The Journal of Applied Science **Vol. 20 No. 2: 52-64 [2021]**
วารสารวิทยาศาสตร์ประยุกต์
doi: 10.14416/j.appsci.2021.02.006
ISSN 1513-7805 Printed in Thailand
ISSN 2586-9663 (Online)

Research Article

Nutritional value and antioxidant activity of some reintroduced underutilized vegetables in Nigeria

Israel O. Otemuyiwa[1]*, Boladale W. Akinbola[1], Ifeoluwa O. Akinyemi[1], Comfort O. Bamiro[1] and Akinsanmi A. Akingbade[1]

[1]Affiliation Department of Chemistry, Obafemi Awolowo University, Ile-Ife, Nigeria
***E-mail:** otemuyisegun@oauife.edu.ng.
Received: 06/12/2020; Revised: 13/05/2021; Accepted: 25/06/2021

Abstract

The study evaluated the nutritional values of eight newly reintroduced vegetables indigenous to Nigerian. The vegetables were analyzed for proximate composition using AOAC methods while minerals and amino acid profile were analyzed using Atomic Absorption Spectrophotometer and amino acid analyzer, respectively. Phytate, tannins and antioxidant activities were measured by Spectrophotometric methods. The results showed that dry matter, ash content, crude fiber, ether extract and crude protein (dry weight basis) ranged from 5.0 to 65.9 %, 6.0 to 16.8 %, 5.0 to 14.6 %. 1.6 to 6.8 % and 10.0 to 15.7 %, respectively. The content of minerals (mg/kg) indicated that iron varied from 6.2 and 100, zinc (0.13 and 4.6), copper (0.03 and 2.07), calcium (24 to 810) and magnesium (34 and 233), whereas chromium, nickel and lead were below lethal level. Aspartic acid and glutamic acid were the most abundant amino acids, the total amino acids (ΣTAA) ranged from 64.6 to 103 g/100 g protein out of which between 44 and 49.6% were essential amino acids. Tannin ranged from 1.0 to 33.4 mg/g catechin equivalent, phytate (1.56 to 9.5 mg /g), total phenol (0.53 to 0.8 mg/g gallic acid equivalent and the percentage radical scavenging antioxidant activity ranged from 69.5 to 90.3 %. The study showed that the vegetables possess high antioxidant activities and sufficient nutrients that could meet the recommended dietary intakes if consumed. Hence, consumption of these reintroduced vegetables could help ameliorate nutrient deficiencies and solve food security challenges among Nigerians.

Keywords: underutilized vegetables, amino acid, antioxidant, minerals, phytonutrient

Introduction

Wild vegetables in particular play significant roles in the livelihood of many communities in the developing countries as food and medicine (Arowosegbe, 2013).

Due to urbanization and oil boom that was experienced in the 1970s in Nigeria, a lot of people migrated from rural areas to seek greener pastures in the cities and urban centres thus farming suffered a lot of setbacks. Civilization and urbanization brought about the growth of restaurants and fast – food joints where ready to eat foods, snacks and food away from home are available and at affordable cost. These away from home foods replaced home made / kitchen foods. The change in food consumption pattern to that of western diets affects farm produce especially cultivation of indigenous vegetables which was regarded as economic waste.

 doi: 10.14416/j.appsci.2021.02.006

In nature, there are many underutilized greens of promising nutritive value which can nourish the human population. Many of them are resilient, adaptive and tolerant to adverse climatic conditions. A large number of these vegetables exist as wild species. These wild species are subjected to continuous danger of extinction as a result of various human and environmental factors causing modification or irreversible changes in the crops natural habit with resultant losses of importance germplasm (Arowosegbe, 2013). This gradual loss of genetic diversity may deprive future generations with useful resources for the enhancement of their health (Aletor et al., 2002). Also, a number of these under-utilized vegetables species known to home, disappeared completely even from the wild.

The change in food consumption pattern had caused a significant shift of disease burden from communicable diseases and undernutrition to chronic, non-communicable diseases (NCDs) such as diabetes and cardiovascular diseases (CVDs) (Frank et al., 2019; Chacha and Laswai, 2020). United Nations Food and Agriculture Organization has widely noted that most widespread and debilitating nutritional disorders, like birth defects, mental and physical retardation, weakened immune systems, blindness and even death has resulted from poor fruits and vegetables consumption habits (FAO,2001).

In order to combat the scourge of food insecurity and diseases especially among the rural communities in Nigerian, intensive campaigns were launched by international organizations to promote the importance of under-utilized vegetables especially in the area of nutrition and economic empowerment especially among women who are key player in the vegetable production.

One of such initiatives is the Nigerian–Canada Underutilized Vegetable Initiatives (NICANVEG), a project sponsored through the Canadian International Food Security Research Fund. The project aimed at enhancing food security, economic growth and conservation of valuable vegetable species. The Nigerian Canada underutilized indigenous vegetable project (NICAVEG) was designed to bring back indigenous vegetable to the dining tables by popularizing their cultivation, marketing and consumption. The initiative is currently promoting cultivation and consumption of the underutilized vegetables in Nigeria and also to reduce poverty and empower the rural women economically.

Although, vegetables can be raised comparatively at lower management costs even on poor marginal lands, they have remained underutilized due to lack of awareness and popularization of technologies for utilization.

