

Review Article

Diversity of Underutilised Vegetables in Africa and Their Potential in the Reduction of Micronutrient Deficiency: A Review

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Abstract: Micronutrient deficiency affects all groups worldwide and is a major public health issue. It has devastating effects on all ages, especially in sub-Saharan Africa. It causes anemia, night blindness, increased mortality in children and pregnant women, osteoporosis in adults and rickets in children, lower infectious disease resistance, weariness, and cognitive impairment. Recent attention has focused on micronutrient deficits. Fortunately, these micronutrients are abundant in vegetables. Many African vegetables are endemic due to various weather variations. Diverse geographical areas on the continent allow for exotic and indigenous vegetable kinds. In Africa, many African Indigenous Vegetables (AIVs) are grown and eaten. Exotic veggies are popular in cities, but rural Africans still prefer indigenous crops. Despite their availability, most of the indigenous vegetables are underutilised and have not been adequately explored due to the decreased attention to their production, consumption and utilization. Due to their diversity, they have a great potential to contribute to food security by providing nutrient rich healthy diets. They are rich in vitamins and minerals and hence make a potential source of micronutrients that can help reduce the reported deficiencies. This paper provides a literature review on the wide variety of underappreciated vegetables grown in Africa, their health benefits, and their potential to alleviate micronutrient shortages. It also investigates the barriers to increasing consumption and explores some of the strategies that have been employed to address these problems. Due to their significant role in ensuring food and nutrition security, along with their rich nutrient composition, there exists an urgent imperative to enhance public awareness regarding their consumption and the attainment of nutritional security.

Keywords: African Leafy Vegetables (ALVs), Indigenous Leafy Vegetables (ILVs), Traditional Leafy Vegetables (TLVs), Orphan Vegetables, Micronutrients Deficiency, Underutilised Vegetables

1. Introduction

Vegetables are a key source of various dietary phytochemicals with positive health benefits and are a major supply of critical elements, such as vitamins and minerals, which help prevent nutritional problems [23]. It is well recognized that eating more vegetables lowers the risk of micronutrient shortages and chronic illnesses [13]. Hundreds of plant species are consumed as vegetables around the World,

whereas tomatoes and onions are the most consumed vegetables globally and also in Africa [10]. Indigenous vegetables are horticultural crops grown in a traditional food system and are either native or introduced that have assimilated into a community's culture and history [9]. In both urban and rural contexts, African native vegetables significantly contribute to the food security of the impoverished [12]. ILV's can be used as the main ingredient or as a secondary seasoning in meals.

Native vegetables play a crucial role in the nutritional

welfare of rural people with limited resources, particularly in developing nations. The majority of native vegetables are also thought to have substances that promote health, like antioxidants. However, their production, consumption, and utilization have not been purposefully explored despite the enormous nutritional, economic, agronomic, and environmental potentials [9]. Because of this disregard, they have been underutilized and their potential value has been undervalued. It is important, therefore, to focus research efforts on the diversification and popularization of such neglected crops. With a mean consumption of 400g per capita per day that is recommended by the WHO, the Sub-Saharan Africa region is said to have the lowest intake of micronutrient-rich crops worldwide [72]. Majority of people in SSA especially school children are micronutrient deficient since their diets consist mainly of cereals and pulses as their main sources of energy and protein [81]. The main issues for school-age children in low-income nations are proven to be nutritional inadequacies, particularly deficiencies of iron, iodine, and vitamin A [30]. Unfortunately, however, iron, vitamin A, iodine, and zinc deficiency have significant negative effects on growth, development, and health. These effects include weakened defenses against infection and cognitive decline as well as increased morbidity and death [6].

Supplementation and fortification are the ideal ways to reduce the prevalence of these disorders. However, these measures are expensive and hence financially unattainable to most people. A food-based strategy has been recommended as a sustainable method for minimizing and controlling micronutrient deficiencies in societies [41]. The richness and diversity of underutilised vegetables can provide alternative solution to mitigating these problems. However, despite recent improvements in the consumption of underutilized vegetables in several African countries, the majority still favour the exotic ones, especially in urban environments. Lack of proper scientifically supported knowledge or comprehension of underutilized leafy vegetables may be a significant factor in guiding consumers to choose exotic over indigenous vegetables. In this article, some of the leafy greens that are often overlooked but have the potential to greatly improve our food and nutritional security are examined. The nutritional content, availability, and suggested processing and preservation methods for various underutilized green vegetables in Africa are all discussed.

2. Diversity and Distribution of ILVs in Africa

Africa is a continent with a rich diversity of leafy vegetables. These vegetables are valuable source of nutrition, providing essential vitamins, minerals, and other health-promoting compounds for many African communities, and they also have potential for commercialization and increased consumption. However, many indigenous leafy vegetables are underutilized. There are over 1,000 species of indigenous leafy vegetables that are cultivated or consumed in Africa [89].

These vegetables vary in terms of their appearance, taste, nutritional content, and cultural significance [60]. Some of the most common indigenous leafy vegetables in Africa include Amaranth (*Amaranthus spp.*), African nightshade (*Solanum spp.*), African spider plant (*Cleome gynandra*), Cowpea greens (*Vigna unguiculata*), Jute mallow (*Corchorus olitorius*), Pumpkin leaves (*Cucurbita moschata*), slender leaf (*Crotalaria ochroleuca*), Waterleaf (*Talinum triangulare*) and Wild spinach (*Amaranthus hybridus*) [32, 44].

