International Multidisciplinary Journal of Emerging Technologies and Applications (IMJETA)
Vol. 1, No. 5, pp. 40-82, August 2026
Received August 06, 2026; Revised August 15, 2026; Accepted August 26, 2026
Published August 31, 2026

Contribution of Gnetum spp to Food Security, Public Health, and Sustainable Development in Gabon: An Integrative Review

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Abstract. Non-timber forest products (NTFPs) play a fundamental role in food security, public health, and the socio-economic equilibrium of rural and peri-urban households in Central Africa. Among these resources, Gnetum africanum Welw. and Gnetum buchholzianum Engl. (locally known in Gabon as Nkumu) stand out as multi-purpose lianas whose edible leaves are highly valued for their nutritional, medicinal, and economic qualities. This integrative review synthesizes multidisciplinary scientific evidence and institutional reports concerning Gnetum spp. in Gabon and the wider Congo Basin. Grounded in a methodical literature screening process inspired by the PRISMA 2020 framework (covering the period 1990–2025), this study analyzes: (1) the botanical, ecological, and geographical distribution of the two species; (2) their detailed nutritional composition, bioactive phytochemicals, and anti-nutritional factors; (3) the impact of traditional and thermal processing methods on nutrient retention and digestibility; (4) traditional ethnobotanical uses and emerging pharmacological applications; (5) the structure, actor network, and economic dynamics of the supply chain; and (6) their contribution to the United Nations Sustainable Development Goals (SDGs). The findings demonstrate that Gnetum spp. leaves represent a rich source of plant proteins, dietary fibers, essential minerals (calcium, iron, potassium, magnesium), and bio-active secondary metabolites (polynols, flavonoids, stilbenes such as gnetol and gnetins). Traditional processing techniques (blanching, steaming, boiling) significantly reduce anti-nutritional compounds (oxalates, phytates, tannins) and enhance nutrient bioavailability, although prolonged heat treatment can deplete thermolabile vitamins. Economically, the Gnetum supply chain constitutes a vital source of income and a key vector for women's empowerment in Gabon. However, the sector faces severe sustainability bottlenecks, including total reliance on wild harvesting, destructive collection practices, habitat loss, post-harvest perishability, lack of quality standardization, and slow progress in domestication and agroforestry integration. To transition from informal exploitation to a sustainable and bioeconomic value chain, this paper proposes an integrated policy framework prioritizing participatory domestication,

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sustainable harvesting guidelines, post-harvest technological innovation, gender-inclusive financing, and institutional recognition of Gnetum spp. within national food security and forestry strategies.

Keywords: Gnetum spp; Non-timber Forest Products; Food Security; Public Health; Sustainable Development.

1. Introduction

Food and nutrition security constitutes one of the major challenges of the 21st century. Despite the progress achieved over recent decades, hundreds of millions of people remain confronted with hunger, malnutrition, and micronutrient deficiencies, particularly in low- and middle-income countries (Food and Agriculture Organization of the United Nations [FAO] et al., 2024). This situation is aggravated by climate change, biodiversity erosion, demographic growth, rapid urbanization, and economic crises, which compromise food availability, accessibility, stability, and biological utilization (FAO et al., 2024; IPCC, 2023). In this context, the diversification of diets based on local food resources represents a priority strategy to strengthen the resilience of food systems and improve the nutritional quality of populations (High Level Panel of Experts on Food Security and Nutrition [HLPE], 2020).

Non-timber forest products (NTFPs) play an essential role in the food systems of tropical regions. They provide foods rich in protein, vitamins, minerals, dietary fiber, and bioactive compounds, while generating substantial income for millions of rural households (Shackleton, Shackleton, & Shanley, 2011; Sunderland, Powell, Ickowitz, et al., 2013). In Central Africa, these resources also play a fundamental role in the preservation of traditional knowledge, poverty reduction, the economic empowerment of women, and the sustainable management of forest ecosystems (Tabuna, 1999; Ingram, Ndumbe, Ewane, & Awono, 2012; Loubelo, 2012). Their contribution thus extends beyond the sole framework of food security to align with the economic, social, and environmental dimensions of sustainable development (Powell et al., 2015).

Among the most emblematic NTFPs of the Congo Basin, Gnetum africanum and Gnetum buchholzianum, commercialized in Gabon under the name Nkumu, occupy a special place (Mialoundama, 1993; Sunderland et al., 1999). These climbing species are widely consumed as leafy vegetables and constitute a major ingredient in many traditional culinary preparations (Okafor, 1983; Shiembo, Newton, & Leakey, 1996). Their strong demand in urban and rural markets bears witness to their food, cultural, and economic importance (Tabuna, 1999; Ingram et al., 2012). The commercialization of Nkumu contributes significantly to the income of local populations, particularly women involved in harvesting, processing, and sales, thereby strengthening the livelihoods of many forest communities (Awono et al., 2009; Loubelo, 2012).

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Nutritionally, several studies show that Gnetum spp. constitutes an important source of plant proteins, dietary fibers, calcium, iron, potassium, and magnesium (Uusiku et al., 2010; Dhellot et al., 2006; Ndzié et al., 2021). The leaves also contain phenolic compounds and other secondary metabolites that may exert antioxidant activity favorable to the prevention of non-communicable chronic diseases (Slavin, 2013; Dada et al., 2021). However, the nutritional composition can be influenced by processing techniques, culinary procedures, and preservation conditions, highlighting the importance of a better mastery of agri-food practices (Van Boekel et al., 2010; Bouchenna & Brikh, 2021).

In Gabon, where forests cover a large part of the national territory, Nkumu constitutes one of the most valued non-timber forest products. It contributes to household food security, supports local economies, and represents a strategic resource in food diversification and rural development policies (Food and Agriculture Organization of the United Nations [FAO], n.d.; Loubelo, 2012). However, the value chain faces several challenges, notably reliance on wild harvesting, limited mastery of domestication techniques, post-harvest losses, insufficient processing infrastructure, and a still-limited structuring of value chains (Sunderland et al., 1999; Ingram et al., 2012).

Furthermore, although research on Gnetum spp. has expanded in recent years, it remains scattered across the fields of nutrition, food science, forestry, economics, public health, and conservation. This fragmentation limits an integrated understanding of the role this resource can play in national food security and sustainable development strategies (Powell et al., 2015; Sunderland et al., 2013). To our knowledge, few reviews offer a multidisciplinary synthesis combining the nutritional, health, socio-economic, environmental, and agri-food dimensions of Nkumu within the Gabonese context.

This review aims to address this gap by offering a critical analysis of the available knowledge on Gnetum spp. Specifically, it examines its nutritional composition, potential health effects, socio-economic importance, the impacts of processing methods, the constraints affecting its valorization, as well as the prospects for sustainable development of the sector in Gabon. This synthesis aims to provide a robust scientific foundation capable of guiding future research work, public policies, and sustainable valorization strategies for non-timber forest products in Central Africa.

2. Literature Review

2.1. Non-Timber Forest Products in African Food Systems

Non-timber forest products (NTFPs) constitute an essential component of food systems in tropical and subtropical regions. They encompass all biological resources of forest origin other than timber, notably fruits, leaves, seeds, mushrooms, roots, barks, and medicinal plants (FAO, n.d.). Several hundred million people depend

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directly or indirectly on these resources to meet part of their food needs and generate complementary income (FAO et al., 2024).

In the Congo Basin—the second largest tropical forest massif in the world after the Amazon—non-timber forest products (NTFPs) constitute an essential component of rural livelihood strategies, contributing substantially to household subsistence and local economies (Tabuna, 1999; Shackleton et al., 2011; Loubelo, 2012). Besides generating income through local, national, and regional trade, these resources play a central role in sustaining vulnerable populations by providing food, medicine, and other essential products (Awono et al., 2009; Ingram et al., 2012). Forest foods, including leafy vegetables such as Gnetum spp., also contribute to dietary diversification and improved nutritional quality while strengthening the resilience of rural communities to seasonal food shortages and other shocks (Sunderland et al., 2013; Powell et al., 2015; Vira et al., 2015).

In addition, NTFPs support the maintenance of indigenous knowledge, traditional food systems, and cultural heritage, which are increasingly recognized as key components of sustainable food systems and biodiversity conservation (Shackleton et al., 2011; HLPE, 2017; FAO et al., 2024). Their importance becomes particularly evident during lean agricultural periods, when forest products frequently serve as safety-net resources, providing both food and income to rural households (Loubelo, 2012; FAO, n.d.).

Beyond their contribution to nutrition, NTFPs also participate in biodiversity conservation, carbon storage, and the maintenance of ecosystem services. Their valorization is currently considered a strategic lever to reconcile local economic development with the sustainable management of natural resources (Shackleton et al., 2011; FAO, n.d.).

2.2. Gnetum spp.: An Emblematic Food Resource of Central Africa

The genus Gnetum comprises several species of forest lianas distributed across the tropical regions of Africa and Asia. In Central Africa, Gnetum africanum and Gnetum buchholzianum represent the most widely exploited species for human consumption (Sunderland et al., 1999; Clark et al., 1999).

Their consumption is particularly important in Cameroon, Gabon, the Republic of the Congo, the Democratic Republic of the Congo, and Equatorial Guinea, where they hold a privileged position in culinary traditions (Tabuna, 1999; Shiembo et al., 1996). In Gabon, Nkumu is considered a heritage food whose consumption extends well beyond simple nutrition to embody cultural and identity dimensions of local populations.

Growing urbanization and evolving dietary habits have driven an increase in demand for Nkumu, leading to an intensification of its commercialization and the

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gradual development of a supply chain connecting forest areas to major urban centers (Ingram et al., 2012; Loubelo, 2012).

