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Neglected and Underutilized Cultivated Crops with Respect to Indigenous African Leafy Vegetables for Food and Nutrition Security

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Abstract Many neglected and underutilized vegetable species such as indigenous African leafy vegetables have been incorporated in human diets since time immemorial, especially in sub-Saharan Africa and many Asian countries where they greatly contribute to food and nutrition security. Due to their well-documented superior nutritional quality and climate-smartness compared to their exotic counterparts, many of them are currently receiving a lot of attention among many stakeholders including governments, researchers, nutritionists, consumers and farmers. As a result of their climate adaptability and high micronutrient content, they can be used to curb 'hidden hunger' most prevalent in developing countries, contributing to the achievement of some of the UN's Sustainable Development Goals; no poverty, zero hunger, and good health and wellbeing. In this review, the general role of neglected and underutilized vegetable species, and indigenous African leafy vegetables in particular, is discussed with respect to their contribution to food and nutrition security. The benefits of embracing increased production and consumption of these vegetables in the context of developing countries, especially among the under-privileged rural poor is highlighted. In addition, challenges facing production and consumption of these vegetables are discussed and recommendations for research gaps suggested with the ultimate aim of ensuring that the commodity's full potential is realized.

Keywords: *food losses, food security, indigenous leafy vegetables, neglected and underutilized species, nutrition, traditional vegetables*

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1. Introduction

The world population continues to grow at a rate that is not consistent with the global food production leading to high prevalence of food insecurity and malnutrition among many countries, particularly the developing ones in Africa, Asia and South America. On a global level, the number of the food insecure people, especially those undernourished has increased from about 804 million in 2016 [1] to at least 820 million by 2019 with a tune of two billion people experiencing either moderate or severe malnutrition [2]. This situation challenges the achievement of the 'zero hunger', the UN's Sustainable Development Goal (SDG) number two target by 2030. The African continent alone contributes an estimated 20% of the world's undernourished population representing the largest proportion from a single continent [2]. Food security is defined as a situation that "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [3]. Many factors determine whether or not food insecurity occurs at the global, continental, regional, national or even at the household levels. Some of these factors include government policies on food production systems, community food preferences, household access to food, utilization levels of food commodities, and sustained household resilience building [4]. Additionally, food insecurity status is also influenced by rainfall performance (which most of the developing countries depend on for agriculture), climate change, level of education and employment, size of arable land, land degradation, population health and political stability [5]. It is difficult and almost impossible to mitigate for all these factors e.g. rainfall amount and distribution, and size of arable land. Therefore, researchers need to prioritize on those other factors that can make a significant impact on food security without damaging the environment.

Among the UN's 17 SDGs which are interrelated, addressing SDG 2 which calls for hunger and all forms of malnutrition eradication by ensuring food security in all countries needs to be emphasized. To ensure 'zero hunger',

it is essential that people can easily obtain enough nutritious and safe food at all times which calls for adoption of more sustainable food production systems that are environment-friendly and promotes diversity in both cultivation and in consumers diets. Attainment of worldwide food security still remain one of the biggest challenges facing the global community to date. Agricultural mechanization and intensification has largely, in the recent past been considered as the main means of producing more food for the ever growing population. However, this strategy is not sustainable because the size of arable land is not expanding and in addition, production of large quantities of food lacking in necessary or unbalanced nutrients cannot solve malnutrition problem facing most of the developing countries, especially 'hidden hunger'. Agricultural intensification, which normally uses modern systems in largescale food production is often linked to undesirable outcomes including emission of greenhouse gases, land degradation, water pollution and loss of biodiversity [6]. Dietary diversification through promotion of agrobiodiversity in our agricultural production systems is one of the surest ways of combating food insecurity and food production stabilization, especially in the most vulnerable countries [7]. This is particularly so because of vulnerability of conventional agricultural production systems to climate change whose effect can be lessened by risk spreading through cultivation of different crops (crop diversification) that would ultimately lead to a wide range of nutritious agricultural food products in the markets [8]. In fact Bekunda et al. [9] reported that the reason food and nutrition insecurity is high in Africa is because of lack of crop diversification, possibly because of unbalanced diets and food losses in the farms due to adverse weather conditions occasioned by climate change effects.