A study by Van et al. [93] indicated originality of ILVs in African regions and their diversity in addition to the domesticated ones that are of great potential for commercialization (Figure 1). The study showed that Northeast and West Tropical Africa were the two main primary regions for at least 16 and 12 vegetables respectively from the study. Fewer species were reported to originate from other SSA regions, with none reported to originate from Madagascar or other countries from the Western Indian Ocean region. Forty-three of the 126 selected species (34%) can be considered to be domesticated, another 42 (33%) to be semi-domesticated, while 41 (33%) are indicated as wild. In another study, high numbers of domesticated vegetables were observed especially in Madagascar by Pierron et al. [77] and the coastal areas of West Tropical Africa, while semi-domesticated vegetables were most prevalent in West and West-Central Tropical Africa. Wild vegetables were most prevalent in Northeast and East Tropical Africa, and Southern Africa. Diversity of indigenous vegetables were introduced by Bantu people from the African mainland after the colonization of the island, and from Asia. It is documented that some domesticated traditional vegetables that were introduced in Africa originated from Asia and the America [40]. This confirms the significant role of humans in crop dispersal, and the interdependence between countries and continents in plants diversity for food and agriculture).

East Africa is home to a wide diversity of ILVs. A study by the Food and Agriculture Organization of the United Nations [29] identified over 200 different species of ILVs that are grown in the region. However, some species are more dominant than others. These species are grown for a variety of reasons, including their nutritional value, their taste, and their adaptability to different growing conditions. They are also relatively affordable and easy to grow, making them an important food source for low-income households. The high representation of wild vegetables in East Tropical Africa and Southern Africa indicates that natural vegetation patterns partly explain the geographical patterns of vegetable diversity in SSA. Tanzania is a hotspot of species richness in these two regions. The high number of indigenous leafy vegetables depict diversity of the wild vegetables that are underutilized due to different reasons [22].

A study conducted by FAO [27] identified 20 dominant ILVS species that are grown in Africa. These species are *Amaranthus hybridus* (spinach), *Solanum spp* (African nightshade), *Cleome gynandra* (African spider plant), *Hibiscus sabdariffa* (Roselle/Hibiscus), *Brassica carinata* (Ethiopian mustard), *Solanum aethiopicum* (African eggplant),

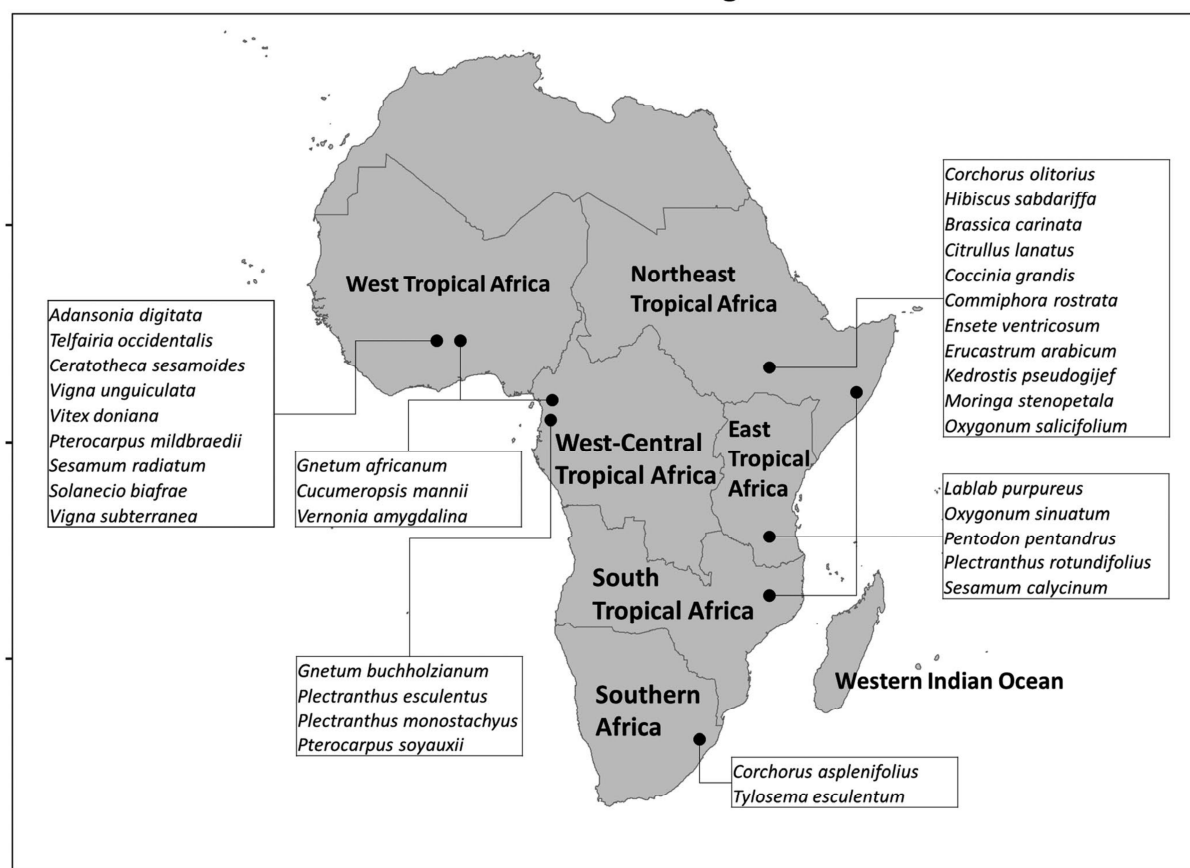
Basella alba (Indian spinach), *Corchorus olitorius* (jute mallow), *Celosia argentea* (queen's tears), *Chenopodium album* (fat hen), *Ipomoea aquatica* (water spinach), *Lactuca sativa* (lettuce), *Moringa oleifera* (moringa), *Ocimum basilicum* (basil), *Portulaca oleracea* (purslane), *Solanum macrocarpon* (fluted pumpkin), *Spinacia oleracea* (spinach), *Talinum triangulare* (water spinach), *Vigna unguiculata* (cowpea leaves), and *Zea mays* (corn leaves).