2.3. Nutritional Composition and Health Value

Traditional African leafy vegetables are recognized for their contribution to healthy and diversified diets. According to the World Health Organization (WHO, 2020), dietary diversity and the regular consumption of nutrient-dense foods, including vegetables, are important components of a healthy diet. Uusiku et al. (2010) further showed that African leafy vegetables constitute important sources of plant proteins, dietary fibers, calcium, potassium, magnesium, iron, vitamins, and antioxidant substances.

Analyses conducted on Gnetum spp. confirm these observations. Several studies report significant levels of plant proteins, often higher than those observed in many leafy vegetables consumed in Africa (Dhellot et al., 2006; Ndzié et al., 2021). The high concentration of dietary fibers also constitutes a major asset for the prevention of digestive and metabolic diseases.

The calcium and iron present in the leaves play a decisive role in preventing anemia and maintaining bone health, while potassium contributes to blood pressure regulation (Slavin, 2013; WHO, 2020).

Comparative Analysis

The data in the table 1 show that Gnetum spp. ranks among the African leafy vegetables with the highest nutritional density. Its protein content is comparable to that of cassava leaves and cowpea leaves, while its fiber content is generally superior to that of most other leafy vegetables. It also constitutes a major source of calcium, iron, magnesium, and bioactive compounds (polyphenols and flavonoids), explaining its nutritional and medicinal value in Central African countries.

Table 1. Comparative nutritional composition of Gnetum spp. and major African leafy vegetables

Leafy Vegetable	Protein (g/100 g MF)	Fiber (g/100 g MF)	Calcium (mg/100 g)	Iron (mg/100 g)	Vitamin C (mg/100 g)	Nutritional Features
Gnetum africanum / G. buchholzianum	5–8	7–12	250–500	3–8	25–55	Very rich in fibers, calcium, magnesium, and phenolic compounds
Amaranthus spp. (Amaranth)	3–4	2–4	215–267	2–4	40–65	Good source of carotenoids and vitamin C
Solanum	4–6	3–5	180–350	4–7	30–60	Rich in proteins,

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scabrum (African nightshade)						iron, and antioxidants
Corchorus olitorius (Jute mallow)	3–5	2–4	180–260	2–5	35–60	High content of mucilage, calcium, and β-carotene
Vigna unguiculata (Cowpea leaves)	4–6	3–5	200–430	4–8	40–90	Excellent source of plant proteins and iron
Manihot esculenta (Cassava leaves)	6–8	4–6	150–250	3–5	90–200	Very rich in proteins, vitamin C, and provitamin A after proper cooking
Hibiscus sabdariffa	2–4	2–4	150–250	2–4	25–45	Good source of polyphenols and organic acids
Cleome gynandra	4–6	3–5	250–350	5–8	40–85	High mineral density and high antioxidant content

On the other hand, the vitamin C content of Gnetum spp. is generally lower than that of fresh cassava leaves, but remains sufficient to contribute significantly to daily intakes when consumed regularly. As with most leafy vegetables, culinary processing strongly influences the retention of water-soluble vitamins and the bioavailability of minerals.

Furthermore, several authors have identified the presence of phenolic compounds, flavonoids, and other bioactive molecules in leafy vegetables. Dada et al. (2021) reported that these phytochemicals are important bioactive constituents associated with the nutritional quality of edible plants, while Bouchenna and Brikh (2021) emphasized that phenolic compounds and flavonoids may exhibit significant antioxidant and anti-inflammatory properties.

Scientific Analysis

As Shown in table 2 to 6, Gnetum spp leaves present a high nutritional density, characterized by a relatively high content of protein, dietary fiber, calcium, iron, and magnesium. They also constitute an important source of bioactive compounds, particularly polyphenols, flavonoids, and carotenoids, which contribute to their antioxidant capacity.

Table 2. Reported biochemical composition of Gnetum spp. (fresh weight basis)

Parameter	Reported Values (per 100 g fresh leaves)	Nutritional Importance
Water (%)	70–82	Maintenance of hydration and texture

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Dry Matter (%)	18–30	Depends on the maturity stage
Protein (g)	5,0–8,5	Good source of plant proteins
Lipids (g)	0,5–2,5	Low fat content
Available Carbohydrates (g)	5–12	Moderate energy source
Dietary Fiber (g)	7–15	Promotes digestive health and satiety
Ash (g)	2–4	Indicator of mineral richness
Energy Value (kcal)	55–95	Low energy density food

Table 3. Mineral composition

Mineral	Reported Values
Calcium	250–550 mg
Potassium	300–700 mg
Magnesium	80–180 mg
Phosphorus	60–150 mg
Sodium	5–35 mg
Iron	3–9 mg
Zinc	0.5–2.5 mg
Copper	0.10–0.40 mg
Manganese	0.5–2.0 mg

Table 4. Vitamin Composition

Vitamin	Reported values
Vitamin C	20–70 mg
β-carotene (provitamin A)	2–8 mg
Vitamin E	1–4 mg
Folates	50–120 µg

Table 5. Main Bioactive Compounds

Family	Presence	Biological role
Polyphenols	High	Antioxidant activity
Flavonoids	High	Protection against oxidative stress
Tannins	Low to moderate	Antimicrobial and antioxidant activity
Saponins	Moderate	Potential hypocholesterolemic effects
Alkaloids	Low	Variable biological activity
Total phenolic compounds	High	Cellular protection
Chlorophylls	Very high	Antioxidant activity
Lutein and zeaxanthin	Present	Ocular health

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Table 6. Antinutritional Factors

Factor	Observed level	Effect of cooking
Oxalates	Low to moderate	20–60% decrease
Phytates	Moderate	Reduction after cooking or blanching
Tannins	Low	Partial reduction
Saponins	Moderate	Decrease by boiling
Nitrates	Low	Generally reduced by cooking

Compared to many African leafy vegetables, Gnetum spp. is distinguished by:

- A high dietary fiber content;
- A high concentration of calcium and iron;
- A low lipid content;
- A richness in phenolic compounds.

Culinary processing, including blanching, boiling, and steam cooking, generally reduces the concentrations of vitamin C through thermal degradation and leaching into the cooking water (Uusiku et al., 2010). Similar reductions have also been reported for several phenolic compounds, whose stability is affected by processing conditions such as temperature and cooking duration (Van Boekel et al., 2010). More broadly, thermal processing is recognized as one of the main factors influencing the nutritional quality and retention of bioactive compounds in plant-based foods (Van Boekel et al., 2010). However, these processing methods can also reduce the concentrations of antinutritional factors, including oxalates, phytates, and tannins, potentially improving the bioavailability of essential minerals such as calcium and zinc (Abera et al., 2023).

Recent evidence further suggests that the reduction of these antinutritional compounds contributes to enhanced mineral utilization and overall nutritional quality of plant-derived foods (López-Moreno et al., 2022). These findings are consistent with current international recommendations emphasizing that food preparation practices can substantially influence nutrient bioavailability and dietary quality (FAO, n.d.).

2.4. Culinary Processing and Nutritional Quality

Culinary preparation strongly influences the nutritional quality of foods. According to Van Boekel et al. (2010), thermal processes can simultaneously improve the digestibility of certain nutrients and cause the degradation of heat-sensitive compounds. Gibson et al. (2006) further emphasized that the bioavailability of micronutrients in plant foods is influenced by the food matrix, interactions with compounds such as phytates, polyphenols, dietary fiber, and oxalic acid, as well as by food processing and preparation practices. These mechanisms are particularly relevant because traditional preparation methods of Nkumu may modify both nutrient retention and mineral bioavailability.

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In the case of Nkumu, traditional preparation methods are particularly diversified. The addition of peanut paste increases energy density as well as protein and lipid contents, while the use of palm oil enriches preparations with carotenoids but also increases their lipid intake.

Conversely, prolonged cooking can lead to a reduction in water-soluble vitamins and modify the availability of certain micronutrients (Van Boekel et al., 2010; Bouchenna & Brikh, 2021).

2.5. Socio-Economic Importance of Nkumu

The trade of Gnetum spp. constitutes an essential economic activity for many rural and urban populations in the Congo Basin. The works of Tabuna (1999), Loubelo (2012), and Kapemba et al. (2023) show that this sector generates regular income for collectors, transporters, wholesalers, retailers, and restaurateurs.

Women occupy a central position in commercial activities related to Nkumu. Their involvement contributes not only to the improvement of family income but also to the funding of children's education, healthcare expenses, and other essential needs (Awono et al., 2009; Loubelo, 2012).

2.6. Challenges of Agri-Food Valorization

Despite its potential, the Nkumu sector remains confronted with several structural constraints: dependency on wild collection in natural environments, high perishability of fresh leaves, low processing capacities, absence of quality standards, and difficulties in accessing regional and international markets (Sunderland et al., 1999; Ingram et al., 2012).

Recent research shows that several strategies could sustainably strengthen the sector: domestication of Gnetum spp., genetic improvement of plants, development of modern conservation techniques, creation of innovative food products, quality certification, and structuring of producer organizations (FAO, n.d.; Powell et al., 2015).

3. Materials and Methods

3.1. Study Type

This study is an integrative literature review aimed at critically synthesizing scientific knowledge regarding the nutritional, health, socio-economic, agri-food, and environmental contributions of Gnetum spp. (Nkumu) in Gabon. Integrative literature reviews are particularly well suited to addressing complex and multidisciplinary research topics because they allow the combination of evidence generated through diverse methodological approaches (Torraco, 2005).

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Unlike a narrative review, the integrative review enables the inclusion of quantitative, qualitative, experimental, and observational studies within a single analytical framework (Whittemore & Knafl, 2005), thereby providing a more comprehensive understanding of complex research questions and facilitating the integration of knowledge from different scientific disciplines (Torraco, 2005). To ensure methodological transparency and improve the quality of evidence synthesis, the review process was conducted in accordance with internationally recognized principles for reporting literature reviews (Page et al., 2021).

