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# Underutilized Nutrient Sources for Malnutrition Interventions in Conflict-Affected Regions of Nigeria: A Review

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## ABSTRACT

Malnutrition remains a critical public health challenge in Nigeria, particularly in conflict-affected and resource-constrained settings where food insecurity, displacement, and limited dietary diversity exacerbate nutrient deficiencies. Beyond insufficient caloric intake, malnutrition represents a complex biochemical disorder characterized by impaired metabolic pathways, disrupted protein synthesis, micronutrient deficiencies, and increased oxidative stress. Conventional nutrition interventions, which often emphasize energy sufficiency, are frequently inadequate in addressing these underlying metabolic and micronutrient imbalances. This review examined the biochemical basis of malnutrition and evaluated the potential of underutilized plant nutrient sources as a sustainable intervention strategy, drawing on evidence from peer-reviewed studies, global health reports, and nutritional databases. Particular emphasis is placed on metabolically active plant components, especially leafy tissues, which are often discarded despite their high concentrations of proteins, essential minerals, vitamins, and bioactive phytochemicals. Evidence indicated that these underutilized plant parts possess substantially greater nutrient density than commonly consumed staple foods, which are typically energy-rich but micronutrient-poor. From a biochemical perspective, these nutrients support key physiological processes, including enzymatic activity, energy metabolism, erythropoiesis, and antioxidant defense, thereby promoting metabolic recovery in malnourished populations. Their local availability, environmental adaptability, and cultural relevance further enhance their suitability for integration into nutrition interventions in vulnerable settings. The incorporation of underutilized plant nutrient sources into dietary and public health strategies represents a practical and sustainable approach to improving nutritional outcomes and addressing the biochemical dimensions of malnutrition in Nigeria.

**Keywords:** Malnutrition, Underutilized plant nutrient sources, Biochemical mechanisms, Conflict-affected regions, Micronutrient deficiency

## INTRODUCTION

Malnutrition remains one of the most persistent and complex public health challenges affecting low- and middle-income countries, with Nigeria bearing a substantial and growing burden, particularly among vulnerable populations such as children under five, pregnant and lactating women, and internally displaced persons (UNICEF, 2019; FAO, 2021). In recent years, the dynamics of malnutrition in Nigeria have been increasingly shaped by widespread insecurity and armed conflict, especially in regions affected by insurgency, banditry, and communal violence. These conflict situations disrupt agricultural production, displace communities, and severely limit access to diverse and nutritious foods, thereby exacerbating both acute and chronic forms of malnutrition.

In Nigeria, the burden of malnutrition is not uniformly distributed but is disproportionately concentrated in regions affected by conflict and socioeconomic instability. The northeastern region, in particular, has experienced prolonged insurgency, resulting in large-scale displacement and disruption of agricultural and food distribution systems. Internally displaced persons (IDPs) often rely on humanitarian food aid, which, while essential, is typically limited in dietary diversity and micronutrient density. This situation perpetuates a cycle of hidden hunger, where individuals meet their caloric needs but remain deficient in essential nutrients required for optimal physiological and biochemical function. Similar patterns are also observed in other low-income and rural communities where poverty, limited food access, and lack of nutritional awareness contribute to chronic undernutrition and poor dietary quality (UNICEF, 2019; FAO, 2021).

Beyond food scarcity, conflict-induced instability introduces additional layers of nutritional vulnerability through the breakdown of healthcare systems, poor sanitation, and increased exposure to infectious diseases. These factors collectively impair nutrient absorption, utilization, and metabolic efficiency, reinforcing a cycle of undernutrition and disease. Consequently, malnutrition in conflict-affected regions is not merely a function of insufficient caloric intake but reflects a complex interplay between environmental disruption, physiological stress, and biochemical dysfunction.