A number of studies have documented the diversity of indigenous leafy vegetables in Africa. A study in Kenya found that there were over 100 different species of leafy vegetables being cultivated or consumed in the country [67]. Another study in Nigeria found that there were over 70 different species of leafy vegetables being cultivated or consumed [70].

A study by Zonneveld et al. [98] identified 126 ILVs that are native to West Africa. These ILVs belong to 31 different botanical families, with the most common families being

Cucurbitaceae, Leguminosae, Amaranthaceae, and Malvaceae. The botanical diversity of ILVs in West Africa is vast. Amaranthaceae family includes amaranth, spinach, and water spinach. Fabaceae family includes cowpea leaves, pigeon pea leaves, and Bambara groundnut leaves. Malvaceae family includes jute mallow, baobab leaves, and sweet potato leaves. Solanaceae family includes African nightshade, eggplant, and pepper leaves. Cucurbitaceae family includes pumpkin leaves, melon leaves, and bitter melon leaves. The following are remarkable African leafy vegetables with their scientific names in West Africa, Amaranth (*Amaranthus spp.*), Cowpea leaves (*Vigna unguiculata*), Jute mallow (*Corchorus olitorius*), African nightshade (*Solanum macrocarpon*), Pumpkin leaves (*Cucurbita spp.*), Spider plant (*Cleome gynandra*), Waterleaf (*Talinum triangulare*), Malabar spinach (*Basella alba*), Ethiopian kale (*Brassica carinata*), Okra (*Abelmoschus esculentus*), and Sweet potato leaves (*Ipomoea batatas*).

Primary regions of diversity of traditional African vegetables



Source: Van Zonneveld et al. [93].

Figure 1. Primary regions of diversity of traditional African vegetables. For each region, the species are listed that have been reported in literature to originate from there or have been domesticated there. The division in regions follow the World Geographical Scheme for Recording Plant Distributions.

3. Challenges Facing the Utilisation of ILVs in Africa

There are a several challenges to the sustainable production

and consumption of ILVs in Africa. These challenges include the low productivity of ILVs, inadequate knowledge about the nutritional value of ILVs. These can be addressed through a variety of interventions including improving agricultural practices, developing markets for ILVs, improving

post-harvest handling practices, and raising awareness about the nutritional value of ILVs [52].

The diversity of ILVs in Africa is facing a number of threats. A major threat is the loss of traditional knowledge about ILVs. Due to rural-urban migration by people and especially the young generations, it is possible to lose some of the indigenous knowledge the information associated with these vegetables. This information includes identification, processing and utilization of ILVs. Climate change is also a threat to the diversity of ILVs. Current changes in rainfall patterns and temperatures, and other unpredictable changes in weather make it difficult to grow some ILVs and may be responsible for some species that have disappeared. Propagation of ILVs occurs naturally and hence changes in weather patterns may destroy or cause complete disappearance of some species/germplasm. It should be noted that some ILVs have undesirable traits, such as a bitter taste or a strong odor, which may limit their utilisation. In addition, some people are not aware of the vitamins, minerals, and other nutrients that are found in these vegetables, as a result, they may prefer to consume more familiar vegetables, such as tomatoes and carrots, which are often perceived to be more nutritious [95].

Poor availability of ILVs limits its utilization. Most ILVs are not widely available in the market. ILVs usually grow naturally and in some cases, they are grown on a small scale by individual farmers. Finally, the low market value of ILVs is also a barrier to their increased utilization. ILVs are often sold at a lower price than other vegetables, such as tomatoes and carrots. This is because they are not as popular, and they may be perceived to be less nutritious [21].

4. The Role of ILVs on Nutrition Security

In SSA, dietary deficiencies, malnutrition, and underweight children are major problems [81]. More than half of all cases of global micronutrient deficiency are found in Sub-Saharan Africa. Although iron, zinc, and vitamin A deficiencies are a global problem, sub-Saharan Africa accounts for 80% of all instances [71]. More than 40% of preschool children in SSA are vitamin A deficient. It has reported that the main cause of anemia in pregnant women and almost 70% of children under five is a lack of iron in the diet [34]. Moreover, rural areas have an especially high prevalence of micronutrient deficiencies. Lack of nutrients is also responsible for mortality and morbidity in women, low birth weight in children and early delivery [87]. A substantial amount of carbohydrates, lipids, proteins, energy, vitamins A, B1, B2, B3, B6, B9, B12, C, folic acid, and minerals Ca, P, Fe, as well as dietary fiber, can be found in underutilized leafy vegetables [37, 48]. Studies have shown the intake of local vegetables help poor households to meet their daily requirements for micronutrients, particularly vitamin A and iron. Therefore, they possess the nutritional power to prevent and treat a number of conditions like kwashiorkor, marasmus, night blindness, anemia, diabetes, cancer,

hypertension, and hidden hunger. See micronutrients distribution of ILVs from table 1 to table 7. For example, a study on prospects and potentials of underutilized leafy Amaranths as vegetable use for health promotion found that Amaranths, green lettuce, and red lettuce indigenous leafy vegetables were a good source of phytochemicals, antioxidants, vitamins A, C, and K, and minerals, magnesium, phosphorous, and potassium [84]. Another study in South Africa reported that indigenous leafy vegetables were a good source of iron. A 100 g (Fresh weight, FW) portion of African nightshade *S. retroflexum* contained 7.2 mg of iron, whereas other traditionally southern African vegetables, such as *C. tridens* (wild jute), *Amaranthus cruentus* (pigweed), *C. olitorius* (Jew's mallow), *V. unguiculata* (cowpea), *C. lanatus* (tsamma melon leaves), *C. gynandra* (spider flower), *Amaranthus hybridus* (cockscorn), and *Bidens pilosa* (blackjack), contained 6.3, 5.1, 3.6, 4.7, 6.4, 2.1, 4.1, and 2.0 mg, respectively [85].