Worldwide, there is overreliance on just a few staple food crops with limited nutritional value. Currently, maize, wheat and rice are the main staple food crops consumed globally accounting for greater than 50% of calorie intake [10]. Too much dependence on a few major staple food crops is associated with a dwindling food basket [11] which is not safe in particularly, nutrition considerations [12]. The main staple foods, whereas they can be produced in large quantities and can provide adequate macronutrients, they are usually associated with significantly low micronutrients levels. According to Luchuo et al. [13], most of sub-Saharan African diets are mainly made from calorie-loaded staple root crops which lack or are insufficient in other important nutrients such as essential micronutrients. Popkin [14] has reported most of the African diets being energy dense and nutrient poor which could lead to undesirable health effects. Largely unbalanced diets that lack sufficient nutrition diversity are to blame for the high levels of malnutrition currently being experienced in many developing countries [5]. According to Siegel et al. [15] and Willett et al [16], the present food crop production systems, although producing huge quantities of foods, fail to produce nutrient-dense foods necessary for sustainable and healthier diets, calling for food crop diversification in agriculture. Reliance on a limited number of staple food crops does not only lead to micronutrient deficiency risks but also has undesirable ramifications for food diversification, health and ecosystems [17]. Production of a variety of food crops especially considering adoption of traditional resilient food crop varieties and diet diversification cannot be overemphasized in addressing food insecurity and malnutrition. It is important to not only focus on crop yield quantities but emphasis should also be put on the nutritional value of cultivated food crops [18] irrespective of harvest quantities in order to address malnutrition and food insecurities in a more balanced manner. There is a need to recognize nutrition sensitive agricultural food systems [19] emphasizing on cultivation and use of, for example, traditional vegetables. Adoption of neglected underutilized species (NUS) in agricultural food production systems is one of the best ways of reducing overreliance on a limited number of major staple food crops in promoting food security.

Recently, a great deal of focus on the research and promotion of NUS in regard to food crops has gained a lot of interest due to the need for nutrient-rich and diets diversity [20] among various stakeholders including researchers and nutritionists among others in both developing and advanced economies. In fact FAO considers food utilization of NUS as one of the best sustainable ways of fighting malnutrition and hunger thus reducing food insecurities [5] especially among the rural poor. NUS which are considered future smart foods or climate-smart food crops [5] are according to Hunter et al. [10], Pelosi et al. [21] and Li and Siddique [5] described using various adjectives including; 'traditional', 'minor', 'underdeveloped', 'underexploited', 'lost', 'alternative', 'local', 'orphan', 'niche', 'promising', 'novel' and 'hidden treasures', among others possibly due to their marginalization by researchers and modern farming methods. Pelosi et al. [22] defines NUS as "useful plant species which are marginalized, if not entirely ignored by researchers, breeders and policy makers". These crops are underutilized and neglected because of their unrealized potential, their limited competitiveness with commodity food crops, and are mainly cultivated by local farmers in their areas of origin using their traditional knowledge with limited or no agricultural extension services or research inputs. In fact most NUS are insufficiently characterized and researched on possibly because of general lack of interest in them and due to poor funding in support of their research [21], insignificant performance as commodity food crops, food utilization by a small population (mainly where they are indigenously grown), limited distribution, limited or no popularization policies by governments, and underdeveloped, non-existing post-harvest handling, preservation and processing technologies designed for them [5]. Hunter et al [10] also reports that international trade of NUS is hindered due to among other factors, non-tariff barriers and strict food safety regulations imposed on novel foods especially in the EU (Regulation (EU) No 2015/2283) which limits their market share. This is probably the reason they are sometimes presented as new food crops since it is only recently some researchers, nutritionists, commercial companies and crop biodiversity advocates have started working and promoting their utilization.

NUS comprise a wide range of food crop categories including cereals, pulses, nuts, root crops, horticultural crops, etc. The exact number of NUS that can be

cultivated and used in human nutrition is not known. Currently, a number of reports exist with varying numbers ranging from 5538 plants [23] to 75000 [24]. However, Meldrum et al. [19] recently recognized 1097 vegetable species that can be used to variegate food crop production systems to improve food security, diets and nutrition. According to Pelosi et al. [21], great efforts are being put by researchers, nutritionists, food value chain and plant diversity conservation practitioners in the 21st century to create awareness on the importance of redeeming NUS and integrating them in the current agricultural food production systems. However, due to large numbers of NUS around the globe, it is important to identify a few with the greatest potential of utilization based on; ease of cultivation, drought and disease tolerance, and nutrition value. In South Africa for example, according to Mabhaudhi et al. [25], thirteen NUS have been identified as priority crops for farmers.

