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NUTRITIONAL AND ANTI-NUTRITIONAL PROFILE OF SPINY AMARANTH (*AMARANTHUS VIRIDIS* LINN)

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ABSTRACT

Proximate composition, Amino acids profile, mineral content and antinutritional factors of tender leaves of *Amaranthus viridis* were evaluated using standard methods of analyses. The leaves had the following proximate compositions on dry weight (DW) basis: ash (21.05%), crude protein (35.11 ± 0.33%), crude lipid (5.26 ± 0.30%), crude fibre (14.04 ± 0.35%), available carbohydrate (24.54 ± 0.71%) and calorific value (530.34 ± 0.01 kcal/100g). The amino acids profile indicates that the leaves are good source of essential amino acids for adults. The leaves are rich in K, Mg, Fe, Mn and Cu when compared to their respective RDA values. Tannins (7,530.21 ± 5.21 mg/100gDW) and phytate (1,326.92 ± 16.57 mg/100gDW) were the plant's predominant antinutrients while total oxalate (202.50 ± 6.50 mg/100gDW) and soluble oxalate (97.50 ± 3.75 mg/100gDW) were in appreciable concentration. The amounts of hydrogen cyanide (13.07 ± 2.38 mg/100gDW) and nitrate (25.35 ± 2.74 mg/100gDW) were below the critical values. The results are an indication that the *Amaranthus viridis* leaves had the potential to be used as source of nutrients in alleviating macro- and micro- nutrient deficiencies.
KEYWORDS: Leafy Vegetables, *Amaranthus viridis*, Nutrients, Amino acids and Antinutrient.

INTRODUCTION

Malnutrition affects millions of people all over the world especially in developing nations. Under-nutrition for the poor people and over-nutrition for the rich segment of the population are two parallel forms of malnutrition affecting the nations (Weingärtner, 2004). Over-nutrition is associated with nutritional transition which is due to urbanisation as such the city dwellers consume mostly refined and junk food ignoring the traditional unrefined food such as fruits and vegetables (Vainio-Maltila, 2000; Weinberger and Swai, 2006; Ganry, 2008). This transition leads to increased risk of non-communicable diseases such as diabetes, hypertension, obesity, cancer and cardiovascular diseases. World Health Organisation (WHO) projected that the percentage of people living with diabetes in developing countries may increase to more than two-folds from 115 million in 2000 to 284 million (about 250% increment) in 2030 (Weingärtner, 2004).

On the other hand, under-nutrition is the major public health problem affecting the developing countries (Müller and Krawinkel, 2005). According to Nnamani *et al.* (2009), the World Health Organization (WHO) estimated that 200 million people in Sub-Sahara Africa are affected with chronic undernutrition. Professor Onimawo, President, Nutrition Society of Nigeria, added that malnutrition is responsible for over 60% of maternal and infant mortality in Nigeria and 41% of children less than five years are chronically malnourished (Daily Trust, 30th March 2010). The Newspaper further reported that Nigeria is the leading country in Africa and 3rd in the world with chronically undernourished children (over 10 million).

Africa has abundant biota and other natural resources as out of 150 food-plants commonly consumed by humans, 115 are indigenous African species (Adebooye and Opabode, 2004). Never the less, it was estimated that 840 million people on the globe do not receive enough energy from their diets to meet their needs; out of which 799 live in developing countries (Kennedy *et al*. (2003). This could be due to non investigation of the biota that could remedy the situation.

Spiny amaranth (*Amaranthus viridis* Linn) also called *Rukubu* in Hausa Language belongs to the family of Amaranthaceae (Plate 1) is an erect (about 60 cm tall) annual or perennial herbs widely found throughout African continent. The leaves are oval (7 cm by 5 cm), which is broad near base, obtuse, acuminate petiole long and reddish. The plant leaves are relish by populate both during the period of food abundance and shortage.

The aim of this study is report the nutritional and antinutritional profile of spiny amaranth (*Amaranthus viridis*) growing wild in the semi arid zone of Nigeria, with the hope that it would be found worthy of tackling the problem of under-nutrition in the society.