The conduct of this review was inspired by the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) (Page et al., 2021), adapted to the integrative nature of the study.

3.2. Literature Search Strategy

A systematic literature search was carried out in several international databases:

- Web of Science
- Scopus
- PubMed
- ScienceDirect
- Google Scholar
- AGRIS
- CAB Abstracts

Institutional reports were also consulted from:

- Food and Agriculture Organization of the United Nations (FAO)
- World Health Organization (WHO)
- Center for International Forestry Research (CIFOR)
- World Bank
- COMIFAC

Searches mainly focused on publications published between 1990 and 2025, while incorporating several prior seminal works when their scientific importance justified it.

3.3. Search Query / Equation

Keywords were combined using the Boolean operators AND and OR.

Examples of queries:

- "Gnetum africanum OR Gnetum buchholzianum"
- "Nkumu"
- "Non-Timber Forest Products" AND "Central Africa"
- "Food security" AND "Gnetum spp."
- "Leafy vegetables" AND Africa
- "Traditional vegetables"

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- "Forest foods"
- "Nutrition"
- "Public health"
- "Value chain"
- "Sustainable development"

Searches were conducted in French and English in order to limit language bias.

3.4. Inclusion Criteria

The following were retained:

- Peer-reviewed scientific articles;
- Systematic and integrative reviews;
- Scientific books;
- Institutional reports;
- Theses and dissertations presenting original data;
- Studies focusing on Gnetum spp. or traditional leafy vegetables of Central Africa;

Publications dealing with nutrition, food security, food processing, forest economy, or sustainable development.

3.5. Exclusion Criteria

The following were excluded:

- Conference abstracts without full text;
- Duplicate publications;
- Articles not presenting usable data;
- Studies not directly related to NTFPs or African leafy vegetables;
- Opinion documents without scientific basis.

3.6. Selection of Studies

Identified references were exported into bibliographic management software in order to remove duplicates.

Selection took place in four steps:

1. Identification of references;
2. Removal of duplicates;
3. Reading of titles and abstracts;
4. Full-text reading of retained articles.

Studies meeting the eligibility criteria were included in the qualitative synthesis.

The conduct of this literature review relied on international recommendations regarding integrative reviews and systematic reviews, notably those proposed by Whittemore and Knafl (2005) as well as the PRISMA 2020 guidelines (Page et al.,

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2021), to ensure a transparent, reproducible, and rigorous selection of the retained scientific publications. Figure 1. PRISMA 2020 flow diagram illustrating the selection process of studies included in this integrative review (adapted from Page et al., 2021).

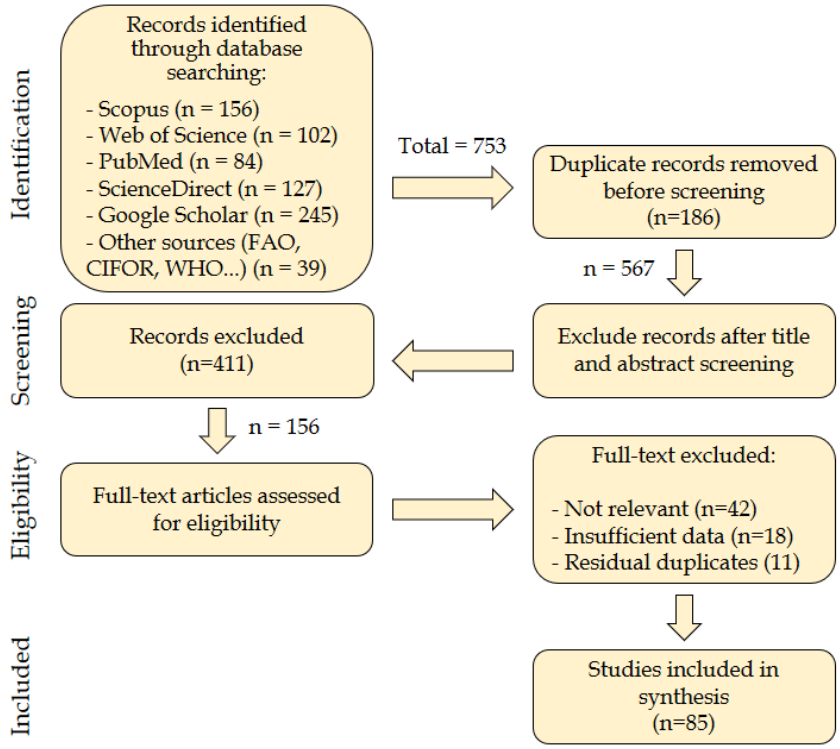

Figure 1. PRISMA flow diagram of study selection

3.7. Data Extraction

For each retained publication, the following information was collected as shown in the table 7.

Table 7. General characteristics of the main studies included

Author	Country	Study type	Subject/Theme	Main results
Sunderland et al. (1999)	Cameroon	Review	Taxonomy	Description of Gnetum species
Tabuna (1999)	Central Africa	Economics	Marketing	Economic importance of NTFPs
Shiembo et al. (1996)	Cameroon	Experimental	Domestication	Cultivation of Gnetum
Dhellot et al. (2006)	Nigeria	Nutrition	Chemical Composition	High protein content
Uusiku et al. (2010)	Africa	Review	Leafy vegetables	High nutritional value
Ingram et al.	Congo Basin	Economics	Value chain	Market

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(2012)				structuring
Powell et al. (2015)	Africa	Nutrition	Dietary diversity	Importance of NTFPs
Ndzié et al. (2021)	Cameroon	Nutrition	Mineral composition	Richness in calcium and iron
Bouchenna & Brikh (2021)	Algeria	Agri-food	Processing	Effects of cooking
Dada et al. (2021)	Nigeria	Biochemistry	Antioxidants	Antioxidant activity

The data were then grouped into five thematic axes:

1. Nutritional composition;
2. Public health;
3. Agri-food processing;
4. Socio-economic importance;
5. Sustainable development.

3.8. Data Analysis

The extracted information underwent a qualitative thematic analysis.

The results were compared in order to identify:

- Convergences between studies;
- Divergences;
- Scientific gaps;
- Research prospects.

When quantitative data were available, they were synthesized in comparative tables to facilitate their interpretation.

3.9. Methodological Limitations

Certain limitations must be highlighted. Available studies on Gnetum spp. remain relatively scarce compared to other major food crops. Furthermore, part of the data originates from technical reports or local studies with heterogeneous methodologies. Finally, the diversity of analytical protocols used in the retained studies may limit direct comparisons of certain nutritional parameters.

Despite these limitations, the diversity of sources utilized allows for a robust synthesis of currently available knowledge and the identification of main research and valorization axes for Gnetum spp. in Gabon.

3.10. Evaluation of Methodological Quality of Studies

The methodological quality of the included studies was assessed according to several criteria adapted to the study type:

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- Clarity of objectives;
- Description of methodology;
- Representativeness of samples;
- Quality of statistical analyses;
- Reproducibility of protocols;
- Relevance of conclusions.

Each publication was classified into three levels (Table 8).

Table 8. Levels of classification of publications

Level	Interpretation
High	Robust methodology and low risk of bias
Moderate	Some methodological limitations
Low	Significant risk of bias

4. Results

4.1. General Characteristics of Retained Studies

The literature strategy identified a body of publications covering Gnetum spp., non-timber forest products, food security, and sustainable development. After applying inclusion and exclusion criteria, the retained studies mainly covered the 1990–2025 period.

Analyzed publications originated mostly from Congo Basin countries, notably Gabon, Cameroon, the Republic of the Congo, the Democratic Republic of the Congo, and Nigeria. They included experimental studies, socio-economic surveys, nutritional analyses, scientific reviews, and institutional reports.

Identified works were grouped into five major themes:

- Nutritional composition;
- Functional properties and health;
- Agri-food processing;
- Socio-economic importance;
- Contribution to sustainable development.

4.2. Nutritional Composition of Gnetum spp.

Consulted studies confirm that Gnetum spp. constitutes one of the most nutrition-rich traditional leafy vegetables in Central Africa.

The leaves notably present:

- A high plant protein content;
- A significant richness in dietary fiber;
- Appreciable concentrations of calcium, potassium, magnesium, and iron;

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- Vitamins and antioxidant compounds.

This composition makes Nkumu a particularly interesting food item for improving the nutritional quality of populations' diets as presented in the tables 9 and 10.

Table 9. Main nutritional constituents reported for Gnetum spp.

Component	Nutritional importance	Main references
Proteins	Tissue building	Dhellot et al. (2006)
Fibers	Digestive health	Slavin (2013)
Calcium	Bone health	Uusiku et al. (2010)
Iron	Anemia prevention	Ndzié et al. (2021)
Potassium	Blood pressure regulation	WHO (2020)
Magnesium	Energy metabolism	Uusiku et al. (2010)
Polyphenols	Antioxidant activity	Dada et al. (2021)

Table 10. Comparative nutritional composition of Gnetum spp. and selected African leafy vegetables (indicative values)

Parameter	Gnetum spp	Amaranth	Cassava leaves	Moringa
Proteins (g/100 g DM)	18–22	15–18	20–28	25–30
Fibers (%)	12-18	9-14	10-13	11-19
Calcium (mg/100 g)	400-600	250-350	180-320	350-450
Iron (mg/100 g)	8-14	6-9	5-8	7-11
Potassium (mg/100 g)	700-1000	600-850	500-750	800-1100
Magnesium (mg/100 g)	120–200	90-150	100-160	150-220

Source: adapted from Uusiku et al. (2010), Dhellot et al. (2006), Ndzié et al. (2021), and other included studies.

4.3. Functional Properties and Health Interest

Identified publications show that bioactive compounds present in Gnetum spp. could contribute to preventing several chronic diseases.

