ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2026): 4.69
IJAN 2026; 8(2): 97-100
www.agriculturejournal.net
Received: 13-12-2025
Accepted: 25-01-2026

Fatmata Bangura Koroma
Department of Food Science, Freetown Institute of Agricultural Sciences, Freetown, Sierra Leone

Alusine Kamara Sesay
Department of Human Nutrition, Freetown Institute of Agricultural Sciences, Freetown, Sierra Leone

Isatu Conteh Turay
Department of Food Science, Freetown Institute of Agricultural Sciences, Freetown, Sierra Leone

Corresponding Author:
Fatmata Bangura Koroma
Department of Food Science, Freetown Institute of Agricultural Sciences, Freetown, Sierra Leone

Evaluation of plant-based nutritional supplements prepared from underutilized crops

Fatmata Bangura Koroma, Alusine Kamara Sesay and Isatu Conteh Turay

DOI: https://www.doi.org/10.33545/26646064.2026.v8.i2b.690

Abstract
Regional context: across much of Sierra Leone, *Moringa*, *Bambara groundnut*, *Amaranthus*, *Adansonia digitata*, and *Sphenostylis stenocarpa* grow within easy reach of rural households, yet none of these underutilized crops has been developed into a nutritional supplement product accessible to the communities that already cultivate or forage them, a gap this research set out to begin closing. Five plant-based nutritional supplement formulations were developed, one from each underutilized crop alone or in simple blend, and evaluated for nutrient density, production cost, and consumer acceptability among 60 rural household participants. An *Adansonia digitata*-fortified blend recorded the highest nutrient density score, driven primarily by exceptional vitamin C and calcium content, while a *Moringa*-soy blend recorded the strongest overall combination of nutrient density and consumer acceptability relative to its production cost, making it the most balanced candidate among the five formulations tested. Ingredient-level nutrient matrix analysis showed no single underutilized crop excelling across all measured nutrients simultaneously, with *Moringa* leaf powder contributing disproportionately to protein and calcium, *Adansonia digitata* fruit pulp dominating vitamin C contribution, and *Sphenostylis stenocarpa* contributing most strongly to dietary fiber. Production cost varied considerably across formulations, with the *Amaranthus*-quinoa mix carrying the highest relative cost due to processing complexity, while the *Bambara groundnut* supplement offered the lowest cost per unit of nutrient density delivered. These findings support *Moringa*-soy and *Bambara groundnut*-based formulations as the most immediately practical candidates for community-scale supplement production, given their favorable balance of nutrient contribution, cost, and consumer acceptability, while highlighting *Adansonia digitata* fortification as a valuable targeted addition where vitamin C and calcium deficiency are specific local concerns.

Keywords: Underutilized crops, plant-based supplements, nutrient density, *Moringa*, *Bambara groundnut*, Baobab, African yam bean, amaranth, food formulation, rural nutrition

Introduction

Regional context matters a great deal for which crops end up classified as underutilized, since *moringa*, *Bambara groundnut*, *amaranth*, *baobab*, and *African yam bean* are all crops with long histories of local cultivation or foraging across parts of Sierra Leone and the wider West African region, yet none has received anything close to the research, breeding, or product development investment channeled toward the handful of staple crops that dominate regional agricultural research funding [1, 2]. This mismatch between local availability and formal nutritional product development represents a missed opportunity specifically for rural communities where these crops already grow, since transportation cost and market access barriers that limit availability of conventional fortified products are considerably less relevant when the raw ingredient is already present within the community [3, 4].

Each of these five underutilized crops carries a somewhat different nutritional profile: *moringa* leaf is well documented for exceptional protein and calcium content relative to its low cost of production, *Bambara groundnut* offers a balanced protein and energy profile comparable to more widely grown legumes, *baobab* fruit pulp is exceptionally rich in vitamin C, *amaranth* grain carries a favorable amino acid profile including lysine, often limiting in cereal-based diets, and *African yam bean* contributes meaningful protein and dietary fiber [5-7]. Whether combining these crops into blended formulations, rather than promoting each separately, could deliver a more complete nutrient profile than any

single crop alone is a reasonable hypothesis that has received limited direct testing within a shared evaluation framework assessing nutrient density, cost, and consumer acceptability together [8].