Plate 1: Spiny Amaranth (*Amaranthus viridis* Linn)

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MATERIALS AND METHODS

Sample Collection and Treatment

Tender leaves of *Amaranthus viridis* were randomly sampled from different locations along River Zamfara at Jega, Kebbi State. Prior to analyses, the samples were identified and authenticated at the Herbarium of the Botany Unit, Usmanu Danfodiyo University, Sokoto, Nigeria. The leaves were separated from the stalk, washed with distilled water, put in separate large paper envelopes and oven dried at 60 ^{o}C to constant weight (Fasakin, 2004). The dried leaves were pulverised in a porcelain mortar, sieved through 20-mesh sieve and stored in plastic containers. The powdered samples were used for the analyses.

Proximate Analysis

The recommended methods of the Association of Official Analytical Chemists (AOAC, 1990) were used for the determination of moisture, ash, crude lipid, crude fibre and crude protein contents. Available carbohydrate was estimated by difference while the calorific value of the sample was determined with high-pressure oxygen bomb calorimeter as described by Dara (2006).

Amino Acids Analysis

The sample's amino acids profile was determined using ion-exchange chromatography techniques with a Technicon Sequential Multisample Amino Acid Analyser (TSM; Technicon Instruments Corporation, Dublin, Ireland) by the method of Adeyeye and Afolabi (2004).

Minerals Analysis

The dried sample (1g) was digested with 24cm^3 of a mixture of concentration HNO_3 (18 cm^3), conc. H_2SO_4 (4 cm^3) and 60% $HClO_4$ (2 cm^3) (Sahrawat *et al.*, 2002). The content was cooled, filtered into a 50 cm^3 volumetric flask and charged with 4cm^3 of 5% $LaCl_3.7H_2O$ and diluted to the volume with distilled water (Guil and Isasa, 1997; Wachasunder and Nafade, 2001). Blank was prepared in similar manner without samples being added. Ca, Mg Co, Cr, Cu, Fe, Mn, Ni and Zn were analysed by atomic absorption spectrometry, Na and K by atomic emission spectrometry and P colorimetrically by the vanadate-molybdate blue method (James, 1995).

Calculations:

$$\text{Element concentration}\left(\text{mg / 00g dry matter}\right)=\frac{\text{X x V}}{\text{W x 10}}$$

Where **X** is the concentration of the element in the sample extract as determined (ppm), **V** is the volume of extract (cm^3) and **W** is the weight (g) of dry sample.

Determination of Ascorbic Acid (Vitamin C)

Vitamin C (ascorbic acid) was determined by titration with 2,6-dichloro-phenolindophenol dye (DCP) as described by James (1995).

Analysis of Antinutritional Factors

Determination of phytate, total and soluble oxalate, hydrocyanic acid, tannins and nitrate were quantify according to the methods describe by Hassan *et al.* (2011).

RESULTS AND DISCUSSION

Proximate analysis.

The results of proximate composition of *A. viridis* leaves are shown in Table 1. The leaves had high moisture content (87.67 ± 1.45 % wet weight) within the range (58.0 to 93.4%) reported for some leafy vegetables consumed in Nigeria (Ifon and Bassir 1980; Ladan *et* al., 1986; Tomori and Obijole, 2000).

The ash content, which is an index of mineral contents, is high (21.05 ± 0.30 %DW). The value was higher than the values reported for other edible leaves such as, *Veronia colorate* (15.86% DW) and *Moringa oleifera* (15.09% DW) reported by Lockett *et al.* (2000), *Solanum americanum* (17.40 %DW) and for *Momordica balsamina* leaves (18.00 % DW) (Hassan and Umar, 2006).

The crude protein content (35.11 ± 0.33%) was also higher than values reported for some lesser known wild leafy vegetables such as *Momordica balsamina* (11.29%), *M. oleifera* (20.72%), *Lesianthera africana* (13.10 – 14.90%), *S. americanum* (11.33%) and *Leptadenia hastata* (19.10%) (Isong and Idiong, 1997; Sena *et al.,* 1998; Lockett *et al*., 2000; Hassan and Umar, 2006). The protein recommended dietary allowance (RDA) for adult is 0.80 g of good quality protein/kg body weight/day (FND, 2002). This is an indication that 70 kg human needs 56 g of protein daily, thus, 100g DW leaves can satisfy about 62.7% of protein recommended daily allowance.