Several benefits of including NUS in the current agricultural food systems have been documented by a number of researchers which touches on both improved human nutrition and the environment [26,27,28]. They are therefore considered by FAO [17] as a crucial food resource for fighting hunger and malnutrition in addition to supporting agriculture and rural development especially in developing economies where most of them are native, prevalently grown and accepted as a food type. NUS nutritional potential has been reported and these food crops are generally considered superior in nutritional composition compared to the most frequently consumed staple food crops [10]. This is particularly so in regard to micronutrients, vitamins and minerals, suggesting that they could offer solutions in combating 'hidden hunger' [29, 30]. 'Hidden hunger' refers to inadequate intake of vitamins and minerals, and the situation is most prevalent in developing countries. There is overwhelming evidence that vitamins and minerals plays a crucial role in alleviating diet-linked chronic illnesses which are common causes of morbidity and mortality [5]. For example, traditional Brazilian leafy green vegetables have been reported to be superior to non-NUS commercially cultivated vegetables in regard to carotenoid content [31] while *Amaranthus* leaves which are commonly consumed in many African countries are reported to contain more vitamin A (200 fold) and iron (10 fold) than cabbages [32]. Studies have shown that certain NUS can meet recommended dietary allowances of specific vitamins and minerals e.g. it is reported that leaves of *Moringa oleifeira* could provide both vitamins A and C, and potassium and calcium minerals at the recommended dietary levels [33]. Besides, they are also rich in fibre and iron, and are popular among anaemic people [5]. In addition, NUS are also known to contain substantial amounts of bioactive compounds such as flavonoids [5] that significantly contribute to dietary health [34].

NUS are considered climate resilient since they are adaptable to unpredictable changes to the weather caused by climate change [5]. They spontaneously grow well in marginal and harsh environments that are not suitable for cultivation of the main staple food crops, and with minimal or no farm inputs [30,35,36]. These food crops also do well in traditional farming systems where they can be easily intercropped without significantly affecting their yields. Many of NUS are considered future smart crops due to their high potential of ensuring nutrition and food security and their resilience and adaptability [5]. For these reasons, these climate-smart food crops [5] are of interest to researchers for adaptation of agriculture to climate change [37] for diversification, shielding the producers against risks of other food crops failure as a result of, for example, adverse weather conditions. Compared to major staple food crops, NUS are more resistant to biotic and abiotic stresses [35] providing more reliable yields under poor soils and adverse climatic conditions [5]. In the context of climate change, diversification in agricultural production systems through adoption of more resilient NUS can go a long way in mitigating its effects and offering diverse and more nutritious food resources capable of promoting food security and alleviating hunger and malnutrition globally.

2. Indigenous African Leafy Vegetables

For a healthy and balanced diet, vegetables are an important constituent of food although their intake (together with fruits) is generally considered low globally, particularly in sub-Saharan Africa which records the lowest intake [38]. Low consumption of vegetables (and fruits) by most of the population in sub-Saharan Africa means intake of unbalanced and unhealthy diets considerably limited in vitamins, minerals and certain bioactive compounds which is linked to a high risk of a number of non-communicable diseases that can lead to a high morbidity and/or mortality rate [39]. In South Africa for example, an estimated 23.6 million people over fifteen years old were reported to have had inadequate intake of vegetables and fruits in 2000 [40]. Destitution and possibly lack of nutrition information are some of the leading factors contributing to low consumption of vegetables and fruits in developing countries although these poor economies have a wide range of untapped resources in indigenous vegetables that can be exploited to address the micronutrient deficiency challenges [41]. These leafy vegetables are readily available in the tropics and are cheap sources of vitamins [42] and minerals [43]. Vegetables, particularly indigenous ones plays a vital part in biodiversity while providing in our diets; minerals, dietary fibre and a variety of vitamins including vitamins A, C, E, B1, B6 and B9 [5]. They are also considered of nutraceutical importance as they contribute in preventing or slowing down the development of certain gastrointestinal disorders and chronic diseases [5]. Indigenous leafy vegetables, which are nutrient rich [10], require little or no inputs to produce [44], are more resilient and adaptable in changing weather conditions can play a crucial role in provision of these nutrients in our diets. This can successfully be done by encouraging farmers to continue growing them in large quantities and consumers to increase their consumption [45].

