Content available at Bio-Research

Journal of Biological Research and Biotechnology
Journal Home page: https://bio-research.com.ng/index.php/home

REVIEW ARTICLE

African Breadfruit (*Treculia africana*) in sub-Saharan Africa: Nutritional Value, Underutilisation, and Biotechnological Prospects, A Review

[1*]Yemisi O. Olagunju [2]Titilope M. Fasuan and [3]Mobolaji T. Oladunjoye
[1]Biotechnology Unit, National Horticultural Research Institute, Ibadan, Nigeria
[2]Food Engineering, National Horticultural Research Institute, Ibadan, Nigeria
[3]Library and Documentation Unit, National Horticultural Research Institute, Ibadan, Nigeria.

ARTICLE INFO

Received: 30th May 2026
Revised: 20th of August 2026
Accepted: 22nd August 2026
Published online: 31st August 2026
DOI: https://dx.doi.org/10.4314br.v24i2.20

e-ISSN: 2705-3822
print-ISSN: 1596-7409

Official. Faculty of Biological Sciences, University of Nigeria.

ABSTRACT

African breadfruit (*Treculia africana*) is indigenous to the humid forests of West and Central Africa, producing large composite fruits whose numerous edible seeds have sustained forest-belt communities, yet the species remains one of sub-Saharan Africa's most neglected food plants. This review synthesises literature on *T. africana* retrieved from six electronic databases (2001-2024) across four dimensions: nutritional and phytochemical composition, pharmacological activity of its bioactive constituents, structural drivers of its underutilisation, and its genetic characterisation and biotechnological improvement prospects. The seeds are carbohydrate-rich (43-81%) and moderately proteinous (up to 23% after processing), with appreciable potassium, phosphorus, and iron, and a lysine content that complements cereal-based diets. Among different processing methods, dehulling was found to significantly reduce saponin content (up to 80%), phytate (71%), and tannin (52%). Research has also confirmed that extracts from different parts like seeds, leaves, bark, and roots display antimicrobial, antioxidant, antidiabetic, and antitumor activities. Among bioactive constituents, citral, geraniol, chlorogenic acid, and α-mangostin stand out; but, further experiments are needed to validate their effects. This article highlights that little research has been done on genomics resources and molecular markers of *T. africana*, in contrast to *Artocarpus altilis*, its relative, which has an assembled genome and validated SSR markers. Established biotechnological tools, molecular markers (SSR, SNP), tissue culture, and genome editing offer a clear pathway to characterise diversity, conserve germplasm, and accelerate domestication. Deploying these alongside standardised nutritional trials and value-chain development is essential to transform *T. africana* into a formally integrated, food security crop for sub-Saharan Africa.

Keywords: *Treculia africana*; African breadfruit; Anti-nutritional factors; Bioactive compounds; Underutilised crops; Food security.

Cite this article: Olagunju, Y. O., Fasuan, T. M., & Oladunjoye, M. T. (2026). African Breadfruit (*Treculia africana*) in sub-Saharan Africa: Nutritional value, underutilisation, and biotechnological prospects a review. *Journal of Biological Research and Biotechnology*, 24(2), 665-672.
Corresponding author: Yemisi O. Olagunju Email. olufolajiyemisi@yahoo.com.
DOI: https://dx.doi.org/10.4314br.v24i2.20

1.0 INTRODUCTION

Food insecurity and malnutrition in sub-Saharan Africa (SSA) are very deeply rooted, pervasive across the region, and have been gradually declining, so to speak. Using the Demographic and Health Survey data of 32 sub-Saharan African countries, the minimum dietary diversity for children in this region aged 6-23 months was identified to be as low as 25.1%. Stunting was found in 28.6% of the children, while wastage was further noted in 9.4% of them (Aboagye et al., 2021). These figures imply that dietary inadequacy is the main cause of this situation, which is, in addition to the lack of adequate calories, a source of lasting effects. The problem is essentially due to a reliance on an extremely limited set of introduced or market-controlled crops rather than on local, nutrition-rich species. The origins of this reliance have only partially been revealed as the lasting results of export-oriented colonial food production systems which diverted fertile land and people's efforts from the indigenous provision of food to cash crop production for foreign markets (Bjornlund et al., 2022). The post-independence continuation of these patterns, including the neglect of indigenous crop research and the concentration of institutional investment in a handful of staple commodities, has reinforced a landscape in which hundreds of nutritionally valuable plant species remain effectively invisible to formal agricultural science and policy. The concept of neglected and underutilised crop species (NUS), plant species that are locally cultivated or wild-harvested and valued within traditional food systems, but marginalised by formal research, breeding, markets, and policy, has attracted growing scholarly and institutional attention over the past two decades as a possible corrective to this imbalance. A review of NUS at sub-Saharan African level showed that despite an increasing number of studies on these crops, these species are still related to specific gender roles and social stigmata; their research is fragmented, development of the crops is not a priority, and more importantly, these crops do not benefit from existing policies (Ndlovu et al., 2024). Research work assessed the ability of the 58 neglected food crops in Africa to provide extra nutrition or maybe take over entirely major crops in certain cases under 2070 climate conditions and discovered that, apart from these species being able to grow over a large area, they also serve as good sources of micronutrients (Van Zonneveld et al., 2023). Nevertheless, the actual change that this potential has been making from theoretical understanding into the food system itself is a slow and patchy one. *Treculia africana* Decne, the African breadfruit, is probably the best example that shows these structural weaknesses.

T. africana is an evergreen type of tree that, in many cases, is unbuttressed, with a height up to 30 metres and the tree regularly produces a mass of fruit of about 30 kilograms per tree containing hundreds of edible seeds (Ojimelukwe & Ugwuona, 2021). It occurs throughout the humid forest areas of West and Central Africa, reaching parts of East Africa, and has been continuously used ethnobotanically for generations, mainly among the Igbo of south-eastern Nigeria (where it is called ukwa), but also in Cameroon, the Democratic Republic of Congo, Ghana, and São Tomé and Príncipe. Its seeds are a high-carbohydrate, moderately protein-rich food especially appreciated during lean periods (Edima-Nyah et al., 2023). Yet it occupies no formal place in national agricultural research portfolios; no dedicated breeding programme or molecular characterisation exists for it anywhere in Africa; and its entry into commercialised food systems has been tentative, localised, and largely unscaled. The scientific literature on *T. africana* is, in relative terms, sparse, geographically concentrated in Nigeria, and dominated by isolated compositional analyses of seeds. Existing reviews treat its nutritional value, medicinal use, or socioeconomic status separately, and none links these to the near-total absence of genetic and biotechnological research on the species. This fragmentation obscures why a plant of documented nutritional and pharmacological value remains outside formal food systems, and leaves crop-improvement efforts without a starting point. By integrating nutritional, pharmacological, socioeconomic, and biotechnological evidence within a single framework, this review identifies the specific research and development gaps whose closure is a prerequisite for domesticating *T. africana* and mainstreaming it into sub-Saharan Africa's food security and climate-adaptation strategies.

This review aims to: (1) collate and compare the proximate, mineral, and phytochemical composition of *T. africana* reported across studies, and appraise how processing modifies its nutrient and anti-nutrient profiles; (2) examine the reported pharmacological activities of its extracts and the bioactive constituents responsible; (3) evaluate the structural factors sustaining its underutilisation despite documented potential; and (4) assess the state of its genetic characterisation and identify biotechnological tools applicable to its improvement, thereby defining priorities for its integration into food security strategies across sub-Saharan Africa.