The crude lipid content (5.26 ± 0.30%) of the leaves was below the range (8.3 – 27.0% DW) reported for some vegetables consumed in Nigeria and Republic of Niger (Ifon and Bassir 1980; Sena *et al.,* 1998). Low lipid content is the factor considered for recommending leafy vegetables in controlling overweight. The estimated carbohydrate content (24.54 ± 0.71%) in *A. viridis* leaves was higher than 20% for *Senna obtusfolia* leaves (Faruq *et al.*, 2002) but similar to that of *Amaranthus incurvatus* leaves (23.7%) (Asibey-Berko and Tayie, 1999). On the other hand, *A. viridis* leaves have lower amount of carbohydrate than *M. balsamina* (39.05 %) (Hassan and Umar, 2006).

The crude fibre content in *A. viridis* leaves (14.04 ± 0.35%) was within the reported values (8.50 – 20.90%) for some Nigerian vegetables (Ifon and Bassir, 1980). One of the drawbacks of using vegetables in human nutrition is their high fibre content, which may cause intestinal irritation and a decrease of nutrient bioavailability (Aletor and Adeogun, 1995; Plessi *et al.*, 1999; Vadivel and Janardhanan, 2000). Apart from negative effect, intake of fibre can stimulate weakening hunger and peristaltic movement, increase excretion of bile acids, lower the serum cholesterol level, risk of coronary heart disease, hypertension, diabetes, colon and breast cancer (Gorecka *et al.,* 2000; Ishida *et al*., 2000; Ramula and Rao, 2003). This ability is due to reduction in the rate of absorption of glucose and fat by fibre (Ekop *et al.,* 2004). The fibre RDA values for children, adults, pregnant and breast-feeding mothers are 19 –25%, 21 – 38%, 28% and 29% respectively. The calorific value of *A. viridis* leaves was high indicating that it could be an important source of dietary calorie. The value is within the range of 84 – 2500 kJ/100g reported for plant foods (Saka and Msonthi, 1994).

Amino acids profile

The amino acid content of *A. viridis* leaves is presented in Table 2. Twenty standard amino acids are commonly found as components of proteins. In this study, only seventeen amino acids were detected possibly due to conversion of the amide glutamine and asparagine to their corresponding amino acids (Salo–Vaananen and Koivistoinen, 1996) and complete destruction of tryptophan during acid hydrolysis (Wathelet, 1999). Among the essential amino acids, leucine and aromatic (phenylalanine and tyrosine) were predominant.

To evaluate the nutritional quality of *A. viridis* leaves, the percentages of the essential amino acids in the samples were tabulated against those of reference standard amino acid profile established for both adults and preschool children by WHO/FAO/UNU (1985) in Table 3. The result indicates that all essential amino acids except lysine and sulphur containing amino acids exceeded the reference value for preschool children while none of the amino acids is limiting for adults.

Minerals and Vitamin C Compositions

Table 4 shows the minerals profile of *A. viridis*. Potassium was the most abundant element (2,391.67 mg/100g DW) in the sample; within the range (750 – 4,953.49 mg/100g DW) reported for *Ipomoea batatas* leaves (Tayie and Asibey-Berko, 2001; Ishida *et al.,* 2000; Monamodi *et al.,* 2003). The value was low compared to *Celosia argentea* (5,200 mg/100g), *Solanum aethiopicum* (5,000 mg/100g) and *Talinum triangulare* (8,000 mg/100g) (Smith, 1983). The high amount of potassium may be due to its abundance in Nigerian soil (Oshodi *et al.,* 1999).

Sodium content (26.67 mg/100g) was low which suggested the possibility of incorporating it into diets of obese patients (Ifon and Bassir, 1979). Sodium concentration in the sample was low compared to potassium content, which agreed with results reported for leafy vegetables (Hassan *et al.,* 2005a,b; 2006; Hassan and Umar, 2008).

Calcium and phosphorus are associated with each other for the development and proper functioning of bones, teeth and muscles (Dosunmu, 1997; Turan *et al.,* 2003). The sample's calcium (110.67 ±15.51 mg/100g DW) and phosphorus (17.20 ± 1.22 mg/100g DW) contents are lower than their respective values of 1533.00 and 257.74 reported in *Amaranthus muricatus* leaves and stems by Escudero *et al.* (1999). The *A. viridis* Ca/P ratio (6.43:1) was higher than the value (1:1) suggested in the Recommended Dietary Allowances for a good intestinal absorption of calcium (Guil and Isasa, 1997; Escudero *et al.,* 1999). Therefore, phosphorus rich food material should be used together with the leafy vegetable.