At the biochemical level, malnutrition represents a state of impaired metabolic homeostasis arising from deficiencies in macronutrients and micronutrients essential for cellular function. In conflict settings where diets are often reduced to monotonous, carbohydrate-dense staples, the intake of essential amino acids, vitamins, and trace minerals becomes severely limited. This compromises critical metabolic pathways, including energy production, antioxidant defense systems, and immune responses, ultimately leading to impaired growth, weakened immunity, and increased morbidity. The situation is further complicated by the emerging dual burden of malnutrition, where micronutrient deficiencies coexist with energy sufficiency, particularly in displaced populations relying on food aid or low-diversity diets (Bailey *et al.*, 2015; FAO & WHO, 2019).

Conventional interventions have largely focused on food aid and caloric supplementation, however, in conflict-affected regions, these approaches often fail to address the underlying issue of nutrient inadequacy. Staple-based food relief, while essential for survival, frequently lacks the micronutrients and biochemical cofactors necessary for restoring metabolic function. As a result, biochemical deficiencies persist even when energy needs are temporarily met, underscoring the need for more nutrient-dense and functionally relevant dietary strategies.

In this context, increasing attention has been directed toward underutilized plant nutrient sources as a sustainable and locally adaptable solution. These include edible leaves, stems, and indigenous plant species that are resilient to harsh environmental conditions and capable of thriving in marginal or disrupted agricultural systems. Such plant materials are often rich in proteins, essential minerals, vitamins, and bioactive phytochemicals that support key metabolic processes. From a biochemical standpoint, metabolically active plant tissues—particularly leaves—serve as concentrated sources of enzyme cofactors and antioxidants necessary for optimal cellular function. Their integration into local diets offers a promising strategy for enhancing nutrient density and mitigating the biochemical consequences of malnutrition in resource-constrained and conflict-affected settings (Uusiku *et al.*, 2010; Gopalakrishnan *et al.*, 2016).

Given the increasing prevalence of food insecurity driven by conflict and displacement in Nigeria, there is a critical need to explore innovative, sustainable, and context-specific nutritional interventions. Leveraging underutilized nutrient sources not only aligns with local food systems but also provides a biochemically relevant approach to improving dietary quality and metabolic health. This review therefore examines the biochemical basis of malnutrition within conflict-affected regions of Nigeria and evaluates the potential of underutilized plant nutrient sources as a viable strategy for nutritional intervention and recovery.

**Biochemical Basis of Malnutrition**

Malnutrition is a complex biochemical and physiological disorder that arises when nutrient intake fails to meet the metabolic demands of the body, leading to widespread disruption of metabolic pathways, altered enzyme activity, and impaired cellular homeostasis (WHO, 2013; FAO & WHO, 2019). Beyond inadequate food intake, malnutrition reflects a state of metabolic dysregulation in which both nutrient deficiency and impaired nutrient utilization interact to compromise physiological integrity and systemic function.

In response to nutrient deprivation, the body initiates adaptive metabolic mechanisms aimed at preserving energy and maintaining essential organ function. These include reductions in basal metabolic rate, preferential nutrient allocation to vital organs, and mobilization of endogenous energy reserves. Hepatic glycogen stores are rapidly depleted, typically within 24 hours, after which the body shifts toward gluconeogenesis using amino acids and glycerol as substrates, while lipolysis is enhanced to supply fatty acids for energy production (WHO, 2013; FAO, 2018). Although these compensatory responses temporarily sustain metabolic function, prolonged nutrient deficiency results in maladaptive outcomes, including progressive muscle protein degradation, negative nitrogen balance, and tissue wasting.

Protein–energy malnutrition represents a major clinical manifestation of these biochemical disturbances and is expressed as marasmus, kwashiorkor, or mixed syndromes. Marasmus is characterized by severe energy deficiency leading to extensive catabolism of skeletal muscle and adipose tissue, whereas kwashiorkor results from inadequate protein intake relative to energy intake and is associated with hypoalbuminemia, oedema, fatty liver, and impaired lipoprotein synthesis (WHO, 2013; Bailey *et al.*, 2015). The reduction in plasma albumin concentration decreases oncotic pressure, promoting fluid accumulation in interstitial spaces and contributing to the clinical presentation of oedema.