Examples of some under-utilized indigenous Nigerian vegetables being promoted are; *Solanum nigrium* (*Odu*), *Verononia amygdalina* (*Ewuro*), *Solanum scabrum* (*Ogumo*), *Solanecio biafrae* (*Worowo*), *Solanum macrocarpon* (*Igbagba*), *Curcibita pepo* (*Elegede*), *Amaranthus cruentus* (*Tete*) *and Bassella alba* (*Amunututu*) (Figure 1).

It is worthy to note that the long-term malnutrition problem of the poor nations cannot be solved by food aid or food trade with the affluent countries but rather by the adequate utilization of indigenous plant foods (Umerah et al., 2019). This is because traditional food resources can make substantial contribution in meeting the nutritional needs of the population, especially the low-income group and particularly in times of seasonal scarcity.

A diet rich in vegetables (more than 5 servings per day) is recommended along with fruits and whole grains; an epidemiological study found that a diet of this composition has a negative association with the risk of chronic diseases. Antioxidants in vegetables are some of the important nutrients besides vitamins, minerals, and fibre which have been reported to contribute to health (Olajire and Azeez, 2011). Plant foods have also been reported to contain anti-nutrients such as tannins, phytate, oxalic acid, and so on which were found to interfere with mineral absorption and organoleptic properties of food. The objectives of this study were

 doi: 10.14416/j.appsci.2021.02.006

to analyze some 'newly' promoted underutilized vegetables for nutrients, anti-nutrients and antioxidant activity. The finding of this study would help us to ascertain that the vegetables will promote adequate nutrient intake without negative impact, if consumed.

Materials and methods

Sample and sample preparations

Vegetables were collected from the Teaching and Research farm of Obafemi Awolowo University, Ile-Ife. The vegetable samples (Figure 1) consist of *Solanecio biafrae* (*Worowo*), *Curcibita pepo* (*Elegede*), *Amaranthus cruentus* (*Tete*), *Bassella alba* (*Amunututu*), *Solanum nigrium* (*Odu*), *Verononia amygdalina* (*Ewuro*), *Solanum scabrum* (*Ogumo*), and *Solanum macrocarpon* (*Igbagba*),

The leaves were detached from the stalk, cut into small sizes, washed to remove unwanted residue and blanched (pour boiling water on the vegetable and leave for 5 min before draining the water). The samples were dried in a vacuum oven (Cole-Parmer Instruments Co., Chicago IL, USA) at 50^o C for 4 h, ground to powder, sieved ((0.85 mm diameter mesh), packed in plastic container and kept in freezer until used.

(a) Local Name: Ewuro (Yoruba)
Botanical Name*: Vernonia amygdalina*

(b) Local Name: Efo Tete (Yoruba)
Botanical Name*: Amaranthus hybridus*

(c) Local Name: Worowo (Yoruba)
Botanical Name: *Solanecio biafrae*

(d) Local Name: Igbo or Igbagba (Yoruba)
Botanical Name: *Solanum macrocarpon*

doi: 10.14416/j.appsci.2021.02.006

(e) Local name: Amunututu (Yoruba)
Botanical Name: *Bassella alba*

(f) Local name: Odu (Yoruba)
Botanical Name: *Solanum nigrum*

(g) Local name: Ogunmo (Yoruba)
Botanical name: *Solanum scabrum*

(h) Local name: Elegede (Yoruba)
Botanical Name*: Solanum biafrae*

Figure 1 Plates a-h showing the pictures of the vegetables

Proximate composition

Moisture, ash, crude lipid, protein, and crude fiber content were determined on the dried samples following methods of association of official analytical chemists (AOAC 2000) methods (934.01, 923.03, 920.39, 960.52, and 920.86, respectively); total carbohydrate was calculated by difference

Carbohydrate = 100 – (Σ fiber, ash, fat, protein, and moisture).

Determination of Mineral Content

The mineral content was determined by wet digestion method. The samples (2.0 g) were digested with nitric and perchloric acids (HNO_3 / $HClO_3$: 4:1, v/v) in presence of hydrogen peroxide in a fume cupboard until colourless solution was obtained, the solution was poured into 50 ml standard flask and made up to mark with distilled water. The solution was taken for mineral determination using Atomic Absorption Spectrophotometer (Alpha 4 Model, FisonsChem-Tech Analytical. UK).

 doi: 10.14416/j.appsci.2021.02.006

Determination of Amino Acid Profile

The amino acid profile of the samples was determined by the AOAC (2000) method number 999.13 using a Sequential Multi-Sample Amino Acid Analyzer (TSM) (Technicon Instruments Corporation, New York) with norleucine as an internal standard.

Amino acid score

The amino acid score was calculated from the expression below:

$$\text{Amino acid score} = \frac{\text{mg of essential amino acid in test sample}}{\text{mg of essential amino acid in 1.0 g reference protein (egg)}} \times 100$$

Phytate

The content phytate was determined by anion exchange method of Harland and Oberleas (1986).

Tannin

The content of tannin was determined by the modified Vanillin- Hydrochloric acid (MV-HCl) method of Price *et al.*, 1978. Catechin was used as standard, the linear range was 0.-1.0 mg/m, $R^2 = 0.967$. The result was expressed as mg catechin equivalent/g (mg CE / g) sample.