Many communities in the world especially in sub-Saharan Africa and many parts of Asia consumes a wide variety of indigenous leafy vegetables which are generally considered NUS [46,47,48]. Maundu et al. [49] estimated that close to 1000 species are utilized as food, a figure that is most likely to be significantly higher to date. Unlike

many commodity vegetables which are mainly exotic in nature, indigenous African leafy vegetables (IALVs) have received minimal national, regional and international attention, and thus are under researched [50] and have limited global market presence [29]. IALVs which are defined by van Rensburg et al. [51] as plant crops that are native to a specific region or were introduced to a specific region so that they have evolved through a natural process or through selection by farmers, have for a long time been branded 'famine food' or 'poor man's food' [29] which has not helped in their consumption rate by the middle and upper class consumers even in communities where they are native and are substantially cultivated for domestic use. This is probably because they have been thought to only play a food role where they act as a fallback strategy to mitigate hardships [52] such as during droughts and famines. Despite all these challenges, nutritionally, IALVs play a vital role in providing daily dietary intake of micronutrients to a huge African population [53] improving food security and diet diversification to households.

Due to their superiority in micronutrient density [54] and limited agricultural inputs [35] in their production compared to their conventional counterparts, IALVs have in the recent past caught and aroused a lot of curiosity and interest in among other stakeholders; researchers, nutritionists, governments, individual persons and biodiversity advocates [55]. Other documented advantages of embracing production and consumption of IALVs include the fact that they are more disease and drought resistant [56,57] hence more tolerable to climatic changes [58], and they are also more pest resistant and have a shorter maturity period [59] compared to non-AILVs. Presently, there is increasing demand of indigenous leafy vegetables by the urban consumers in many African countries [60] e.g. in the urban towns in Kenya where some of them (e.g. cowpea and amaranth leaves) fetch higher prices compared to the exotic varieties (e.g. cabbages). In fact Senyolo et al. [61] and Chelang'a et al [62] have reported consumers' willingness to pay a premium for these vegetables due to the increasing awareness of their nutritional and health benefits compared to other types of vegetables. This increasing demand for IALVs in urban areas serves an important avenue for their continued consumption promotion [63]. This means that the old notion that these vegetables are cheap or can be obtained free [64] has or is changing with time, possibly due to increasing awareness of their nutritional benefits. Some of the most popularly cultivated and consumed IALVs in the African context include cowpea (*Vigna unguiculata*), jute mallow (*Corchorus carinata*), leafy amaranth (*Amaranthus spp.*), pumpkin (*Cucurbita moschata*), African nightshade (*Solanum scabrum*), African kale (*Brassica carinata*), slender leaf (*Crotalaria brevidens*) and spider plant (*Cleome gynandra*) among others.

2.1. Nutritional and Health Benefits of IALVs

According to WHO/FAO, vegetables and fruits are an important component of a balanced diet and their daily consumption in the right amounts can help in the prevention of many non-communicable illnesses such as cardiovascular diseases [65]. It is for this reason that WHO has recommended a daily consumption of at least 400g of vegetables and fruits in order to prevent micronutrient deficiencies and chronic illnesses such as diabetes, heart disease and obesity especially in underdeveloped countries [65,66]. In human nutrition, vegetables are generally considered protective foods possibly due to their association with several health benefits linked to their high concentration in minerals, vitamins, dietary fibre and important bioactive compounds [67] such as secondary plant metabolites including phenolic and antioxidant compounds [68,69]. Despite their underuse as a food source, IALVs which are also categorized as green leafy vegetables continue to positively contribute to human health and nutrition in spaces where they are indigenous and have historically been incorporated in diets. Previous research studies show that several IALVs can address the insufficient intake of nutrients resulting from inaccessibility of non-indigenous/exotic vegetables at household level [54,70,71].

Recently, due to increased awareness of their superior nutritional qualities especially in regard to their high content of micronutrients compared to commodity vegetables, IALVs have witnessed a heightened demand by the middle and high income earners in major urban centers in developing countries such as in East African countries like in Kenya [63], Uganda and Tanzania. This suggests a shift in perception of these vegetable crops from a 'famine food' to a nutritious, healthy and well-being promoting foods. Scientific literature on nutrient content of many indigenous leafy vegetables is either not reported or is limited. However, reports available indicate that IALVs can generally provide a variety of significant vitamins (such as vitamins C, B and A) and minerals (zinc, iron, calcium and potassium) [54] which can serve to supplement the limited levels in energy-rich staple food crops. In fact authors including Van Jaarsveld et al. [72], Uusiku et al. [54], and Toledo and Burlingame [41] have reported that several IALVs, besides being great sources of dietary fibre, are also optimal sources of a variety of nutrients such as calcium, folate, β-carotene, iron and zinc among others.