The main reported effects concern:

- Reduction of oxidative stress;
- Cardiovascular protection;
- Improvement of intestinal transit;
- Prevention of certain nutritional deficiencies.

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Dietary fibers play an essential role in regulating blood glucose and cholesterol, while phenolic compounds participate in neutralizing free radicals.

4.4. Effects of Processing Methods

Culinary processes significantly influence the nutritional quality of preparations made from Nkumu.

The main observations from the literature show that:

- Moderate cooking improves digestibility;
- Prolonged cooking decreases certain water-soluble vitamins;
- Adding peanut increases protein and lipid content;
- Palm oil improves energy intake but increases lipid density.

These results as presented in the table 11 highlight the importance of optimizing culinary processes to preserve the product's nutritional qualities.

Table 11. Effects of processing methods on the nutritional quality of Gnetum spp. and main African leafy vegetables.

Processing method	Effects on macronutrients	Effects on micronutrients	Effects on bioactive compounds	Effects on antinutritional factors	Overall impact
Blanching	Low losses of proteins and fibers	Moderate decrease in vitamin C (10–40%) and water-soluble vitamins	Slight reduction in polyphenols and flavonoids	Reduction of oxalates, phytates, and tannins (20–50%)	Improves overall nutritional quality by reducing antinutritionals while preserving most nutrients.
Boiling	Little effect on proteins; slight loss of soluble carbohydrates	Significant losses in vitamin C (30–70%) and B vitamins; leaching of certain minerals	Notable reduction in phenolic compounds (20–60%)	Strong reduction of oxalates, phytates, and tannins (30–70%)	Trade-off between decrease in antinutritional factors and losses of micronutrients.
Steam cooking	Good retention of proteins and fibers	Better vitamin retention than boiling	High preservation of polyphenols and antioxidant activity	Moderate reduction of antinutritional factors	One of the most favorable methods for preserving nutritional quality
Sun drying	Apparent concentration of nutrients due to water loss	Partial degradation of vitamin C and carotenoids depending on duration and exposure	Moderate decrease in phenolic compounds	Little direct effect	Facilitates preservation but can alter heat- and light-sensitive vitamins
Mechanical drying (hot	Good protein stability	Variable losses of heat-sensitive	Moderate reduction in	Low effect	More reproducible than sun drying

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air)		vitamins depending on temperature	antioxidants		when parameters are controlled
Fermentation	Potential improvement in protein digestibility	Possible increase in bioavailability of certain minerals	Release or transformation of certain phenolic compounds	Significant reduction of phytates and tannins	Process favorable to nutrient bioavailability
Freezing	Preservation of proteins and fibers	Good retention of vitamins when the cold chain is respected	Slight modification of bioactive compounds	No significant effect	Effective method for preserving long-term nutritional quality
Repeated reheating	Little effect on proteins	Progressive degradation of vitamins and antioxidants	Decrease in antioxidant activity	No additional benefit	To be limited due to cumulative losses of sensitive compounds.

Synthesis of Observed Effects

Processing methods simultaneously modify the nutritional composition and nutrient bioavailability of leafy vegetables. Thermal treatments generally lead to a decrease in water-soluble vitamins, notably vitamin C and certain B-group vitamins, as well as a reduction in phenolic compounds and antioxidant activity. On the other hand, they effectively reduce antinutritional factors such as oxalates, phytates, and tannins, which can improve the absorption of calcium, iron, and zinc.

For Gnetum spp., steam cooking appears to be the best compromise between nutrient preservation and the reduction of antinutritional compounds. Boiling is effective for decreasing the latter, but also causes significant leaching of water-soluble vitamins and certain minerals when the cooking water is discarded. Blanching, when carried out for a short duration, limits nutritional losses while improving sanitary quality and digestibility.

Drying processes make it possible to extend shelf life but can lead to variable losses in vitamin C and carotenoids, particularly during prolonged sun drying as we can see in the table 12 below. Fermentation constitutes an interesting strategy for improving mineral bioavailability thanks to the degradation of phytates and tannins. Finally, freezing remains one of the most effective methods for preserving nutritional quality, provided that the cold chain is maintained.

Table 12. Main bioactive compounds identified in Gnetum spp.

Compound family	Main identified compounds	Reported biological effects	Common analytical methods
Total phenolic compounds	Phenolic acids, phenolic derivatives	Antioxidant activity, protection against oxidative stress	Folin-Ciocalteu, HPLC-UV

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Flavonoids	Quercetin, kaempferol, myricetin, glycosylated derivatives	Antioxidant, anti-inflammatory, cardioprotective activities	HPLC-DAD, HPLC-MS/MS
Stilbenoids	Resveratrol, gnetol, gnemonosides, gnetins	Antioxidant, neuroprotective, potential anticancer activities	HPLC-MS/MS, LC-MS
Carotenoids	β-carotene, lutein, zeaxanthin	Vitamin A precursors, ocular health, antioxidant activity	HPLC
Chlorophylls	Chlorophyll a, chlorophyll b	Antioxidant activity, cellular protection	Spectrophotometry, HPLC
Vitamin C	Ascorbic acid	Antioxidant, collagen synthesis, enhancement of iron absorption	HPLC, titration
Vitamin E	α-Tocopherol	Protection of cell membranes against oxidation	HPLC
Saponins	Triterpene saponins	Potential hypocholesterolemic and immunomodulatory effects	Colorimetric methods, HPLC
Tannins	Condensed and hydrolyzable tannins	Antimicrobial and antioxidant activities; antinutritional effect at high concentrations	Vanillin-HCl, Folin-Denis
Alkaloids	Total alkaloids (low concentrations)	Diverse biological activities depending on structure	Acid-base extraction, HPLC
Dietary fibers	Cellulose, hemicelluloses, pectins	Digestive health, microbiota modulation, satiety	Enzymatic AOAC methods

Species of the genus Gnetum are particularly recognized for their richness in stilbenoids, a family of polyphenols relatively rare in leafy vegetables, see table 13 below.

Table 13. Main stilbenoids specific to Gnetum spp.

Molecule	Reported biological activity
trans-Resveratrol	Antioxidant, anti-inflammatory, cardioprotective
Gnetol	Antioxidant, neuroprotective, anti-inflammatory
Gnetin C	Cytoprotective, potential anticancer activity
Gnemonosides A–D	Antioxidant activity and potential metabolic effects
Gnetins	Inhibition of lipid oxidation and modulation of inflammatory pathways

Nutritional Importance

Gnetum spp. leaves stand out from other African leafy vegetables by having:

- A high content of phenolic compounds;
- A richness in flavonoids and stilbenoids (notably gnetol and gnetins), characteristic of the genus Gnetum;

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- A significant concentration of carotenoids (β-carotene, lutein, and zeaxanthin);
- An appreciable content of vitamin C, contributing to protection against oxidative stress and the improvement of iron absorption;
- A high proportion of dietary fiber, promoting digestive health.

These compounds confer an interesting functional potential to Gnetum spp. leaves, likely contributing to the prevention of chronic conditions such as cardiovascular diseases, type 2 diabetes, and certain cancers. However, these effects rely mainly on experimental and preclinical studies; clinical evidence in humans remains limited.

4.5. Socio-Economic Importance

The Nkumu value chain represents an important income-generating activity for rural populations.

Studies show that:

- Women constitute the main actors in marketing;
- Generated income contributes directly to household food security;
- The Nkumu trade fosters the local economy.

However, several constraints still limit the development of this value chain, see in table 14 below:

- Low market structuring;
- Absence of quality standards;
- Logistical difficulties;
- Significant post-harvest losses.

Table 14. SWOT analysis of the Nkumu value chain

Strengths	**Weaknesses**
High nutritional value	Dependency on wild harvesting
High demand	Low processing
Cultural importance	Limited conservation
Opportunities	Threats
Development of innovative products	Overexploitation
Export	Climate change
Domestication	Deforestation

4.6. Contribution to Sustainable Development

Literature analysis shows that the sustainable valorization of Gnetum spp. directly contributes to several Sustainable Development Goals (SDGs).

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The results in table 15 above show that Gnetum spp. is not merely a traditional food item, but a strategic resource capable of simultaneously supporting nutrition, public health, local economic development, and sustainable forest resource management.

Table 15. Contribution of Gnetum spp. to SDGs

SDG	Contribution
SGD1	Poverty reduction
SDG2	Food security
SDG3	Health and well-being
SDG5	Women's empowerment
SDG8	Employment and economic growth
SDG12	Responsible production
SDG13	Climate change adaptation
SDG15	Conservation of forest ecosystems

4.7. Synthesis of Main Results

This review highlights several major findings:

- Gnetum spp. possesses a particularly interesting nutritional composition.
- Processing methods strongly influence the nutritional quality of preparations.
- The value chain represents an important source of income for rural households.
- The valorization potential remains largely underexploited.
- Better structuring of the value chain could strengthen Nkumu's contribution to food security and sustainable development in Gabon.

5. Discussion

5.1. The Nutritional Potential of Gnetum spp. in Sustainable Food Systems

The results of this review confirm that Gnetum spp. constitutes one of the most promising traditional leafy vegetables in Central Africa from a nutritional standpoint. The various analyzed studies highlight a composition rich in plant proteins, dietary fibers, calcium, iron, potassium, and magnesium, as well as bioactive compounds of potential interest for human health (Dhellot et al., 2006; Uusiku et al., 2010; Ndzié et al., 2021). This nutritional richness gives Nkumu a potential role in preventing micronutrient deficiencies, which remain frequent in several sub-Saharan African countries (FAO et al., 2024).

As presented in the tables 16 and 17 above, compared to several African leafy vegetables, Gnetum spp. presents interesting contents of proteins and minerals, making it a valuable complement to diets dominated by cereals and tubers. However, the differences observed between studies highlight the influence of ecological conditions, leaf maturity stage, and analytical methods used.

