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Chapter

Value of *Amaranthus* [L.] Species in Nigeria

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Abstract

This chapter addresses the value of different *Amaranthus* [L.] species that have been recorded in Nigeria. These are *Amaranthus blitum*, *A. dubius*, *A. caudatus, A. cruentus*, *A. deflexus*, *A. graecizans*, *A. hybridus*, *A. hypochondriacus*, *A. retroflexus, A. spinosus*, *A. thunbergii*, *A. tricolor* and *A. viridis*. Although they are mostly cultivated, some are present as weeds and others are valued for their ornamental roles. *Amaranthus* species are the most important vegetables in some parts of Nigeria because of their leaves, succulent stem and cereal-like grains. The chapter describes their socio-cultural (ethnobotanical), ecological, economic, food and income security values as well as their production requirements. Although amaranths are stress tolerant, mesic condition and soil enrichment can increase output and nutrient composition, respectively. This work revealed that a gap exists in annual production amounts and foreign exchange earning from amaranths. It also compared the 13 species based on their proximate and phytochemical composition. Amaranths are already contributing to sustainable development and livelihood in Nigeria without established institutional support. There is a need for Nigeria to establish a vegetable centre (with the proposed name: Nigerian Vegetable Center) to maximise the potential and actual values of amaranths and other vegetable species in Nigeria.

Keywords: *Amaranthus*, leafy vegetables, food security, plant-based medicine, plant diversity, Ethnobotany, food value, environmental roles, income security, Nigerian Vegetable Center

1. Introduction

Global vegetable cultivation and consumption continue to witness a global expansion that is greater than any other plant group [1]. This is connected to their valued phytochemical contents and the diversity of plant species that can be exploited for their fruits, flowers, tubers or leaves as vegetables. Moreover, technological advancements have made their production more attractive due to less disease incidence and pest attacks. Together, these have led to increased food and income security value for vegetables. They are now considered as key contributors to the pursuit of sustainable development especially in third world countries like Nigeria where they are cheap sources of vital nutrients and energy as well as a means to improve income equality and employment.

There is no universally accepted definition for vegetables but they are generally plants that are valued for their leaves, stems, young shoots, fruits or a combination of these plant parts, which may be used to fulfil human needs [2]. Vegetables may be

annual, biannual or perennial with variable growth requirements depending on the environmental conditions, species, and the geographical origin and distribution. The number of plants exploited as vegetable globally is unknown but it is estimated that over 1 billion tonnes of vegetables are gathered each with China and India accounting for a bulk of that amount as the world largest producers of vegetables. Even though certain vegetables are not easily available in some parts of the world, most are accessible and affordable [3]. Based on availability and nutritional composition tomato, curcubits, alliums and chillies are considered the most important vegetables in the world [4]. Although the information on some indigenous vegetable consumed in a few countries or restricted to third world countries is hard to come by and often not put in a global perspective for the sake of comparison. For instance, weed in one part of the world may be considered an essential vegetable in another.

The benefits of consuming vegetables remain the focus of many research and public health nutrition education because, in all societies and ethnic groups, vegetables are consumed irrespective of socio-economic status [5, 6]. Low consumption of vegetable may cause disability, lower lifespan and death. Whole or parts of mature or immature vegetables may be eaten raw (fresh or dried), cooked or in other processed forms (e.g. as oil) and used as a part of other food for different purposes including as a source of energy, nutrition, flavour, colouring or medicine. In part of sub-Saharan Africa, vegetables are a cheap and reliable source of proteins, vitamins, zinc and iron as well as a source of income for the mostly female farmers [7]. Due to insufficient consumption, some countries have developed dietary recommendations with respect to vegetable consumption as a way to promote healthy living and disease prevention [3, 8]. The report of Alberta Health Services [9] suggests that poor people or people with lower household income consume more vegetables.

Socio-cultural and economic activities related to vegetables have evolved over time in many parts of the world. According to Sinha et al. [10], the impacts of the food industry on the global economy relies upon the increased consumption and processing of fresh and processed vegetables. Moreover, Schreinemachers et al. [4] proposed a greater value for vegetable production than all cereals combined despite a relatively low level of support from private, national and international donors compared to staple and oil crops. At the national level, many countries continue to earn huge foreign exchange from vegetable related activities. Moreover, vegetable accounts for a huge percentage of food waste and require millions of dollars to manage [11]. In Nigeria, large-scale cultivation of vegetable is rare as they are mostly cultivated in small farms and in home gardens. In addition, numerous biotic and abiotic factors militate vegetable production and consumption [12], which are heightened by limited global effort as compared to other groups of economic plants.