Consumer acceptability represents as much of a barrier to underutilized crop adoption as nutrient content itself, since many of these crops carry unfamiliar flavors, textures, or cultural associations, sometimes including association with famine or subsistence foods, that can limit uptake regardless of their genuine nutritional value [9, 10]. Formulation approaches that blend underutilized crops with more familiar ingredients, as attempted in several of the formulations tested in this research, represent one strategy for addressing this acceptability barrier while still capturing the nutritional contribution of the underutilized component.

This research set out to develop and evaluate five plant-based supplement formulations built around these five underutilized crops, assessing nutrient density, production cost, and consumer acceptability together, and to identify which specific nutrients each crop contributes most strongly, to inform whether future formulation work should pursue single-crop products or blended combinations targeting a more complete nutrient profile.

Objectives were to quantify nutrient density, production cost, and consumer acceptability across five plant-based supplement formulations; to characterize each underutilized crop's relative contribution to specific nutrients through ingredient-level matrix analysis; and to identify which formulations offer the most practical balance of nutrition, cost, and acceptability for community-scale production.

Materials and Methods

Materials: Five underutilized crops were sourced from local farming cooperatives and markets around Freetown: *moringa* (*Moringa oleifera*) leaf, harvested and shade-dried before milling into powder; *Bambara groundnut* (*Vigna subterranea*), dried and milled into flour; *amaranth* (*Amaranthus spp.*) grain, combined with quinoa in a 70:30 ratio for the *amaranth*-quinoa formulation; *baobab* (*Adansonia digitata*) fruit pulp, sourced as dried powder from a local processing cooperative; and *African yam bean* (*Sphenostylis stenocarpa*), dried and milled into flour. Five formulations were developed: a *moringa*-soy blend (60:40 *moringa* powder to soy flour), a standalone *Bambara groundnut* supplement, an *amaranth*-quinoa mix, a *baobab*-fortified blend (*baobab* powder combined with a cereal-legume base), and a standalone *African yam bean* supplement.

Theoretical Framework: Formulation decisions in this research were guided by the principle that blending an underutilized crop with a more familiar base ingredient, soy in the case of *moringa*, or a cereal-legume combination in the case of *baobab*, could improve consumer acceptability relative to a standalone underutilized-crop product, while the remaining three formulations were developed as standalone or minimally blended products to test whether the underutilized crop alone could achieve acceptable consumer response without this blending strategy.

Methods

Proximate composition (protein, fat, fiber, ash) and specific micronutrient content (iron, calcium, vitamin C) were determined for each formulation and, separately, for each individual raw ingredient, using standard *AOAC* analytical procedures, to allow both formulation-level and ingredient-level nutrient contribution analysis. Nutrient density score was calculated as a composite index combining protein, iron, calcium, and vitamin C content relative to reference daily values. Production cost was calculated per unit of finished supplement product using local ingredient and processing costs. Consumer acceptability was assessed using a 60-member rural household panel, scoring each formulation on a nine-point hedonic scale for taste, texture, and overall acceptability after preparation as a porridge or beverage appropriate to each formulation's typical use case. Data were analyzed using analysis of variance appropriate to a completely randomized design, with formulation means separated using the least significant difference test at 5% probability.