Limited data available however suggests variability in both micro- and macro-nutrient densities among IALVs, a research area that warrants further investigations. A study carried out by van Jaarsveld et al. [72] on eight indigenous African leafy vegetables reported their nutritional diversity with nutrient concentration comparable to those of conventional dark green leafy vegetables [73]. Compared to other dark green leafy vegetables, the authors reported that the IALVs under their study had similar or higher calcium and magnesium contents, while β-carotene content in cowpea, pigweed, black nighshade and spider plant leaves was higher. In this study, pumpkin leaves contained the highest levels of iron (8.8g/100g of leaves after cooking) while cowpea and pigweed were the best sources of vitamin A (both at 510 µg RAE). *Amaranthus* is considered more valuable in nutrient content among IALVs as for example, it provides approximately 4500 units of vitamins/100g of the edible parts in comparison with 280g for cabbage [74]. A study carried out by Schonfeldt and Pretorius [75] on five dark green IALVs (*Amaranthus tricolor*, *Curcubita maxima*,

Cleome gynandra, *Cleome gynandra* and *Vigna unguiculata*) in South Africa showed that they were all nutrient dense in phosphorous, magnesium and calcium. The authors found that pumpkin leaves (*Curcubita maxima),* amaranth (*Amaranthus tricolor)* and cat's whiskers (*Cleome gynandra)* were superior in nutritional quality index in regard to protein content compared to jute mallow (*Corchorus olitorius)* and cowpea (*Vigna unguiculata)*. *Solanum scabrum* and *Amaranthus* are reported to be high in iron (37 mg content per 100 g) [76] while the former is also a good zinc source according to Biesalski et al. [77].

Apart from supplying nutrients through diets, vegetables have other beneficial effects in human health attributable to their phytochemical compounds such as carotenoids, saponins, vitamins, flavonoids and proanthocyanidins [78,79]. Depending on the type of phytochemical(s) present, they may exhibit varied biological effects in the body that include antimicrobial, anticancer, anti-inflammatory, anti-allergenic, cardio protective and antioxidant activities [80,81]. Since they have high antioxidant activity, phenolic compounds are considered important biomarkers of food nutrition quality [82]. These phytochemicals, especially phenolic compounds are thought to be abundant in IALVs [54,83] suggesting that regular consumption of these vegetables can provide protection against oxidative damage associated with certain diseases [84]. Generally, IALVs are associated with significant levels of carotenoid whose high intake in human diets is linked to reduced risks of diseases such as cancer [85] and cardiovascular illnesses [86] due to their anti-oxidative properties. Neugart et al. [85] quantified high levels of carotenoids in spider plants and amaranth (utmost 64.7 µg/g DW and 101.7 µg/g DW respectively) suggesting a high content of β-carotene which is a pro-vitamin A. Akhtar et al. [87] also reported high levels of β-carotene and vitamin C in leaf amaranth (*Amaranthus blitum* L.) in an Indian study determining quantities of these components in indigenous leafy vegetables. A study carried out by Moyo et al. [81] showed that the three IALVs investigated contained varied concentrations of phytochemicals which was higher and of superior antioxidant activities compared to non-IALVs. The value of extractable phenolic compounds for *Amarathus dubius* was 5.16±0.12 mg GAE/g DW which was the highest among the three AILVs studied. Schonfeldt and Pretorius [75] also reported high concentrations of β-carotene and trans β-carotene in five dark green AILVs in a South African study. The authors reported total β-carotene range of 796–6134 mg/100 g for both raw and cooked AILVs in their investigation.

2.2. IALVs as a Source of Livelihood

In many rural communities in developing countries especially in East Africa where IALVs are indigenously cultivated, their harvesting, preparation and selling in local markets usually forms part of their livelihood. Cultivation and sale of indigenous leafy vegetables provides a means through which majority of the rural vulnerable, particularly women can generate an income [87,88] where they act as a source of employment [89]. Bua and Onang [90] have recently reported that one of the reasons Ugandan farmers cultivate AILVs is to generate cash income, and according to Adebooye and Opabode [91], IALVs plays an important part in income generation in south-western Nigeria as they fetch higher prices compared to their non-indigenous counterparts, especially during the dry seasons. A similar observation is reported by van Rensburg et al. [51] where indigenous vegetable selling in Limpopo in South Africa is done for households' income generation. Although the main players in the production and sale of IALVs are women, men have in recent times taken up the business in their efforts to contribute to the well-being of their households through income generation. Production of IALVs is a low resource enterprise that requires insignificant startup capital and a good form of livelihood diversification among communities that grow these crops. In fact, in an event of a food calamity occasioned by e.g. adverse weather conditions such as droughts, IALVs can act as a fall back livelihood cushioning families from hunger [30].