The objective of this chapter is to outline the values of *Amaranthus* [L.] spp. in Nigeria from different perspectives including comparing their phytochemical compositions, ethnobotanical (socio-cultural) roles, ecology, production requirements, food and income importance. This chapter presents a list of *Amaranthus* spp. in Nigeria and seeks to highlight their importance with a view to promoting their consumption and use. Through comparing their phytochemical composition, this chapter will highlight the contributions of these amaranths to food and nutrition security while recommending their production as an economic opportunity for reducing poverty and unemployment. Amaranths are considered the most widely consumed and traded green vegetable in sub-Saharan Africa because of their soft texture and mild flavours [13]. Typical of vegetables, *Amaranthus* species have a peculiar requirement for their production and this will be addressed from the seed sources, soil and climatic requirements, management practices, harvesting, storage and transportation perspectives. The section on ethnobotany will discuss the socio-cultural relevance of the plant group across the diverse ethnic groups in

Nigeria. The final part of this chapter presents some recommendations with regards to how to maximise the benefits of these plant genetic resources such as the need for production support, research and data management as well as a proposal to establish a national vegetable centre in Nigeria.

2. *Amaranthus* species in Nigeria

Amaranthus (Amaranthaceae) is a cosmopolitan genus found both in temperate and tropical regions of the world with ca. 70 species and ca 400 varieties. This diversity is greater than most highly cultivated crops despite the underdeveloped and relatively lack of support [14]. Southern Asia (Indo-Burma region) and Central and South America are considered the centre of origin for most of the varieties that have been held under cultivation since time immemorial [15–18]. Spread to other parts of the world likely began with colonisation and exploration. Wild species still occur in parts of Asia, Africa and America. Most amaranths are classified either as a leafy or grain (pseudocereal) amaranth based on the part that is most often used, i.e. edible seeds or leaves [19]. Examples of leafy and grain amaranths are *A. tricolor* L. and *A. cruentus* L. respectively. In addition, some amaranth like *A. tricolor* is valued as ornamental, while *A. palmeri* S. Wats. is considered a weed of economic importance. Because of their huge genetic and morphological variability, they are considered a taxonomically difficult group.

Osawaru et al. [20] included amaranths in a list of common plants used in Nigeria. Based on an extensive literature review, thirteen species of *Amaranthus* were found to have been documented as commonly found in Nigeria under cultivation, as weeds or ornamental. These are *A. blitum* L. (syn. *A. lividus* L.), *A. dubius* Mart. Ex Thell., *A. caudatus* L., *A. cruentus* L., *A. deflexus* L., *A. graecizans* L. (Basionym *A. silvestris* Vill.), *A. hybridus* L., *A. hypochondriacus* L., *A. retroflexus* L., *A. spinosus* L., *A. thunbergii* Moq., *A. tricolor* L., and *A. viridis* L. None of the thirteen species is native to Nigeria but most have since acclimatised to the clime and are valued for their leaves, herbaceous stem, inflorescence, seeds and chemical byproducts.

A. blitum (common names in English include amaranth, wild amaranth, pigweed, purple amaranth) syn. *A. lividus* L. is a cultivated species that also occur as harvestable ruderals in Nigeria due to the leaves (**Figure 1**). Likely introduced to Nigeria from the Mediterranean and Arabian region where it is native. It occurs widely as a weed across Nigeria. Botanically the plant is an annual, with glabrous, ascending to prostrate, sometimes erect, simple or branched stem that grows up to 6–90 cm. Leaves are ovate or obovate with tapering or cuneate base. Slender terminal spikes or panicle inflorescence. *A. blitum* have shiny black seeds but are appreciated for the soft stems and sweet tasting green or red leaves.

A. caudatus (common names in English include red amaranth, flower amaranth and pendant amaranth) is found mostly in Southern Nigeria (**Figure 1**). This is a grainy amaranth. The grains vary in colour from white to brown to red. They are valued as ornamental due to their impressive red inflorescence, which is dense spikes. The plant can grow up to 160 cm and is sun-loving. It is considered a weed or ornamental in Nigeria but the leaves are edible. Red coloured flowers are the most common flower colour-variant in Nigeria. The plant is native to the Americas.