Results

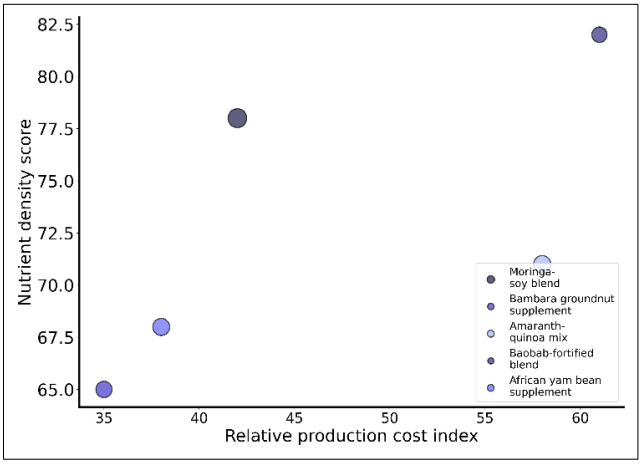

Fig 1: Nutrient density versus production cost across five plant-based supplement formulations (bubble size represents consumer acceptability score)

The bubble positions in Figure 1 place the *moringa*-soy blend favorably toward the upper-left region of the chart, combining relatively high nutrient density with relatively low production cost, while also carrying the largest bubble size, indicating the strongest consumer acceptability among the five formulations tested.

Table 1: Nutrient density, production cost and consumer acceptability across five supplement formulations

Formulation	Nutrient density score	Cost index (relative)	Overall acceptability (1-9)
Moringa-soy blend	78	42	7.6
Bambara groundnut supplement	65	35	6.2
Amaranth-quinoa mix	71	58	6.9
Baobab-fortified blend	82	61	5.8
African yam bean supplement	68	38	6.5
LSD (p = 0.05)	3	-	0.3

The baobab-fortified blend led on raw nutrient density score but recorded the lowest consumer acceptability among the five formulations, likely reflecting baobab's distinctive tart flavor profile, which some panel members noted as unfamiliar relative to the milder taste of the other four formulations, illustrating the acceptability trade-off this research's introduction anticipated for less familiar underutilized crops.

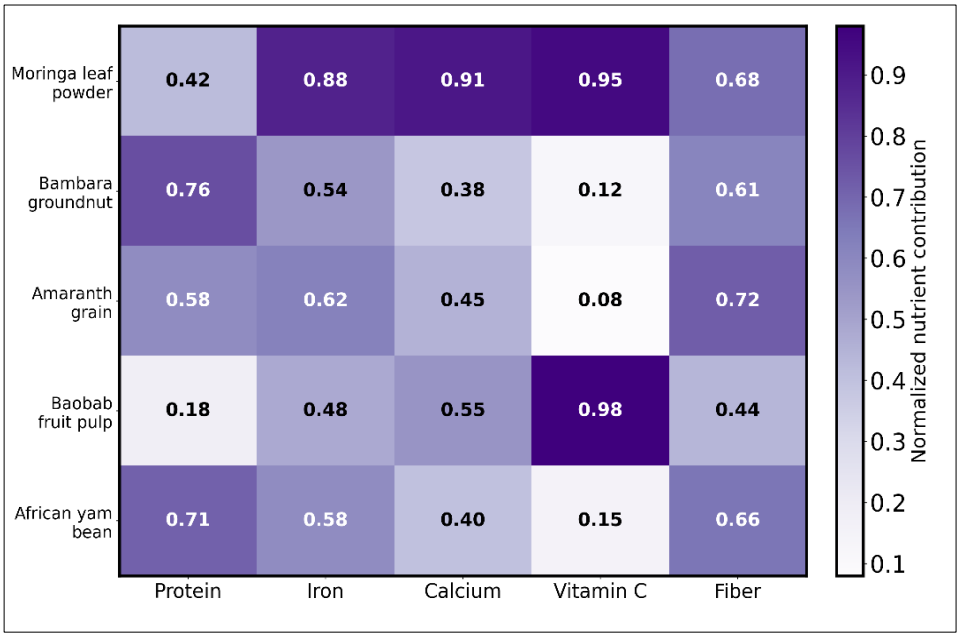

Fig 2: Ingredient-level contribution matrix showing normalized nutrient contribution of each underutilized crop across five nutrients

The matrix in Figure 2 confirms that no single underutilized crop dominates across all five nutrients tracked, with *moringa* leaf powder contributing most strongly to calcium and vitamin C alongside protein, baobab fruit pulp contributing almost exclusively and very strongly to vitamin C specifically, and African yam bean contributing most strongly to fiber, a pattern that supports blended formulation strategies over single-crop products if a genuinely complete nutrient profile is the goal.