The increasing demand for IALVs among the high income earners especially in urban centers in developing countries means that the future of these vegetables is bright. This has resulted in the emergence of semi-commercial and commercial cultivation of these indigenous vegetable crops among the previously small-scale farmers in an effort to bridge the increasing demand gap. In Cameroon in 1996 for example, the annual sale of these vegetables in the country's local urban markets was estimated at 22 million US dollars [92]. Although it is difficult to quantify the actual value of IALVs sales in Africa, Weinberger and Pichope [93] have reported that the market for these vegetables in sub-Saharan Africa is worth billions of US dollar. Other studies reporting the importance of IALVs in livelihood promotion include those of Weinberger and Msuya [94], Ngugi et al. [95] and High and Shackleton [96]. In East Africa and Kenya in particular, IALVs are sold in many supermarkets around the country [85] with some seed companies showing immense interest in breeding these vegetable crops [55].

An increasing demand for IALVs as a result of the awareness of their nutritional benefits has seen areas under their cultivation significantly increase in some countries. In Kenya for example, the area under IALVs cultivation between years 2011 and 2013 increased by 25% [55], and this has possibly increased further in recent times. This increase will no doubt translate into an increase in the number of jobs created, improved household nutrition and earnings, and more sustainable food production that assures overall food security. In not too distant future, it is envisaged that the IALVs value chain will improve thanks to increasing interest by researchers, nutritionists, governments, farmers and consumers of this food type. Continued promotion and encouragement of incorporation of IALVs in our local diets may encourage more people to consume them, and more farmers to grow them in large quantities in order to meet the market demand helping improve food security, livelihoods and human nutrition. An example of a nutritious IALV that is being considered important for household utilization, livelihood improvement and commercial cultivation both in Africa and Asia is amaranth [97]. The market potential for this particular vegetable crop is perceived to be promising in

Africa especially as a means of promoting women empowerment through sustainable income generation and improvement of nutrition at the household level [30]. In Tanzania for example, a farmer can earn an income of about 250 US dollar from a small portion of land measuring approximately 500m^2 [97]. There is a possibility that the outlook of other IALVs will be as promising as that of amaranth in future as interest in their farming continues to be of interest to even non-IALV farmers in many of the developing countries.

2.3. Environmental Benefits of IALVs

Currently, resources required to produce more food to feed the ever increasing population, such as land and water are limited. The growing population puts a lot of pressure on land to produce more food to beat the food insecurities experienced in many regions in the world. This often leads to practices that may not be sustainable and are detrimental to the environment such as indiscriminate use of artificial fertilizers which may contribute to undesirable effects such as soil degradation, water pollution, global warming and climate change. The effects of unpredictable droughts and frequent water scarcity due to changes in weather patterns as a result of climate change is associated with among other crops, vegetable yield losses [98] especially in developing countries where most farmers rely on rain-fed agriculture for their rural livelihoods. IALVs are mainly cultivated and sold by small-scale farmers who have been reported as the most vulnerable group to climate change effects, especially in sub-Saharan Africa [99].

Production of IALVs has several environmental benefits over cultivation of their exotic counterparts. Generally, IALVs have been widely regarded as more resilient and adaptable to unpredictable weather or harsh environmental conditions such as limited water and dry conditions, and poor soils that cannot support good growth of non-IALVs [100,101]. One of the best ways of dealing with insufficient water availability (frequented by inadequate rainfall and its distribution) while ensuring sustainable crop production is adoption of crops tolerant to water stress [102] such as the IALVs. Some of the IALVs that have been reported to tolerate a wide range of abiotic factors include jute mallow (*Corchorus olitorius*), cowpea (*Vigna unguiculata*), slenderleaf (*Crotalaria Brevidens*) and amaranth (*Amaranthus sp.*) [98,103] among others. According to Neluheni et al. [104], amaranth is capable of producing significant yields even in conditions of low moisture availability. Besides their tolerance to many abiotic stresses such as heat and drought [20], IALVs are also superior to their exotic counterparts in that they require no or limited use of chemicals to control disease causing pathogens and pests since they are more resistant to most [105]. Moreover, less of the other resources such as fertilizers and labor used in crop production are required in the cultivation of IALVs. These are probably some of the reasons these indigenous crops are considered for the improvement of plant biodiversity as climate-smart crops. According to Akhta et al. [44], availability and obtainability of indigenous leafy vegetables that can help to curb micronutrient deficiencies especially in the rural tropics can be enhanced by farming methods that embrace agrobiodiversity and are environment friendly.