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Table 16. Comparison of main traditional Gabonese recipes based on Gnetum spp. (Nkumu) (part 1)

Traditional preparation	Main ingredients	Processing method	Nutritional characteristics
Plain Nkumu	Gnetum spp. leaves, water, salt	Washing, cutting, boiling in water	Rich in fibers, plant proteins, calcium, iron, and magnesium; low lipid content
Nkumu with peanut paste	Gnetum spp., peanut paste, onion, garlic, spices	Cooking then incorporation of peanut paste	Increase in proteins, unsaturated lipids, and energy density
Nkumu with smoked fish	Gnetum spp., smoked fish, tomato, onion	Simultaneous cooking of ingredients	High intake of animal proteins, heme iron, and fatty acids
Nkumu with meat or game	Gnetum spp., fresh meat or game, condiments	Prolonged simmering	Richness in proteins of high biological value, iron, and zinc
Nkumu with palm oil	Gnetum spp., red palm oil, condiments	Cooking with addition of oil at the end or during preparation	Increased intake of lipids, carotenoids, and vitamin E
Mixed Nkumu (fish + peanut paste)	Gnetum spp., smoked fish, peanut paste, condiments	Combined cooking	High intakes of proteins, quality lipids, minerals, and energy

Table 17. Comparison of main traditional Gabonese recipes based on Gnetum spp. (Nkumu). Part 2.

Traditional preparation	Assets	Limitations
Plain Nkumu	Preserves mineral richness and low energy density	Possible losses of water-soluble vitamins during prolonged cooking
Nkumu with peanut paste	Improvement of energy intake and satiety	Higher energy value; risk of excess lipid intake depending on amount used
Nkumu with smoked fish	Good nutritional balance; improvement of protein quality	Potentially high sodium intake depending on smoked fish
Nkumu with meat or game	Complete meal with high nutritional	Long cooking time that may reduce certain bioactive compounds in leaves

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	value	
Nkumu with palm oil	Improvement of fat-soluble carotenoid absorption	High energy density; nutritional quality depends on amount of oil used
Mixed Nkumu (fish + peanut paste)	Very complete preparation from a nutritional standpoint	High variability depending on family recipes and ingredient proportions

Source: Synthesis produced from scientific literature (Shiembo et al., 1996; Sunderland et al., 1999; Dhellot et al., 2006; Awono et al., 2009; Ingram et al., 2012; FAO, n.d.).

5.2. Influence of Processing Methods on Nutritional Quality

Culinary processes constitute a determining factor in the nutritional quality of preparations based on Nkumu. Results show that cooking generally improves the digestibility of plant tissues and reduces certain antinutritional factors. Conversely, prolonged exposure to heat can lead to significant losses in water-soluble vitamins and alter the availability of certain bioactive compounds (Van Boekel et al., 2010; Bouchenna & Brikh, 2021).

The incorporation of ingredients such as peanut paste or palm oil increases energy density and improves lipid intake, while modifying the overall nutritional composition of the preparations. These observations highlight the importance of promoting processing methods that reconcile nutritional quality, sanitary safety, and sensory acceptability as presented in the below table 18.

Table 18. Nutritional comparison

Criterion	Palm nut sauce	Peanut sauce	Clear soup/sauce	Saut
Protein retention	★★★★☆	★★★★★	★★★★★	★★★★★
Vitamin C retention	★★☆☆☆	★★☆☆☆	★★★☆☆	★★★★☆
Bioavailability of carotenoids	★★★★★	★★★★☆	★★☆☆☆	★★★★☆
Reduction of antinutritional factors	★★★★★	★★★★★	★★★★☆	★★★☆☆
Energy density	Very high	High	Low to moderate	Moderate
Overall nutritional quality	Very good	Excellent	Excellent	

Scientific Analysis

Traditional Gabonese recipes based on Gnetum spp. exhibit distinct nutritional profiles, mainly determined by added ingredients and preparation techniques. Simple preparations, composed essentially of Nkumu leaves, maintain low energy density while providing appreciable amounts of fiber, plant proteins, and essential

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minerals. The addition of peanut paste or palm oil increases the energy value of dishes and improves the intake of essential fatty acids and fat-soluble compounds, while the incorporation of smoked fish or meat enriches preparations with high biological value proteins and micronutrients such as heme iron and zinc.

However, prolonged cooking processes, frequently used in traditional cooking, can lead to losses of water-soluble vitamins and a reduction in certain bioactive compounds. Conversely, the presence of lipids promotes the bioavailability of carotenoids and other fat-soluble molecules. Recipe optimization should thus aim for a balance between nutritional quality, sanitary safety, sensory acceptability, and preservation of compounds of nutritional interest.

5.3. Contribution to Food Security

The results confirm that Gnetum spp. contributes to several dimensions of food security as defined by the FAO: availability, access, biological utilization, and stability. Its presence in urban and rural markets, regular consumption, and nutritional value make it a strategic food for diversifying diets and strengthening their quality. This contribution falls within the conceptual framework of food security defined by the FAO, which relies on four complementary dimensions: physical availability of food, economic and social access, biological utilization, as well as the stability of these three dimensions over time. Non-timber forest products, including Gnetum spp., play an increasing role in strengthening the food resilience of rural and urban populations by diversifying food and income sources. International reports also emphasize their importance in the transition toward more sustainable and resilient food systems in the face of economic, health, and climate crises (HLPE, 2020; FAO et al., 2024).

In rural areas, harvesting and marketing Nkumu also constitute an adaptation strategy to lean periods and agricultural income fluctuations. This role is particularly important in forest communities dependent on natural resources. Beyond their food function, non-timber forest products constitute adaptation mechanisms against agricultural market fluctuations and extreme climate events. Their sustainable exploitation contributes to income diversification, poverty reduction, and the improvement of household resilience in tropical regions (Vira et al., 2015; Shackleton et al., 2011).

Analysis

The nutritional value of preparations based on Gnetum spp. depends closely on culinary processes and associated ingredients (see table 19 and 20). Fresh leaves constitute an excellent source of plant proteins, dietary fibers, and essential minerals, but their low lipid content limits the bioavailability of certain fat-soluble compounds. Water boiling overall preserves macronutrients while causing a decrease in water-soluble vitamins and a slight loss of minerals through leaching.

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Table 19. Nutritional contribution of Gnetum spp. (Nkumu) according to main preparation methods. Part. 1

Preparation method	Effects on proteins	Effects on lipids	Effects on fibers
Fresh Nkumu (chopped)	Preservation of plant proteins	Very low lipid content	Maximum fiber content
Water boiling	Slight modification of proteins	Low lipid content	Slight decrease in soluble fibers
Nkumu with peanut paste	Slight modification of proteins	Large increase in unsaturated lipids	Good fiber preservation
Nkumu with palm oil (Nyembwè)	Little effect on proteins	Large increase in lipids	Good fiber preservation
Nkumu O'fula	Variable intake depending on associated ingredients	Moderate lipid intake	Good fiber preservation
Nkumu with fish or meat	Large increase in high biological value proteins	Lipid intake variable according to animal source	Fibers little modified

Table 20. Nutritional contribution of Gnetum spp. (Nkumu) according to main preparation methods. Part. 2

Preparation method	Effects on minerals	Effects on vitamins and bioactive compounds	Overall nutritional contribution
Fresh Nkumu (chopped)	High concentration of calcium, iron, magnesium, and potassium	Best preservation of vitamins and phenolic compounds	Low-energy food, rich in micronutrients and fiber
Water boiling	Mineral losses by leaching into cooking water	Decrease in water-soluble vitamins (vitamin C, B vitamins)	Balanced preparation but with a slight reduction in micronutrients
Nkumu with peanut paste	Enrichment in magnesium, phosphorus, and zinc	Better bioavailability of fat-soluble compounds	Energy-rich preparation adapted to high nutritional needs
Nkumu with palm oil (Nyembwè)	Minerals overall preserved	Improved absorption of carotenoids and vitamin E	Energy-dense preparation, favorable for fat-soluble micronutrient absorption
Nkumu O'fula	Minerals generally well preserved	Depends on cooking time and ingredients used	Balanced preparation combining

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			nutritional density and sensory quality
Nkumu with fish or meat	Enrichment in heme iron, zinc, and vitamin B12	Little effect on plant compounds if cooking is controlled	Complete preparation with excellent nutritional quality

Source: Adapted from scientific literature on Gnetum spp. and African leafy vegetables (Shiembo et al., 1996; Dhellot et al., 2006; Uusiku et al., 2010; Ingram et al., 2012; Sunderland et al., 2013; FAO et al., 2024).

The addition of peanut paste significantly improves the energy density and nutritional quality of preparations thanks to a complementary contribution of proteins, unsaturated fatty acids, and minerals. Similarly, the use of red palm oil increases lipid intake and promotes the absorption of carotenoids and vitamin E, thus contributing to better bioavailability of fat-soluble compounds. Preparations combining Nkumu with fish or meat enrich dishes with high biological value proteins, heme iron, zinc, and vitamin B12, thereby improving their overall nutritional quality.

Overall, traditional Gabonese recipes demonstrate that culinary combinations allow complementing the intrinsic nutritional qualities of Gnetum spp. However, excessive cooking can lead to the degradation of heat-sensitive vitamins and a reduction in certain bioactive compounds. It therefore appears essential to promote culinary practices that preserve the nutritional value of leaves while guaranteeing their sensory acceptability and sanitary safety. Observed nutritional benefits also depend on interactions between nutrients and culinary processes. Controlled cooking promotes the reduction of antinutritional factors while improving the bioavailability of several essential micronutrients, particularly iron, calcium, and carotenoids. These interactions illustrate the importance of adapting traditional processes in order to optimize simultaneously the nutritional quality and functional value of preparations (Van Boekel et al. (2010)).