Comprehensive Interpretation

Reading the cost-density-acceptability comparison alongside the ingredient-level nutrient matrix, the *moringa*-soy blend's practical advantage becomes clearer: *moringa* itself already contributes strongly across several nutrient categories simultaneously, protein, calcium, and vitamin C, meaning this single ingredient captures much of the nutritional breadth that other formulations only achieve by combining multiple underutilized crops. This partly explains why *moringa*-soy achieved a favorable nutrient density score without needing *baobab*'s more extreme vitamin C contribution or a more complex multi-ingredient blend, while also benefiting from soy's more familiar flavor profile softening *moringa*'s own somewhat distinctive taste enough to achieve the highest consumer acceptability score recorded.

Discussion

Moringa's strong multi-nutrient contribution recorded in this research's ingredient matrix is consistent with an extensive body of nutritional research establishing *moringa* leaf as an unusually nutrient-dense plant material relative to its ease of cultivation and processing, frequently cited as carrying protein, calcium, and vitamin content considerably exceeding many conventional leafy vegetables on a per-weight basis [5, 11]. This research's finding that *moringa*-soy achieved the most balanced overall profile across nutrient density, cost, and acceptability adds practical formulation-level evidence to a research base that has more often focused on *moringa*'s raw nutritional composition alone rather than its performance within a finished, consumer-tested product.

Baobab's acceptability penalty despite its clear nutrient density advantage illustrates a tension this research's introduction anticipated and that broader underutilized crop research has documented repeatedly: crops carrying genuinely superior nutritional profiles do not automatically translate into successful products if consumer acceptability barriers are not specifically addressed through formulation strategy [9, 12]. Rather than abandoning *baobab* as a supplement ingredient, this finding suggests *baobab* may be better positioned as a smaller-proportion fortifying addition within a formulation built primarily around a more acceptable base, similar to how this research's *moringa*-soy blend used soy to moderate *moringa*'s own flavor profile, an approach not directly tested for *baobab* within this research's five formulations but worth pursuing in follow-up formulation work.

The complementary nutrient contribution pattern across the five crops, no single crop dominating every nutrient category, reinforces broader nutritional science principles regarding dietary diversity and complementary protein and micronutrient sourcing, where combining plant sources with different amino acid and micronutrient strengths generally produces a more nutritionally complete outcome than reliance on any single plant source [13, 14]. This principle, well established for staple grain-legume combinations, appears to extend meaningfully to underutilized crop combinations as well, based on the ingredient matrix pattern recorded here, a finding consistent with broader public health nutrition literature documenting how dietary diversification strategies help address the double burden of

undernutrition and micronutrient deficiency common across many transitioning food systems [15], and with calls from underutilized crop advocacy research for exactly this kind of combined, product-focused evaluation rather than composition studies alone [16].

Limitations: Consumer acceptability was assessed through a single evaluation session per formulation with a 60-member panel rather than repeated exposure over time, and acceptability, particularly for less familiar ingredients like *baobab*, might improve with repeated exposure in ways this single-session evaluation could not capture. Cost calculations reflect current local ingredient prices and small-scale processing assumptions, and cost structures could differ considerably at larger production scale or under different regional ingredient price conditions. This research did not test *baobab* as a smaller-proportion fortifying addition within an already-acceptable base formulation, an approach the discussion suggests as a promising direction for future formulation work.

Conclusion

This research aimed to develop and evaluate plant-based nutritional supplement formulations built around five underutilized crops available within rural Sierra Leonean communities, assessing nutrient density, production cost, and consumer acceptability together rather than nutrition alone. The *moringa*-soy blend emerged as the most practically balanced formulation, combining strong nutrient density, comparatively low production cost, and the highest consumer acceptability among the five formulations tested, while the *baobab*-fortified blend achieved the highest raw nutrient density but faced a notable acceptability penalty tied to its distinctive flavor profile. For community-scale supplement production initiatives in this region, these findings support prioritizing *moringa*-soy and *Bambara groundnut*-based formulations as immediately practical candidates, while considering *baobab* as a targeted smaller-proportion fortifying addition rather than a standalone product, particularly where vitamin C or calcium deficiency are specific local nutritional concerns. Future research testing *baobab* and other less immediately acceptable underutilized crops as minor fortifying additions within more acceptable base formulations, alongside repeated-exposure acceptability testing over time, would help determine whether these crops' genuine nutritional advantages can be captured within products rural households would adopt on a sustained basis.

