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BIOACTIVE COMPOUNDS IN UNDERUTILIZED WEST AFRICAN LEAFY VEGETABLES AND LEGUMES: A SYSTEMATIC REVIEW OF EXTRACTION, PROCESSING, BIOACCESSIBILITY, AND FOOD APPLICATION EVIDENCE (2015–2025)

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ABSTRACT

Background: Indigenous and underutilized leafy vegetables and legumes are part of West Africa's diverse food systems and contain compounds of potential nutritional and functional value. Evidence on their bioactive profiles, extraction, processing, digestion, and food uses, however, is spread across different species and study designs. Objective: This review examined primary studies published from 2015 to 2025 on bioactive compounds in selected underutilized or indigenous West African leafy vegetables and legumes. The review focused on compound profiles, extraction and processing methods, bioaccessibility, and food applications. Methods: PubMed/MEDLINE, Google Scholar, and African Journals Online were searched in July 2026. Three reviewers screened records against predefined criteria using the PRISMA 2020 framework. The protocol was registered prospectively in PROSPERO (CRD420261429099). The search yielded 51 records; six duplicates were removed, 45 records were screened, 29 full texts were assessed, and 17 primary studies met the inclusion criteria. Results: Phenolics and flavonoids were the most commonly reported compound groups. Most studies used conventional solvent extraction; ultrasound-assisted and pressurized liquid extraction appeared less often. Few studies directly examined bioaccessibility through digestion, as many measured phytochemical content or biological activity without assessing gastrointestinal release. Plant part, genotype, and processing conditions influenced reported phytochemical profiles and antioxidant outcomes. Food-related applications included beverage formulation and the use of plant extracts as preservatives. Conclusion: Selected underutilized West African plant foods may be useful sources of bioactive compounds, but differences in methods and the limited number of digestion studies constrain comparisons and conclusions about health effects. Future work should use standardized extraction and digestion methods and assess safety and performance in food matrices.

Keywords: phytochemicals, green extraction, gastrointestinal digestion, food processing, underutilized species

1. INTRODUCTION

Interest in the relationship between diet and health has grown alongside concern about non-communicable diseases. Plant-derived compounds—including phenolics, flavonoids, carotenoids, alkaloids, and saponins—have been studied for activities such as antioxidant and antimicrobial effects and enzyme inhibition (World Health Organization, 2023; Popoola et al., 2023). In food research, identifying a compound is only a starting point. Its stability during processing, release from the food matrix during digestion, potential bioaccessibility, and safety also matter when assessing its possible value.

West Africa is home to a wide range of leafy vegetables, grain legumes, and other indigenous or underused plant foods. Species discussed in the literature include Moringa oleifera, Vernonia amygdalina, Corchorus olitorius, Vigna unguiculata, Vigna subterranea, Parkia biglobosa, and Tetrapleura tetraptera. Although these resources may contribute to nutrition and functional-food development, their use in formal food systems remains uneven (Abberton et al., 2022; Tan et al., 2020; Popoola et al., 2023).

Previous reviews have often concentrated on a single crop or considered evidence from Africa or the wider world. Reviews of Moringa and underutilized African legumes describe a broad range of phytochemicals, but findings on extraction, processing, digestion, and food applications remain scattered across species and study types (Kashyap et al., 2022; Fitri et al., 2025; Popoola et al., 2023). Bringing this evidence together in a West African food-resource context can help show which findings are well supported, where comparisons are difficult, and which questions need further study.

This review synthesized primary research published from 2015 to 2025 on selected indigenous or underutilized West African plant foods. Its objectives were to identify reported bioactive compounds; describe extraction and processing methods; assess the amount and type of evidence on digestion and bioaccessibility; and summarize food applications and remaining research gaps.

2. LITERATURE REVIEW

Plant foods contain a range of bioactive compounds, including phenolic acids, flavonoids, carotenoids, alkaloids, saponins, tannins, and terpenoids. Underutilized African legumes and leafy vegetables are of interest because they offer both nutritional value and phytochemical diversity and may broaden dietary choices (Abberton et al., 2022; Popoola et al., 2023). Research on Moringa oleifera has reported phenolics and other compounds in different edible parts. Studies of cowpea and Bambara groundnut have also found differences related to cultivar, genotype, seed fraction, and processing.

