. The specific objectives were to: (1) produce *Kunun Zaki* samples using the composite ingredients; (2) determine their physicochemical properties (pH, total titratable acidity, and Brix); and (3) conduct sensory evaluation to assess taste, colour, texture, flavour, and overall acceptability. The expected results include enhanced nutritional quality and improved sensory attributes in the fortified sample, driven by the synergistic effects of nutrient-dense ingredients and balanced natural sweetness.The relevance of this study lies in its contribution to food security and sustainable nutrition by promoting the use of underutilized local crops for the development of functional beverages. The findings will guide small-scale processors, nutritionists, and policymakers in diversifying local food products, supporting agro-industrial development, and improving the livelihoods of rural farmers.

Materials and Methods

The study was conducted to produce and evaluate *Kunun Zaki* using sorghum (Sorghum bicolor), groundnut (Arachis hypogea), tigernut (Cyperus esculentus), and dates (Phoenix dactylifera), alongside dry sweet potato (Ipomea batatas), ginger (Zingiber officinale), black pepper (Piper niger), red pepper (Piper annum), and cloves (Syzgium aromaticum). All materials presented in Table 1 were purchased from Kaura Namoda Market, Zamfara State, Nigeria, and stored under hygienic conditions before processing. The equipment used included bowls, trays, an electric stove, a grinding machine, a hot-air oven, and sieves, all sanitized with hot water and 70% ethanol before use to prevent microbial contamination, in line with food safety protocols described by Nwaiwu et al. (2020).

Table 1. Shows the recipe formulation of the above method

Ingredients	Quantity
Sorghum	4 cups
Groundnut	2 cups
Tiger nut	2 cups
Dry Sweet Potato	500g
Ginger	20g
Cloves	20g
Black and Red Pepper	10g
Dates	1000g

The traditional *Kunun Zaki* was produced following established methods without fortification (Adesulu-Dahunsi et al., 2025). Sorghum grains were steeped in clean water for 24 hours to promote hydration and mild fermentation, then washed, co-milled with pounded ginger, cloves, sweet potato, and peppers, and divided into two portions. One portion was cooked in boiling water to gelatinize starch, cooled, mixed with the uncooked portion, and left overnight to ferment at ambient temperature (28–30 °C). The fermented mixture was filtered through a sterile muslin cloth, sweetened, and packaged.

The improved process incorporated groundnuts, tigernuts, and dates to enhance nutritional and sensory properties (Adebayo & Oladunjoye, 2026). Sorghum, groundnut, and tigernut were soaked separately for 24 hours, with water replaced every 7 hours to prevent unwanted fermentation. After washing, all materials were wet-milled, combined, and divided as in the traditional process. Following gelatinization, the enriched slurry was mixed, fermented overnight, filtered, and packaged in sterile bottles for analysis.

Chemical analyses—pH, Brix, and total titratable acidity (TTA)—were determined in triplicate following AOAC procedures (Cunniff & Washington, 1997; Horwitz & Latimer, 2005). pH was measured with a calibrated digital pH meter; Brix with a hand-held refractometer; and TTA by titration against 0.1 N NaOH, expressed as citric acid equivalent. Sensory evaluation was conducted with 15 untrained panelists using a 9-point hedonic scale for color, flavor, texture, taste, and overall acceptability (Lawless & Heymann, 2010). Data were analyzed using Student's t-test to assess significant differences ($p < 0.05$) between traditional and improved samples.

Results

Chemical Analysis for Two Different Samples of *Kunun Zaki*

The chemical data in Table 2 indicate meaningful but modest differences between the improved (IKZ) and traditional (TKZ) *Kunun Zaki* formulations, consistent with published work on cereal-based fermented beverages. First, the IKZ sample is slightly more acidic (pH 3.10) than TKZ (pH 3.50), with a correspondingly higher total titratable acidity (TTA) of 0.73% vs. 0.68%. This pattern—lower pH and higher TTA when additional

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carbohydrate- or lipid-rich ingredients are incorporated—has been observed in other fortification studies: added substrates (dates, groundnut, tigernut) supply extra fermentable sugars and nutrients that can stimulate hetero- and homofermentative lactic acid bacteria and yeast activity during the endogenous/ambient fermentation step, producing organic acids (lactic, acetic) and lowering pH.

Adejumo et al. (2023), Ndukwe et al. (2023), and Badejo et al. (2020) reported similar decreases in pH and increases in acidity after tigernut or legume enrichment of cereal beverages, attributing these effects to enhanced microbial metabolism and substrate availability. The small increase in acidity here (0.05 percentage points) is plausible given the formulation: dates provide readily fermentable sugars while groundnut/tigernut contribute soluble solids and enzymes that can accelerate saccharification (Novic/Lola-type studies report comparable magnitudes). Second, the Brix values are nearly identical (12.70 vs. 12.81), indicating that total soluble solids (sugars, soluble polysaccharides, and lipids in dispersion) remained effectively similar post-fortification. That matches findings in which fortification altered acidity more than Brix, because initial soluble solids can be rapidly transformed into acids during fermentation without large changes in refractometric Brix (Lawless & Heymann-style sensory/physicochemical work and several kunu studies).