Determination of Total Phenol

Total phenolics were determined colorimetrically using folin-ciocalteau reagents according to method of Velioglu *et al.*, (1998). Gallic acid was used as the standard. The results were expressed as mg gallic acid equivalent /g (mg GAE/g sample).

Measurement of Total Antioxidant Activity

The free radical scavenging activity using the 2, 2 - diphenyl-1-picryl-hydrazil (DPPH) reagent was determined according to Brand-Williams *et al.*, (1995) To 0.5ml of the extract sample 4.0ml of the methanol and 4 mL of 0.1 mmol /L methanolic solution of DPPH was added and stirred. A blank probe was obtained by mixing 4 mL of 0.1 mmol / L methanolic solution of DPPH and 200 µL of deionized distilled water (ddH_2O). After 30 min. of incubation in the dark at room temperature, the absorbance was read at 517 nm against the prepared blank. Free radicals scavenging activity of DPPH in percent (%) was calculated using the formula given below. All analyses were done in triplicate.

$$\text{Free radical scavenging activity (\%)} = \frac{(A_{blank} - A_{sample})}{A_{blank}} \times 100$$

Statistical analysis

Statistical analysis of data was performed using Microsoft Excel Statistical Package (Microsoft Corporations, USA) and Graph-Pad Instat-3 Package (Graph Pad software Inc, USA). Results were expressed as mean and standard deviation of triplicate analysis. Analysis of variance (ANOVA) was employed to determine significant variations among the samples. The values were considered to be significantly different at $p \leq 0.05$.

 doi: 10.14416/j.appsci.2021.02.006

Results and discussion

The results of proximate composition of the vegetables expressed as dry weight were presented in Table 1. The vegetable with high moisture content would require a lot of vegetables to obtain appreciable dry matter in other words consumer would require to consume a lot of the vegetable enough to meet daily requirements for essential nutrients. The moisture content ranges from 34.4 to 95%, these values compare favourably with values reported in literature for vegetables (Fayeme 1999; Oulai *et al* 2014). The high moisture content may induce a greater activity of water-soluble enzymes and co-enzymes involved in metabolic activities of these leafy vegetables (Oulai et al 2014) an indication of quality deterioration and wastage within short period of time. Methods like blanching and sun-dry are traditional methods employed in vegetable preservation.

The content of ash ranged between 6.0% and 19.4%, the highest ash content was reported for *S. macrocarpon.* The ash content is a parameter that gave an idea of amount of the mineral content of the samples. Sample with high ash contents is expected to have high concentration of various mineral (Elinge *et al*, 2012).

The crude fiber value was least in *B. alba* (5.0%) and the highest value was recorded by *C. pepo* (14.6 %). The fibre values obtained in this study were similar to values reported for most of the leafy vegetables (Odhav *et al*, (2007). Vegetables are known to contain high fibre wich as been documented to be of great importance in health and wellbeing of human being. Fibre is useful for maintaining bulk, motility, increasing intestinal peristalsis by surface extension of food in the intestinal tract, curing nutritional disorder and for food digestion (Olaiya and Adebisi, 2009). Also, it lowers blood cholesterol level and reduces the risk of various cancers (Nkafamiya *et al.,* 2010). However, emphasis has been placed on keeping fibre intake low in the nutrition of infants and weaning children in order to prevent irritation of the gut mucosa (Bello *et al*, 2008).

The lipid content was lowest in *B. alba* (1.6 %) and highest in *C. pepo* (6.8%), the values were within the range (0.01 to 3.73% and 1.17 – 4.90 %) reported by Kwenin *et al.,* 2011 and Oulai et al 2014, respectivey for some vegetables. The values obtained for lipids in these samples confirmed the findings of many authors which showed that leafy vegetables are poor sources of lipids (Ejoh *et al*., 1996) and therefore, contribute very little to the energy value of a meal (Olaiya and Adebisi, 2009). However, it is important to note that diet providing 1 – 2 % of its caloric energy as fat is said to be sufficient to human beings, as excess fat consumption could lead to cardiovascular disorders such as atherosclerosis, cancer and aging (Kris- Etherton *et al*., 2002). Due to low fat content, consumption of large quantity of vegetables could be recommended to individuals suffering from obesity.

The protein content ranged from 10.0 to 15.7%, the value obtained for protein in this study compared favourably to the range of 2.4 and 8.10 % obtained for leafy vegetables by Adebayo *et al* (2013) and also 4.83 to 11.75% observed by Otitoloju, (2014).

The protein requirement of a moderately active children is 0.8g / kg body weight (WHO,1998), it implied that a child whose body weight is 45kg would require to eat about 100g of the vegetable to satisfy half of the daily requirements for protein. Thus, vegetables could serve as an alternative source of protein especially among rural dwellers who could not afford the cost of meat.

The level of carbohydrate was between 36.8 and 57.4 %, the value would compose not only sugar and cellulose but other component such as lignin and pectin. In absolute terms, consumption of vegetable would give less than the recommended dietary allowances (RDA) of

 doi: 10.14416/j.appsci.2021.02.006

300 g carbohydrate per day (Whitney and Rolfes, 2005), hence it has to be mixed with other sources of carbohydrate food (Agbaire and Emoyen, 2011).