5.4. Socio-Economic Importance and Women's Empowerment

The review highlights the importance of the Nkumu value chain in local economies. Women occupy a central position in harvesting, processing, and marketing activities, which promotes their economic empowerment and contributes to household well-being (Awono et al., 2009; Ingram et al., 2012). Several studies conducted in Congo Basin countries show that marketing non-timber forest products constitutes an essential source of income for rural women. These activities strengthen their economic autonomy, promote household food security, and contribute to maintaining traditional knowledge related to the use of forest resources (Shackleton et al., 2011; Vira et al., 2015).

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However, the value chain remains largely informal and suffers from a lack of structuring. Difficulties in accessing financing, absence of quality standards, post-harvest losses, and low processing capacities limit value addition.

SWOT analysis of the Gnetum spp. (Nkumu) value chain in Gabon

Strengths:

- Abundant forest resource in several regions of Gabon and the Congo Basin.
- High nutritional value (proteins, fiber, calcium, iron, magnesium, and bioactive compounds).
- High cultural acceptability and widespread traditional consumption.
- High potential for the development of functional foods and processed products.
- Important source of income for rural households, particularly women.
- Contribution to food security and diet diversification.

Weaknesses:

- Strong dependency on wild harvesting.
- Low level of domestication and controlled production.
- Significant post-harvest losses due to limited shelf life.
- Lack of quality standards, traceability, and certification.
- Inadequate processing and storage infrastructure.
- Scientific data still limited on certain functional properties and nutrient bioavailability.

Opportunities:

- Growing demand for natural and nutrient-rich foods.
- Development of the non-timber forest product value chain in national policies.
- Integration of Nkumu into nutrition and food security programs.
- Development of new processing and preservation technologies.
- Valorization in regional and international non-timber forest product markets.
- Strengthening of research, domestication, and agroforestry programs.

Threats:

- Overexploitation of wild stands in the absence of sustainable management.
- Deforestation, habitat fragmentation, and climate change.
- Urbanization and decline of traditional culinary knowledge.
- Competition with other commercialized leafy vegetables.
- Product quality variability linked to harvesting and processing methods.
- Weak structuring of producer organizations and difficulties in accessing financing.

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Source: Synthesis compiled from scientific literature on Gnetum spp. and non-timber forest products (Shiembo et al., 1996; Sunderland et al., 1999; Awono et al., 2009; Ingram et al., 2012; Sunderland et al., 2013; FAO et al., 2024).

Analysis

The SWOT analysis highlights that the Gnetum spp. value chain relies on considerable strengths, notably its high nutritional value, cultural importance, and economic role for rural households. These characteristics make it a strategic resource to strengthen food security and support livelihoods, particularly in forest communities.

However, several constraints limit its development. Dependency on wild harvesting, low domestication levels, post-harvest losses, and the absence of quality standards reduce the competitiveness of the value chain and increase resource vulnerability.

Development prospects are nevertheless significant. Growing interest in functional foods, non-timber forest product valorization policies, and advances in agrifood processing offer opportunities for economic diversification and improved food security. In parallel, the domestication of Gnetum spp., development of agroforestry systems, and value chain strengthening could reduce pressure on natural populations while increasing producer income.

Conversely, deforestation, climate change, weak organization among actors, and competition with other leafy vegetables represent threats that could jeopardize the sustainable development of this value chain. Implementing integrated public policies combining research, conservation, technological innovation, and producer support appears indispensable to ensure resource sustainability. Climate projections indicate that changes in precipitation regimes, temperature increases, and the intensification of extreme events may affect tropical forest ecosystems and the distribution and productivity of forest species (IPCC, 2023). In this context, these changes may also represent potential risks for the conservation and sustainable availability of Gnetum spp., particularly in areas where the species is already subject to harvesting pressure.

5.5. Challenges of Domestication and Sustainable Management

Despite growing demand, production still relies mainly on wild harvesting. This dependency can exert increased pressure on wild Gnetum spp. populations, particularly when harvesting practices are not sustainable.

Developing domestication programs, disseminating high-performing plant material, and implementing agroforestry practices emerge as priorities to ensure resource sustainability and reduce overexploitation risks (Sunderland et al., 1999; Shiembo et al., 1996).

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Analysis

The table 21 above shows that the Gnetum spp. value chain relies mainly on leaf harvesting in natural environments, followed by collection, artisanal processing, marketing, and consumption activities. Each link contributes to economic value creation while influencing the nutritional and sanitary quality of the final product.

Table 21. Gnetum spp. (Nkumu) value chain in Gabon

Chain link	Main actors	Activities performed	Added value	Main constraints
Production / Harvesting	Harvesters, rural communities, forest loggers	Leaf harvesting in natural forests or experimental plantations	Raw material availability	Dependency on wild stands, limited accessibility, seasonality, overexploitation risks
Collection and aggregation	Collectors, cooperatives, local traders	Sorting, aggregation, basic packaging	Build-up of commercial volumes	Lack of organization, low traceability, post-harvest losses
Primary processing	Women processors, households, small artisanal units	Washing, cutting, blanching, cooking, drying, or packaging	Improved sanitary quality, extended shelf life	Rudimentary equipment, lack of technical standards
Marketing	Retailers, wholesalers, urban and rural markets	Sale of fresh or processed leaves	Income generation and market access	Price fluctuations, transport costs, low logistical capacity
Secondary processing	Restaurateurs, agro-processors, emerging food industry	Preparation of traditional dishes, ready-to-eat products, packaging	Product diversification and increased added value	Low industrialization, lack of investment and certifications
Consumption	Households, restaurants, institutions	Consumption in various culinary forms	Improvement of dietary nutritional quality	Variability of culinary practices and nutritional quality
Research and institutional support	Universities, research institutes, ministries, NGOs, technical partners	Research, domestication, training, public policy development	Innovation, productivity improvement, and sustainable management	Limited funding, insufficient institutional coordination

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Source: Adapted from literature on non-timber forest products and the Gnetum spp. value chain (Shiembo et al., 1996; Sunderland et al., 1999; Awono et al., 2009; Ingram et al., 2012; Sunderland et al., 2013; FAO et al., 2024).

Harvesting is carried out mostly by rural communities, whose traditional knowledge allows for the exploitation of the resource (see figure 2). However, strong dependency on wild stands constitutes a vulnerability factor, particularly in a context of deforestation, urbanization, and climate change. The development of domestication and agroforestry systems emerges as a priority strategy to secure supply while limiting pressure on natural populations.

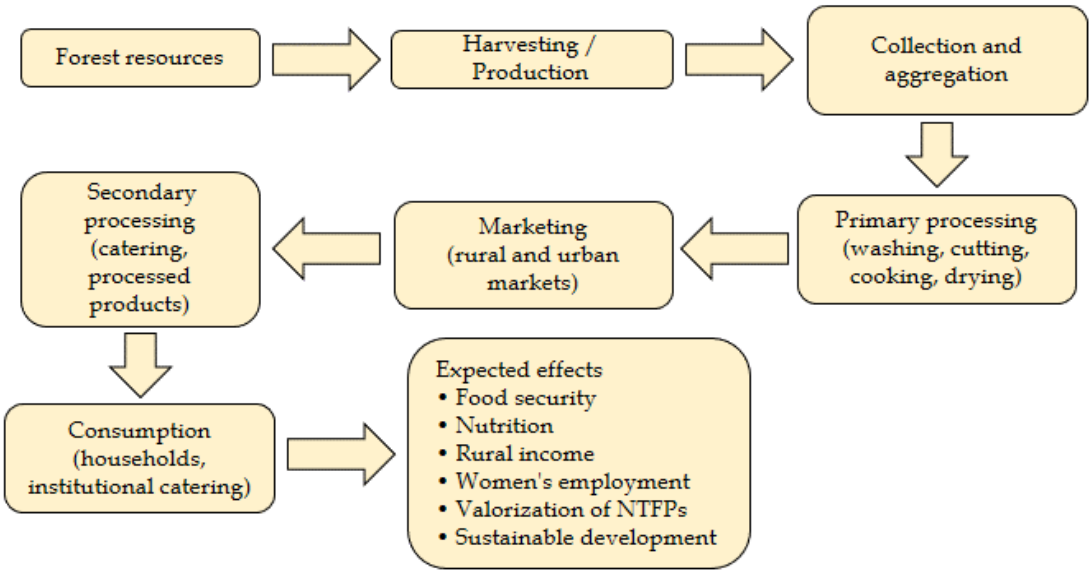

Figure 2. Simplified representation of the Gnetum spp. value chain

Processing steps are essentially artisanal and play a decisive role in the quality of marketed products. Culinary processes and preservation techniques directly influence nutritional composition, shelf life, and the acceptability of preparations. The absence of quality standards, adapted infrastructure, and modern processing technologies nevertheless limits the competitiveness of the value chain.

The marketing of Nkumu represents an important source of income for many households, particularly for women who occupy a central position in processing and sales activities. Despite this socio-economic importance, actors remain confronted with difficulties related to transport costs, lack of collective organization, weak market structuring, and limited access to financing.

Strengthening the value chain requires an integrated approach combining research, technological innovation, structuring of producer organizations, infrastructure improvement, product certification, and the development of favorable public policies. Such an approach would simultaneously improve the nutritional quality of

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products, the income of value chain actors, and the sustainable management of forest resources.

5.5. Contribution to Sustainable Development Goals

The results show that the sustainable valorization of Nkumu contributes directly to several Sustainable Development Goals, notably poverty eradication (SDG 1), zero hunger (SDG 2), health promotion (SDG 3), gender equality (SDG 5), decent work (SDG 8), responsible consumption (SDG 12), and the protection of terrestrial ecosystems (SDG 15).