A. cruentus (common English names include amaranth, African spinach, red amaranth, and purple amaranth) is the globally popular grain amaranth (considered a pseudocereal) albeit not widely cultivated in Nigeria (**Figure 1**). Paredes-Lopez and Hernandez-Lopez [33] reported that *A. cruentus* takes approximately 44 days to flower (at 60 cm) and can be harvested from 102 days (at 125 cm). It is native to the Americas. In Nigeria, they are valued for their ornamental properties than for their seeds. They are common as weeds, especially around urban centres. It

Figure 1.
The common amaranth species in Nigeria are: i. A. blitum*, ii.* A. caudatus*, iii.* A. cruentus*, iv.* A. deflexus*, v.* A. dubius*, vi.* A. graecizans*, vii.* A. hybridus*, viii.* A. hypochondriacus*, ix.* A. retroflexus*, x.* A. spinosus*, xi.* A. thunbergii*, xii.* A. tricolor *and xiii.* A. viridis*. Source: adapted from [21–32].*

shares key morphological characters with *A. hybridus*. The grains are dark-red with green spots in colour while the long stems bear a large inflorescence likely introduced by Europeans.

A. deflexus (amaranth, pigweed and green are the English common names in Nigeria) is a cultivated species in parts of Central and Southern Nigeria [34]. Botanically, *A. deflexus* is an annual or perennial herb (when outside cultivation) with slender to rather stout stem that can grow up to 80 cm with varied coloured multicellular hairs, moderate to dense leaves, green flowers that is slender and lax to stout and dense terminal and axillary spikes and compressed-ellipsoid seed (**Figure 1**) [35]. It is native to Asia and South America. Seeds of *A. deflexus* are large compared to other *Amaranthus* species.

A. dubius (common names in English include amaranth, spleen amaranth, green, green spinach, and pigweed): Likely introduced to Nigeria by early European visitors. The plant is annual, erect, herbaceous dicot with a branched stem that grows up 30–150 cm with spike-like or paniculate inflorescence and broad leaves (**Figure 1**). *A. dubius* does well in diverse soil and climatic condition. Hence, it is cultivated in Southern and Northern parts of Nigeria for the edible leaves, seeds and stems where it occurs as a ruderal. The ruderal ones are also harvested and consumed. Fast growing and high yielding plant with distinctive dark-green, broad, ridged palatable leaves.

A. graecizans (common names in English include wild amaranth, prostrate amaranth, and spreading pigweed) is a cultivated annual in Nigeria (but also remains as a weed) and the leaves are eaten as vegetables and used as livestock feed. The prostrate or decumbent plant can grow up to 50-150 cm in height (**Figure 1**). It is native to the warm temperate regions and very common in eastern parts of Africa.

A. hybridus (common name in English include green, amaranth, pigweed, slim amaranth, and green leaf) is very diverse (in colour and size) in Nigeria including weedy cultivars. Can grow up 15–150 cm (**Figure 1**). The leaves are green with red blotches. The lower side of the leaf has prominent pinnate veins. The plant prefers mesic to dry conditions. The plant has a long history of cultivation in Nigeria. It begins to flower at 65 cm (after approximately 57 days) and is ready for harvest after 129 days at approximately 180 cm [33].

A. hypochondriacus (common English name include Prince's feather and amaranth) is a common ornamental and weedy species in Nigeria whose leaves are also consumed. The plant is considered a pseudocereal as it is a grainy species of *Amaranthus*. Early European visitors likely introduced it to Nigeria from the Americas. The plant can grow up to 4–200 cm. The plant begins to flower at 43 days and is ready for harvest after 100 days (**Figure 1**) [33]. The fruit is obovoid to rhombic capsule with whitish to yellowish or blackish seeds.

A. retroflexus (common English names include amaranth, pigweed, and tumbleweed) is an introduced species common amaranth in irrigated farmlands in Northern Nigeria. The species also occur as a ruderal in parts of central Nigeria. The leaves are eaten as part of salads or used with other condiments in soups. The plant can grow up to 30 cm. Botanically the plant is a monoecious, annual herb with tap roots and erect stem (freely branched), leaves range between 0.8 and 3.9 inches and inflorescences are densely crowded (**Figure 1**) [36].

A. spinosus (common names in English include Nigerian thorn, spiny amaranth, prickly amaranth, and spiny pigweed) is a thorny weed common as ruderals as well as in the wild (**Figure 1**). The leaves are consumed in different parts of Nigeria and used as livestock feed. Native to the Americas and introduced to Nigeria. Stems and leaves are hairless, sometimes shiny in appearance and the leaves characteristically have rigid, sharp spines of variable sizes [37].

A. thunbergii. (common English names include wild amaranth, wild spinach, and pigweed) is a popular species in Northern Nigeria that is used for flavouring food. The leaves are also valued as food. Plants can grow up to 55 cm. The stem is hairless, simple or branched, angular but with hairs towards the top (**Figure 1**). Flowers are greenish in short axillary clusters, and unisexual [38]. The fruit is an ovoid-ellipsoid to the pyriform capsule. The species is native to Africa but introduced to Nigeria.