Table 1 Ash, ether extract, protein, fibre and carbohydrate content of vegetables (as % dry matter)

Samples	Local name	Dry Matter	Ash	Lipid	Protein	Fibre	CHO
Curcibita pepo	*Worowo*	7.7 ± 0.2^{g}	11.6 ± 0.01^{d}	6.8 ± 0.04^{a}	14.6 ± 0.01^{c}	14.6 ± 0.05^{a}	40.4 ± 0.1^{d}
Solanecio biafrae	*Elegede*	28.2 ± 0.5^{d}	12.2 ± 0.01^{d}	2.7 ± 0.1^{b}	13.7 ± 0.23^{b}	11.2 ± 0.06^{b}	46.2 ± 0.1^{c}
Amaranthus cruentus	*Tete*	24.9 ± 1.0^{e}	16.8 ± 0.6^{b}	2.4 ± 0.2^{b}	12.8 ± 0.03^{d}	10.5 ± 0.3^{d}	47.5 ± 0.4^{b}
Bassella alba	*Amunututu*	5.0 ± 0.02^{h}	6.0 ± 0.01^{d}	1.6 ± 0.0^{f}	10.0 ± 0.01^{a}	5.0 ± 0.01^{c}	57.4 ± 0.01^{a}
Solanum macrocarpon	*Igbagba*	20.3 ± 0.6^{f}	19.4 ± 0.2^{a}	3.8 ± 0.2^{b}	15.2 ± 0.1^{b}	11.8 ± 0.1^{b}	36.8 ± 0.03^{e}
Solanum scabrum	*Ogunmo*	34.9 ± 0.6^{c}	15.7 ± 0.5^{b}	3.9 ± 0.6^{b}	15.3 ± 1.5^{b}	11.8 ± 0.1^{b}	40.3 ± 0.1^{d}
Verononia amygdalina	*Ewuro*	40.3 ± 0.9^{b}	13.9 ± 0.4^{c}	6.5 ± 0.4^{a}	11.6 ± 0.2^{c}	13.5 ± 0.3^{a}	44.5 ± 0.4^{c}
Solanum nigrium	*Odu*	65.9 ± 1.2^{a}	14.3 ± 0.02^{c}	5.5 ± 0.5^{c}	15.7 ± 0.1^{c}	13.8 ± 0.5^{a}	44.7 ± 0.2^{c}

Mean ± SD = Mean and standard deviation of triplicate analysis
Values in the column with the same superscript are not significantly different $P<0.05$

Minerals

Mineral is important for body's metabolic activities. The micro elements such as iron, zinc and copper ranged from 6.2 to 100 mg/ kg, 0.13 to 4.6 and 0.03 to 2.07 mg/kg, respectively, while the macro-elements, calcium and magnesium respectively ranged from 24mg to 810 mg/kg and 34 to 233 mg/kg; heavy metals such as chromium, nickel and lead ranged from 0.01 to 0.8, 0.01 to 0.69 and 0.2 to 2.8 mg/kg, respectively. The results obtained for minerals confirmed the report that vegetables are viable sources of essential elements needed by the body for growth and development. For instance, the soluble minerals like calcium (Ca), magnesium (Mg), and iron (Fe), help in the maintenance of acid base balance of the hydrogen ion concentration of the body tissues. They help complete the absorption of vitamins, proteins, fats and carbohydrates of the food (Islam *et al*, 2004); calcium and iron furnish all the cells and tissues of the body with the elements and nutritional enzymes which they need.

Iron plays numerous biochemical roles in the body, including oxygen binding in hemoglobin and acting as an important catalytic center in many enzymes such as the cytochrome oxidase (Oulai *et al*., 2014) while zinc is required in the body for the maintenance of sense of smell, building of proteins, triggering nzymes and functions as neurotransmitter. The United State Food, Drug and Agriculture (USDA) (2014) recommend that zinc should be consumed in low quantity, because it disrupts absorption of copper and iron.

The contents of both lead and copper reported in this study are generally lower than 0.5 mg/100 g and 4.0 mg/100 g permissible levels for lead and copper, respectively, (FAO/WHO,1991). However, the joint FAO/WHO Expert Committee for Additives and Contaminants (JECFA) (Codex Alimentarius Commission, 1995) has reduced the value, for tolerable lead consumption per week (provisional tolerable weekly intake – PTWI) from 0.05 mg/kg body weight to 0.025 mg and copper is 3.5 mg/kg. The reason for the reduction is that research has revealed further harmful potentials in lead even at a very low level of contamination. Also, this specification considers the body weight, the greater the weight of the body the less the adverse effect of lead on the body, it implies that children are more vulnerable to the effects of lead than adults (Chove et al, 2006). Nickel and chromium are essential elements at low concentration and a toxic element when intake is at concentration higher than 12 mg and 10 mg respectively per day for adults (Othman, 2001).