Micronutrient deficiencies further exacerbate the biochemical basis of malnutrition due to their essential roles as cofactors in enzymatic reactions, regulators of redox balance, and modulators of gene expression. Iron deficiency impairs haemoglobin synthesis and oxygen transport, thereby limiting oxidative metabolism and ATP generation. Zinc deficiency disrupts numerous metalloenzymes and transcriptional processes, while vitamin A deficiency compromises epithelial integrity and immune function. Iodine deficiency interferes with thyroid hormone synthesis and metabolic regulation (WHO, 2013; Bailey *et al.*, 2015).

At the level of core metabolic pathways, micronutrient deficiency has profound effects on energy production systems. The pyruvate dehydrogenase (PDH) complex, which catalyzes the conversion of pyruvate to acetyl-CoA, requires several B-vitamin cofactors including thiamine, riboflavin, niacin, and pantothenic acid. Deficiency of these cofactors reduces PDH activity, leading to decreased flux through the tricarboxylic acid (TCA) cycle, impaired ATP production, and accumulation of lactate (FAO & WHO, 2004; WHO, 2013) . Similar micronutrient dependencies are observed in the electron transport chain, amino acid metabolism, and fatty acid oxidation, illustrating the central role of micronutrients in maintaining metabolic efficiency.

Malnutrition also disrupts protein metabolism and hormonal regulation. Reduced amino acid availability limits the synthesis of structural proteins, enzymes, peptide hormones, and plasma transport proteins such as albumin and transferrin. Negative nitrogen balance, resulting from increased protein catabolism and insufficient intake, leads to muscle wasting, impaired immune defense, and delayed tissue repair. Hormonal alterations, including changes in insulin and cortisol levels, further modify substrate utilization and promote catabolic processes (WHO, 2013; FAO & WHO, 2019).

Oxidative stress constitutes another critical biochemical consequence of malnutrition. Deficiencies in antioxidant nutrients reduce the capacity of endogenous defense systems, leading to accumulation of reactive oxygen species and subsequent damage to lipids, proteins, and nucleic acids. This oxidative imbalance contributes to inflammation, immune dysfunction, and increased susceptibility to infection (WHO, 2013; Sies, 2015).

Importantly, malnutrition increasingly presents as a dual burden in which micronutrient deficiencies coexist with caloric adequacy or excess, particularly in populations consuming energy-dense but nutrient-poor diets. In conflict-affected regions of Nigeria, this imbalance is further intensified by displacement, food system disruption, and reliance on monotonous staple-based diets or food aid, which provide sufficient energy but lack essential micronutrients required for optimal metabolic function (FAO, 2021; FAO, 2023). As a result, biochemical dysfunction persists despite apparent energy sufficiency, underscoring the need for nutrient-dense and functionally relevant dietary interventions.

Collectively, these biochemical alterations demonstrate that malnutrition is fundamentally a disorder of metabolic integrity, affecting energy production, protein turnover, redox balance, and immune function. Understanding these mechanisms provides a critical foundation for the development of targeted nutritional strategies. In this context, underutilized plant nutrient sources offer significant potential, as they provide essential amino acids, vitamins, minerals, and bioactive compounds capable of restoring metabolic pathways and supporting biochemical recovery (FAO, 2018; Oyeyinka & Oyeyinka, 2018).

## Underutilized Plant Nutrient Sources as a Strategy for Malnutrition Intervention

Malnutrition in conflict-affected and other resource-constrained settings is driven not only by insufficient food availability but also by limited dietary diversity and poor nutrient quality. In such environments, diets are often dominated by staple foods that provide adequate caloric intake but lack essential micronutrients and high-quality proteins required for optimal metabolic function. This imbalance contributes to persistent biochemical deficiencies, even in populations receiving food aid or meeting basic energy needs, thereby reinforcing the need for nutrient-dense, locally accessible dietary solutions (FAO & WHO, 2019; FAO, 2021).