The extraction method can affect both the quantity and type of compounds measured. Laboratory studies commonly use hydroethanolic or methanolic solvents, whereas

ultrasound-assisted and pressurized liquid extraction have been reported less frequently. Results from different studies should therefore be interpreted with care, taking account of solvent composition, solid-to-liquid ratio, temperature, extraction time, analytical method, and the properties of the compounds being measured.

Processing can further change the composition and properties of plant foods. Blanching, boiling, steaming, frying, dehulling, and fermentation may affect phenolic retention, antioxidant activity, antinutritional factors, digestibility, and sensory quality. An antioxidant or antimicrobial effect observed in an extract does not, by itself, demonstrate bioaccessibility. Bioaccessibility concerns the portion of a compound released from the food matrix during digestion and made available for potential absorption.

Taken together, the literature points to the need to consider plant material, extraction and processing conditions, analytical results, digestion-related findings, and food applications in one synthesis. This review addresses these areas while recognizing that differences between study methods and the small number of studies using standardized digestion models limit the conclusions that can be drawn.

3. METHODOLOGY

3.1 Review design and protocol registration

The review was prepared with reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). The protocol was registered prospectively with the International Prospective Register of Systematic Reviews (PROSPERO; CRD420261429099).

3.2 Eligibility criteria

Studies were eligible if they were peer-reviewed journal articles in English, published between January 2015 and December 2025, and reported primary evidence on bioactive compounds in leafy vegetables or legumes native to, or widely cultivated and consumed in, West Africa. Eligible topics included extraction, processing, digestion or bioaccessibility, and functional-food applications. Laboratory, digestion, animal, and relevant computational studies were considered when they directly addressed the review objectives. Conference abstracts, book chapters, theses, grey literature, secondary reviews, and studies published outside the specified period were excluded. Reviews found during searching were used only for background context.

3.3 Search strategy

PubMed/MEDLINE, Google Scholar, and African Journals Online (AJOL) were searched in July 2026. Search terms covered underutilized, neglected, and indigenous plant foods; leafy vegetables and legumes; West Africa and selected country names; bioactive compounds; extraction; bioaccessibility or bioavailability; and functional-food or nutraceutical applications. A broad strategy was used because terminology for

underutilized crops varies across sources. Only studies published from January 2015 to December 2025 were eligible.

3.4 Study selection

Search records were managed in Zotero, and duplicate records were removed before screening. Three reviewers (A.A.R., M.K.-K., and Y.A.) screened titles and abstracts and then assessed the full texts of potentially eligible papers. Differences were resolved through discussion and consensus. Seventeen primary experimental studies were included. Figure 1 summarizes the selection process.

3.5 Data extraction

The reviewers used a standardized form to record the authors and publication year, study country, plant species and part, extraction or processing procedure, analytical method, main bioactive compounds or compound groups, principal findings, any explicit digestion or bioaccessibility results, antinutritional factors, and study limitations.

3.6 Quality assessment

Study quality was assessed with Joanna Briggs Institute critical appraisal tools selected to suit each study design. The findings were summarized descriptively because the included studies differed in design and outcome measures. No combined numerical quality score was calculated, and quality ratings were not used to produce a pooled estimate.

3.7 Data synthesis

The findings were grouped into four themes: bioactive compound profiles; extraction and processing methods; digestion and bioaccessibility evidence; and potential food applications. Percentages were reported only when the number of studies supporting the calculation was clear from the included-study table. Digestion and bioaccessibility findings were kept distinct from biological activity and food-preservation results.