In addition to their nutritional value, indigenous leafy vegetables also have the potential for commercialization. A study in Tanzania found that there was a potential for exporting indigenous leafy vegetables to other countries [42]. These vegetables are grown in a variety of agro-ecological zones, from the humid tropics to the semi-arid savannas. They are typically cultivated on small-scale farms, and are often used to address food security and nutrition challenges [8].

4.1. Vitamins Content of Underutilized Leafy Vegetables

Vitamins are categories of extremely complex molecules that are organic in nature, present in food in small amounts, and necessary for regular metabolism of the body [43]. There are thirteen which include Vitamins B1, B2, B3, B5, B6, B9, B12, biotin, and vitamin C which are water soluble vitamins as opposed to vitamins A, E, K, and D, which are fat soluble vitamins. Vitamin deficiency poses major health risks because vitamins are crucial for human health, growth, development, reproduction, and maintenance. Since the human body cannot synthesize vitamins, consuming them through diet is absolutely necessary. As it has been reported in numerous studies, leafy vegetables are rich in vitamins [38]. According to Sarkar et al. [83] the approximate composition of leafy vegetables shows the presence of beta carotene, vitamin E, K, B and vitamin C. Further majority of underutilized leafy vegetables contain significant amount of vitamin A and C [17].

Vitamin A (β -Carotene) content of underutilized leafy vegetables

Vitamin A deficiency affects up to 190 million young children and more than 15 million expectant mothers who live in underdeveloped nations [25]. A lack of vitamin A is estimated to affect 42.4% of young children in sub-Saharan Africa [51]. Given the prevalence of vitamin A insufficiency in underdeveloped nations, the importance of underutilized leafy vegetables as providers of vitamin A is even more important. Throughout life, vitamin A is necessary for eyesight, reproduction, immune system health, cellular differentiation, and proliferation [78]. Humans ingest dietary provitamin A primarily as β -carotene, α -carotene, and β -cryptoxanthin, which is frequently present in foods like

carrots, sweet potatoes, green leafy vegetables, and other fruits and vegetables with an orange to red color [19]. Plasma retinol content serves as the indicator of vitamin A insufficiency. There is evidence that eating foods rich in carotenoids, such as vegetables, can help prevent a number of chronic degenerative diseases [20]. An adult need about 50 g of popular leafy crops like amaranth to receive enough beta-carotene to meet their needs [57]. The analysis conducted on selected underutilized leafy vegetables from west Nigeria revealed the vitamin A content with the range of 3.9 -6.1 and 1.5 – 9.0 mg/100g DW for raw and boiled vegetables (Table. 1). This is in agreement with the study conducted by Nyadanu & Lowor [66], which showed similar content of vitamin A in underutilized leafy vegetables from Ghana.

Thiamine (Vitamin B1) content of underutilized leafy vegetables

Thiamine (vitamin B1) is an essential micronutrient that plays a role in many important biological processes, including energy metabolism, nerve function, and heart health. Thiamine deficiency causes beriberi, a major public health

problem in developing countries. The recommended dietary allowance (RDA) for thiamine for adults is 1.2 mg/day for women and 1.4 mg/day for men. However, pregnant and lactating women have higher RDAs of 1.4 mg/day and 1.8 mg/day, respectively [58]. A study by Nguyen et al. [58] found that ILVs from 10 different African countries contained thiamine levels ranging from 0.06 mg/100 g to 0.58 mg/100 g. The highest thiamine levels were found in the leaves of *Amaranthus* spp. (0.58 mg/100 g), *Corchorus olitorius* (0.54 mg/100 g), and *Talinum triangulare* (0.49 mg/100 g). A study by Adeola et al. [4] found that the thiamine content of amaranth leaves ranged from 0.06 to 0.12 mg/100 g, while the thiamine content of jute mallow leaves ranged from 0.08 to 0.16 mg/100 g. Another study by Akande et al. [7] found that the thiamine content of sweet potato leaves ranged from 0.08 to 0.14 mg/100 g, while the thiamine content of water spinach leaves ranged from 0.10 to 0.18 mg/100 g. These findings suggest that ILVs can be a significant source of thiamine in the diet, especially for populations with limited access to other nutrient-rich foods.

Table 1. Vitamin A and C content of selected underutilized leafy vegetables from different African countries.