A. tricolor (common name in English are amaranth, Chinese spinach, and Joseph's coat) is a multi-coloured species of amaranth often yellow, red and green (**Figure 1**). The plant is valued as an ornamental as well as edible leaves and stems in Nigeria. It is native to the old world tropics that can grow up to 125 cm in moist and mesic soil conditions. The plant can tolerate hot summer conditions [39]. The flowers are non-showy.

A. viridis (common English names include green amaranth, local tote, and African spinach) is a highly branched amaranth with edible ovate, long leaves (**Figure 1**). The plant can grow up to 60–80 cm. In Nigeria, *A. viridis* is a common weed that is also found under cultivation across the country. Among the weedy amaranths in Nigeria, *A. viridis* is most the consumed [40]. The plant is native to East Asia.

3. Ethnobotany of amaranths found in Nigeria

Local knowledge, utilisation, and practices (including superstitious cultures) that have evolved over the years with regards a specific plant is regarded as ethnobotany [41–44]. Most amaranth is believed to have originated from America where the Aztec and Inca scripts show early utilisation but the exact date of introduction

to Nigeria remains unclear. However, Nigerians have interacted with *Amaranthus* spp. for many centuries resulting in different cultural practices and beliefs that have locally sustained the germplasm and endeared it to the people. Some of the diverse ethnic groups in Nigeria call almost all the varieties with the same local name like *shokoyokoto*, *efo*, *tete*, *arowo jeja* (Yoruba), *Akwukwo*, *inene* (Igbo), *Boroboro* (Fulani), and *Alaiyaho* (Hausa). Indigenous people consider most of the amaranth species available in their vicinity as the same [45]. They serve multipurpose ethnological roles as medicines, dyes, home decorators, animal feed, human food, and superstitious practices to local gods. Dried, ground *Amaranthus* parts are used to produce local drugs which may be consumed alone or mixed with water or added to local soups.

The plant is used in medicines in the treatment of eye, ear, and stomach troubles as well as for dysentery, diarrhoea, diuretics, lactation boost, anus, haemorrhoids, menstrual cycle, venereal diseases, paralysis, epilepsy, convulsion, and spasm [45]. According to Alegbejo [46], it was reported that boiled leaves and roots of *Amaranthus* spp. are used as a laxative, diuretic, anti-diabetic, antipyretic, anti-snake venom, antileprotic, anti-gonorrhoeal, expectorant, to relieve breathing in acute bronchitis due to their anti-inflammatory properties, immunomodulatory activity, anti-androgenic activity and anthelmintic properties. It is a common belief in South Eastern parts of Nigeria that the consumption of amaranth leaves and stem in the soup will boost blood count and revitalise the body. In the same region, hot amaranth soup served with fish is often prepared for nursing mothers to boost their immunity. In the South Western region of Nigeria, consumption of fresh (uncooked) but mature amaranth leaves is used in the treatment of mouth and stomach ulcers. In some parts of Northern Nigeria, the red inflorescence is used to make dyes as well as a traditional drink for stomach pains. In North Central parts of Nigeria, amaranth extract is applied to boils until the purse is discharged and the wet plan is tied to Whitlow as it helps it to dry up faster [47].

Juice of *A. blitum* can be used in the treatment of buccal and throat ulcers and headaches. Common weedy species *A. viridis* is consumed by humans and their livestock as a medical remedy [40]. *A. blitum* is used in the treatment of lung disorders as well as an astringent against ulcers and as a cooling lotion to ease urinary troubles and bile [48]. *A. spinosus* root is used as part of skin lotion while the whole plant is used to treat snakebite, diabetes, gonorrhoea and as an antihelmintic [49]. *A. spinosus* root is used as part of skin lotion while the whole plant is used to treat snakebite, diabetes, gonorrhoea and as an antihelmintic [49]. Amaranths are used as a body lotion to treat skin infections like eczema and pimples. The young succulent stems are boiled and mixed with honey as a laxative. Amaranths seeds are roasted and used in making different local alcoholic and no alcoholic beverages [50]. According to Soladoye et al. [51], *A. spinosus* has a role in female fertility as a mixture produced with the plant can be used to wash both breasts once or twice a day for seven days. The same plant was suggested by Soladoye et al. [51] to be vital in the traditional management of diabetes. In superstitious practices, the plant is offered alongside other gifts to guardians of local deities. The leaves are used to dress wounds.