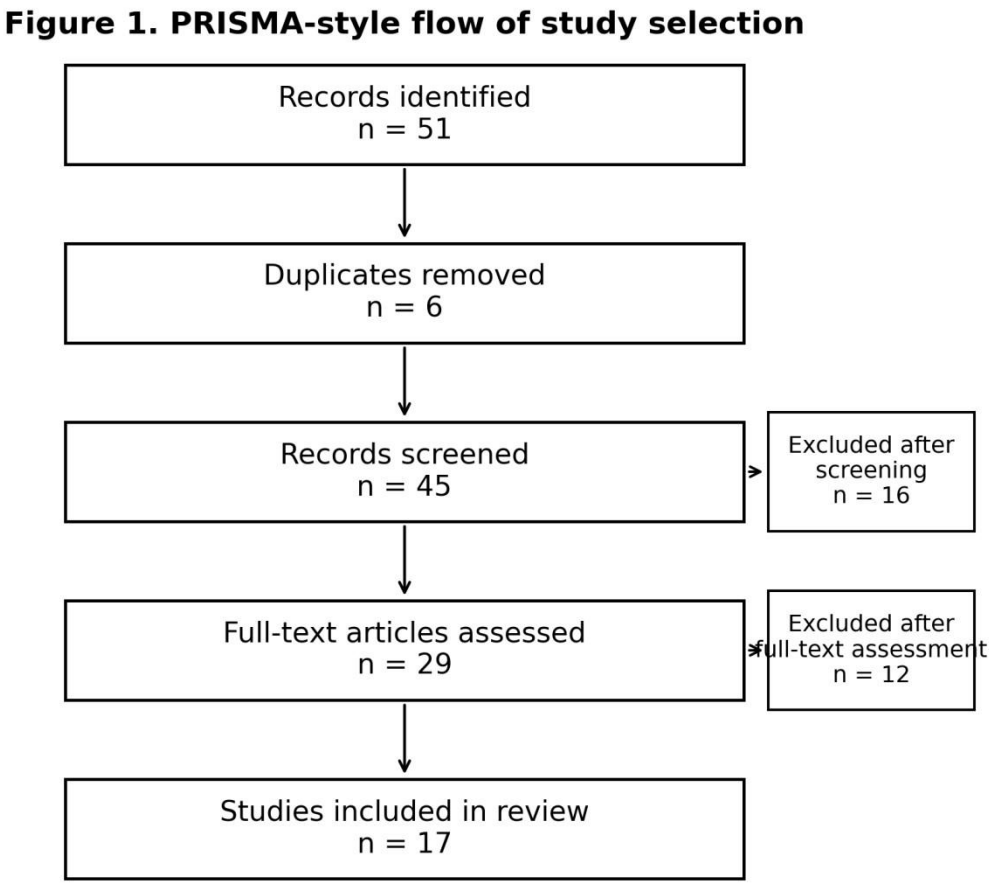


Figure 1. PRISMA-style flow of study selection.

4. RESULTS AND DISCUSSION

4.1 RESULTS

Search results and study selection

The search identified 51 records. After six duplicates were removed, 45 records remained for title and abstract screening. Sixteen were excluded at this stage because they did not meet the criteria, for example because of geographic mismatch, a broad global focus without a relevant crop-specific contribution, or non-peer-reviewed publication status. The full texts of 29 records were assessed, and 12 were excluded. The final review included 17 primary experimental studies.

Characteristics of included studies

The 17 included studies were published between 2016 and 2025, with more appearing from 2021 onward. Studies were conducted in Nigeria, Ghana, Burkina Faso, Cameroon, and Guinea-Bissau, as well as in countries outside West Africa where the plant species are native to, or commonly cultivated and consumed in, the region. The review therefore distinguished the location where an experiment was conducted from the plant's regional origin or relevance to West African diets.

The studies examined Moringa oleifera, Vernonia amygdalina, Corchorus olitorius, Vigna unguiculata, Vigna subterranea, Parkia biglobosa, Tetrapleura tetraptera, and Cleome gynandra. The plant materials included leaves, seeds, flowers, fruits, roots, and bark. This range broadens the review but also makes direct comparison more difficult.