MALAWI			
Specie name	Vitamin A	Vitamin C (mg/100g)	[16]
<i>Amaranthus</i> spp.		45.5026 ± 0.00	
<i>Bidens Pilosa</i>		60.7198 ± 0.00	
<i>Galinsoga parviflora</i>		148.8364 ± 0.00	
BENIN			
Specie name	Vitamin A	Vitamin C (ng/100g)	[5]
<i>Crassocephalum crepidioides</i>		9.17	
<i>Crassocephalum rubens</i>		3.60	
NIGERIA			
Specie name	Vitamin A	Vitamin C (ng/100g)	[74-75]
<i>F. capensis</i>	6.25	42.29	
<i>F. thonningii</i>	1.82	59.69	
<i>M. arboreus</i>	1.06	40.23	
<i>M. pruriens</i>	2.47	30.84	
<i>P. santalinoides</i>	2.81	19.34	
<i>V. doniana</i>	0.53	91.28	
<i>Abelmoscus esculentu</i>	6.1 ± 0.4	33.9 ± 1.0	[24]
<i>Adansonia digitata</i>	18.0 ± 0.5	73.0 ± 1.0	
<i>Amarathus dubius</i>	4.6 ± 0.2	50.0 ± 2.4	
<i>Amarathus viridis</i>	5.7 ± 0.1	29.7 ± 2.9	
<i>Basella alba</i>	3.9 ± 0.01	72.0 ± 1.8	
<i>Basella rubra</i>	4.0 ± 0.1	52.0 ± 2.0	
<i>Crassocephalum crepidioides</i>	5.8 ± 0.01	5.0 ± 0.1	
<i>Launaea taraxacifolla</i>	5.4 ± 0.1	19.0 ± 1.4	
<i>Senecio biafrae</i>	2.5 ± 0.2	7.0 ± 0.7	
<i>Solanum americanum</i>	10.7 ± 0.5		
<i>Solanum macrocarpon</i>	7.5 ± 0.3	70.0 ± 6.6	
<i>Talinum triangulare</i>	1.8 ± 0.02	8.8 ± 1.9	
<i>Vernonia amygdalina</i>	14.1 ± 0.4	5.0 ± 1.4	

Riboflavin (Vitamin B2) content of underutilized leafy vegetables

With regard to energy and protein metabolism, riboflavin functions as a coenzyme and is necessary for a number of oxidation processes inside the cell [18]. Glossitis, angular stomatitis, red eyes with a burning feeling, and seborrheic dermatitis, which is characterized by scaly skin between the nose and angles of the lips, are some of the clinical symptoms linked to the deficiency of riboflavin [88]. Depending on age,

physiological status, and amount of activity, the recommended safe daily intake of this vitamin ranges from 0.7 to 2.2 mg/day [57]. There is good evidence that most SSA diets are insufficient in riboflavin [86]. Utilization of underutilized leafy vegetables could be an option for the reduction of vitamin B2 deficiencies in the region. Several studies have reported the amount of riboflavin in underutilized leafy vegetables. Boedecker et al. [12], reported the significant amount of riboflavin in underutilized leafy vegetables commonly utilized

in Benin. Another study conducted by Van Jaarsveld *et al.* [92], found riboflavin content in raw African leafy vegetables ranged between 0.03 and 0.21 mg/100g. These data are close to the results of riboflavin content (0.63-1.73mg/100g) obtained in *P. santalinoides*, *C. olitorius*, and *M. arboreus* were samples from Nigeria [91].

Nicotinic Acid (Vitamin B3) composition of underutilized leafy vegetables

For different physiological activity groups, the daily requirement for this vitamin varies from 8 to 26 mg niacin equivalents [11]. Deficiency of this vitamin cause disease called Pellagra. This is a condition brought on by a severe nicotinic acid deficit in the diet [79]. Tropical communities are more vulnerable to pellagra since their main staple food is maize which has small amount of nicotinic acid. Since vegetables contain high amount of nicotinic acid [14] can be utilized to prevent or reduce the severity of pellagra. Niacin content of about 0.234 and 0.658 mg/100g in raw and cooked *Amarthaus* spp was reported by Ruth *et al.* [82]. In another study by Nwankwo *et al.* [65], revealed the niacin content of underutilized leafy vegetables from Nigeria with the level of 1.45 mg/100g DW and 0.74 mg/100g DW for *Cassia tora* and *Sesamum indicum* leaves, respectively.

Table 2. Riboflavin content per 100 g edible portion of underutilized of raw African leafy vegetables.

Specie name	Riboflavin content
Black nightshade	0.17
Pigweed	0.05
Jew's mallow	0.03
Tsamma melon	0.10
Spider flower	0.21

Source: Van Jaarsveld *et al.* (2014).

Ascorbic Acid (Vitamin C) content of underutilized leafy vegetables

Vitamin C is an essential nutrient that plays a role in a variety of bodily functions, including immune function, wound healing, and collagen production. It is also a powerful antioxidant that can help protect the body against damage from free radicals. A number of studies have shown that ILVs can be a good source of vitamin C. For example, a study in Nigeria found that the vitamin C content of uncultivated ILVs ranged from 50 to 72 mg/100 g, compared with commonly cultivated species like *Celosia argentea*, *Corchorus olitorius* and *Amaranthus hybridus*, which ranged from 7.8 mg to 43 mg/100 g [2]. Another study in South Africa found that the vitamin C content of different ILVs ranged from 10 to 50 mg/100 g [50]. These studies suggest that IILVs can be a good source of vitamin C,

especially when compared to some commonly cultivated leafy vegetables. Another study by Oguntona *et al.* [69] found that the vitamin C content of fresh spider plant leaves (*Chlorophytum comosum*) was 94.6 mg/100 g. This is also more than 10 times the RDI for vitamin C. Another study by Mibei and Ojije [48] found that the vitamin C content of fresh nightshade leaves (*Solanum aethiopicum*) was 104.3 mg/100 g. This is more than 10 times the RDI for vitamin C. The highest vitamin C concentration was found in the underutilized leafy vegetables, *C. olitorius*, *Amaranthus* spp, *Boabab leaf*, and *S. macrapocorn* at 3214 IU, 2149 IU, 2911 IU, and 2341 IU DW basis, respectively [66]. Additionally, Ejoh *et al.* [24] conducted a thorough review of underutilized leafy vegetables and discovered that the vitamin C content of leaves varies between cultivars and in the wild, ranging from 5 to 73 g/kg FW g (Table 1). The use of underutilized leafy vegetables may help to significantly reduce the region's ongoing vitamin C deficit, which affects 60% of children in SSA [81].