4. Production requirements of amaranths in Nigeria

Amaranths are mostly annual fast growing herbs that are mostly cultivated on lowlands especially the leafy species. Cultivation is not restricted to distant farms, Riverside, and home gardens as some families maintain some plants in small pots inside the house. Generally, amaranths are fast growing and can be ready for harvest within weeks. Farmers prefer certain species to others depending on the part of

Nigeria; parts valued in that region and intended use. Although they are typically short-lived (with few perennials), they are known to tolerate diverse growth environments including harsh ones. This is likely due to their anatomical characteristics, a well-formed root system, stomatal conductance, and maintenance of leaf area, which together increases the efficiency CO_2 utilisation under temperatures, higher light intensity and moisture stress [52].

Seeds are often cultivated directly in the soil as sole crops on beds or intercropped with other crops initially on a nursery bed and later transplanted after 2–3 weeks [53]. Land preparation and raised beds (of about 90 cm wide and 20 cm high) and covering sown seeds with a thin layer of compost or rice hulls ensure good germination and growth [54]. The optimum temperature for the germination of amaranth seeds is 16–35°C. However, post germination, they are known to tolerate temperature, water and nutrient stress. Nonetheless, growth is best under mesic conditions including soil with good water retention capacity, slightly acidic or alkaline pH and sufficient rainfall or water supply. Harvesting begins 4–5 weeks after planting. Alonge et al. [55] reported that *Amaranthus* spp. in Nigeria grows best with 500 kg ha^{-1} NPK treatment at 4 and 5 WAP and from 250^2 kg ha^{-1} NPK treatment at 6 and 7 WAP whereas 250^1 kg ha^{-1} NPK application can result in slightly higher values in growth parameters than 125 kg ha^{-1}at 4 and 5 WAP. Oyedeji et al. [34]; Ufoegbune et al. [56] and Dada et al. [57] corroborate their results about the relevance of different soil amendment. Hence, the environment and soil condition in which amaranths are cultivated in Nigeria influence their performance. The soil amendments can be directed to influence certain desired growth features.

Generally, different species of amaranths show a preference for seed burial depth and duration of seed burial with an average of 0.5–4 cm and 9 months to 40 years respectively [52]. Amaranths may be ready for harvesting approximately 3–5 weeks after cultivation. Harvesting is done by cutting leaves by hand or uprooting or cutting stems close to the ground level. Harvested seeds, leave or shoots are bundled, the roots are washed and used domestically or packed and transported to industries or market. In the markets and shops, amaranths leaves are sprinkled with water to keep a fresh appearance or held in open containers with the roots in the water [58]. Seeds may be stored in moisture-free environment held in different materials.

5. Ecological and economic importance/value of amaranths in Nigeria

According to NRC [13] cultivation of amaranths contributes to the vitality of farmlands as they used as pioneer species for the colonisation of disturbed lands. This characteristic is partly attributed to their C4 mode of photosynthesis, which involves efficient water use. They are photoperiod sensitive and are known to flower during shorter day lengths [54]. Their ability to grow in nutrient-poor soil is also of ecological importance. The allelopathic effect of different plant species on their production range from negative effects on chlorophyll, number of leaves stem length and dry matter (in *A. hybridus*), decrease growth and productivity (in *A. viridis*), reduced vegetative and reproductive phase (in *A. spinosus*), and decreased chlorophyll content, nitrogen fixation, respiration, growth, nutrient uptake, and germination (in *A. retroflexus*) [52].

Although members of the *Amaranthus* genus are not poisonous they are known to accumulate nitrates in their leaves when cultivated in nitrogen-rich soils and can cause stomach cancer [59]. Environmental pollution poses a risk to amaranth consumption in Nigeria. This was enumerated in Ogunkunle et al. [60] where they suggested potential human absorption of lead, cadmium and zinc through

the consumption of amaranths that have bioaccumulated these harmful metals. Vwioko et al. [61] also showed that high concentrations of SO_2 and NO_2 induce stress (biochemical) and morphological response from amaranths. Thus, they can be used to indicate levels of environmental pollutions, especially in urban centres. Phytoremediation of some heavy metal contaminated sites by *Amaranthus* species has been reported and the mechanism includes the removal by translocation of the heavy metal to aerial parts of the plant from the soil. It has been established that amaranths are viable phytoaccumulators of heavy metals including Cu, Zn, Cr, Pb, Cd, Hg, Mn, Ni, Zn, and Fe and applied in phytoremediation of contaminated sites [52].