Table 1. ***Characteristics and principal findings of the 17 primary studies included in the systematic review.***

Study	Plant material	Location	Extraction / analysis	Principal finding / interpretation
Ben Yakoub et al. (2018)	Corchorus olitorius; leaves	Tunisia	Ethanol–water maceration; LC–ESI–MS	Phenolics and flavonoids were reported alongside antioxidant activity; no digestion study was identified.
Moyo et al. (2018)	Cleome gynandra; leaves	South Africa	Solvent extraction; ICP–MS	Phytochemicals and minerals were characterized; no digestion study was identified.
Moloto et al. (2020)	Vigna unguiculata; leaves	South Africa	Methanol–water extraction; HPLC-DAD	Phenolics, carotenoids, and flavonoids varied by cultivar; biological activity does not establish bioaccessibility.
Seke et al. (2023)	Vigna unguiculata; leaves	South Africa	Solvent extraction; INFOGEST digestion	Blanching retained more compounds than boiling; digestion affected compounds and antioxidant outcomes.
Ibrahim et al. (2016)	Parkia biglobosa; leaves	Nigeria	Sequential solvent extraction; butanol fraction	Animal-model evidence concerned pancreatic β-cell function; this was not a direct bioaccessibility measure.
Adeloye and Agboola (2022)	Parkia biglobosa; seeds / juice blends	Nigeria	Juice extraction; Folin–Ciocalteu assay	Reported antioxidant properties and sensory acceptance of juice blends.
Guzzetti et al. (2021)	Corchorus olitorius; leaves	Italy	Pressurized liquid extraction; UHPLC-QTOF-MS	A range of phenolic compounds and antioxidant capacity were reported; no explicit digestion study was identified.
Sombie et al. (2018)	Vigna unguiculata; seeds	Burkina Faso	80% methanol; DPPH, ABTS, FRAP	Phenolic content varied by genotype; antinutritional factors

				were also reported. No direct digestion study was identified.
Ampem Danso et al. (2024)	Vernonia amygdalina; leaves	Ghana	Methanolic/aqueous extraction; MTT assay	In vitro antioxidant and anticancer-related activity was assessed; this was not direct bioaccessibility evidence.
Oresanya et al. (2024)	Multiple African leafy vegetables	Nigeria / Africa	Microtiter-plate assays; HPTLC	Phytochemical profiling was reported; no explicit digestion study was identified.
Nameni et al. (2024)	Vigna unguiculata and Vigna subterranea; seeds	Cameroon	Steaming/frying; TPC/TFC and DPPH	Culinary processing changed phenolic content and antioxidant activity; these are not direct bioaccessibility measures.
Fernandes et al. (2021)	Moringa oleifera; flowers, fruits, seeds	Guinea-Bissau	Hydroethanolic/aqueous extraction; HPLC-DAD-ESI/MS	Flowers showed high phenolic content; no explicit digestion study was identified.
Djeujo et al. (2023)	Vernonia amygdalina; leaves and roots	West Africa (as reported)	Ethanol/methanol extraction; HPLC-MS; ADMET	Luteolin and vernodalol showed α-glucosidase-inhibition potential; bioaccessibility was not measured.
Oyeyinka et al. (2021)	Vigna subterranea; seeds	Nigeria	Aqueous/ethanolic extraction; DPPH, FRAP, antimicrobial assays	The ethanolic extract showed stronger antioxidant and antimicrobial activity; no direct bioaccessibility measure was reported.
Adedayo et al. (2021)	Vigna subterranea; whole and dehulled seeds	South Africa	80% methanol; HPLC, DPPH, FRAP	Seed coats contained more phenolics; dehulling reduced the measured phenolic content.
Anyamele et al. (2023)	Tetrapleura tetraptera; fruits, seeds, bark, leaves	West Africa (as reported)	Ethanol, methanol, water, and hexane; GC-MS/HPLC	Broad phytochemical diversity and potential biological activities were reported; toxicological considerations were noted.
Al-Baidhani et al. (2024)	Moringa oleifera; leaves	Iraq / West African plant resource (as reported in the original manuscript)	Ultrasound-assisted extraction; HPLC	Extracts were tested for beef-patty preservation; this was not a direct bioaccessibility study.