2.0 METHODOLOGY

This narrative review was conducted through systematic searches of six electronic databases: Google Scholar, Scopus, PubMed, AJOL (African Journals Online), AGRIS, and ScienceDirect. Searches covered literature published from January 2001 to December 2024, with English-language peer-reviewed articles retained for synthesis. Search queries were structured around three thematic clusters: species-specific terms ("*Treculia africana*", "African breadfruit", "ukwa") combined with "nutritional composition", "anti-nutritional factors", "phytochemical", "bioactive compounds", "antimicrobial", "antioxidant", "antidiabetic", "processing", "genetic diversity", and "molecular markers"; contextual terms on neglected and underutilised crops and food security in sub-Saharan Africa; and comparative terms on *Artocarpus altilis* and molecular breeding of orphan crops. Articles were eligible if they reported original data or substantive review of *T. africana* or a directly relevant comparator species, particularly its congener *Artocarpus altilis*. Studies were excluded if they were duplicates, conference abstracts without full text, non-peer-reviewed sources, or papers in which *T. africana* was only incidentally mentioned. Reference lists of retrieved articles were screened for additional sources through backward citation tracking. The authenticity of every source was verified through its Digital Object Identifier (DOI) or, where no DOI existed, through the publisher's official record, to confirm bibliographic accuracy and exclude fabricated or predatory-source citations. Extracted data were synthesised thematically and are presented in tabular and graphical form where appropriate.

3.0 RESULTS

3.1 Nutritional composition of *Treculia Africana*

3.1.1 Proximate composition of seeds and pulp

The nutritional composition of *T. africana* seeds has been extensively characterised using standard proximate analysis. However, the reported values vary substantially across studies, a pattern attributable to differences in geographical origin, ecotype, degree of maturity at harvest, and, most consequentially, the processing method applied before analysis. Table 1 summarises the composition ranges reported across key studies, with the specific sources for each parameter indicated. The influence of thermal processing on the macronutrient fractions is illustrated in Figure 1, which compares the crude protein, crude fat, crude fibre, and ash contents of raw, cooked, and toasted seeds from a single study (Runsewe-Abiodun et al., 2018), showing that all four fractions increased with thermal processing.The crude protein content in dehulled raw *T. africana* seeds has been reported to reach 18.32% (Ijeh et al., 2011), comparable with many well-known grain legumes and higher than major staple cereals. Processed samples generally show higher protein levels than raw ones; Runsewe-Abiodun et al. (2018) reported 18.25% in boiled seeds compared with 16.32% in raw seeds, and Obiakor-Okeke and Nnadi (2014) detected up to 23.52% protein in processed portions, mainly due to moisture-loss concentration effects. At the lower extreme, Obiakor-Okeke and Nnadi (2014) recorded raw protein as low as 3.45%, indicating that ecotypic and environmental variation remains largely uncharacterised and represents a major knowledge gap. To place these values in dietary context, Table 2 compares *T. africana* with the region's dominant staples. Set against these staples, *T. africana* seeds carry roughly twice the protein of maize and rice and a markedly higher iron concentration, while their protein content sits below that of cowpea-positioning the species as a mineral-dense complement to cereal staples rather than a direct protein substitute (Godfrey et al., 2024). Carbohydrates consistently dominate the composition (43.49-80.65% depending on processing and study location (Okoronkwo et al., 2020). Minerals occur mainly as potassium and phosphorus; Godfrey et al. (2024) recorded potassium at 1,941.53 mg/100 g in seeds from Kogi State, among the highest reported for any indigenous seed legume in Nigeria, together with iron up to 39.50 mg/100g, though iron bioavailability is constrained by anti-nutritional factors.

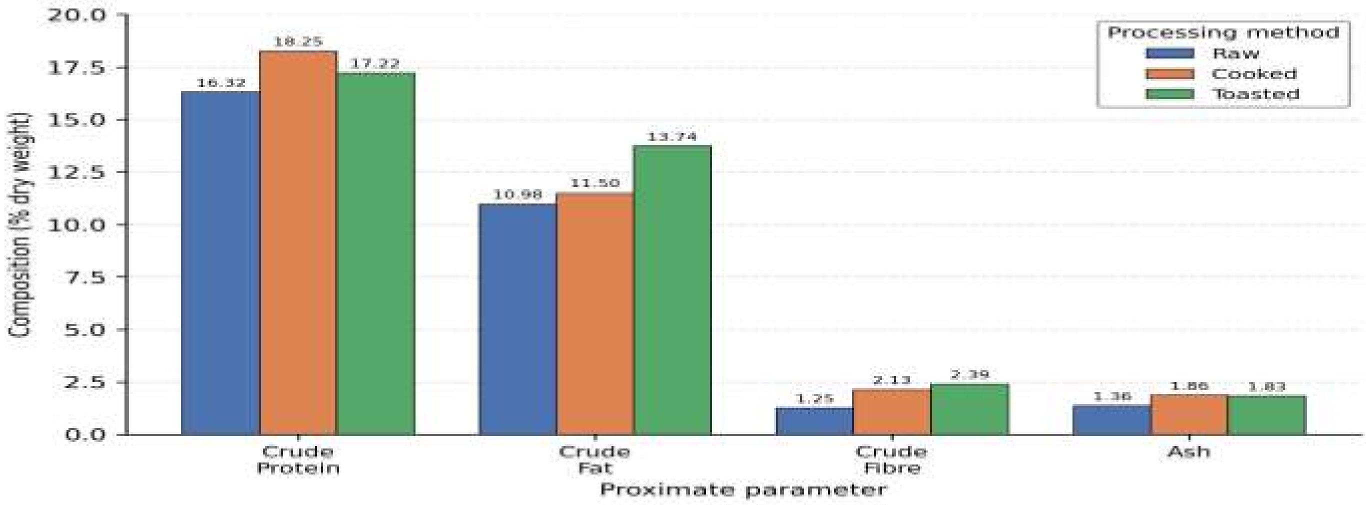

*Figure **1**. Effect of traditional processing on the proximate composition of Treculia africana seeds. Values (% dry weight) for raw, cooked, and toasted seeds are from Runsewe-Abiodun et al. (2018), determined by AOAC methods. Crude protein, fat, fibre, and ash all increased with thermal processing.*

3.1.2 Amino acid profile and protein quality

The amino acid profile of *T. africana* seeds, though less studied compared to nutrient content, presents an irregular but somewhat reassuring picture. Okoronkwo et al. (2020) indicated that six amino acids, aspartic acid, glutamic acid, alanine, leucine, tyrosine, and lysine in their study were above the 1.0% minimum reference level that are usually compared according to FAO/WHO standards. Lysine, as the limiting amino acid in cereal-based staples of SSA, is abundantly found in these foods, which could serve nutritionally as a complement to maize or sorghum-based basic foods. When compared with the amino acid content of Vigna subterranea (Bambara groundnut) at the same conditions, Godfrey et al. (2024) found that *T. africana* contained fewer essential amino acids, thus *T. africana* should likely be looked at as a dietary combination protein source rather than as an isolated source for complete protein. By Edima-Nyah et al. (2023), it was evidenced that pre-germinated *T. africana* provides more total essential amino acids than both intact and shelled seed varieties. This illustrates the fact that physical treatments before consumption can lead to enhancement of nutritional quality.