This integrated approach confirms that Gnetum spp. constitutes not merely a food resource, but a potential lever for public policies reconciling nutrition, economic development, and biodiversity conservation as presented in the table 22.

Table 22. Contribution of Gnetum spp. (Nkumu) to Sustainable Development Goals (SDGs)

Sustainable Development Goal	Contribution of Gnetum spp.	Mechanisms of action
SDG 1: No Poverty	Income generation for rural households	Harvesting, processing, and marketing of Nkumu leaves, creation of local jobs, and diversification of income sources.
SDG 2: Zero Hunger	Improvement of food security and nutritional quality	Contribution of plant proteins, fiber, essential minerals, and diet diversification.
SDG 3: Good Health and Well-being	Promotion of healthy eating and prevention of nutritional deficiencies	Consumption of a food rich in micronutrients and bioactive compounds capable of contributing to the prevention of nutrition-related diseases.
SDG 5: Gender Equality	Strengthening of women's economic empowerment	Strong involvement of women in harvesting, processing, and marketing activities.
SDG 8: Decent Work and Economic Growth	Development of local value chains	Job creation, valorization of non-timber forest products, and development of small rural enterprises.
SDG 12: Responsible Consumption and Production	Promotion of sustainable management of natural resources	Valorization of forest resources, improvement of processing methods, and reduction of post-harvest losses.
SDG 13: Climate Action	Contribution to food system resilience	Diversification of food resources and development of agroforestry systems adapted to climate change.
SDG 15: Life on Land	Conservation of forest biodiversity	Promotion of sustainable harvesting practices, domestication of Gnetum spp., and preservation of forest ecosystems.
SDG 17: Partnerships for the	Strengthening of scientific and	Collaboration between research institutes, universities, public authorities, NGOs,

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Goals	institutional cooperation	and technical partners for the sustainable development of the value chain.

Source: FAO et al., 2024.

Analysis

The analysis of the literature shows that the valorization of Gnetum spp. contributes directly or indirectly to several Sustainable Development Goals of the 2030 Agenda. At the nutritional level, the richness of the leaves in plant proteins, fiber, calcium, iron, and other micronutrients makes it a high-value food capable of strengthening food security and reducing nutritional deficiencies, thus meeting the goals of combating hunger and promoting health.

On the socio-economic front, the Nkumu value chain represents an important source of income for rural households. Harvesting, processing, and marketing activities are predominantly carried out by women, promoting their economic empowerment and participation in local development. This dynamic contributes simultaneously to poverty reduction, job creation, and the strengthening of rural economies.

From an environmental standpoint, the sustainable management of Gnetum spp. constitutes a lever for the conservation of Congo Basin forest ecosystems. The development of reasoned harvesting practices, progressive domestication of the species, and its integration into agroforestry systems allow for a reduction of pressure on natural stands while improving the resilience of production systems face to climate change.

Finally, achieving these goals requires integrated governance combining public authorities, research institutes, universities, community organizations, the private sector, and technical and financial partners. Capacity building for producers, improvement of processing technologies, establishment of quality standards, and development of evidence-based public policies constitute essential conditions to ensure the sustainability of the value chain as presented in the figure 3 below.

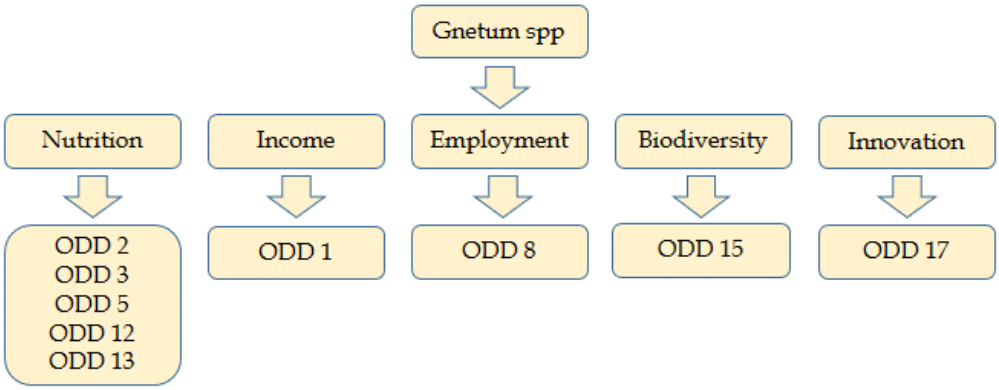

Figure 3. Integration of Gnetum spp. into the Sustainable Development Goals.

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5.6. Study Limitations

This review presents several limitations as shown in the table 21 below. The availability of studies specifically dedicated to Gabon remains limited, which led to the integration of works conducted in other Congo Basin countries. Furthermore, analytical protocols used differ across studies, making certain quantitative comparisons delicate. Finally, data regarding the long-term health effects of Gnetum spp. consumption remain insufficient.

Table 21. Comparative synthesis of main nutritional studies on Gnetum spp.

Reference	Country	Type of study	Main parameters studied	Main results	Identified limitations
Shiembo et al. (1996)	Cameroon	Descriptive study	Chemical composition of leaves	Highlighted richness in proteins, fiber, and minerals; nutritional interest of leaves	Limited number of samples and little-studied geographical variability
Dhellot et al. (2006)	Nigeria	Biochemical analysis	Proteins, lipids, carbohydrates, fiber, minerals	Confirmation of high content in plant proteins, calcium, potassium, and iron	Absence of evaluation of culinary processes
Uusiku et al. (2010)	Sub-Saharan Africa	Comparative review	Nutritional value of African leafy vegetables	Gnetum spp. ranks among vegetables richest in proteins and micronutrients	Few data specific to Gabon
Sunderland et al. (2013)	Central Africa	Multidisciplinary review	Nutrition, socio-economics, biodiversity	Importance of non-timber forest products in food systems and livelihoods	Few quantitative data specific to Gnetum spp.
Ndzié et al. (2021)	Cameroon	Nutritional analysis	Biochemical and mineral composition	Confirmation of richness in fiber, proteins, and essential minerals	Poor comparison of different preparation methods
Bouchenna & Brikh (2021)	International review	Bibliographic review	Effects of processing methods	Highlighted influence of cooking on nutritional quality of leafy vegetables	Study not specific to Gnetum spp.
Present	Gabon /	Integrative	Nutrition,	Integrated vision	Dependency

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review	Central Africa	review	processing, health, socio-economics, sustainable development	linking nutritional composition, culinary processes, value chain, and contribution to SDGs	on quality and availability of published studies

Source: Synthesis produced from available scientific literature on Gnetum spp. and African leafy vegetables.

Comparative Analysis

Scientific literature shows consensus on the high nutritional value of Gnetum spp. Available studies systematically indicate that the leaves constitute an important source of plant proteins, dietary fiber, and essential minerals, notably calcium, iron, magnesium, and potassium. These characteristics distinguish Gnetum spp. from many other leafy vegetables consumed in Central Africa.

Despite this convergence, quantitative differences are observed between studies. They can be attributed to several factors: ecological conditions, soil characteristics, leaf development stage, species studied (Gnetum africanum or Gnetum buchholzianum), analytical methods employed, and processing methods prior to analysis. These elements explain the reported variations in contents of proteins, fiber, lipids, and micronutrients.

Most works focus on the chemical composition of fresh leaves. In contrast, the effects of traditional recipes, culinary treatments, and nutrient bioavailability remain relatively understudied. Similarly, interactions between nutritional quality, food security, economic development, and forest resource conservation are rarely addressed in an integrated manner.

The present review distinguishes itself through its multidisciplinary approach. It links nutritional data with processing methods, the value chain, socio-economic challenges, and sustainable development goals. This perspective broadens the field of analysis and highlights the potential role of Gnetum spp. as a strategic resource for more sustainable food systems.

Main convergences identified in the literature:

- Richness in plant proteins and dietary fiber.
- High contents of calcium, iron, magnesium, and potassium.
- Nutritional importance for Central African populations.
- Socio-economic interest as a non-timber forest product.
- High potential to contribute to food security.

Main research gaps:

- Few studies conducted specifically in Gabon.

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- Limited data on nutrient bioavailability after processing.
- Small number of studies comparing different traditional recipes.
- Lack of analyses on bioactive compounds and their physiological effects.
- Few integrated economic evaluations of value chains.
- Insufficiency of research on domestication and agroforestry production.

Comparative Analysis

Socio-economic studies converge in recognizing Gnetum spp (see table 22). as one of the most important non-timber forest products in Central Africa. Its marketing generates regular income for rural and urban households while supporting the livelihoods of thousands of actors involved in harvesting, transport, processing, and sales. Trade extends beyond local markets to supply regional commerce as well as exports to Europe and America aimed at African diasporas.

Table 22. Comparative synthesis of main socio-economic studies on Gnetum spp.

Reference	Study area	Theme	Main results	Limitations
Shiembo (1994)	Central Africa	Sustainable NTFP management	Early alert on overexploitation of natural stands of Gnetum spp.	Few quantitative data
Sunderland et al. (1999)	Congo Basin	NTFP trade	Regional economic importance of Gnetum spp. and development of cross-border trade	Limited data on household incomes
Awono et al. (2009)	Cameroon	Marketing	NTFP markets constitute an important source of income for producers and traders	Analysis centered on certain markets
Ingram, Ndumbe & Ewane (2012)	Cameroon–Nigeria	Value chain	Over 2,500 actors participate in the value chain; major role of women in harvesting and trade; trade structured around several regional circuits.	Little information on other Congo Basin countries
Tieguhong et al. (2015)	Cameroon	Governance	Transaction costs, regulatory complexity, and corruption reduce profitability and foster unsustainable exploitation.	Results mainly from the Cameroonian context
FAO (2016)	Central Africa	NTFPs and food security	Gnetum spp. contributes to food security, rural income, and feeds regional trade as well as export to the diaspora; domestication is recommended to limit pressure on wild populations.	Few detailed economic indicators

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Present review	Gabon / Central Africa	Integrative synthesis	Integration of nutritional, economic, social, environmental, and institutional dimensions into the same analysis	Dependency on published data

A recurring result is the central role of women, who dominate harvesting, artisanal processing, and marketing activities. The value chain thus contributes to their economic empowerment, even if segments with higher added value (transport, export, wholesalers) are often more controlled by men.