Table 3. Selected ILVs and their vitamin C composition.

ILVS	Vitamin C content (mg/100g)	Reference
Amaranthus hybridus	20-30	[2]
Chenopodium album	40-50	[50]
Corchorus olitorius	15-20	[2]
Kalanchoe pinnata	30-40	[50]
Lampranthus multiradiatus	50-60	[50]
Talinum triangulare	10-20	[2]
Vernonia amygdalina	30-40	[50]
Chlorophytum comosum	94.6	[70]
Solanum aethiopicum	104.3	[48]

4.2. Mineral Composition of Underutilized Leafy Vegetables

Underutilized leafy vegetables are an important source of minerals in the African diet. However, many indigenous leafy vegetables that are rich in minerals are underutilized. Lack of minerals in the body led to a number of physiological problems. Mineral deficiency reduces working capacity, increases morbidity due to infections, and a greater risk of death associated with pregnancy and childbirth. A study conducted on the mineral composition of African nightshade (*S. retroflexum*) has revealed that African nightshade leafy vegetables are rich in Potassium, Calcium, and Magnesium and phosphorous as indicated in table 4. The study of micronutrients potential of underutilized vegetables done by Chacha and Lwasai [15] revealed that minerals content of *Momordica foetida*, *Vigna vexillata*, *Launea cornuta*, and *Basella alba* are rich sources of micronutrients and crucial in daily human diet to curb hidden hunger as shown in table 4.

Table 4. Minerals composition of African nightshade per 100 g fresh weight compared with other commercial vegetables.

ILVS	K (mg)	P (mg)	Ca (mg)	Mg (mg)	Fe (mg)	Cu (mg)	Zn (mg)
<i>S. retroflexum</i> (African nightshade)	257	36	199	92	7.2	0.16	0.56
<i>S. villosum</i>	0	0	412	0	12	0	0
Spinach	558	49	99	79	2.71	0.13	0.53
Lettuce	141	20	18	7	0.41	0.025	0.15
Rapini (broccoli raab)	196	73	108	22	2.14	0.042	0.77

Source: Yuan *et al.* [96]

Iron (Fe) content of underutilized leafy vegetables

Iron is an important mineral for red blood cell production and its deficiency cause anemia. It is also involved in a number of other bodily functions, such as oxygen transport and energy metabolism. The recommended daily intake of iron for adults is 8 mg for women and 18 mg for men. A number of indigenous leafy vegetables are good sources of iron. For example, moringa leaves contain 10 mg of iron per 100 g [26]. Other leafy vegetables that are high in iron include African nightshade (9 mg per 100 g), spider plant leaves (8 mg per 100 g), and cassava leaves (7 mg per 100 g). Women are more likely to develop anemia during pregnancy or after delivery, especially if their unborn children have low birth weights and are undernourished [96]. Moringa leaves contain 10 mg of iron per 100 g, which is twice the recommended daily intake for women [28].

Calcium (Ca) content of underutilized leafy vegetables

Together with phosphate, calcium plays a crucial function in the growth and preservation of bones and supplies the majority of the bone's strength. In addition to being necessary for the development of teeth, calcium is also essential for many other bodily processes. For instance, calcium is transported throughout the body via the bloodstream, where it

is crucial for blood clotting. Underutilized leafy vegetables are good source of calcium [73].

Calcium is an important mineral for bone health. It is also involved in a number of other bodily functions, such as muscle contraction and blood clotting. The recommended daily intake of calcium for adults is 1,000 mg for women and 1,200 mg for men. A number of indigenous leafy vegetables are good sources of calcium. For example, amaranth leaves contain 200 mg of calcium per 100 g [26]. Other leafy vegetables that are high in calcium include jute mallow (180 mg per 100 g), water spinach (170 mg per 100 g), and sweet potato leaves (160 mg per 100 g).

Zinc (Zn) content of underutilized leafy vegetables

Zinc is an important mineral for a number of bodily functions, including immune function, wound healing, and protein synthesis. The recommended daily intake of zinc for adults is 11 mg for women and 15 mg for men. A number of indigenous leafy vegetables are good sources of zinc (Table 5). For example, jute mallow leaves contain 2 mg of zinc per 100 g [26]. Other leafy vegetables that are high in zinc include water spinach (1.8 mg per 100 g), sweet potato leaves (1.6 mg per 100 g), and African nightshade (1.5 mg per 100 g).

Table 5. Micronutrients content of selected underutilized leafy vegetables.