Underutilized plant nutrient sources represent an important but often overlooked component of sustainable nutrition strategies. These include lesser-known edible plant species as well as underexploited parts of commonly cultivated crops, particularly leaves, stems, and aerial tissues that are frequently discarded or used only for medicinal purposes. Many of these plant materials possess significantly higher concentrations of proteins, vitamins, minerals, and bioactive phytochemicals compared to the more commonly consumed storage organs such as roots and tubers (Uusiku *et al.*, 2010; Gopalakrishnan *et al.*, 2016). Their integration into dietary systems offers a practical approach to improving nutrient density without requiring major changes in food habits or agricultural systems.

From a biochemical perspective, metabolically active plant tissues, especially green leaf materials, are rich in essential micronutrients and enzyme cofactors required for critical metabolic pathways. These include iron, zinc, magnesium, and B-vitamins that support processes such as oxidative phosphorylation, amino acid metabolism, and fatty acid oxidation. The presence of antioxidant compounds such as carotenoids, flavonoids, and polyphenols further enhances their capacity to mitigate oxidative stress and support immune function, which are often compromised in malnourished individuals (Sies, 2015; FAO, 2018). Consequently, underutilized plant sources provide a multi-target biochemical advantage by simultaneously addressing macronutrient and micronutrient deficiencies.

In Nigeria, several underutilized plant sources demonstrate significant nutritional and biochemical potential for addressing malnutrition. Cocoyam (*Colocasia spp.*) leaves, for example, are rich in protein, dietary fiber, iron, calcium, and provitamin A carotenoids. Unlike the tubers, which are primarily carbohydrate-based, the leaves provide essential amino acids and micronutrients necessary for restoring nitrogen balance and supporting haemoglobin synthesis. Similarly, other indigenous leaf vegetables such as fluted pumpkin (*Telfairia occidentalis*) and African spinach (*Amaranthus spp.*) are abundant in iron, folate, vitamin C, and bioactive phytochemicals that contribute to improved hematological status and antioxidant defense (FAO, 2018; Oyeyinka & Oyeyinka, 2018).

The biochemical relevance of these plant sources is particularly evident in their ability to influence key nutritional biomarkers. The protein content and amino acid composition of leaf plants support the synthesis of plasma proteins such as albumin and prealbumin, thereby contributing to the correction of protein–energy malnutrition. Their micronutrient composition enhances enzymatic function and metabolic efficiency, while iron and folate support erythropoiesis and improve haemoglobin levels. In addition, vitamin C present in many plant leaves enhances the bioavailability of non-heme iron, facilitating its absorption and utilization in the body (FAO & WHO, 2004; WHO, 2020).

In resource-constrained and conflict-affected settings, the advantages of underutilized plant nutrient sources extend beyond their biochemical composition. These plants are often resilient to harsh environmental conditions, require minimal agricultural inputs, and are readily available in local communities. Their cultivation and utilization can therefore improve food system resilience and reduce dependence on external food aid. Furthermore, their cultural familiarity enhances acceptability and sustainability of dietary interventions, which are critical factors in long-term nutritional recovery (FAO, 2018; FAO, 2021).

Despite their potential, the utilization of these plant resources remains limited due to factors such as lack of awareness, inadequate processing methods, and concerns regarding antinutritional factors or toxicity. However, appropriate processing techniques, including cooking, fermentation, and drying, can significantly reduce antinutrient content and improve nutrient bioavailability. Scientific validation and nutritional profiling of these plants are therefore essential for promoting their safe and effective use as part of integrated nutrition strategies (Gopalakrishnan *et al.*, 2016; FAO, 2018).