3.1.3 Anti-nutritional factors and their mitigation through processing

It should be emphasised that the processing methods discussed here: dehulling, malting, cooking, roasting, and defatting, are primarily culinary operations applied to render the seed safe and palatable for consumption; the accompanying reductions in anti-nutritional factors are consequences of these food-preparation steps rather than laboratory procedures performed for analytical purposes. The raw seed contains several anti-nutritional substances that limit its nutritive value, including phytate, tannin, oxalate, saponin, and trypsin inhibitors. Table 3 summarises anti-nutrient concentrations and the reductions achieved by specific processing methods. Among the processing methods examined, dehulling was the single most effective operation, achieving reductions of 70.69% in phytate, 79.95% in saponin, 65.62% in oxalate, 51.72% in tannin, and 48.17% in trypsin inhibitor activity, largely because these compounds are concentrated in the seed coat (Edima-Nyah et al., 2023). Cooking and roasting eliminated tannin and phytate to undetectable levels in whole seeds (Obiakor-Okeke & Nnadi, 2014). Samtiya et al. (2020) provide an instructive broader framework: anti-nutritional factors in legumes and cereals are almost universally reducible to safe levels through appropriate combinations of processing, and their presence in raw seeds should not be viewed as an absolute barrier to utilisation. Boiling of dehulled seeds, practised domestically in south-eastern Nigeria, was confirmed by multiple studies to produce a nutritionally adequate final product (Obiakor-Okeke & Nnadi, 2014; Runsewe-Abiodun et al., 2018; Onyenibe, 2019), though Nwaigwe & Adejumo (2015) cautioned that prolonged boiling can reduce the crude protein fraction. Beyond its macronutrient and mineral value, *T. africana* owes much of its traditional and emerging medicinal reputation to a diverse array of bioactive secondary metabolites, considered in the following section.

3.2 Bioactive compounds and pharmacological properties

3.2.1 Phytochemical profile

Treculia Africana houses secondary metabolites in all its parts: seeds, leaves, stembark and roots. Several phytochemical tests have established that the plant is a storehouse of different phytochemicals: alkaloids, flavonoids, tannins, saponins, steroids, terpenoids, cardiac glycosides, and anthraquinones (Ojimelukwe & Ugwuona, 2021; Onyenibe, 2019). The phytochemical profile reported for *T. africana* is a result of the extraction solvent and technique, making it a factor that makes comparison across studies very difficult. Ethanol and methanol extraction, such as those used by Kareem et al. (2024) and Oeyipo & Onasoga (2015), tend to yield more phenolics, flavonoids, and glycosides, while non-polar methods, such as the petroleum ether Soxhlet used by Godfrey et al. (2024), tend to favour fatty acids and terpenoids. Further, the isolation techniques such as column chromatography (Ajayi et al., 2017), HPLC-DAD (Yimgang et al., 2025), and RP-TLC (Moody et al., 2014) will decide which components are actually separated and characterised. GC-MS technique was used by Karem et al. (2024) to identify 10 bioactive compounds in ethanol seed extract; citral and geraniol being two of those pharmacologically active compounds most important. Citral is known to have antioxidant, anti-inflammatory, and antidiabetic effects, while geraniol has been found to possess antimicrobial, anticancer, and antioxidant properties, respectively. Another study done by Bennett et al. (2022), also utilised GC-MS and found nine bioactive compounds in seeds, while there were fifteen of them in the pulp. Eze et al. (2025) carried out a comparison among various cultivars of Anambra State's *T. africana* and found differences in the levels of phenolics, flavonoids, carotenoids, and vitamin C between the cultivars which is a result of such characteristics of different cultivars. As a result, the decision of which part of the plant to use, for instance, is a matter that must be taken with consideration of the cultivar as well. Table 4, gives a summary of the main bioactive chemicals found across the various papers in this review.

Table 1. Proximate and mineral composition of *Treculia africana* seeds and pulp (ranges across reviewed studies).

Nutrient Parameter	Raw/Fresh Range	Processed Range	Source(s)
Moisture (%)	75.07-85.77	8.00-9.50	Bennett & Isaiah, 2022; Okoronkwo et al., 2020.
Crude Protein (%)	3.45-18.32	16.32-23.52	Obiakor-Okeke & Nnadi, 2014; Ijeh et al., 2011; Runsewe-Abiodun et al., 2018.
Crude Fat (%)	1.31-13.90	10.98-15.70	Ijeh et al., 2011; Obiakor-Okeke & Nnadi, 2014
Crude Fibre (%)	1.25-12.40	1.69-2.39	Runsewe-Abiodun et al., 2018; Bennett & Isaiah, 2022; Okoronkwo et al., 2020.
Ash (%)	0.35-8.68	1.36-2.54	Obiakor-Okeke & Nnadi, 2014; Bennett & Isaiah, 2022; Runsewe-Abiodun et al., 2018.
Carbohydrate (%)	1.08-80.65	65.90-69.93	Bennett & Isaiah, 2022; Obiakor-Okeke &Nnadi, 2014; Okoronkwo et al., 2020
Iron (mg/100 g)	1.10-39.50	1.74-8.00	Obiakor-Okeke & Nnadi, 2014; Godfrey et al., 2024; Okoronkwo et al., 2020; Ijeh et al., 2011.
Potassium (mg/100 g)	6.90-1941.53	582.76	Obiakor-Okeke & Nnadi, 2014; Godfrey et al., 2024; Okoronkwo et al., 2020.
Calcium (mg/100 g)	5.34-163.82	42.90	Ijeh et al., 2011; Okoronkwo et al., 2020; Godfrey et al., 2024.
Phosphorus (mg/100 g)	13.25-315.95	176.87	Obiakor-Okeke & Nnadi, 2014; Godfrey et al., 2024; Okoronkwo et al., 2020.

Table **2.** Nutritional composition of *Treculia africana* seeds compared with common sub-Saharan staple foods (per 100 g edible portion)

Food	Protein (g)	Carbohydrate (g)	Fat (g)	Fibre (g)	Iron (mg)
T. africana (seed)[a]	16.5	37.4	1.9	4.8	39.5
Maize, white (*Zea mays*)[b]	9.4	73.6	4.2	1.9	3.6
Rice, milled (*Oryza sativa*)[b]	7.0	79.9	0.5	0.4	1.7
Cowpea (*Vigna unguiculata*)[b]	23.5	60.0	1.4	4.9	5.7

[a] Godfrey et al. (2024); [b] FAO Food Composition Table for Use in Africa. Comparator values derive from a different analytical source than the *T. africana* data.

Table **3.** Anti-nutritional factors in *Treculia africana* seeds and their reduction by processing method.

Anti-nutrient	Level range (raw → processed)	Most effective reduction (method)	Source
Tannin	0.58% → 0.28% (flour); 46.65 → absent (seed)	51.72% by dehulling; eliminated by cooking/roasting	Edima-Nyah et al., 2023; Obiakor-Okeke & Nnadi, 2014.
Phytate	7.13 → 2.09 mg/100g (flour); 102.00 → absent (seed)	70.69% by dehulling; eliminated by cooking/roasting	Edima-Nyah et al., 2023; Obiakor-Okeke & Nnadi, 2014.
Saponin	11.12% → 2.23%	79.95% by dehulling	Edima-Nyah et al., 2023.
Oxalate	0.32 → 0.11 mg/100g	65.62% by dehulling	Edima-Nyah et al., 2023.
Trypsin inhibitor	13.76 → 7.82 TIU/mg	48.17% by dehulling	Edima-Nyah et al., 2023.
Alkaloid	0.91%	Reduced by processing	Okoronkwo et al., 2020.

Table **4.** Principal bioactive compounds identified from *Treculia africana* across plant parts and analytical methods.