Table 2 Mineral content of vegetables (mg /kg dry weight basis)

Samples	Mg	Ca	Fe	Zn	Cu	Ni	Pb	Cr
C. pepo	233 ± 0.04^b	24 ± 0.01^h	13 ± 0.03^f	0.6 ± 0.05^d	0.37 ± 0.002^c	0.43 ± 0.06^e	0.05 ± 0.001^d	0.08 ± 0.004^b
S. biafrae	65 ± 0.01^d	637 ± 0.1^c	15 ± 0.03^e	1.7 ± 0.2^c	0.88 ± 0.003^b	0.7 ± 0.01^d	0.23 ± 0.001^b	0.007 ± 0.001^e
A. cruentus	189 ± 0.1^a	649 ± 0.7^b	57 ± 0.1^b	3.1 ± 0.3^b	1.1 ± 0.14^b	2.3 ± 0.07^b	0.27 ± 0.04^b	0.09 ± 0.005^b
B. alba	34 ± 0.03^h	71 ± 0.04^g	2.1 ± 0.0^h	0.13 ± 0.04^e	0.03 ± 0.002^d	0.2 ± 0.01^e	0.01 ± 0.002^d	0.01 ± 0.001^d
S. macrocarpon	38 ± 0.08^g	810 ± 0.2^a	6.2 ± 0.1^g	1.5 ± 0.01^c	1.96 ±0.006^a	2.2 ± 0.01^b	0.17 ± 0.001^c	0.09 ± 0.002^b
S. scabrum	54 ± 0.01^e	268 ± 0.9^e	44 ± 0.31^c	1.9 ± 0.03^c	0.95 ± 0.004^b	2.6 ± 0.01^a	0.25 ± 0.006^b	0.03 ± 0.0007^c
V. amygdalina	44 ± 0.01^f	263 ± 0.2^f	30 ± 0.01^d	3.3 ± 0.02^b	1.79 ±0.005^a	2.8 ± 0.04^a	0.29 ± 0.005^b	0.1 ± 0.0004^b
S. nigrium	142 ± 0.01^c	430 ± 0.1^d	100 ± 0.7^a	4.6 ± 0.04^a	2.07 ±0.007^a	1.3 ± 0.06^c	0.69 ± 0.01^a	0.8 ± 0.0007^a

Mean ± SD = Mean and standard deviation of triplicate analysis
Values in the same column with different superscript are significantly different at P < 0.05

Amino acids and protein quality

The quality of proteins in foods were evaluated according to its content of essential amino acids in comparison to the reference amino acid (egg) (used in calculating amino acid scores) and the amino acid pattern requirements for children (FAO/WHO, 1991). From Table 3, the content of essential amino acids such as lysine, leucine isoleucine ranged from 4.00 to 6.15 g, 6.31 - 9.61 and 3.11- 5.71g / 100 g protein respectively. Lysine was the limiting amino acid in *C. pepo* and *A. cruentus* while sulphur amino acid is the limiting amino acid in other samples.

Lysine plays an important role in protein synthesis while sulphur containing amino acids serve as precursors of essential molecules that are involved in the methylation process and in the development and maintenance of brain and nerves

The total aromatic and sulphur amino acids ranged from 6.81 to 9.69 g and 1.96 to 3.11 g, repectively. The range of total amino acids (ΣTAA) (64.6 to103 g) and that of the essential amino acid (ΣTEAA) (34.4 to 49.6%) compared favourably with the recommended value of total amino acid (90.9 g) and essential amino acid (36%) of quality protein source (FAO/WHO. 1991).

Of all vegetables under investigation, *S. macrocarpon* could be regarded as vegetable with highest protein quality because it recorded highest value for almost all essential amino acids whereas *C. pepo* could be regarded as the poorest in terms of amino acids quality. However, all the vegetable samples studied could adequately meet the recommended requirements for essential amino acid in school children aged 2-5 y.

The results showed that glutamic acid and aspartic acid were the most abundant non – essential amino acids. The glutamic acid is easily hydrolyzed to its negative anionic form, glutamate which joins forces with sodium salt to form monosodium glutamate (MSG), this compound could contribute to improvement of the flavor and taste of vegetable soup.

Vol. 20 No. 2: 52-64 [2021]
doi: 10.14416/j.appsci.2021.02.006

Tryptophan was not analyzed due to its fast destruction in the acidic medium to which the samples were subjected before analysis.

Table 3 Amino acid profile and amino acid scores (in parenthesis) of some underutilized vegetables (g/100g Protein)