.	<i>Momordica foetida</i>	<i>Vigna vexillata</i>	<i>Launea cornuta</i>	<i>Basella alba</i>
Moisture content (%)	95 ± 0.00 ^c	78 ± 1.41 ^a	84 ± 1.41 ^b	92.5 ± 0.71 ^c
Minerals (mg/100 g)				
Ca	421.03 ± 3.61 ^c	85.28 ± 4.67 ^{ab}	60.29 ± 4.26 ^a	134.11 ± 17.16 ^b
Fe	21.05 ± 1.77 ^c	4.28 ± 0.23 ^a	6.04 ± 0.43 ^a	13.4 ± 1.70 ^b
Mg	1,151.91 ± 49.47 ^c	191.12 ± 19.64 ^a	301.56 ± 21.31 ^a	524.5 ± 121.08 ^b
Zn	21.1 ± 1.84 ^c	4.28 ± 0.23 ^a	6.05 ± 0.42 ^a	13.4 ± 1.70 ^b
Vitamins (mg/100 g)				
Beta carotene	5.5 ± 0.77 ^b	2.5 ± 0.40 ^a	3.84 ± 0.50 ^a	6.67 ± 0.30 ^b
B vitamins				
B ₁	58.34 ± 2.67 ^a	18.94 ± 0.69 ^a	25.22 ± 0.60 ^a	182.95 ± 47.76 ^b
B ₂	0.76 ± 0.06 ^c	0.18 ± 0.01 ^a	0.24 ± 0.02 ^a	0.54 ± 0.12 ^b
B ₃	0.12 ± 0.02 ^a	0.09 ± 0 ^a	0.1 ± 0.02 ^a	0.43 ± 0.06 ^b
C	46.52 ± 3.70 ^a	136.71 ± 35.84 ^b	120.88 ± 11.26 ^{ab}	198.08 ± 47.46 ^b

Source: Chacha and Laswai, [15]

Phytochemical Composition of underutilized leafy vegetables

Natural bioactive substances called phytochemicals are well-known for their positive effects on health. Numerous chronic diseases, including cancer, diabetes, heart disease, and Alzheimer's disease, have been demonstrated to be prevented by phytochemicals. Phytochemicals can have additional impacts on human health, such as antioxidant, detoxification enzyme modulation, immune system stimulation, inflammation reduction, steroid metabolism modulation, antibacterial, antihelmintic, and antiviral properties [63, 68]. Further, they have a significant role in determining the color, flavor, and scent of fruits and particularly vegetables [39]. Table 6 indicates percentage distribution of antioxidant potential on selected ILVS's.

Table 6. Antioxidant potential of selected SSA underutilized leafy vegetables.

African leafy vegetables	Antioxidant capacity (%)
<i>Amaranthus sp</i>	45
<i>Basella alba</i>	89
<i>B. Pilosa</i>	54
<i>Celosia argentea</i>	90
<i>C. album</i>	42
<i>Cleome monophylla</i>	84
<i>Corchorus olitorius</i>	45
<i>Crassocephalum sp.</i>	89
<i>G parviflora</i>	76
<i>Hibiscus esculentus</i>	56
<i>J. flava</i>	96
<i>Manihot utilissima</i>	90
<i>Momordica balsamina</i>	94
<i>Nasturtium aquatica</i>	100
<i>Ocimum gratissimum</i>	11
<i>Oxygonum sinuatum</i>	92
<i>P. oleracea</i>	96

African leafy vegetables	Antioxidant capacity (%)
<i>Sisymbrium thellungii</i>	99
<i>Solanum sp.</i>	92
<i>Structum sp.</i>	22
<i>Urtica dioica</i>	100
<i>Vernonia amygdalina</i>	56
<i>Xanthosoma mafaffa</i>	99
<i>Amaranthus sp.</i>	1
<i>Cleome gynandra</i>	1.6
<i>Solanum macrocarpon</i>	0.9
<i>Amaranth viridus</i>	10.90

Source: Oseni *et al.* [74]

Significant amount of Anthocyanin, carotenoid, flavonoids, oxalate and tannin in underutilized leafy vegetables *namely* *Ficus capensis*, *Pterocarpus santalinoides*, *Vitex doniana*, *Ficus thonningii*, *Mucuna pruriens* and *Myrianthusarboreus* were reported by Otitoju *et al.* [75]. Udochukwu *et al.* [90] evaluated the concentration (mg/100g) of some of these phytochemicals in underutilized bitter leafy vegetables (*V. amygdalina* and *O. Gratissimum*) and found that *Vernonia amygdalina* contained higher levels of bioactive compounds than *Ocimum gratissimum*, with the exception of phytate and cyanogenic glycosides as indicated in Table 7.

Table 7. Phytochemical analyses of *Vernonia amygdalina* and *Ocimum gratissimum* (mg/100g).

Phytochemical	V. amygdalina	O. Gratissimum
Oxalate	3.48	0.75
Phytate	3.95	5.56
Tannin	9.62	2.48
Saponins	5.97	3.52
Flavonoid	4.89	1.74
Cyanogenic glycoside	1.11	2.38
Alkaloids	2.16	1.07
Anthraquinone	0.14	0.31
Steroid	0.38	0.30
Phenol	3.24	0.73

Source: Udochukwu *et al.* [90]

5. Processing and Preservation of Indigenous Vegetables

One way to improve the utilization of ILVs is to develop and adopt appropriate processing and preservation technologies. Processing can help to extend the shelf life of ILVs, improve their marketability, and make them more accessible to consumers [31]. There are a number of different processing methods that can be used for ILVs, including drying, blanching, canning, boiling, fermentation, malting, milling, and popping, roasting, steaming, and wet milling. The most common method for processing ILVs in Africa is drying. Drying reduces the water content of the vegetables, which helps to prevent spoilage. Dried ILVs can be stored for long periods of time and transported to distant markets. However, drying can also lead to losses of nutrients, especially vitamin C [76].