Compound	Plant Part / Method	Reported Bioactivity	Source
Citral	Seeds (GC-MS)	Antioxidant, anti-inflammatory, antidiabetic	Kareem et al., 2024.
Geraniol	Seeds (GC-MS)	Antimicrobial, anticancer, antioxidant	Kareem et al., 2024.
Chlorogenic acid	Leaves (HPLC-DAD)	α-Glucosidase inhibition, antidiabetic	Yimgang et al., 2025.
α-Mangostin	Leaves (HPLC-DAD)	First reported in this species; antidiabetic	Yimgang et al., 2025.
Isovitexin	Leaves (column chromatography)	Antioxidant, anti-inflammatory	Ajayi et al., 2017; Akeghware et al., 2025.
Phyllocoumarin	Bark/twigs (isolation)	Antimicrobial	Ojimelukwe & Ugwuona, 2021.
Catechin	Bark/twigs (isolation)	Broad-spectrum antimicrobial	Ojimelukwe & Ugwuona, 2021.
Licoagrochalcone A	Root bark (bioassay)	Antibacterial	Moody et al., 2014.
Bergapten	Root bark (RP-TLC)	Antibacterial, coumarin derivative	Moody et al., 2014.
Steroidal saponin glycosides	Bark (phytochemical)	Anti-biofilm, gastrointestinal activity	Nugbemado et al., 2022.

3.2.2 Antimicrobial activity

The antimicrobial effects of *T. africana* extracts are among the most extensively investigated pharmacological properties of the species. Oyeyipo and Onasoga (2015) found that crude methanolic extracts of stem bark inhibited 95.24% of 21 tested microbial species, including Gram-positive, Gram-negative, and Candida species, with minimum inhibitory concentration (MIC) values of 78-156 µg/mL; catechin isolated from that study inhibited all tested microorganisms, indicating a principal active constituent. It was reported by Belay et al. (2019) that a water-based ethanolic bark extract was capable in vitro to kill some of the common gastrointestinal pathogens like Salmonella typhi, Shigella dysenteriae, Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus aureus with the minimum inhibitory concentration being 3.125 to 25 mg/mL. Nugbemado et al. (2022) studied *T. africana* stem bark extract as a possible antimicrobial resistance (AMR) modulator and their results showed that it could prevent pump efflux of the bacteria of two species Mycobacterium aurum and M. smegmatis, the ability to form biofilms was blocked by 56.70% and 59.10% respectively and a combined action between the extract and ciprofloxacin was noted against Pseudomonas aeruginosa and Proteus mirabilis. These findings present *T. africana* as a plant reservoir of molecules which could assist in fighting the world-wide threat of microbial resistance. Oyeyipo and Onasoga (2015) demonstrated that even after using different solvents (ethanol, acetone, water) and temperatures (4°C, 100°C), the root and stem bark extracts retained their antibacterial activities and the results imply the thermally stable nature of the compounds. The following section presents a summary of the antioxidant and antidiabetic potential of *T. africana*.

3.2.3 Antioxidant and antidiabetic activities

The total antioxidant capacity, DPPH radical scavenging, ferric reducing antioxidant power (FRAP), nitric oxide inhibition, and metal-chelating assays were investigated by Ajayi et al. (2017) as methods for determining the antioxidant potential of leaves of *T. africana*. They found that all five methods revealed strong to moderate antioxidant activities of the tested samples. After bioassay-guided fractionation, isovitexin (apigenin-6-C-glucopyranoside) and 2, 3-dihydrokaempferol-3-O-glucopyranoside were isolated and these compounds were, apparently, reported for the first time in this species by Kareem et al. (2024), who also measured their DPPH free-radical scavenging abilities to be dose-dependent, while the tumour-reducing effect was very substantial with 89.67% as indicated in a crown gall test. The ability of *T. africana* to combat diabetes was investigated from ethnopharmacology and experimental points of view simultaneously. Yimgang et al. (2025) observed in vitro antidiabetic effects in leaf extracts and further confirmed its major constituents chlorogenic acid and α-mangostin, in particular α-mangostin being a new find for this species. Eleazu et al. (2018) reported that administration of alcohol (ethanol) extract of cooked *T. africana* seeds improved the capacity to tolerate sugar and the levels of various lipids for healthy albino rats when they were given orally in the form of glucose. Ogbonnia et al. (2012) tested root bark extract in alloxan-diabetic rat models in combination with Tapinanthus globiferus and found that the mixture produced significant postprandial glycaemic reductions but failed to reduce alloxan-induced diabetic blood glucose levels, a divergent outcome that illustrates the context-sensitivity of anti-hyperglycaemic effects and the importance of experimental standardisation. Mohammed & Tajuddeen (2022), reviewing antidiabetic compounds from African medicinal plants for 2015-2020, confirmed that despite promising in vitro and in vivo evidence, no compound from African ethnomedicinal plants had progressed to clinical trial investigation-a finding that applies with particular force to *T. africana*.

3.3 Drivers of underutilisation in sub-Saharan Africa

3.3.1 Socioeconomic and cultural dimensions

The limited use of *T. africana* in mainstream food systems arises not from any single cause but from the interaction of consumer perceptions, unsupportive agricultural policy, and inadequate market infrastructure. Indigenous crops across sub-Saharan Africa are frequently perceived by consumers as foods of the rural poor, a perception that lowers their desirability in urban markets and discourages commercial investment (Ndlovu et al., 2024). This phenomenon has been recorded for *T. africana* in Nigeria. Okonkwo & Ubani (2012) observed that the tree is mostly grown in home gardens and secondary forests, with women as the main processors, who have little access to equipment or market information; the lack of formal HACCP-compliant processing methods leads to quality fluctuations that undermine market trust. Uluocha et al. (2016) reported that in Okigwe Agricultural Zone, Imo State, much of *T. africana* trading occurred in small-scale weekly markets with incomes between ₦2,500 and ₦4,500, and identified labour, transportation, and local taxation as major constraints. Poor storage facilities, seasonal supply concentration, and undocumented value chains characterise NTFP marketing in Nigeria more generally (Okunlola et al., 2025). Despite these constraints, *T. africana* already sustains measurable economic activity: regular weekly trading incomes have been documented in Imo State, Nigeria (Uluocha et al. (2016), while the trade in *T. africana* and allied tree products was found to be economically significant in São Tomé and Príncipe (Schimetka & Ingram, 2024), together indicating a functioning value chain on which formal development could build. Schimetka & Ingram (2024) also reported that weak statutory governance and the absence of customary governance arrangements leave the sustainability of harvesting at risk, especially as NTFPs are integrated into forest landscape restoration initiatives without suitable governance frameworks. It should be noted that this socioeconomic evidence base is concentrated in Nigeria, with only limited documentation from other range states such as Cameroon, the Democratic Republic of Congo, Ghana, and São Tomé and Príncipe. The barriers described here are therefore best understood as illustrative of a broader sub-Saharan pattern rather than as uniformly established across the region (Leakey et al. 2022).