Sample	***C. pepo***	***S. Biafrae***	***A. cruentus***	***B. alba***	***S. nigrium***	***V. amygdalin***	***S. scabrum***	***S. macrocarpo***	***FAO/WHO RDA****
Lys	4.00 (0.68)	4.99 (0.86)	4.35(0.75)	4.99 (0.86)	5.4 (0.93)	6.5 (1.12)	6.01(1.03)	6.34 (1.09)	5.80
Leu	6.31 (0.95)	8.10 (1.33)	7.93 (1.20)	6.93 (1.05)	6.97(1.05)	7.06 (1.06)	7.33 (1.11)	9.61 (1.45)	6.60
Ileu	3.51 (1.25)	3.11(1.11)	3.89 (1.38)	4.02 (1.43)	4.17 (1.48)	3.65 (1.30)	4.64(1.65)	5.71 (2.03)	2.80
Tyr[1]	3.38 (1.16)	3.06 (1.25)	2.58 (1.09)	3.22 (1.09)	1.77 (1.07)	2.09 (1.04)	2.74 (1.18)	3.22 (1.53)	6.30
Phe[1]	3.97	4.82	4.23	4.81	4.82	5.35	5.58	6.42	
Cyst[2]	0.66 (0.78)	1.13 (0.85)	0.79 (0.86)	0.93 (0.80)	1.32 (0.82)	1.19 (0.94)	1.39 (0.93)	1.39 (1.24)	2.50
Met[2]	1.30	0.99	1.25	1.09	0.73	1.17	0.94	1.72	
Thr	3.36 (0.98)	3.27 (0.96)	3.41 (1.00)	3.11 (0.99)	3.55 (1.04)	4.02 (1.18)	3.83(1.12)	4.72 (1.38)	3.40
Val	3.98 (1.37)	4.21 (1.20)	5.26 (1.5)	4.36 (1.24)	5.55 (1.58)	6.10 (1.74)	5.17 (1.47)	6.54 (1.86)	3.50
His	1.63	2.01	2.41	1.91	2.10	2.88	2.44	2.60	1.90
					Non- Essential Amino Acids				
Arg	4.34	5.02	4.59	4.85	4.17	6.89	5.19	6.04	8.00
Asp	6.58	9.01	8.97	9.01	11.53	11.34	10.97	11.44	5.30
Glu	8.05	11.55	10.06	9.68	10.73	13.26	11.32	14.60	5.60
Pro	2.34	3.08	2.97	3.19	4.35	4.04	3.93	5.10	9.43
Gly	3.74	4.01	5.20	4.16	4.60	5.62	4.96	5.91	7.12
Ala	3.97	5.64	4.94	4.02	5.25	6.10	5.37	6.64	3.11
Ser	3.51	3.67	2.97	3.35	3.29	3.62	4.02	5.56	9.90
ΣTAA	**64.6**	**77.7**	**75.8**	**73.6**	**80.3**	**90.9**	**85.8**	**103**	**90.9**
ΣEAA (%)	**32.1 (49.6)**	**33.7 (43.3)**	**26.1 (34.4)**	**35.4 (48)**	**36.4 (45)**	**40.1 (44)**	**40.1 (46.7)**	**48.3 (46.8)**	**32.8 (36)**
ΣArAA	**7.35**	**7.88**	**6.81**	**8.03**	**6.59**	**7.44**	**8.32**	**9.64**	**9.64**
ΣSAA	**1.96**	**2.12**	**2.04**	**2.02**	**2.05**	**2.36**	**2.33**	**3.11**	**5.0**

*ref amino acid (FAO/WHO, 1991) – requirement for preschool children 2-5 y 1 amino acid score of tyr and phe 2 amino acid score of met and cys ΣTAA- sum of total amino acid: ΣTEAA- sum of total essential amino acid: ΣArAA- sum of aromatic amino acid: ΣSAA- sulphur amino acid

doi: 10.14416/j.appsci.2021.02.006

Antinutrients and antioxidants

Tannin, an antinutritional compound which have been reported to decrease protein digestibility and palatability (Jacobek 2015) ranged from 1.0 in *A. cruentus* to 33.4 mg/g catechin. Tannins especially the hydrolysable tannins are water soluble and could be leached out of the plant tissue during blanching and processing of vegetable therefore, the value reported in this study could not pose any health risk for the consumers. However, consumption of vegetables with moderate concentration of tannin is good for human health due to its antioxidant activity (Oduse *et al*, 2012).

Phytate ranged from 1.56 in *A. cruentus* to 9.5 in *S. nigrium*. The problem with phytate in food is that it can bind some essential mineral and nutrients in the digestive tract which could result in mineral deficiency diseases (Bello *et al*, 2008). Phytate forms complexes with proteins thus negatively affecting protein digestibility, solubility and functionality (Ajala, 2009). A diet containing between 10 and 60 mg/g phytate, if consumed over a long period of time that has been reported to decrease bioavailability of minerals in monogastric animals (Elinge *et al*, 2012). However, the phytate content of these samples may not pose any health hazard to the consumers because it is far below lethal level.

Table 4 Anti-nutrient and Antioxidant content in sampled vegetables (dry weight basis)

Vegetables	**Tannin** (mg/g Catechin)	**Phytate** (mg / 100 g)	**Phenolic** (mg/g GAE)	**Antioxidant** activity (% DPPH)
Curcibita pepo	33.4 ± 1.6^{a}	9.27± 0.3^{a}	0.63 ± 0.01^{bc}	81.9 ± 0.9^{c}
Solanecio biafrae	23.5 ± 0.3^{b}	6.49 ± 0.4^{c}	0.77 ± 0.02^{a}	69.5 ± 1.1^{e}
Amaranthus cruentus	1.0 ± 0.1^{g}	1.56 ± 0.2^{f}	0.71 ± 0.03^{b}	90.3 ± 1.5^{a}
Bassella alba	10.4 ± 0.4^{c}	2.49 ± 0.3^{e}	0.77 ± 0.01^{a}	87.3 ± 3.0^{b}
Solanum macrocarpon	3.2 ± 0.4^{e}	7.54 ± 0.2^{b}	0.60 ± 0.06^{cd}	75.1 ± 1.6^{d}
Solanum scabrum	7.5 ± 0.1^{d}	5.10 ± 0.2^{d}	0.78 ± 0.01^{a}	73.3 ± 0.8^{de}
Vernonia amygdalina	5.9 ± 0.4^{d}	7.8 ± 0.1^{b}	0.80 ± 0,04^{a}	80.9 ± 2.4^{c}
Solanum nigrium	1.7 ± 0.1^{f}	9.5± 0.02^{a}	0.53 ± 0.01^{d}	73.0 ± 3.05^{dc}

Mean ± SD Mean and standard deviation of triplicate analysis
Values in the column with the same superscript are not significantly different $P < 0.05$