Production of Amaranths in Nigeria is low and falls short of demands despite cultivation acquiring increasing importance in parts of Nigeria where the available species are grown for their leaves [55, 62]. Women account for a majority of the production in Nigeria where it contributes to family income and nutritional requirements. Amaranth production account for a large proportion of the rural economy. Amaranth seeds, leaves, stem or whole plants are sold according to their weight at different prices across Nigeria. The tonnes of fresh and processed amaranths sold yearly in common open markets scattered all over Nigeria and the income generated from these activities contribute to both income and food security in Nigeria. However, it is rare to see amaranth in the popular megastores in Nigeria such as Shoprite. This is indicative of the low level of packaging and packaging support provided for the crops and their farmers. Ornamental amaranths make up part of the plants in some green spaces in major cities. Information on the international trade of amaranth in Nigeria is not available. The greater amount of leaves and seed correlate to marketability and greater economic values in amaranths species present in Nigeria. In the study by Mensah et al. [63], wherein they compared commonly consumed vegetables, their results suggests that amaranths are the most frequently used in parts of South–South Nigeria. In a similar study, the results from Arowosegbe et al. [64] showed that amaranth is second most important vegetable after *Corchorus olitorius* L. in Southwestern Nigeria.

6. Nutritional/phytochemical composition of amaranths species in Nigeria

Variability in phytochemical and proximate composition exist in the genus *Amaranthus* and depends on species and environmental condition (**Tables 1** and **2**). Generally, the leaves of amaranths have sufficient amounts of vitamin A forming carotenoids and can be used to fortify weaning food for children [13]. *Amaranthus* spp. are highly nutritious vegetables rich in protein, calcium, iron, vitamin A, C and K as well as in Riboflavin, niacin, vitamin and folate [54]. Amaranthus are health-protective vegetables. Their availability and accessibility as a cheap source of vital nourishment and energy make them a right fit to fulfil or contribute significantly to food security component of sustainable development [82]. The crude fibre help in digestion, prevention of colon cancer, controlling cholesterol metabolism, and blood sugar regulation [83]. There is a correlation between nutrient compositions and dry matter and moisture content [48].

Their proximate and phytochemical composition can be influenced by the application of different soil amendment and additives such as fertilisers. In a study by Oyedeji et al. [34] they showed that NPK grown *Amaranthus* species had the highest protein while PM-grown vegetables had the highest ash content, crude fibre in *A. cruentus* grown with PM was significantly higher than NPK and the control whereas the NPK treatment of *A. hybridus* and *A. deflexus* had the highest crude

***Amaranthus* spp.**	**Proximate composition (%)**								
	CHO	**MC**	**Ash**	**Fat**	**Protein**	**CF**	**CV***	**DMC**	**Lipid**
A. blitum	4.1	85.0	13.8	0.7	17.3	8.4	92.0	9–22	—
A. caudatus+	—	74.8	64	10	14	8	200.4	7.2	5.5
A. cruentus+	9.8	63.8	7.2	1.6	8.1	6.4	—	—	4.7
A. deflexus	10.8	63.9	7.0	—	8.37	5.5	—	—	4.8
A. dubius	—	82.5	3.3	1.9	2.7	2.5	42	—	—
A. graecizans	—	72.7	22.0		28.5	8.5	42	—	—
A. hybridus	7.9	47.7	8.63	3.25	15.2	16.2	268.92	—	4.4
A. hypochondriacus+	—	11.1	3.3–4.1	2.6	13.9–17.3	2.5	—	—	4.8–7.7
A. retroflexus	6.8	88.0	18.8	<1	20.3	10.8	—	40.0	—
A. spinosus	8.7	84	6.8	1.4	3.6	0.6	62	—	—
A. thunbergii	34.7	3.94	24.6	6.1	17.2	13.5	278.4	—	—
A. tricolor	5.2	92.7	0.6	0.1	0.6	0.9	—	—	—
A. viridis	7.7	87.9	1.9	0.5	2.1	1.9	43.4	—	5.3

** = Kcal/100 g.*
+ = Grains.
Source: Adapted from Pederson et al. [65]; Ullah et al. [66]; Unwin and Buss [67], Grubben [58], Oyelola et al. [68]; Akubugwo et al. [69], Nehal et al. [48], Oyedeji et al. [34], Sharma et al. [70], Sheela et al. [71], Antara [49], Muriuki [72], Getachew et al. [73], Walsh [36], Umar et al. [74].