3.3.2 Post-harvest losses, processing infrastructure, and value chain gaps

Post-harvest loss is among the most technically tractable but practically persistent barriers to *T. africana* utilisation. The fresh seed's high moisture content (75-85% in flesh portions), Bennett et al. (2022) renders it highly perishable, and the absence of cold chain infrastructure in rural producing areas means that significant proportions of the harvest are lost before reaching markets. Processing to reduce moisture, through roasting or drying, extends shelf life considerably Runsewe-Abiodun et al. (2018), but the labour intensity of traditional processing-manually dehulling seeds after prolonged cooking-limits both the volume that can be processed per household and the consistency of product quality. A systematic review of 44 research articles on African breadfruit was conducted by Umezurike (2019). He observed that only 4.05% of studies addressed commercialisation, and that while prototype seed dehulling machines had been developed, none had been refined to commercial readiness through entrepreneurial investment. This is consistent with the structural critique of Chivenge et al. (2015) and Popoola et al. (2022), both of whom argued that NUS face a research investment deficit that creates self-reinforcing underdevelopment: the absence of agronomic, post-harvest, and value chain data makes the commercial case for investment difficult to construct. Leakey et al. (2022), reviewing three decades of indigenous tree domestication in Africa, identified the testing of putative cultivars, participatory domestication, and selection of elite trees as the most persistently under-researched areas across all African NUS, findings directly applicable to *T. africana*, for which none of these activities has been reported. Omotayo and Aremu (2020) reached a similar conclusion in their study of ten African indigenous fruit trees, arguing that concerted multidisciplinary research involving plant breeders, molecular biologists, food scientists, and horticulturists is necessary for transformation.

3.3.3 Climate, agronomic research deficit, and geographic distribution

Treculia africana is one of the most widely distributed tree species throughout the humid forest zones of West and Central Africa, although its distribution has not been formally mapped at a resolution suitable for either conservation or breeding programme planning. The tree's reliance on humid forest conditions means it could be threatened as climate becomes drier and more variable across the forest-savanna transition zones of West Africa (Van Zonneveld et al., 2023). However, no climate-niche modelling has been conducted for the species to date. Devkota et al. (2025) showed that NUS in general have higher water productivity and greater heat tolerance than the major staples grown in drylands. Even so, the agronomic performance of *T. africana* under different rainfall and temperature regimes has not been systematically characterised, meaning there are currently no environmental adaptation data to inform selection criteria for future breeding programmes. This very absence makes *T. africana* a priority species for inclusion in research programmes focused on climate-resilient tree systems, given its perennial habit, low external input requirements, and natural adaptation to humid tropical conditions. Nkwonta et al. (2023), reviewing NUS for food security in Nigeria and Uganda, identified *T. africana* as a crop urgently in need of systematic research, noting that political, sociocultural, and infrastructural factors have jointly prevented commercialisation. Shembe et al. (2023) documented the same pattern in South Africa, where reduction in indigenous plant food consumption in favour of ultra-processed foods is most pronounced among younger consumers, and where social perception of indigenous foods as 'poverty foods' obstructs intergenerational knowledge transfer.

3.3.4 Food product development as a bridge to commercialisation

In the absence of formal breeding programmes, a parallel stream of research has explored the potential of *T. africana* as a functional ingredient in composite food formulations. Okenyi (2022) demonstrated that blends of boiled *T. africana* and fermented sorghum flour could produce nutritionally superior porridge products containing 14.24-15.75% crude protein with acceptable sensory properties compared to a commercial control. Ihemeje et al. (2023) found that inclusion of African breadfruit flour at 15% in wheat-based snacks produced the most sensorily acceptable product, improving protein, ash, and mineral content without compromising taste, texture, or colour ratings. These product development studies collectively establish proof of concept for *T. africana*'s functional versatility across porridges, snack bars, composite flours, and ready-to-cook preparations, but they share a common limitation: they remain laboratory-scale, lacking pilot-scale validation, population-level consumer acceptance studies, shelf-life assessment under realistic storage conditions, and economic viability analysis across the value chain. Umezurike (2019) identified globally viable market opportunities for *T. africana* seed oil as a domestic and industrial oil, seed meal for confectionery, and flour for diet therapy, and argued that purpose-driven translational research is essential to realise these opportunities. Without that translational step, the accumulated product development literature risks becoming a repository of unrealised potential rather than a foundation for commercial scale-up.

3.4 Genetic characterisation and biotechnological prospects

3.4.1 Current state of genetic knowledge for *Treculia africana*

Perhaps the most striking lacuna in the *T. africana* literature is the near-complete absence of genetic characterisation data. No published study, to the authors' knowledge, has conducted molecular marker-based diversity assessment, germplasm profiling, or population genetics analysis for the species. The five-cultivar phenotypic comparison by Eze et al. (2025) in Anambra State, Nigeria, documenting variation in bioactive compound profiles across cultivars, represents the closest approximation to diversity characterisation available, but this work employed spectrophotometric and chromatographic phenotyping rather than molecular tools. The absence of a reference genome, molecular marker datasets, or population structure analysis places *T. africana* behind nearly every other tree crop of comparable food importance in tropical Africa. This stands in stark contrast to its congener *Artocarpus altilis* (Pacific breadfruit), which has received a draft genome assembly Sahu et al. (2020), microsatellite-based germplasm characterisation across 349 accessions in Oceania and the Caribbean Zerega et al. (2015), next-generation sequencing-based SSR marker development De Bellis et al. (2016), transcriptome screens for positive selection in domesticated varieties Laricchia et al. (2018), and studies of the molecular mechanisms of dwarfism relevant to harvest management (Zhou & Underhill, 2021). This body of work reflects decades of investment in a species that, while botanically related to *T. africana*, is distributed across the Pacific and Caribbean rather than Africa and does not face the same food security context. The contrast illustrates the depth of the research investment gap that *T. africana* confronts.

3.4.2 Applicable biotechnological tools and lessons from comparable species

The molecular tools required to begin systematic genetic improvement of *T. africana* are well established and increasingly accessible. Bunjkar et al. (2024) reviewed the application of molecular markers-RFLPs, RAPDs, AFLPs, SSRs, and SNPs-in genetic diversity assessment and germplasm characterisation, demonstrating their utility for identifying genetic subpopulations, selecting diverse parents for crossing, and enabling marker-assisted selection (MAS) for target traits such as elevated protein content, reduced anti-nutritional factors, and yield. Ramesh et al. (2020) noted that integrating next-generation sequencing with association mapping has substantially reduced the cost and time required to characterise genetic variation in undercharacterised crop species. Beyond marker-based diversity work, the assembled *Artocarpus altilis* genome (Sahu et al. 2020) offers a usable reference scaffold against which *T. africana* sequence data could be aligned, accelerating gene discovery. Tissue culture and micropropagation would permit rapid multiplication of elite accessions once identified, while genome editing and metabolic-engineering approaches offer longer-term routes to enhancing nutritional traits and bioactive-compound yield. These advances mean that initiating a molecular characterisation programme for *T. africana* is now considerably more feasible than it would have been a decade ago. The value of SSR and RAPD markers in the genetic diversity analysis of African leafy vegetables, a crop group that shares with *T. africana* scattered wild populations, scant domestication, and the unavailability of formal germplasm collections (Omondi et al. 2016). The cassava genomics case of Ghana by Adjebeng-Danquah et al. (2020), offers a methodologically instructive example; they genotyped 89 cassava accessions using 35 SSR markers and revealed two subpopulations with an average polymorphic information content (PIC) of 0.45, sufficient resolving power to select breeding parents with confidence. The combined use of morphological, physiological and molecular markers to screen crop genotypes for adaptation, as applied to rice on problematic soils Saheed et al. (2026), illustrates the kind of integrated approach that could be extended to *T. africana* germplasm. Analogous work for *T. africana* would require, first, organised germplasm collection throughout the species' distribution range, followed by marker development and diversity evaluation to identify the most valuable conservation and breeding accessions. Popoola et al. (2022) argued that advanced omics, speed breeding, and genome editing should be considered fundamental, not optional, if orphan legumes are to significantly enhance food security within the constraints set by population growth and climate change in SSA. Vilakazi et al. (2025) concurred, framing the neglect of legume mainstreaming, underdeveloped value chains, limited market demand, and the absence of genetic improvement as mutually reinforcing barriers that can be overcome only through coordinated policy change, international cooperation, and targeted breeding.