The choice of processing method will depend on a number of factors, such as the type of ILVS, the desired shelf life,

retention of sensitive micronutrients and the availability of equipment. It is important to note that some processing methods can cause losses of nutrients, so it is important to choose a method that will preserve the nutritional value of the vegetables as much as possible [59]. In recent years, there has been a growing interest in the development of new processing technologies for. These technologies aim to improve the shelf life, reduce nutrient losses, and make them more appealing to consumers. Some of the promising new technologies include microwave drying, supercritical fluid drying and encapsulation. Microwave drying can be used to dry ILVs without the need for blanching, which can help to preserve nutrients. Supercritical fluid drying method is very gentle and it preserves the nutritional value of the vegetables. Encapsulation helps to protect the vegetables from oxidation and moisture, and it also makes them more convenient to use [45].

The keeping quality of the produce is considerably improved by temperature control by cooling, which slows the development and reproduction of bacteria that cause rotting as well as physiological changes (such as transpiration and respiration) that cause water loss [33]. The best way to achieve this benefit of temperature control, though, is through refrigeration, which is expensive, and perhaps out of reach for the majority of small-scale underutilized leafy vegetable farmers in developing nations [36]. In order to keep their food as fresh as possible, street merchants of vegetables in developing countries frequently sprinkle water on it in underdeveloped nations. While this strategy may be beneficial in the short term, such as for a few hours to a day, without significantly affecting product quality, it is ineffective over the long term and frequently results in quality losses if the products are not purchased within a day. The application of water to the vegetables may also promote the growth of microorganisms and the emergence of postharvest illnesses [80], raising worries about both food safety and postharvest losses due to spoiling.

Being extremely perishable and seasonal crops, leafy vegetables are often dried. Sun drying, one of the most prevalent, affordable, and widely used ways of food preservation in the tropics, is primarily used to provide fresh produce during times of scarcity [35]. Vegetables that have been dried greatly reduce their water activity, which lowers the risk of deterioration, particularly from the action of spoilage microbes that are deprived of free water for their metabolic processes. Vegetable drying techniques of all kinds, including sun, oven, and solar drying, are described in the literature [94]. A recent study by Misci *et al.* [49] exploring the potential for fermentation as a tool to contribute to food security and nutritional quality of underutilized leafy vegetables with respect to *Cucurbita sp.* is one example of a promising method of leafy vegetables preservation that does not require the use of electricity and has also been shown to improve nutritional quality. However, it is crucial to gather scientific knowledge on the impacts of preservation and/or processing procedures on specific leafy vegetables (such as effects on nutrient content) better choice of processing method.

The impact of various processing techniques on the nutritional qualities, nutrient changes, and bioavailability of underutilized leafy vegetables should be understood.

Several studies have investigated the effects of different processing and preservation methods on the micronutrient content of ILVs. According to studies, ascorbic acid decreased by 19% in cooked amaranth, 61% in dry *Vernonia amygdalina*, and over 100% in dried *Adonsonia digitata* [97]. A study by Mwaisenyi et al. [54] found that sun-drying and cooking can lead to significant losses of β -carotene, vitamin C, and iron in indigenous leafy vegetables from Tanzania. A study by Naamani et al. [56] found that the levels of β -carotene, vitamin C, and iron in sun-dried and cooked *Amaranthus*, *Corchorus olitorius*, and *Cleome gynandra* were significantly lower than in the fresh leaves. The authors attributed this loss of nutrients to the heat and oxygen exposure during processing and cooking. A study in Nigeria found that boiling significantly reduced the vitamin C content of uguwu (*Tetragonia tetragonioides*) leaves, while steaming had no significant effect on the vitamin C content [1]. Another study by Mwasenyi [55] found that the levels of provitamin A, vitamin C, and zinc in freeze-dried and air-dried amaranth leaves were significantly higher than in the fresh leaves. The author suggested that freeze-drying may be a more effective way to preserve the nutrients in than air-drying.

A number of studies have investigated the effect of processing on the mineral content of ILVs. In general, boiling and steaming are the most common processing methods used for ILVs in Africa. These methods can lead to significant losses of minerals, particularly water-soluble minerals such as potassium, magnesium, and calcium. For example, a study by Nwagwu et al. [64] found that boiling and steaming of African nightshade (*Solanum macrocarpon*) resulted in losses of potassium of up to 60% and 50%, respectively. A study in Tanzania found that sun drying increased the iron content of mchicha (*Amaranthus hybridus*) leaves by 100%, while oven drying had no significant effect on the iron content [53]. A study by Nnaji et al. [62] found that boiling and steaming of jute mallow leaves reduced the iron content by 25% and 30%, respectively, while fermenting the leaves increased the iron content by 20%.

The type of mineral also affects how it is affected by processing. For example, iron is more susceptible to losses during processing than calcium. A study by Mbagwu et al. [46] found that boiling and steaming of African nightshade leaves reduced the iron content by 30% and 40%, respectively, while the calcium content was not significantly affected. Boiling and steaming have been shown to reduce the levels of phytates, oxalates, and tannins, which are antinutrients that can interfere with the absorption of minerals. A study by Nnaji et al. [61] found that boiling and steaming of amaranth leaves reduced the phytate content by 50% and 60%, respectively.

There have been a number of studies that have investigated the effect of processing on the color pigments of ILVs. For example, a study by Adebawale et al. [3] found that blanching caused the loss of anthocyanins, carotenoids, and chlorophylls

in amaranth leaves. Another study by Mbewe et al. [47] found that drying caused the concentration of carotenoids and anthocyanins in moringa leaves.

It is important to note that the results of these studies may vary depending on the specific ILVs being studied, the processing and preservation methods used, and the storage conditions. However, the overall evidence suggests that processing and preservation can have a significant impact on the micronutrient content of ILVs. Therefore, it is important to choose processing and preservation methods that will minimize nutrient loss.

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Conflicts of Interest

The authors declare no conflicts of interest relevant to this article.

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