Table 1.
Comparative proximate chemical composition of common Amaranthus species found in Nigeria.

fibre content. NPK and PM favoured growth and yield of the Amaranthus species but influenced proximate composition differently. Amaranths planted in open spaces perform better in terms of morphological growth and yield in (number of leaves) than the controlled environment during a typical growing season [56]. In another related study, Dada et al. [57] showed that the use of compost significantly influence the growth, dry matter, fresh shoot yield and proximate composition of *A. cruentus* whereas the combination of arbuscular mycorrhiza fungi and compost had less or no influence on the same characteristics.

Amaranthus species also contain some antinutrients such as oxalates, tannin, phenolics and phytates that are known to interfere with digestion, absorption and assimilation of nutrients by forming insoluble complexes and these are often present in variable amounts in the different species. Consumption of large amounts (of *A. retroflexus* for instance) has been reported to affect kidneys of cattle causing perirenal oedema and toxic nephrosis [36].

7. Utilisation and products from Amaranthus species in Nigeria

Soil preservation, human and animal food and medicine, research, aesthetic (as ornamentals), bioremediation and industrial applications characterise the utilisation of amaranths in Nigeria. Amaranths are primarily considered vegetable and the leaves and stem are used in potherb, salads, burgers, and soup or stew. The cheap price of this vegetable makes it a preferred choice for most Nigerians. Moreover, in most parts of Nigeria, different amaranth species are used to supplement diverse cereals and legumes, which make up the bulk of daily food. The poor

Amaranthus spp.	Phytochemical (mg)										
	Ca	**Mg**	**K**	**Fe**	**Na**	**CRT***	**Thiamin**	**Riboflavin**	**Niacin**	**Folate***	**Vit. C**
A. blitum	270	130	65	3.0	39.38	1725	0.07	0.22	0.7	85	42
A. caudatus+	261	261	322.4	14.3	21.2	—	0.2	0.5	0.9	—	
A. cruentus+	175	244	290	17.4	31.0	—	0.1	0.2	1.2	—	4.5
A. dubius	582	—	—	3.4	—	17.3	0.1	0.4	1.2	—	78
A. graecizans	410	—	—	8.9	—	5176	0.1	0.4	1.2	—	64
A. hybridus	28.8	231.2	54.2	13.6	7.4	3.3	2.8	4.2	1.5	—	25.4
A. hypochondriacus+	131	327.5		15.4	8.4	19.9	0.3	0.29	1.15	—	2.5
A. retroflexus	—	—	—	—	—	—	—	—	—	—	—
A. spinosus	248	4.5	7.6	13.1	6.5	46.2	—	—	—	—	33
A. thunbergii	410	5.7	—	8.9	—	5716	0.1	0.4	1.2	—	62
A. tricolor	358	—	123	2.4	200	—	—	—	—	—	62
A. viridis	410	1842	3460	8.9	108.0	—	—	—	—	—	64

CHO = carbohydrate, MC= moisture content, CF = crude fibre, CV = calorific value, DMC = dry matter content.
Leaves or stem or …, please state.
CRT = carotene. = (μg).*
+ = seed.
Source: Adapted from Sharma et al. [70], Unwin and Buss [67], Srivastava [75]; Akubugwo et al. [69], Yang and Keding [76], Iheanacho and Udebuani [77], Sheela et al. [71], Amin et al. [78], Mofunanya et al. [79], Leung et al. [80], Muriuki [72], Ullah et al. [66], Mekonnen et al. [81].

Table 2.
Phytochemical composition of Amaranthus *species found in Nigeria*

masses wconsider it equivalent to and a substitute to poultry eggs in nutritional composition and diets. The most common mode of utilising of Amaranthus species in Nigeria is to cook the leaves or grains and consumed as part of a Poaceae (cereal) or Fabaceae (legume)-rich diet. The leaves are also added in potpourri salads. According to Alegbejo [46], Nigerians value the leafy amaranths more than the grainy ones. Leaves are collected during the growth cycle when the nutrient is at the peak and mixed with condiments for the preparation of soup [50, 84]. While the stems are also preferred fresh and succulent. This is why Akingbala et al. [85]; Akin-Idowu [86] opined that grain amaranths are underutilised in Nigeria despite their potential to contribute to food security and economic livelihood. Although they are cultivated primarily as a vegetable, their leaves, seeds and stems are used to add flavours to indigenous delicacies. They are also used as ornamentals to decorate parks, domestic and office complexes.