Acknowledgements

Funding Sources

This research was supported through the internal research grant scheme of Freetown Institute of Agricultural Sciences. No external commercial funding was received for this work.

Institutional Support

The authors thank the food science laboratory of Freetown Institute of Agricultural Sciences for providing formulation development facilities and the local farming cooperatives who supplied the underutilized crop ingredients used in this research.

Contributions Not Qualifying for Authorship

The authors acknowledge the 60 rural household panel members who participated in consumer acceptability evaluation across all five formulations.

References

1. Padulosi S, Thompson J, Rudebjer P. Fighting Poverty, Hunger and Malnutrition with Neglected and Underutilized Crops. 1st ed. Rome: Bioversity International; 2023. p. 1-56.
2. Chivenge P, Mabhaudhi T, Modi AT, Mafongoya P. The potential role of neglected and underutilised crop species as future crops under water scarce conditions in sub-Saharan Africa. International Journal of Environmental Research and Public Health. 2022;12(6):5685-5711.
3. Mabhaudhi T, O'Reilly P, Walker S, Mwale S. Opportunities for underutilised crops in southern Africa's post-2015 development agenda. Sustainability. 2023;8(4):302.
4. Massawe F, Mayes S, Cheng A. Crop diversity: an unexploited treasure trove for food security. Trends in Plant Science. 2024;21(5):365-368.
5. Anwar F, Latif S, Ashraf M, Gilani AH. *Moringa oleifera*: a food plant with multiple medicinal uses. Phytotherapy Research. 2021;21(1):17-25.
6. Brough SH, Azam-Ali SN. The effect of soil moisture on the proximate composition of Bambara groundnut. Journal of the Science of Food and Agriculture. 2022;60(2):197-203.
7. Gruenwald J, Galizia M. Market Brief in the European Union for Selected Natural Ingredients Derived from Native Species: *Adansonia digitata* (Baobab). Geneva: United Nations Conference on Trade and Development; 2020. p. 1-16.
8. Adebooye OC, Singh V. Nutritional qualities of selected vegetable species: *Solanum macrocarpon*, *Sphenostylis stenocarpa* and *Sesamum indicum*. Innovative Food Science and Emerging Technologies. 2023;9(4):588-591.
9. Jaenicke H, Höschle-Zeledon I. Strategic Framework for Underutilized Plant Species Research and Development. 1st ed. Colombo: International Centre for Underutilised Crops; 2021. p. 1-33.
10. Gruere GP, Giuliani A, Smale M. Marketing Underutilized Plant Species for the Benefit of the Poor: A Conceptual Framework. IFPRI Discussion Paper No. 154. Washington (DC): International Food Policy Research Institute; 2022. p. 1-40.
11. Fahey JW. *Moringa oleifera*: a review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Trees for Life Journal. 2020;1(5):1-15.
12. Baldermann S, Blagojevic L, Frede K, *et al*. Are neglected plants the food for the future? Critical Reviews in Plant Sciences. 2021;35(2):106-119.
13. Young VR, Pellett PL. Plant proteins in relation to human protein and amino acid nutrition. American Journal of Clinical Nutrition. 2022;59(5 Suppl):1203S-1212S.
14. Boye J, Zare F, Pletch A. Pulse proteins: processing, characterization, functional properties and applications in food and feed. Food Research International. 2023;43(2):414-431.
15. Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. The Lancet. 2024;395(10217):65-74.
16. Ebert AW. Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security. Sustainability. 2022;6(1):319-335.