Recommendations

The body of literature reviewed here is characterised by several patterns that, considered together, define the intellectual boundaries of current knowledge and the directions in which future work is most urgently needed. The most immediate and consequential gap is the complete absence of molecular genetic data for *T. africana*. No population-level diversity study, germplasm collection strategy, marker-assisted breeding programme, or genome sequence exists for this species. This is not a modest deficiency in an otherwise well-developed research landscape; it is the foundational absence that prevents any systematic crop improvement effort. Without knowledge of the genetic diversity extant in natural populations, it is impossible to identify elite accessions for domestication, design crossing strategies, assess adaptation to varied ecological conditions, or protect the species' genetic resources from erosion as forest cover declines. Addressing this will require deliberate, externally funded research partnerships between African universities, national agricultural research systems, and international institutions.

Second, while the compositional literature is broad, it is methodologically fragmented. Reported nutrient values span ranges so wide-crude protein from 3.45% to 23.52%, iron from 1.10 to 39.50 mg/100g-that the data as a whole cannot support confident nutritional recommendations. This variation is partly real, reflecting genuine ecotypic and processing-related differences, but also partly methodological, reflecting inconsistencies in sample preparation and analytical protocols. The field requires standardised, multi-location studies using common protocols and well-characterised ecotypes to produce reference data that could underpin food composition tables, dietary guidelines, or product specifications.

Third, the pharmacological literature, while offering provocative preliminary evidence for antidiabetic, antimicrobial, and antioxidant activities, has not advanced beyond in vitro and rodent-model investigations. Mohammed & Tajuddeen (2022) observed that this characterises the entire field of African ethnopharmacology, not *T. africana* alone. The absence of human clinical data means no health claim for *T. africana* can be substantiated to the standards required for pharmaceutical development or functional food certification. The compound α-mangostin, identified for the first time in *T. africana* leaves by Yimgang et al. (2025), and the chalcone licoagrochalcone A Moody et al. (2014) study, represent candidates with sufficient mechanistic specificity to warrant isolation, structure-activity studies, and pre-clinical progression, but this work remains to be undertaken.

Fourth, the socioeconomic and value chain literature is geographically concentrated in south-eastern Nigeria, with limited representation of *T. africana*-growing communities in Cameroon, the Democratic Republic of Congo, Central African Republic, or East Africa. Because structural barriers to utilisation are context-specific, generalisations drawn entirely from Nigeria may not translate to the design of effective interventions elsewhere.

Finally, there is a structural disconnect between the food product development literature, which demonstrates considerable formulation creativity, and the commercial development and policy literature, which is almost entirely absent. The scientific inputs for transformation exist in scattered form but have never been assembled into an integrated development pathway (Leakey et al. 2022). This is partly a scientific problem-requiring translational research on processing technology, value chain governance, and consumer behaviour-and partly a political one, requiring recognition of *T. africana* in national agricultural research plans and biodiversity strategies.

Conclusion

Treculia africana represents one of sub-Saharan Africa's most consequential cases of unrealised nutritional potential: a species of genuine nutritional richness, pharmacological breadth, and ecological versatility, producing high-energy, protein-rich seeds annually from a tree requiring no external inputs, tolerant of humid tropical conditions, and already embedded in the culinary and ethnomedicinal traditions of millions across the continent's forest belt. That formal agricultural science, policy, and commercial investment have largely ignored it reflects structural biases historically favouring introduced commodities over indigenous crops.

Molecular characterisation of *T. africana*'s genetic diversity is the single most important scientific priority; it would unlock breeding potential, identify elite accessions for domestication, and illuminate environmental adaptation. Standardised multi-environment nutritional trials are equally needed to resolve compositional variance, and the pharmacological pipeline requires targeted isolation, mechanism-of-action studies, and clinical evidence before therapeutic claims can be responsibly advanced. At the food-systems level, progress depends on resolving post-harvest bottlenecks; mechanised seed processing exists in prototype form, and scaling it is an engineering and entrepreneurial challenge suited to development investment. The baobab trajectory-from traditional use to international market recognition through applied research and value chain development (Meinhold et al. 2022)-offers a plausible template. Integrating ecologically adapted, culturally familiar species like *T. africana* into diversified food systems is not an alternative to mainstream agricultural development but a necessary complement, and a strategic contribution to climate-resilient food production. The scientific case is already substantial; what remains is the institutional commitment to act on it.

Acknowledgments
The authors are grateful to the National Horticultural Research Institute, Ibadan, Nigeria, for institutional support during the preparation of this review. No external funding was received for this study.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests
The authors declare that they have no competing financial or non-financial interests in relation to the work described.

Conflict of Interest
The authors declare that they have no conflict of interest.

Author contributions
Olagunju Y.O.: Conceptualisation, Methodology, Literature collection, Writing, original draft, Visualisation. Fasuan T.M.: Writing, review & editing, Supervision. Oladunjoye M.T.: Literature collection, Documentation support, Writing, review & editing. All authors read and approved the final manuscript.

REFERENCES

Aboagye, R. G., Seidu, A. A., Ahinkorah, B. O., Arthur-Holmes, F., Cadri, A., Dadzie, L. K., Hagan, J. E., Jr., Eyawo, O., & Yaya, S. (2021). Dietary diversity and undernutrition in children aged 6-23 months in sub-Saharan Africa. *Nutrients*, *13*(10), 3431. https://doi.org/10.3390/nu13103431

Adjebeng-Danquah, J., Manu-Aduening, J., Asante, I. K., & Agyare, R. Y. (2020). Genetic diversity and population structure analysis of Ghanaian and exotic cassava accessions using simple sequence repeat (SSR) markers. *Heliyon*, *6*(1), e03154. https://doi.org/10.1016/j.heliyon.2019.e03154

Ajayi, O. S., Aderogba, M. A., Obuotor, E. M., & Majinda, R. R. T. (2017). Antioxidant activities of the extracts and isolated compounds from Treculia africana (Decne) leaf. *Nigerian Journal of Natural Products and Medicine*, *21*, 32–38.

Akeghware, O., Avwioroko, O. J., Anigboro, A. A., & Tonukari, N. J. (2025). Comparative bioactive constituents and antioxidant capacity of Tetrapleura tetraptera aqueous, ethanolic and methanolic fruit extracts. Journal of Biological Research and Biotechnology, 23(3). https://doi.org/10.4314/br.v23i3.7

Belay, S., Assefa, A., & Tedila, H. (2019). A review on medicinal plants against some human pathogenic bacteria in South East Ethiopia. *Journal of Biology, Agriculture and Healthcare*, *9*(19), 16–26. https://doi.org/10.7176/JBAH/9-19-03

Bennett, V., & Isaiah, T. D. (2022). Proximate, nutritional and phytochemical analysis of Treculia africana (African breadfruit) Decne in South-south, Nigeria. *World Journal of Innovative Research*, *12*(4), 19–23. https://doi.org/10.31871/WJIR.12.4.10

Bjornlund, V., Bjornlund, H., & van Rooyen, A. (2022). Why food insecurity persists in sub-Saharan Africa: a review of existing evidence. *Food Security*, *14*(4), 845–864. https://doi.org/10.1007/s12571-022-01256-1

Bunjkar, A., Walia, P., & Sandal, S. S. (2024). Unlocking genetic diversity and germplasm characterization with molecular markers: strategies for crop improvement. *Journal of Advances in Biology & Biotechnology*, *27*(6), 160–173. https://doi.org/10.9734/JABB/2024/v27i6873