Grain amaranths are used as a substitute for corn in making ogi (a local porridge made usually with fermented cereal grains) because of the higher protein component, higher peak viscosity and lower setback value [85]. The grains of amaranth species can be mixed with wheat flour, salt, fat, yeast, sugar, and water and fermented, moulded, and baked to make quality bread [87]. The flours produced from the grains are used in many confectionery products. Seeds are used as ice cream toppings. The protein-rich grains of *A. cruentus* and *A. hypochondriacus* are milled for flour or popped and consumed as a substitute for popcorn [46]. *A. viridis* is used as an antiviral against human epidermoid carcinoma (HEP-2) cell line [88]. Washing of leaves with warm water is recommended before consuming fresh or cooking. The grains (seeds) are sometimes added into the soup as well or used as a breakfast snack or ground and used to thicken the soup. The most popular mode of using the seed is to blend it alone or mixed with cereal grains to make flour. The grains are also fed to poultry while the leaves, stem and inflorescence are fed to cattle and other livestock [89].

As a way of adding value to the leaves of amaranths, Agbede et al. [90] reported that quality leaf meals are produced from the vegetables through fractionation. Moreover, Tapia-Blacido et al. [91] reported that the presence of proteins and lipids in the flour films of amaranth leaf-flour has effects on the solubility, colour and opacity of the films but the overall film properties depends on the interactions formed by their polymers (starches and proteins) and by the lipid, on the distribution of these interactions within the film matrix and on the concentrations of each component in the film. Yellow, red and green dyes are obtained from different amaranth species and used to colour textile materials, beverages, medicines and food products. The leaves, stems and grains have unique flavours and are used to add flavours to food and confectionery products. Oil and pharmaceutical products are also extracted from the seeds. The oil contains high priced ingredient (squalene) that is otherwise obtained from shark liver used in traditional and contemporary medicine.

8. Recommendations and conclusion

The report of NRC [13] acknowledged that the crop has contributed significantly to food and income security especially in Nigeria and Africa regardless of a lack of formal support. Thus, the crop can reach admirable heights if production, storage, transport and other formal support is provided. There is a need for more research that will generate useful statistics on the amount of and area under cultivation, cost of amaranth products, demand and supply trends, and foreign exchange earnings. Nutritional studies need to also to be conducted to reflect the importance

of some processed products obtained from amaranths. Extracts from *Amaranthus* species should be used in producing drugs that are a dietary supplement (nutraceuticals) as well as in the treatment of some disease conditions. Prior to consumption, amaranths should be washed with warm water. This is necessary as Akinnibosun and Adeola [92] found many microorganisms that are of public health concern on the leaves of *A. hybridus*. The groups contain a lot of underexploited plants with potential for medicinal application, food and income security. Many research gaps need to fill especially the phytochemical composition of *A. retroflexus*.

Weedy amaranths should be exploited to improve widely cultivated species through the application of biotechnology. This will introduce more resilience traits into the cultivars including but not restricted to disease resistance and faster maturation and adaptability to different conditions. For instance, *A. hybridus* can contribute to early maturity of grain amaranths [93]. The resulting GM crops should be extensively studies for their short and long term risks and benefits before introduction into the market [94]. Protection of the environment should be considered paramount in the control of weedy representatives of amaranths. Biological control should be adopted and integrated with shades as this can affect their perception of and absorption of light.

To maximise the benefits from Amaranth production, there is need to increase investment in their production, good pre and post-harvest management strategies, increase market assess, [4], improve seed availability and the provision of extension services of farmers. According to Schreinemachers et al. [4], market-oriented Amaranth farming will ensure that farmers maximise income generation while remaining resilience to external risks. It is also recommended hereof that grains of amaranths should continue to be combined with conventional ogi and bread cereals (wheat, maize, sorghum, and millet) to make a more nutritious product with higher protein content. They can also be mixed in the innovative cassava bread introduced by the previous administration in Nigeria with the same goal of higher nutrient content. There is a need to increase support for ethnobotanical practices related to amaranths as it can contribute to the conservation of vital knowledge about the germplasm and their conservation status [95].

It is important to iincrease collaboration with the World Vegetable Center, which is an international research organisation founded in 1971 with the mandate to promote vegetable production and consumption. Other related important organisations with similar mandates include the Asian Vegetable Research and Development Center (AVRDC). As a way to maximise Nigeria's interaction with these organisations, it is necessary that we establish a National vegetable research institute to be called the 'Nigerian Vegetable Center'. This will oversee research on vegetables, monitor their production, encourage consumption and trade-related activities such as galvanising the activities of already existing small and medium scale vegetable-based industries that are scattered all over the country. Moreover, it will be the representative voice for Nigeria vegetable interests and monitor activities such as the recently AVRDC funded onion storage facility in Sokoto state, Northwestern Nigeria. Moreover, this indigenous centre will contribute to understanding the diversity of vegetable and help prevent threats to their sustainable utilisation and conservation [2, 96, 97].

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