Importantly, underutilized plant-based interventions offer a sustainable and scalable approach to addressing malnutrition in diverse settings where conventional strategies may be insufficient or unsustainable. Their value lies not only in their availability and adaptability but also in their superior nutritional composition relative to commonly consumed staple foods. While staple diets in many low-income and conflict-affected settings are predominantly energy-dense but micronutrient-poor, underutilized plant parts, particularly leaf tissues, provide a richer supply of proteins, essential minerals, vitamins, and bioactive compounds required for optimal metabolic function. This nutritional disparity is especially critical in populations experiencing complex forms of malnutrition, where multiple biochemical deficiencies coexist.

The contrast between commonly consumed plant parts and their underutilized counterparts is quantitatively evident when their nutrient compositions are compared. In many cases, plant leaves and other discarded or underexploited tissues contain significantly higher levels of protein, dietary fiber, and micronutrients than the staple portions typically consumed. This difference underscores the potential of these plant materials to enhance dietary quality and correct metabolic imbalances. A comparative summary of selected staple foods and their underutilized plant parts is presented in Table 1.

**Table 1: Comparative Nutritional Composition of Commonly Consumed and Underutilized Plant Parts**

| Plant | Part | Protein (g) | Fiber (g) | Carbohydrate (g) | Vitamin A (µg) | Vitamin C (mg) | Key Biochemical Implication | Reference |
|---|---|---|---|---|---|---|---|---|
| **Cassava** | Tuber | 1–2 | 2–4 | 85–90 | ~10 | ~20 | Energy source but low micronutrient density | (FAO, 2023) |
| | Leaves | 21–29 | 15–20 | 35–45 | 6000–8000 | 80–120 | Supports enzyme synthesis, immune function, and haemoglobin production | (FAO, 2023; Adepoju et al., 2024) |
| **Cocoyam** | Tuber | 3–5 | 2–3 | 75–80 | ~5 | ~15 | Primarily carbohydrate source with limited micronutrient contribution | (FAO, 2023) |
| | Leaves | 7–10 | 3–5 | 10–15 | 2000–4000 | 50–90 | Enhances nitrogen balance and metabolic enzyme activity | (FAO, 2023) |
| **Plantain** | Fruit | 3–4 | 6–8 | 70–75 | ~30 | ~10 | Provides dietary energy but limited micronutrie | (FAO, 2023) |

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| | | | | | | | nts | |
| | Leaves | 8–12 | 10–15 | 25–35 | 3000–5000 | 60–100 | Supports antioxidant defense and erythropoiesis | (FAO, 2023) |
| **Melon** | Seeds | 28–32 | 4–6 | 10–15 | ~0 | ~5 | High protein source but limited micronutrients | (Adewale et al., 2023) |
| | Leaves | 18–22 | 8–11 | 12–18 | 1500–3000 | 40–70 | Supports gut health and redox balance | (Adewale et al., 2023) |
| **Water melon** | Fruit | 4–6 | 3–5 | 80–85 | ~25 | ~8 | Hydrating energy source with low micronutrient density | (Oluwole et al., 2024) |
| | Leaves | 10–14 | 6–9 | 14–20 | 2500–4500 | 50–85 | Supports metabolic regulation and antioxidant systems | (Oluwole et al., 2024) |

**Source:** *Compiled and adapted from FAO (2023), Adepoju et al. (2024), Adewale et al. (2023), and Oluwole et al. (2024).*

Table 1 highlights the nutritional disparity between commonly consumed staple foods and underutilized plant parts in typical diets. While staple foods provide the bulk of dietary energy, they are limited in essential amino acids, vitamins, and mineral cofactors required for metabolic processes. In contrast, underutilized plant leaves and aerial tissues are significantly richer in micronutrients and bioactive compounds that support enzyme function, erythropoiesis, and antioxidant defense. This contrast underscores the potential of incorporating these plant materials into diets as a strategy for correcting biochemical deficiencies associated with malnutrition (FAO, 2018; FAO & WHO, 2019).