Bioactive compound profiles

Phenolics and flavonoids were the bioactive groups most often reported. Studies of Corchorus olitorius leaves identified compounds such as quinic-acid derivatives, quercetin, caffeic acid, and other phenolics (Ben Yakoub et al., 2018; Guzzetti et al., 2021). Research on cowpea leaves and seeds reported differences in phenolics, flavonoids, carotenoids, and related compounds among cultivars or genotypes (Moloto et al., 2020; Sombie et al., 2018; Seke et al., 2023). In Bambara groundnut, seed coats had higher measured phenolic levels

than cotyledons, suggesting that dehulling can change the phytochemical profile of the remaining material (Adedayo et al., 2021).

Other reported compounds included alkaloids, saponins, tannins, terpenoids, and essential-oil constituents. Tetrapleura tetraptera showed a broad range of phytochemicals (Anyamele et al., 2023). Parkia biglobosa leaves were reported to contain several secondary-metabolite groups and were investigated in an animal model for diabetes-related outcomes (Ibrahim et al., 2016). Studies of edible Moringa oleifera parts also reported phenolics, flavonoids, and other phytochemicals (Fernandes et al., 2021; Al-Baidhani et al., 2024).

Extraction and processing technologies

Conventional solvent extraction was the most common approach. Hydroethanolic and methanolic solvents were frequently used to recover phenolic compounds. Ethanol–water extraction of Corchorus olitorius and hydroethanolic extraction of Moringa oleifera were associated with recovery of phenolic constituents (Ben Yakoub et al., 2018; Fernandes et al., 2021). Differences in solvent mixtures, solid-to-liquid ratios, extraction times, temperatures, and analytical assays mean that the protocols cannot be ranked reliably against one another using the reported results alone.

Fewer studies used intensified or so-called green extraction methods. Pressurized liquid extraction was used to characterize phenolics in Corchorus olitorius, while ultrasound-assisted extraction of Moringa oleifera leaves produced extracts that were tested for food-preservation purposes (Guzzetti et al., 2021; Al-Baidhani et al., 2024). Because these approaches were represented by relatively few studies, the evidence does not show that they consistently outperform conventional extraction across West African plant foods.

Processing also affected the measured phytochemical content. In cowpea leaves, blanching and boiling produced different patterns of compound retention. Studies of cowpea and Bambara groundnut seeds likewise found that culinary processing changed total phenolic content and antioxidant activity (Seke et al., 2023; Nameni et al., 2024).

Bioaccessibility and digestion-related evidence

Only a small part of the evidence base used standardized digestion models. The most directly relevant study applied the INFOGEST in vitro digestion approach to cowpea leaves and found that processing affected the behaviour of functional compounds during digestion (Seke et al., 2023). Other studies examined antioxidant or antimicrobial activity, enzyme inhibition, animal outcomes, or food preservation. These findings indicate possible functional value, but they should not be described as evidence of bioaccessibility unless the release or availability of compounds during gastrointestinal digestion was measured.

Overall, the included literature provides limited direct evidence on digestion-based bioaccessibility. Keeping this outcome separate from compound concentration and biological activity is important because the measures answer different questions.

Antinutritional factors

Phytates, tannins, and other antinutritional factors were discussed particularly in studies of legumes. Research on cowpea and Bambara groundnut indicates that genotype, seed fraction, and processing can influence phytochemical and antinutritional profiles (Sombie et al., 2018; Adedayo et al., 2021; Nameni et al., 2024). These compounds should be considered in the context of the whole food, since some can limit mineral availability while also showing biological activity in experimental settings.

Functional food application potential

Potential food uses reported in the included studies included beverage blends, natural preservatives, and the addition of bioactive extracts to food products (Adeloye & Agboola, 2022; Al-Baidhani et al., 2024). Before commercial use, products would need assessment of sensory acceptability, storage stability, dose, interactions with the food matrix, safety, and regulatory requirements.

4.2 DISCUSSION

Evidence strength and interpretation

Across the selected plant foods, phenolics and flavonoids were the most frequently reported phytochemical groups. This pattern agrees with broader reviews of underutilized African legumes and crops originating in West Africa (Popoola et al., 2023; Elegbeleye et al., 2022). However, a high phytochemical content does not establish a health benefit in humans. Much of the available evidence comes from in vitro, ex vivo, computational, or preclinical work. Tests such as DPPH, FRAP, α-glucosidase inhibition, and antimicrobial assays measure specific experimental effects rather than clinical outcomes.