Chivenge, P., Mabhaudhi, T., Modi, A. T., & Mafongoya, P. (2015). 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*, *12*(6), 5685–5711. https://doi.org/10.3390/ijerph120605685

De Bellis, F., Malapa, R., Kagy, V., Lebegin, S., Billot, C., & Labouisse, J.-P. (2016). New development and validation of 50 SSR markers in breadfruit (Artocarpus altilis, Moraceae) by next-

generation sequencing. *Applications in Plant Sciences*, *4*(8), 1600021. https://doi.org/10.3732/apps.1600021
Devkota, K. P., Devkota, M., Mabhaudhi, T., Nangia, V., Attaher, S., Boroto, R. J., Timsina, J., & Siddique, K. H. M. (2025). A blueprint for building resilience and food security in MENA and SSA drylands: diversifying agriculture with neglected and underutilized species. *Food and Energy Security*, *14*(1), e70046. https://doi.org/10.1002/fes3.70046
Edima-Nyah, A. P., Ntukidem, V. E., Ekanem, M. C., Ojimelukwe, P. C., & Nwabueze, T. U. (2023). Effect of processing and substitution levels of Ukwa (Treculia africana) on the anti-nutrient factors, in-vitro starch and protein digestibility and total essential amino-acid content of snack bars. *Frontiers in Sustainable Food Systems*, *6*, 1071821. https://doi.org/10.3389/fsufs.2022.1071821
Eleazu, K., Maduabuchi, P., & Eleazu, C. (2018). Effect of ethanol extract of boiled breadfruit (Treculia africana) seed on the oral glucose tolerance, lipid profile, and body weight of normoglycemic albino rats. *Food Science & Nutrition*, *6*(4), 904–911. https://doi.org/10.1002/fsn3.620
Eze, H. N., Afam-Ezeaku, A., & Eziamaka, C. (2025). Assessment of bioactive compounds in five breadfruit (Treculia africana) cultivars in Anambra State, Nigeria. *Newport International Journal of Biological and Applied Sciences*, *6*(3), 40–44. https://doi.org/10.59298/NIJBAS/2025/6.3.40440000
Food and Agriculture Organization. (2012). *West African food composition table.*
Godfrey, E. O., Ejike, O. O., Ojoniko, A. W., Esther, I. I., Faith, O., Ugbedeojo, A. A., & Bilkisu, A. I. (2024). Evaluating the nutritional and chemical composition of Treculia africana and Vigna subterranea L. seeds collected from Kogi State, Nigeria. *Jordan Journal of Pharmaceutical Sciences*, *17*(4), 767–782. https://doi.org/10.35516/jjps.v17i4.2480
Ihemeje, A., Akujobi, I., & Ofoegbu, D. (2023). Nutrient and organoleptic assessment of snacks produced from wheat and African breadfruit (Treculia africana). *Journal of Agriculture and Food Sciences*, *20*(2), 155–171. https://doi.org/10.4314/jafs.v20i2.10
Ijeh, I., Ejike, C. E., Nkwonta, O. M., & Njoku, B. C. (2011). Effect of traditional processing techniques on the nutritional and phytochemical composition of African bread-fruit (Treculia africana) seeds. *Journal of Applied Sciences and Environmental Management*, *14*(4), 169–173. https://doi.org/10.4314/jasem.v14i4.63314
Kareem, K. O., Holdbrooke, S., Aina, O. O., Bamgbose, D. J., Ochuko, C., Olunaike, G., Ojuko, F. N., & Otun, A. A. (2024). Phytochemical and GC-MS profiling of ethanol extract of African breadfruit (Treculia africana Decne) seeds. *Discover Plants*, *1*, 47. https://doi.org/10.1007/s44372-024-00050-x
Laricchia, K. M., Johnson, M. G., Ragone, D., Williams, E. W., Zerega, N. J. C., & Wickett, N. J. (2018). A transcriptome screen for positive selection in domesticated breadfruit and its wild relatives (Artocarpus spp.). *American Journal of Botany*, *105*(5), 915–926. https://doi.org/10.1002/ajb2.1095
Leakey, R. R. B., Tientcheu Avana, M.-L., Awazi, N. P., Assogbadjo, A. E., Mabhaudhi, T., Hendre, P. S., Degrande, A., Hlahla, S., & Manda, L. (2022). The future of food: domestication and commercialization of indigenous food crops in Africa over the third decade (2012-2021). *Sustainability*, *14*(4), 2355. https://doi.org/10.3390/su14042355
Meinhold, K., Dumenu, W. K., & Darr, D. (2022). Connecting rural non-timber forest product collectors to global markets: the case of baobab (Adansonia digitata L.). *Forest Policy and Economics*, *134*, 102628. https://doi.org/10.1016/j.forpol.2021.102628
Mohammed, A., & Tajuddeen, N. (2022). Antidiabetic compounds from medicinal plants traditionally used for the treatment of diabetes in Africa: a review update (2015-2020). *South African Journal of Botany*, *146*, 585–602. https://doi.org/10.1016/j.sajb.2021.11.018
Moody, J., Fukushi, Y., Tahara, S., & Olatunji, B. (2014). Bioactivity-monitored isolation of antibacterial principles of Treculia africana stem bark. *Planta Medica*, *80*(16), LP27. https://doi.org/10.1055/s-0034-1395083
Ndlovu, M., Scheelbeek, P., Ngidi, M., & Mabhaudhi, T. (2024). Underutilized crops for diverse, resilient and healthy agri-food systems: a systematic review of sub-Saharan Africa. *Frontiers in Sustainable Food Systems*, *8*, 1498402. https://doi.org/10.3389/fsufs.2024.1498402
Nkwonta, C. G., Auma, C. I., & Gong, Y. (2023). Underutilised food crops for improving food security and nutrition health in Nigeria and Uganda-a review. *Frontiers in Sustainable Food Systems*, *7*, 1126020. https://doi.org/10.3389/fsufs.2023.1126020
Nugbemado, I. N., Danquah, C. A., & Ofori, M. (2022). Hydroethanolic stem bark extract of Treculia africana Decne (Moraceae) shows antimicrobial resistance modulatory effects. *South African Journal of Botany*, *148*, 546–551. https://doi.org/10.1016/j.sajb.2022.05.031
Nwaigwe, J. O., & Adejumo, B. A. (2015). Qualities of African breadfruit (Treculia africana) seed flour as influenced by thermal processing methods and duration. *International Journal of Technology Enhancements and Emerging Engineering Research*, *3*(4), 102–107.
Obiakor-Okeke, P. N., & Nnadi, C. C. (2014). The effect of different processing methods on the nutrient and anti-nutrient composition of African breadfruit (Treculia africana). *International Journal of Nutrition and Food Sciences*, *3*(4), 333–339. https://doi.org/10.11648/j.ijnfs.20140304.25
Ogbonnia, S. O., Anyika, E. N., Mbaka, G. O., Anyakora, C., Igbokwe, N. H., & Adeleke, F. (2012). Antihyperglycaemic and antihyperlipidaemic effects of aqueous ethanol extract of Tapinanthus globiferus leaves and Treculia africana root bark. *Agriculture and Biology Journal of North America*, *3*(6), 237–246. https://doi.org/10.5251/abjna.2012.3.6.237.246
Ojimelukwe, P. C., & Ugwuona, F. U. (2021). The traditional and medicinal use of African breadfruit (Treculia africana Decne): an underutilized ethnic food of the Ibo tribe of South East, Nigeria. *Journal of Ethnic Foods*, *8*, 21. https://doi.org/10.1186/s42779-021-00097-1
Okenyi, C. A. (2022). Comparative evaluation of the microflora and biochemical constituents of sorghum-African breadfruit blends for complementary foods. *Stamford Journal of Microbiology*, *12*(1), 8–14. https://doi.org/10.3329/sjm.v12i1.63337
Okonkwo, E. U., & Ubani, O. N. (2012). Application of HACCP to post-harvest processing of African breadfruit Treculia africana Decne in Nigeria. *African Journal of Agricultural Research*, *7*(32), 4536–4542. https://doi.org/10.5897/AJAR11.392
Okoronkwo, K. A., Nwagbaoso, O. C., & Okoronkwo, B. C. (2020). Chemical and amino acid composition of African breadfruit (Treculia africana). *INOSR Applied Sciences*, *6*(1), 1–10.
Okunlola, M. I., Onyekwelu, J. C., Oluwajuwon, T. V., Adeniyi, A. O., & Ojo, M. O. (2025). Marketing of non-timber forest products in Nigeria: a case of Akure metropolis. *Environment, Development and Sustainability*, *27*(3), 7595–7614. https://doi.org/10.1007/s10668-023-04208-7
Omondi, E. O., Debener, T., Linde, M., Abukutsa-Onyango, M., Dinssa, F. F., & Winkelmann, T. (2016). Molecular markers for genetic diversity studies in African leafy vegetables. *Advances in Bioscience and Biotechnology*, *7*(3), 188–197. https://doi.org/10.4236/abb.2016.73017
Omotayo, A. O., & Aremu, A. O. (2020). Underutilized African indigenous fruit trees and food-nutrition security: opportunities, challenges, and prospects. *Food and Energy Security*, *9*(3), e220. https://doi.org/10.1002/fes3.220
Onyenibe, N. S., Oluwafunmilola, J. O., & Nwawuba, S. U. (2019). The effect of processing methods on the nutritional quality of African breadfruits (Treculia africana) seeds. *Indonesian Food and Nutrition Progress*, *16*(2), 60–66. https://doi.org/10.22146/ifnp.45545
Oyeyipo, O. O., & Onasoga, M. F. (2015). Antimicrobial potency of hydro, acetone and ethanolic extracts of Treculia africana Decne root and stem bark. *Journal of Applied Sciences and Environmental Management*, *19*(4), 697–703. https://doi.org/10.4314/jasem.v19i4.17
Popoola, J. O., Aworunse, O. S., Ojuederie, O. B., Adewale, B. D., Ajani, O. C., Oyatomi, O. A., Eruemulor, D. I., Adegboyega, T. T., & Obembe, O. O. (2022). The exploitation of orphan legumes for food, income, and nutrition security in Sub-Saharan Africa. *Frontiers in Plant Science*, *13*, 782140. https://doi.org/10.3389/fpls.2022.782140
Ramesh, P., Mallikarjuna, G., Sameena, S., Kumar, A., Gurulakshmi, K., Reddy, B. V., Reddy, P. C. O., & Sekhar, A. C. (2020).