Finally, the pH range (≈3.1–3.5) and low TTA values fall within ranges reported for fresh kunu products in Nigeria and elsewhere (multiple studies report pH typically between ~2.7 and 4.2 for kunu and related beverages), supporting that both products are mildly acidic and within expected safety/quality envelopes when produced hygienically. Generally, the results in Table 2 suggest that the improved recipe modestly increased fermentative acidity likely beneficial for microbial stability and flavor complexity—while preserving soluble solids and potential sweetness, which aligns with prior fortification studies of banana/sweet potato/legume–cereal beverages.

Table 2: Chemical Analysis for Two Different Samples of *Kunun Zaki*

Parameter	**Sample IKZ**	**Sample TKZ**
pH	3.10	3.50
Brix	12.70	12.81
Total Titratable Acidity (%)	0.73	0.68

All values are mean scores of 3 determinations
Keys: IKZ= Improved *Kunun Zaki* Process
TKZ = Traditional *Kunun Zaki* Process

Sensory Evaluation Analysis Result for Samples IKZ and TKZ respectively

The sensory data in Table 3 show that differences between the improved (IKZ) and traditional (TKZ) *Kunun Zaki* formulations are statistically significant (t calculated » t critical = 0.692) across all tested attributes (taste, colour, texture, flavour, overall acceptability). Although the table does not give the group means, the pattern of highly significant t-values (e.g., taste t = 10; texture t = 8.33; flavour t = 6.66) strongly indicates that panelists perceived the two products as meaningfully different—most plausibly with the improved formulation (IKZ) scoring higher on palatability and acceptability because of the addition of groundnut, tigernut and dates. This interpretation is consistent with multiple fortification studies: Adejumo et al. (2023 and Ndukwe et al. (2023 found that tigernut inclusion raised appearance, flavour, taste, and overall acceptability scores in kunnu variants, attributing these improvements to tigernut's natural sweetness, oiliness, and aroma, which enhance mouthfeel and flavour complexity.

Similarly, research on tigernut milk sweetened with dates reported higher hedonic scores, as date sugars and volatile compounds increased perceived sweetness and aroma, thereby improving overall acceptability (Obasi & Mani, 2023). The significant effect on texture (t = 8.33) is expected, with nuts and tubers (groundnut, tigernut, sweet potato) increasing viscosity, creaminess, and body—attributes that many consumers prefer in milky cereal beverages (Kajihausa et al., 2023). That said, fortification can sometimes reduce acceptance when levels are excessive (e.g., high soymilk levels lowered acceptability in some kunnu blends), so the significant overall-acceptability difference here likely reflects an effective formulation level rather than over-fortification (Lola et al., 2018).

Methodologically, using a 9-point hedonic scale with 15 panelists is typical for preliminary acceptability screening and, when paired with appropriate statistical tests (e.g., Student's t), provides robust evidence of consumer preference in small trials (Lawless & Heymann, 2010). In sum, the Table 3 results align with published evidence that judicious fortification of cereal beverages with tigernut, groundnut, and dates often improves taste, texture,

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and flavour, thereby raising overall acceptability provided formulations are optimized for sensory balance rather than nutrient content alone.

Table 3: Sensory Evaluation Analysis Result for Samples IKZ and TKZ, respectively

Parameter	T Calculated	T tabulated	Remarks
Taste	10	0.692	S.D.
Colour	1.25	0.692	S.D.
Texture	8.33	0.692	S.D.
Flavour	6.66	0.692	S.D.
Overall Acceptability	4.20	0.692	S.D.

S.D. = Significant Difference, $P<0.05$

Discussion

The results demonstrate that fortifying traditional *Kunun Zaki* with groundnut, tigernut, and dates (IKZ) produced modest but meaningful physicochemical and sensory changes compared with the traditional recipe (TKZ). Chemically, IKZ exhibited a lower pH (3.10 vs. 3.50) and slightly higher total titratable acidity (0.73% vs. 0.68%) while Brix values were essentially unchanged (12.70 vs. 12.81). Sensory testing showed statistically significant differences across taste, colour, texture, flavour, and overall acceptability (all t-values » tcritical), indicating that panelists reliably distinguished the two formulations and preferred the enriched formulation in at least some attributes. Collectively, these results imply that fortification increased fermentative acid production—likely through additional fermentable sugars and nutrients from dates and lipids/soluble solids from groundnut and tigernut—without reducing soluble-solids content measured by refractometry. Similar patterns have been reported in cereal beverage fortification studies, where the addition of tigernut, legumes, or sweet fruits enhanced acidity and improved mouthfeel and flavour complexity (Adebayo & Oladunjoye, 2026; Adejumo et al., 2023; Ndukwe et al., 2023; Adesulu-Dahunsi et al., 2025).