Extraction technology and food-matrix effects

Conventional solvent extraction remains common, in part because it is accessible for laboratory studies. For food use, researchers must also consider solvent choice, residual solvent limits, energy requirements, and scale-up. Ultrasound-assisted and pressurized liquid extraction may improve mass transfer and help target particular compounds, but the small evidence base does not establish that either method is superior across plant species and food matrices. Future comparisons should use consistent designs and report solvent composition, solid-to-liquid ratio, extraction time and temperature, energy input, and recovery yield.

Bioaccessibility as the major translational gap

For functional-food research, the amount of a compound measured in an extract is not the same as the amount released during digestion or available for absorption. A compound may be altered during processing or digestion and may not remain accessible in the same form.

The current evidence therefore supports further work on digestion and absorption; it does not justify definitive claims about dietary health effects.

Implications for West African food systems

Research opportunities extend beyond extracting isolated compounds. Developing foods that retain useful phytochemicals while remaining acceptable to consumers may be equally important. Fermentation, germination, controlled blanching, and other traditional or improved processing methods can affect antinutritional factors, digestibility, sensory properties, and compound stability. These effects should be examined in the final food product, not only in isolated extracts.

Research priorities

The findings point to five priorities. First, extraction procedures and analytical reporting should be standardized to improve comparisons across studies. Second, researchers should distinguish total compound content from the fraction released during digestion. Third, safety and toxicological testing should accompany claims about concentration or biological activity. Fourth, food-application studies should measure sensory acceptance, storage stability, and changes during processing. Finally, research should cover a wider range of West African locations and plant species, using clear and consistent criteria to define underutilized foods.

Strengths and limitations

A key strength of this review is that it brings together evidence on compound profiles, extraction and processing, digestion-related outcomes, and food applications within a West African food-resource context. Predefined eligibility criteria, screening by three reviewers, Zotero record management, reference to PRISMA 2020, and prospective PROSPERO registration support transparency. The review also has limitations. Only three databases or search platforms were used, so relevant papers indexed solely in Scopus, Web of Science, or other regional sources may have been missed. Restricting eligibility to English-language, peer-reviewed articles may have introduced language and publication bias. Differences in plant parts, extraction methods, analytical procedures, and outcome definitions prevented meaningful quantitative meta-analysis. Some experiments were conducted outside West Africa on plants relevant to the region; these studies are not equivalent to research conducted within West African food systems. Finally, few included studies directly measured bioaccessibility using digestion models, so conclusions in this area remain tentative.

5. CONCLUSION

The selected indigenous and underutilized West African plant foods contain phenolics, flavonoids, and other phytochemical groups that have shown antioxidant, antimicrobial, enzyme-inhibitory, or related activity in experimental studies. Conventional solvent extraction was most common, while ultrasound-assisted and pressurized liquid extraction appeared in relatively few reports. The main gap is not evidence that these compounds occur in the plants, but the lack of standardized research linking their measured content with processing stability, gastrointestinal release, bioaccessibility, and performance in real foods. Future studies should apply consistent extraction and digestion methods, assess safety, validate findings in food matrices, and evaluate sensory properties, storage stability, and scale-up. Such evidence would help determine how these plant resources can be used responsibly in diverse, value-added foods across West Africa.

Declarations

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Author Contributions

Conceptualization: A.A.R.; Methodology: A.A.R., M.K.-K., and Y.A.; Investigation and screening: A.A.R., M.K.-K., and Y.A.; Data curation: A.A.R.; Formal analysis: A.A.R.; Writing—original draft: A.A.R.; Writing—review and editing: A.A.R., M.K.-K., and Y.A. All authors approved the final manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability

The data supporting the findings are presented in the article. Screening decisions and the data-extraction form may be obtained from the corresponding author upon reasonable request. The review protocol is registered in PROSPERO (CRD420261429099).

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