The literature also emphasizes that growing demand exerts increasing pressure on natural populations of Gnetum spp. Harvesting remains predominantly based on wild stands, which increases risks of overexploitation when sustainable management practices are insufficient. Several authors recommend the domestication of the species, its integration into agroforestry systems, and the implementation of more effective regulations to guarantee resource sustainability.

Finally, works dedicated to governance show that institutional constraints (administrative complexity, high transaction costs, low transparency) limit the development of the value chain. Better producer organization, harmonized quality standards, adapted infrastructure, and a more favorable regulatory environment would improve the competitiveness and sustainability of this value chain.

Main convergences in the literature:

- Gnetum spp. is a strategic NTFP for rural economies in Central Africa.
- The value chain generates significant income along the entire value chain.
- Women play a predominant role in harvesting, processing, and trade.
- Growing demand stimulates national, regional, and international markets.
- Domestication and agroforestry are considered promising solutions to secure supply and preserve natural resources.

Main identified gaps:

- Few quantitative studies specific to Gabon.
- Insufficiency of comparative economic analyses between Congo Basin countries.
- Poor documentation on net incomes of different value chain actors.
- Limited data on the impact of processing innovations and certification.
- Few evaluations of the effect of public policies on the economic performance of the value chain.

5.7. Research Perspectives

Future work should focus on the below and summarized in the table 23:

- The in-depth characterization of bioactive compounds in Gnetum spp.;

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- The evaluation of nutrient bioavailability after culinary processing;
- The development of innovative preservation and processing technologies;
- The economic analysis of the value chain;
- The effects of domestication on nutritional quality and productivity;
- The evaluation of the impact of public policies for non-timber forest product valorization.

Strengthening collaborations between researchers, public institutions, private actors, and local communities will foster the development of a sustainable, competitive, and value-creating Nkumu chain to the benefit of food security and sustainable development in Gabon.

Table 23. Main research priorities for Gnetum spp. (Nkumu)

Research domain	Identified gaps	Priority perspectives
Nutritional composition	Data variability according to regions and analytical methods	Standardize analytical protocols and compare populations of Gnetum *africanum* and Gnetum *buchholzianum* in different ecological contexts.
Bioactive compounds	Limited data on polyphenols, flavonoids, and other secondary metabolites	Identify, characterize, and quantify bioactive compounds and evaluate their antioxidant, anti-inflammatory, and cardiometabolic activity.
Nutrient bioavailability	Few studies on actual nutrient absorption after consumption	Conduct bioavailability and bioaccessibility studies according to different traditional recipes.
Food processing	Insufficient data on the effect of culinary processes	Study the influence of cooking techniques, drying, fermentation, and preservation on nutritional and functional qualities.
Sanitary safety	Poor documentation on microbiological and chemical contaminants	Develop studies on sanitary quality, contaminants, heavy metals, and good hygiene practices.
Domestication and agroforestry	Persistent dependency on natural stands	Develop domestication programs, varietal selection, and integration into agroforestry systems.
Economy and value chain	Few quantitative economic analyses	Evaluate profitability of different value chain links, transaction costs, and mechanisms of value creation.
Consumer acceptability	Few behavioral studies	Analyze consumer preferences, perception of quality, and determinants of food choices.
Public policies	Weak evaluation of existing measures	Evaluate effectiveness of NTFP management policies and propose adapted governance models.
Climate change	Still limited data	Study response of Gnetum spp. to

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		climate change and develop adaptation strategies.

Analysis

The available literature highlights significant progress regarding the nutritional composition and socio-economic role of Gnetum spp. However, several areas remain insufficiently documented and merit in-depth investigations.

At the nutritional level, future research should move beyond simple chemical characterization of leaves to examine actual nutrient bioavailability and the effects of traditional culinary processes. Gabonese recipes combining Nkumu with peanut paste, smoked fish, palm oil, or other ingredients offer a particularly relevant context to study food interactions, cooking-induced modifications, and micronutrient absorption (Van Boekel et al., 2010; Uusiku et al., 2010; FAO et al., 2024).

The identification of bioactive compounds also represents a priority. Current knowledge on polyphenols, flavonoids, antioxidant compounds, and other secondary metabolites remains fragmentary. Approaches combining metabolomics, high-performance chromatography, and spectrometric analyses would allow for better characterization of these molecules and evaluation of their potential effects on the prevention of non-communicable diseases.

Technological aspects also require further exploration. Processing methods directly influence nutritional quality, microbiological stability, and the shelf life of preparations. Developing technologies adapted to local realities could simultaneously improve sanitary safety, product quality, and commercial value.

From a socio-economic perspective, research should integrate quantitative analyses of the value chain to identify wealth creation mechanisms, logistical constraints, transaction costs, and factors influencing value chain competitiveness. Particular attention should be paid to the role of women, who remain the main actors in harvesting, processing, and marketing.

Finally, sustainable development of the value chain relies on better knowledge of interactions between Gnetum spp., agroforestry systems, climate change, and public policies. Domestication of the species, improvement of cultivation practices, and implementation of certification mechanisms could help reduce pressure on natural populations while strengthening producer income.

Proposed scientific priorities:

Future research could be structured around six strategic axes:

1. Characterize the genetic diversity of Gnetum spp. to identify ecotypes of nutritional, agronomic, or technological interest.

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2. Evaluate the effects of traditional and innovative processes on the nutritional quality, bioactive compounds, and sanitary safety of preparations.
3. Develop sustainable production systems based on agroforestry, domestication, and genetic resource conservation.
4. Structure the value chain through improved processing, certification, traceability, and market access.
5. Measure the health impacts of regular Gnetum spp. consumption through clinical, epidemiological, and interventional studies.
6. Strengthen public policies by producing scientific data useful for sustainable management of non-timber forest products and their integration into national food security strategies.

6. General Conclusion and Recommendations

6.1. General Conclusion

This integrative review highlights the strategic role of Gnetum spp. (Nkumu) in the food systems of Gabon and, more broadly, Central Africa. Analysis of the literature confirms that this non-timber forest resource constitutes far more than a simple traditional vegetable. Through its richness in plant proteins, dietary fiber, essential minerals (calcium, iron, potassium, and magnesium), and bioactive compounds, Gnetum spp. represents a food of high nutritional value capable of contributing to the improvement of food and nutritional security as well as the prevention of certain chronic diseases.

Beyond its nutritional qualities, Nkumu plays a major socio-economic role. Its collection, processing, and marketing generate significant income for many rural households, with particularly strong involvement of women. This value chain thus contributes to poverty reduction, livelihood improvement, and the dynamism of local economies.

The study also shows that processing techniques significantly influence the nutritional quality of Gnetum spp. preparations. While certain processes improve digestibility or product acceptability, others can lead to losses in micronutrients and bioactive compounds. Optimization of processing methods thus emerges as an essential lever to preserve the nutritional qualities of Nkumu.

Despite its considerable potential, several constraints still limit the sustainable development of this value chain. Dependency on wild harvesting, post-harvest losses, low levels of agrifood processing, absence of quality standards, insufficiency of domestication programs, and weak value chain structuring hinder the full valorization of this resource.

In the context of food transitions, the fight against malnutrition, and climate change, Gnetum spp. constitutes a strategic resource capable of contributing simultaneously to several Sustainable Development Goals, notably combating poverty, food

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security, health promotion, gender equality, inclusive economic growth, and forest ecosystem conservation. Its sustainable valorization requires an integrated approach associating scientific research, technological innovation, public policies, the private sector, and local communities.

Finally, this review underscores the need to strengthen scientific knowledge on Gnetum spp. to better characterize its nutritional composition, functional properties, processing effects, and socio-economic impacts. This information will be essential to support the development of evidence-based policies and promote sustainable exploitation of this resource for the benefit of present and future generations.

6.2. Recommendations

Based on the findings of this review, several recommendations can be formulated.

For Researchers

- Deepen the biochemical and nutritional characterization of the different Gnetum species present in Gabon;
- Study the bioavailability of nutrients after the main processing methods;
- Conduct research on the functional properties and bioactive compounds of Nkumu;
- Evaluate the health impacts of its regular consumption through clinical and epidemiological studies;
- Strengthen interdisciplinary research combining nutrition, forestry, economics, and public health.

For Public Authorities

- Integrate Gnetum spp. into national food security and nutrition policies;
- Promote national domestication and sustainable production programs;
- Support the structuring of producer organizations and cooperatives;
- Develop quality and health safety standards tailored to the sector;
- Strengthen training mechanisms for producers and processors.

For Economic Actors

- Develop modern preservation and processing technologies;
- Diversify Nkumu-derived products to increase their added value;
- Improve supply chains to reduce post-harvest losses;
- Encourage product certification to access new national and international markets.

For Technical and Financial Partners

- Support applied research programs on non-timber forest products;
- Fund initiatives for the domestication and sustainable management of Gnetum spp.;

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- Assist agrifood valorization projects and the development of local value chains;
- Promote partnerships between universities, research institutes, the private sector, and community organizations.

Declarations

Funding Declaration: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
Conflicts of Interest: The authors declare that they have no conflicts of interest.
Data Availability: All data used originate from the publications cited in this review.
Acknowledgements: To Almighty God who gives me the strength every day to move forward, to my family for their unconditional support, and to the institutions, laboratories, and individuals who contributed to this work.

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