The phenolic content of plants contributes directly to their antioxidant action (Mohamed *et al,* 2011). The phenolic antioxidant activity depends on the structure of the molecules, and the number and position of the hydroxyl group in the molecules (Michalak, 2006). The total phenol (Table 4) ranged from 0.53 to 0.80 mg/g GAE, the highest value was reported for *V. amygdalina.* The values of the phenolic content obtained compared with the report of Ajayi et al., 2020. The percentage DPPH radical scavenging activity ranged from 69.5 to 90.3 %. DPPH assay measures the ability of analyte to scavenge free radical, thus *A. cruentus* which recorded high percentage would be the vegetable with the best antioxidant activity, this observation was corroborated by the report of Ajayi et al., (2020) that *A. hybridus* (a specie of Amaranthus) recorded best antioxidant activity.

 doi: 10.14416/j.appsci.2021.02.006

Studies have shown that consumption of polyphenol - rich vegetables is associated with low incidence of non – communicable diseases such as cardiovascular disorder, diabetes and cancer, thus, consumption of vegetable is important not only for nutrients but also for their nutraceutical properties.

It can be deduced from the findings of this study that A.cruentus recorded a better content of proteins, mineral, antioxidant activity compared to other vegetable which could be the reason for its wide consumption among folks in Nigeria.

Conclusion

The findings of this study indicated that underutilized Nigerian vegetables contain high level of fibre, mineral and protein with balanced essential amino acids. The antinutritional compounds were very low while heavy metals were at micro level. The samples contain high content of phenolic compound with excellent radical scavenging activity. Reintroduction of these vegetables into Nigerian menu could help ameliorate mineral deficiency diseases, protein-energy malnutrition and radical induced non-communicable diseases.

Acknowledgement(s) (if necessary)s

Researchers appreciate the Nigerian–Canada underutilized Vegetable Initiatives (NICANVEG), and the Management of Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, for the supply of vegetable samples used in this study.

References

Adebayo, O. R., Farombi A. G., & Oyekanmi A. (2013). Proximate, mineral and anti-nutrient evaluation of pumpkin pulp (*Cucurbita Pepo*). *Journal of Applied Chemistry, 4*, 25-28.

Agbaire, P. O., & Emoyan, O. O. (2012). Nutritional and Anti-nutritional levels of Some Local Vegetables from Delta State. *Nigeria African Journal of Food Science, 6*, 8-11.

Ajala, L., (2009). The effect of boiling on the nutrients and antinutrients in two non conventional vegetables. *Pakistan Journal of Nutrition*, *8*, 430-1433.

Ajayi, I. O., Otemuyiwa., I. O., Adeyanju, A. A., & Falade, O. S. (2021). Vegetable polyphenols inhibit starch digestibility and phenolic availability from composite diets in-vitro*. Journal of Agricultural Food Research, 3*, 100116. https://doi.org/10.1016/jafr2021.100116

Aletor, O., Oshodi, A. A., & Ipinmoroti, K. (2002). Chemical composition of common leafy vegetables and functional properties of their leaf protein concentrates. *Food Chemistry, 78*, 63-68.

AOAC. (2000). *Official mehods of analysis of the association of official analytical chemists* (17^{th} ed.). Washington: Association of Official Analytical Chemists.

Arowosegbe, S. (2013). Preliminary domestication and cultivation efforts on some medicinally importance wild vegetables in ado-Ekiti. *Bio-Science Research Bulletin*, *29*(2), 101–107.

Bello, M. O., Falade, O. S., Adewusi, S. R. A. & Olawore, N. O. (2008). Studies of Some Lesser-Known Nigerian Fruits. *African Journal of Biotechnology*, *7*, 3972-3979.

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of free radical method to evaluate antioxidant activity. *Journal of Food Science Technology*, *28*, 25-30.

Chacha, J. S., & Laswai, H. S. (2020). Micronutrients potential of underutilized vegetables and their role in fighting hidden hunger. *International Journal of Food Science*. https:\\doi.org/10.1155/2020/9408315

Chove, B. E., Ballegu, W. R., & Chove, L. M. (2006). Copper and Lead levels in two popular leafy vegetables grown around Morogoro Municipality. *Tanzania Health Research Bulletin*, *8*(1), 37-40.

Consultation, J. F. W. E. (1991). Protein quality evaluation. *Food and Agriculture Organization of the United Nations: Rome, Italy*.

Ejoh, A. R., Tchouanguep, M. F., & Fokou, E. (1996). Nutrient composition of the leaves and flowers of Colocasia esculenta and the fruits of Solanum melongena. *Plant Food for Human Nutrition*, *49*, 107-112.

Elinge, C. M., Muhammad, A., Atiku, F. A., Itodo, A. U., Peni, I. J., Sanni, O. M., & Mbongo, A. N. (2012). Proximate, mineral and anti-nutrient composition of pumpkin (Cucurbitapepo) seeds extract. *International Journal of Plant Research, 2*(5), 146-150.

FAO/WHO Expert Committee for Additives and Contaminants (JECFA). (1995). Codex Alimentarius Commission.

Fayeme, P. O. (1999). *Nigerian Vegetables in Ibadan*. Nigeria, Longman Educational Books.

Food and Agriculture Organization of the United Nations. (2001). Food and Agriculture Organization of the United Nations, *Food balance sheets: a handbook*. FAO.