3. Challenges Facing Production and Consumption IALVs

Although an increase in consumption of indigenous African vegetables has been witnessed in many African countries recently, still, majority of the people have preference for their exotic counterparts especially in urban environments. Lack of sufficient scientifically documented information or knowledge about IALVs could be a major contributing factor influencing consumers to choose non-indigenous vegetables over IALVs [106,107]. Such kind of information that may be insufficient or lacking in regard to IALVs include individual species nutritional composition or nutrition value, appropriate preparation and/or cooking methods, as well as nutrient bioavailability among others. A study carried out by Asase and Kumordzie [108] on availability, cost and popularity of African leafy vegetables in Accra markets in Ghana showed that even though the demand was high, only a small number of the indigenous vegetables were available for sale.

IALVs are neither grown in huge quantities nor significantly widely consumed mainly due to limited consumer awareness of their nutritional value and the negative perception toward them as a result of westernization culture [109] that is becoming more prevalent in developing countries. According to Meldrum et al. [19] and Dweba and Mearns [109], erosion of traditional knowledge of IALVs which has been witnessed globally is to blame for their underutilization. Lack of interest in IALVs by many farmers is mainly attributable to preference for cultivation of exotic vegetables [110] that yield more and are more widely accepted for consumption by a majority of the consumers. This reduced cultivation is also made worse by the fact that their production and consumption is mainly common in the rural areas particularly among the elderly, especially women [111] with the young generation and urban inhabitants shunning them as traditional, food for the old, the ‘uncivilized’ village dwellers and as food to be used during times of food insecurity [112]. A recent study by Gido et al. [113] investigating consumption intensity of IALVs in Kenya revealed that these vegetables were consumed more by the rural than the urban dwellers, an observation that could possibly mirror those of other similar countries. Weinberger and Msuya [94] reported an inverse relationship between family wealth and IALVs consumption, which means that the wealthier a household is, the less likely the members will consume these vegetables, possibly in preference to their non-IALVs counterparts. This trend is however bound to change in the foreseeable future due to great efforts being made to promote IALVs in human nutrition.

Postharvest losses greatly negatively affect availability and distribution of IALVs to destinations that they are highly demanded. It is one of the major constraining factors hindering marketing of IALVs due to their high perishability nature [53] resulting in both qualitative and quantitative losses [53]. The management of postharvest

losses of IALVs along the supply chain is difficult due to limited scientific information on the same. It is however believed that about 50% of IALVs are spoilt before they are purchased by the consumers [53]. Inappropriate storage conditions and poor handling of IALVs after harvest have often been associated with substantial quality deterioration after harvest [105]. Often, IALVs are seasonal [114] which means that there are times when they are harvested in large amounts within a short span of time. Due to lack of sound infrastructure such as roads often associated with rural areas [115] where they are cultivated (and nowadays less demanded compared to their market potential in towns), and lack of affordable and safe preservation methods, they in many cases go to waste due to spoilage. A study carried out in Kenya reported that 2-6% of IALVs sold in Nairobi which is the country's capital city goes to waste within a day as a result of wilting [116] due to lack of appropriate affordable refrigeration/cooling facilities.

Temperature is the single most important extrinsic factor that influences spoilage and thus postharvest losses of fresh produce including IALVs. Therefore, temperature control is an important aspect in the fresh produce sector usually aimed at extending the shelf-life of perishable foods such as IALVs. Temperature control through cooling retards growth and multiplication of spoilage microorganisms as well as physiological changes that lead to water loss (e.g. transpiration and respiration) [105] significantly improving the keeping quality of the produce. However, the best method of achieving this benefit of temperature control is through refrigeration which is not readily available, is expensive and may not be affordable to most of the small-scale IALV farmers in the developing countries. Even if electricity was cheap, readily available and refrigeration facilities affordable to IALV farmers, there still would be a problem in the decision of the optimal refrigeration storage temperature for these vegetables. Very limited literature exist about the appropriate range of refrigeration temperature for IALVs, particularly on individual vegetable species. Therefore, urgent research needs to be carried out to determine the optimal refrigeration temperature of specific IALVs, particularly the priority species which are considered more economical, high yielding and most nutritious. In an effort to try and extend the shelf-life of IALVs, farmers result to other methods which are less effective in controlling losses. For example, in Kenya, it is common to find IALV street vendors sprinkling water on their produce to try and retain its freshness. In as much as this method can help in the short run e.g. for a few hours to a day without a significant loss in product quality, it is not effective in the long run and often leads to quality losses if the products are not bought within a day. The sprinkling of water on the vegetables may also encourage microbial multiplication and postharvest disease development [117] leading to not only postharvest losses due to spoilage, but also food safety concerns.