Beyond their nutritional composition, the functional integration of these plant materials into local diets requires consideration of preparation methods, portion sizes, and frequency of consumption. Incorporating these plant parts into commonly consumed dishes such as soups, sauces, and composite meals can significantly enhance nutrient intake without drastically altering dietary habits. This approach ensures both practicality and sustainability in real-world settings.

The nutritional superiority of underutilized plant parts translates directly into functional biochemical benefits that are essential for the reversal of malnutrition. The relatively high protein content and improved amino acid profile of leaf plant tissues support the restoration of nitrogen balance and promote the synthesis of critical plasma proteins such as albumin and transferrin, thereby improving protein status and reducing the risk of oedema associated with protein–energy malnutrition. In addition, the abundance of micronutrients such as iron, zinc, and B-vitamins enhances the activity of key metabolic enzymes involved in energy production, including those of the pyruvate dehydrogenase complex and the tricarboxylic acid cycle. These nutrients also support erythropoiesis and improve haemoglobin levels, thereby enhancing oxygen transport and cellular respiration. Furthermore, the presence of antioxidant compounds such as carotenoids and polyphenols contributes to the reduction of oxidative stress, stabilizes cellular structures, and supports immune function. Collectively, these biochemical effects demonstrate that the incorporation of underutilized plant nutrient sources into diets can facilitate metabolic recovery and improve clinical outcomes in malnourished populations (FAO & WHO, 2004; Sies, 2015; WHO, 2020).

**Challenges and Considerations in the Utilization of Underutilized Plant Nutrient Sources**

While underutilized plant nutrient sources present significant potential for addressingS malnutrition, several challenges must be considered to ensure their effective and safe integration into dietary systems. One major limitation is the presence of antinutritional factors such as oxalates, phytates, tannins, and cyanogenic glycosides, which can interfere with nutrient absorption and reduce bioavailability. For instance, high levels of oxalates in certain leaf vegetables may limit calcium absorption, while phytates can chelate essential minerals such as iron and zinc, thereby reducing their bioavailability. In the case of cassava leaves, the presence of cyanogenic compounds necessitates adequate processing to prevent toxicity. However, traditional processing methods such as boiling, fermentation, and drying have been shown to significantly reduce these antinutritional factors and enhance nutrient availability (EFSA, 2012; FAO, 2018).

Another important consideration is the issue of awareness and acceptability. Despite their nutritional value, many underutilized plant species are often neglected due to cultural preferences, lack of knowledge regarding their preparation, or perceptions of them as “famine foods.” This limits their incorporation into regular diets, particularly among urban populations. Addressing this challenge requires targeted nutritional education and community-based interventions aimed at promoting the benefits and safe use of these plant resources.

Furthermore, variability in nutrient composition due to environmental factors, soil conditions, and plant maturity stages may influence the consistency of nutritional benefits. Standardization of cultivation practices, along with comprehensive nutritional profiling, is therefore essential to ensure reliability and reproducibility in their use as dietary interventions.

In conflict-affected regions, additional challenges such as insecurity, limited access to farmland, and disruption of local food systems may further constrain the availability and utilization of these plant resources. Nonetheless, their resilience and adaptability to marginal conditions position them as valuable components of sustainable nutrition strategies. Addressing these challenges through integrated approaches involving research, policy support, and community engagement will be critical for maximizing the potential of underutilized plant nutrient sources in combating malnutrition.

## CONCLUSION

Leveraging underutilized plant nutrient sources therefore represents a strategic and sustainable pathway for addressing the biochemical and public health dimensions of malnutrition in Nigeria and similar settings. By aligning biochemical insights with the utilization of locally available food resources, this approach offers significant potential for improving nutritional outcomes, enhancing metabolic health, and advancing long-term food and nutrition security. Continued research focusing on nutrient bioavailability, intervention efficacy, and large-scale implementation will be critical in translating this potential into measurable public health impact.

## CONFLICTS OF INTEREST

The author declares no conflicts of interest

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