Frank, S. M., Webster, J., McKenzie, B., Geldsetzer, P., Manne-Goehler, J., Andall-Brereton, G., Dismand, H., Mongal, S. G., Brice, W. B., Roy, W. M., Adil, S., Zhaxybay, Z., Andrew, S., Demetre, L., Abla, M. S., Bolormaa, N., Krishna, K. A., Khem, B. K., Gibson, B. K., Mary, T. M., Joao, S. M., Rifat, A., Till, B., Sebastian, V., & Jaacks, L. M. (2019). Consumption of fruits and vegetables among individuals 15 years and older in 28 low- and middle-income countries. *The Journal of nutrition*, *149*(7), 1252-1259. https://doi. org/10.1093/jn/nxz040

Harland, B. F., Oberleas, D., & Collaborators: Ellis R Gelroth J Gordon D Phillips K Ranhotra G Shah BG Stoecker B Trick KD Zymonas J. (1986). Anion-exchange method for determination of phytate in foods: collaborative study. *Journal of the Association of Official Analytical Chemists*, *69*(4), 667-670.

Islam, M. R., Paul, D. K., & Shaha, R. K. (2004). Nutritional Importance of Some Leafy Vegetables in Bangladesh. *Pakistan Journal of Biological Science*, *7*, 1380-1384.

Kris-Etherton, P. M., William, S. H., & Lawrence, J. A. (2002). Fish Consumption, Fish Oil, Omega-3 Fatty Acids, and cardiovascular disease. *Circulation, 106*(21), 2747–2757. https://doi.org/10.1161/01.CIR.0000038493.65177.94

Kwenin, W. K. J., Wolli, M., & Dzomeku, B. M. (2011). Assessing the nutritional value of some African indigenous green Leafy Vegetables in Ghana. *Journal of Animal and Plant Sciences*, *10*, 1300- 1305.

Michalak, P. J. (2006). Phenolic compounds and their antioxidant activity in plants growing under heavy metal stress. *American Journal of Plant Sciences*, *15*, 523-530.

Mohamed, I. S., Abdelhady, A. A., & Ludger, B. (2011). Total phenolic content and antioxidant activity of standardized extracts from leaves and cell cultures of three callistemon species. *American Journal of Plant Sciences*, *2*, 847-850.

National Research Council. (1989). *Committee on Diet and Health. Diet and health: implications for reducing chronic diseases risk*. Washington (DC): National Academies Press, US.

Nkafamiya, I. I., Osemeahon, S. A., Modibbo, U. U., & Aminu, A. (2010). Nutritional status of non-conventional leafy vegetables, Ficus asperifolia and Ficus sycomorus*. African Journal of Food Science, 4*(3), 104-108.

Odhav, B., Beekrumb, S., Akulaa, U., & Baijnath H. (2007). Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal. *Journal of Food Composition and Analysis, 20*, 430-435.

Oduse, K. A., Idowu, M. A., & Adegbite, A. A. (2012). Chemical and phytochemical profile of some uncommon green leafy vegetables consumed in south west. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *1*, 22-26.

Olaiya, C., & Adebisi, J. (2009). Phytoevaluation of the nutritional values of ten leafy vegetables in south-western Nigeria. *The Internet Journal of Nutrition and Wellness*, *9*, 2-4.

Olajire, A. A., & Azeez, L. (2011). Total antioxidant activity, phenolic, flavonoid and ascorbic acid contents of nigerian vegetables. *African Journal of Food Science and Technology, 2*, 22-29.

Othman, O. C. (2001). Heavy metals in green vegetables and soils from vegetable gardens in Dar Es Salaam. *Tanzania Journal of Science*, *27*, 38-48.

Otitoju, G. T. O., Ene-Obong, H. N., & Otitoju, O. (2014). Macro and micro nutrient composition of some indigenous green leafy vegetables in south-east zone nigeria. *J Food Process Technol*, *5*(389), 2.

Oulai, P., Lessoy, Z., Megnanou, R., Doue, R., & Sébastien, N. S. (2014). Proximate composition and nutritive value of leafy vegetables consumed in northern côte d'ivoire, *European Scientific Journal*, *10*(6), 212-227.

Pearson, D. (1976). *Chemical analysis of foods* (7th ed.). Churchill, Livingstone, London.

Price, M. L., Van Scoyoc, S., & Butler, L. G. (1978). A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. *Journal of agricultural and food chemistry*, *26*(5), 1214-1218.

Umerah, N. N., Asouzu, A. I., & Okoye, J. I. (2019). Nutraceutical and Health Benefits of Two Underutilized Leafy Vegetables (Pterocarpus santalinoides and Napoleona imperialis). *European Journal of Nutrition & Food Safety*, *11*(3), 143-155.

USDA. (2014). *National Nutrient Database for Standard Refrences Release 20*. https://www.healthaliciousness.com

Velioglu, Y. S., Mazza, G., Gao, L., & Oomah, B. D. (1988). Antioxidant activity and total phenolics in selected fruits, vegetables and grain products. *Journal of Agriculture and Food Chemistry*, *46*(10), 4113-4117.

Whitney, E., DeBruyne, L. K., Pinna, K., & Rolfes, S. R. (2010). *Nutrition for health and health care*. Cengage Learning.

World Health Organization. (1998). *International Obesity Task Force: Obesity preventing and managing the global epidemic*. Geneva: WHO.