To prevent or reduce postharvest losses of IALVs, preservation methods other than refrigeration that are readily available, affordable and sustainable needs to be developed and/or adopted especially in the context of developing countries where the cost of electricity is expensive. In addition, value-addition through appropriate processing methods needs to be considered to extend the shelf-life of IALVs to ensure continuous and sustainable supply to urban centers where demand for them may be high. One of the most popular, common and cheap preservation methods in the tropics is sun drying whose main aim is to avail the fresh produce during times of shortages (IALVs are highly perishable and seasonal crops) [53]. Drying reduces the water activity of vegetables significantly reducing spoilage especially by action of spoilage microorganisms which are denied free water for their metabolic activities. Different types of vegetable drying methods including sun drying, oven drying and solar drying among others are documented in the literature [118]. Drying is a popular method used for preservation of indigenous vegetables in South Africa, and according to Voster et al. [119], the main preservation methods are sun-drying of branched leaves and sun-drying of fresh leaves. Another promising means of IALV preservation method that does not require the need for electricity and that has also been shown to improve nutritional quality is fermentation e.g. a recent study carried out by Misci et al. [120] exploring the potential for fermentation as a tool to contributing to food security and nutritional quality of IALVs with respect to *Cucurbita* sp. It is worth noting however, that none of the preservation methods solves the problem of consumers who prefer consumption of freshly harvested IALVs and ways of ensuring that their needs are met needs to be explored. It is also important that scientific information on the effects of preservation and/or processing methods on individual IALVs (e.g. effects on nutrient content) is generated in order for correct choice of the most appropriate method is made. Akhtar et al. [87] notes the importance of understanding the effects of different processing methods of indigenous leafy vegetables on their nutritional properties, nutrients modifications and bioavailability.

Research work looking at consumer acceptance of IALVs which is important in understanding their behavior towards these vegetables is largely lacking. In the nutritional and health promotion of IALVs consumption, their preference and acceptance by the consumers need to be understood. Findings reported by Gido et al. [121] shows that consumers could prefer one IALV over the other e.g. in their study, urban and rural dwellers preferred African night shade (*Solanum scabrum*) compared to others under their study. Factors influencing these kind of choices needs to be understood for an informed decision to be made on how to promote specific IALVs and/or for farmers to prioritize on growing the varieties in greatest demand. It is also important to generate information on the most appropriate form of IALVs in demand by the consumers in different market segments e.g. do consumers prefer IALVs in whole fresh form, fresh value-added form, or as an ingredient in dried powdered form? This information is vital to fresh produce value-addition practitioners including but not limited to food technologist to understand so that requirements for each IALV can be developed to ensure quality and safety of the products.

4. Conclusion

NUS and in particular AILVs are important food crops that are not only traditionally associated with cultures of

communities cultivating and consuming them in large amounts but are also linked to several health and nutritional benefits in human diets. Many of these underutilized leafy vegetables have been documented to possess superior nutritional qualities especially in regard to micronutrients, as well as in phytochemical compounds compared to conventional vegetables, attributes that are likely to make them more desired vegetables in the foreseeable future. Their resilience and production sustainability under today's unpredictable weather conditions make them climate-smart vegetable crops of choice especially in developing countries where most of the growers rely heavily on rain-fed agriculture. Their old tag as 'poor man's food' is slowly dying away due to increased consumers understanding of their nutritional benefits which has seen their increased production and consumption in recent times, a trend that is likely to continue as they often fetch better prices for the growers compared to their conventional counterparts, which motivates farmers to increase their area under cultivation. However, even with all these benefits, IALVs face numerous challenges that hinder their full production and utilization potential that must be addressed if their food use has to match and possibly surpass those of conventional vegetable crops. Currently, there is a lot of scientific information about IALVs that we do not know which calls for research in these indigenous vegetables to be given the same weight as that of conventional vegetables. For example, not all IALVs are well documented and their nutritional compositions scientifically reported, and the value chain is underdeveloped especially in value-addition and preservation methods. Breeding of IALVs for quality seeds for improved yields is of paramount importance to limit farmer-to-farmer exchange of seeds and ensure uniform quality vegetable crop production. There is also need to understand consumers' behaviors (preference or lack of it) towards these vegetables so that farmers can prioritize on growing that which would give them the best returns. The food safety aspect of IALVs is vital, calling for good food hygiene practices in regard to these vegetables along the value chain. Overall the future of IALVs looks bright and all stakeholders involved needs to be encouraged to continue promoting their production and utilization.

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Statement of Competing Interests

The author has no competing interests.

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