Advancements in molecular marker technologies and their applications in diversity studies. *Journal of Biosciences*, *45*, 123. https://doi.org/10.1007/s12038-020-00089-4

Runsewe-Abiodun, T. I., Aliyu, A. O., & Oritogun, K. S. (2018). Evaluation of nutrients and anti-nutrient properties of traditionally prepared Treculia africana Decne (bread fruit diet and toasted seeds). *African Journal of Food, Agriculture, Nutrition and Development*, *18*(2), 13272–13286. https://doi.org/10.18697/ajfand.82.16630

Saheed, M., Konyeme, T. E., & Ikhajiagbe, B. (2026). Screening of rice genotypes for adaptability to ferruginous ultisol using morphological, physiological and molecular markers. Journal of Biological Research and Biotechnology, 24(1), 445–453. https://doi.org/10.4314/br.v24i1.18

Sahu, S. K., Liu, M., Yssel, A., Kariba, R., Muthemba, S., Jiang, S., Song, B., Hendre, P. S., Muchugi, A., Jamnadass, R., Kao, S.-M., Featherston, J., Zerega, N. J. C., Xu, X., Yang, H., Van Deynze, A., Van de Peer, Y., Liu, X., & Liu, H. (2020). Draft genomes of two Artocarpus plants, jackfruit (A. heterophyllus) and breadfruit (A. altilis). *Genes*, *11*(1), 27. https://doi.org/10.3390/genes11010027

Samtiya, M., Aluko, R. E., & Dhewa, T. (2020). Plant food anti-nutritional factors and their reduction strategies: an overview. *Food Production, Processing and Nutrition*, *2*(1), 6. https://doi.org/10.1186/s43014-020-0020-5

Schimetka, L. R., & Ingram, V. J. (2024). Leveraging the value chain-landscape governance nexus for non-wood forest products and tropical forest restoration. *Forest Policy and Economics*, *169*, 103340. https://doi.org/10.1016/j.forpol.2024.103340

Shembe, P. S., Ngobese, N. Z., Siwela, M., & Kolanisi, U. (2023). The potential repositioning of South African underutilised plants for food and nutrition security: a scoping review. *Heliyon*, *9*(6), e17232. https://doi.org/10.1016/j.heliyon.2023.e17232

Uluocha, O. B., Udeagha, A. U., Udofia, S. I., & Duruigbo, C. I. (2016). Socio-economic contribution of African breadfruit (Treculia africana Decne) toward sustainable livelihood in eastern Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, *8*(2), 40–57.

Umezurike, A. C. (2019). Breadfruit research and opportunities for future commercial development. *International Journal of Horticulture, Agriculture and Food Science*, *3*(4), 165–172. https://doi.org/10.22161/ijhaf.3.4.2

Van Zonneveld, M., Kindt, R., McMullin, S., Achigan-Dako, E. G., N'Danikou, S., Hsieh, W.-h., Lin, Y.-r., & Dawson, I. K. (2023). Forgotten food crops in sub-Saharan Africa for healthy diets in a changing climate. *Proceedings of the National Academy of Sciences*, *120*(14), e2205794120. https://doi.org/10.1073/pnas.2205794120

Vilakazi, B., Mafongoya, P. L., Odindo, A. O., & Phophi, M. M. (2025). The role of neglected grain legumes in food and nutrition security and human health. *Sustainability*, *17*(1), 350. https://doi.org/10.3390/su17010350

Yimgang, V. L., Pangrazzi, E., Djeujo, F. M., Dongmo Melogmo, Y. K., Tchinda Taghu, F. L., Toghueo Kouipou, R. M., Fekam Boyom, F., & Froldi, G. (2025). In vitro antidiabetic activity of Treculia africana leaf extracts: identification of chlorogenic acid and α-mangostin. *Journal of Pharmacy and Pharmacology*, *77*(4), 501–510. https://doi.org/10.1093/jpp/rgaf003

Zerega, N., Wiesner-Hanks, T., Ragone, D., Irish, B., Scheffler, B., Simpson, S., & Zee, F. (2015). Diversity in the breadfruit complex (Artocarpus, Moraceae): genetic characterization of critical germplasm. *Tree Genetics & Genomes*, *11*, 4. https://doi.org/10.1007/s11295-014-0824-z

Zhou, Y., & Underhill, S. J. R. (2021). Differential transcription pathways associated with rootstock-induced dwarfing in breadfruit (Artocarpus altilis) scions. *BMC Plant Biology*, *21*, 261. https://doi.org/10.1186/s12870-021-03013-6