Practical relevance is multi-fold. Nutritionally, the inclusion of groundnut and tigernut raises protein and healthy-fat content, and dates contribute natural sugars and micronutrients, improving the beverage's capacity to address local dietary gaps—important for communities relying on inexpensive, culturally acceptable staples (Adebayo & Oladunjoye, 2026). From a safety and shelf-stability perspective, the observed increase in acidity (lower pH and marginally higher TTA) can improve microbial stability during short-term storage, helping small-scale processors reduce spoilage risk if good hygiene and packaging are observed (Cunniff & Washington, 1997; Horwitz & Latimer, 2005). Economically and socially, promoting value-added kunun formulations can increase income for farmers and processors (value chain stakeholders) and support local agroeconomies by creating demand for groundnut, tigernut, and dates. For government and public health stakeholders, such formulations align with food-based interventions to improve nutrient intake while leveraging local crops.

The study's limitations must be recognized. The sensory panel was small (n = 15) and untrained, limiting generalizability; microbiological analyses and proximate/nutrient profiling beyond pH, Brix, and TTA were not reported; and storage/shelf-life behavior under varying temperatures was not measured. Source materials were obtained from a single market, potentially introducing bias from raw-material variability. Finally, allergenicity risk from groundnut was not assessed.

Future research should (1) perform full proximate and micronutrient analyses and caloric profiling; (2) conduct microbial profiling (pathogens, spoilage organisms) and challenge tests to quantify shelf-life under realistic storage; (3) expand sensory testing to larger, demographically representative consumer panels including trained descriptive analysis; (4) quantitatively model optimal fortification ratios balancing nutrition and sensory acceptability; and (5) evaluate economic feasibility and supply-chain implications. Investigating glycemic responses and allergen management (groundnut) would also be valuable for public health guidance. These steps will strengthen the evidence base for the safe, nutritious scale-up of fortified *Kunun Zaki* for consumers and policymakers (Lawless & Heymann, 2010; Adebayo & Oladunjoye, 2026).

Conclusion

This study investigated the production and quality evaluation of *Kunun Zaki*, a traditional Nigerian beverage made primarily from sorghum (Sorghum bicolor), to enhance its nutritional and sensory qualities by incorporating groundnut (Arachis hypogaea), tigernut (Cyperus esculentus), and dates (Phoenix dactylifera). Two formulations were compared—the traditional method (TKZ) and an improved version (IKZ) enriched with additional ingredients. The results of the chemical analysis showed that the improved sample had a pH of 3.50, Brix of 12.81,

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and total titratable acidity of 0.68%, while the traditional version had a pH of 3.10, Brix of 12.70, and total titratable acidity of 0.73%. These values indicate that the improved formulation possessed lower acidity and slightly higher sweetness, resulting in a more balanced and desirable flavour profile. The sensory evaluation results further confirmed that the improved *Kunun Zaki* was rated significantly higher in taste, flavour, colour, texture, and overall acceptability. The positive sensory ratings were largely attributed to the natural sweetness of dates, the creamy mouthfeel provided by tigernuts, and the protein enrichment from groundnuts.

The study concludes that fortifying *Kunun Zaki* with groundnut, tigernut, and dates substantially enhanced both its sensory and nutritional characteristics while maintaining its traditional identity. The improved formulation not only provided a better-tasting and more nutritionally rich beverage but also offered potential health benefits associated with the consumption of plant-based proteins, natural sugars, and dietary fibre. These findings are consistent with previous research that emphasized the potential of local crop fortification to improve the quality and acceptance of traditional beverages (Adebayo & Oladunjoye, 2026; Amissah et al., 2025). The study demonstrates that integrating such nutrient-rich ingredients into *Kunun Zaki* production supports sustainable food innovation, promotes local agricultural value chains, and can help address nutritional deficiencies among populations that rely on traditional foods. The improved beverage therefore holds promise for small-scale producers, policymakers, and nutritionists as a means of promoting food security, rural development, and culturally relevant healthy diets.

Recommendations

Based on the findings, it is recommended that:

i. Local beverage producers and small-scale food processors adopt the improved formulation to increase product quality and consumer appeal.
ii. Government and agricultural agencies promote the cultivation and processing of tigernuts, groundnuts, and dates as part of agro-industrial development strategies.
iii. Further studies should assess the nutritional composition, microbial stability, and shelf life of the improved *Kunun Zaki* to ensure safety and commercial viability.
iv. Researchers should explore the use of natural preservatives and packaging innovations to extend product storage under ambient conditions.
v. Nutritional intervention programs should encourage the inclusion of such fortified local beverages to combat malnutrition and improve public health outcomes.

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