Magnesium is an important mineral element in connection with circulatory diseases such as ischemic heart disease and calcium metabolism in bone (Ishida *et al.,* 2000). In this study, the leafy vegetable had significant amount of magnesium (403.13 mg/100g). Studies carried out on some leafy vegetables of southern Burkina Faso and Niger Republic (Smith *et al*., 1996) show high amount of magnesium in leaves of *Boerhavia diffusa* (389.5 mg/100g), *Solanum aethiopium* (317.8 mg/100g) and *Adansonia digitata* (274.2 mg/100g). High magnesium concentration is expected since Mg is a component of leaves chlorophyll. The value is within the range reported in some green vegetables (Ladan *et al.,* 1996).

Iron is an essential trace element for haemoglobin formation, normal functioning of the central nervous system and in the oxidation of carbohydrates, proteins and fats (Adeyeye and Otokiti, 1999). From the results, *A. viridis* had iron content of 419.00 mg/100DW. Ladan *et al.* (1996) also reported high iron content (110 – 325 mg/100g) in some green leafy vegetables consumed in Sokoto.

Copper is an essential trace element in human body and exist as an integral part of copper proteins ceruloplasmin, which is concerned with the release of iron from the cells into the plasma and is involved in energy metabolism (McDonald *et al*., 1995; Adeyeye, 2002). The Cu content of the sample is 2.87 mg/100g DW comparable to the values reported in some tropical leafy vegetables such as bitter leaf (2.32 mg/100g) (Ibrahim *et al.,* 2001), 1 – 2.5mg/100g in some leafy vegetables found in Cross Rivers State, Nigeria (Ifon and Bassir, 1979), 1.2-1.8mg/100g in Yola, Nigeria (Barminas *et al*., 1998) and in some wild leafy vegetables of Republic of Niger (Sena *et al.,* 1998). High amount of copper was also reported in some leafy vegetables. For instance Wallace *et al.* (1998) reported that lettuce (*Launaea taxaracifloria*), have copper content within the range of 3 – 10mg/100g, *Xanthasomes mafaffa* have 5.43 mg/100g) and *Ipomoea involucrate* (5.83 mg/100g). Much higher value was also reported in *Eraphorbia hirta* leaves (14.7mg/100g) (Wallace *et al*., 1998).

Manganese is another microelement essential for human nutrition; it acts as activator of many enzymes (McDonald et al., 1995). *A. viridis* has Mn content of 19.53 mg/100g lower than 15-115mg/100g reported in some leafy vegetables of Cross Rivers State, Nigeria (Ifon and Bassir, 1979), but within the range (0.98 – 38.0mg/100g) reported in some wild leafy vegetables of Republic of Niger (Sena *et al.*, 1998). Aletor *et al*. (2002) reported appreciable amount of manganese (mg/100g) in leaves of *V. amygdalina* (14.4), *Solanum africana* (19.4), *A. hybridus* (41.5) and *Telfaria occidentalis* (26.2). The manganese content is also higher than that of some cultivated green leafy vegetables such as spinach (0.5mg/100g), lettuce (0.3mg/100g) and 0.2mg/100g in cabbage (Turan *et al.,* 2003).

Zinc is involved in normal function of immune system. The *A. viridis* leaves zinc content is 1.30 mg/100gDW, comparable with most values reported for green leafy vegetables in literatures (Ifon and Bassir, 1979; Ibrahim *et al.,* 2001). Low zinc content was in agreement with previous findings which reported that generally vegetables do not have a high concentration of zinc (Gutiérrez *et al*., 2008).

Chromium in trivalent state is an essential trace element that potentiates insulin action and thus influences carbohydrate, lipid and protein metabolism (Duran *et* al., 2008). The concentration of chromium in *A. Viridis* is 1.53 ± 0.57 mg/100gDW, which is high compared to 0.25 – 1.5 mg/100gDW reported in some wild vegetables of Japan (Itoh *et al*., 2007). The recommended dietary intake of chromium was 0.05 – 0.2 mg/kg/day. The result indicated that the leaves could be regarded as good supplement of this element. However, excessive intake of this element has an adverse effect on human health.

Cobalt is a unique indispensable microelement mineral in human nutrition because it is not an ionic form of the element that is dietary essential rather vitamin B_{12} (House, 1999). The concentration of cobalt in the sample is 0.33 mg/100g. The value was high when compared to 0.037 – 0.048 mg/100g reported in three wild leafy vegetables of Republic of Niger (Glew *et al*., 2005). Even though the RDA value of this element was not set, the maximum level of daily intake without detriment to health was 0.3 mg.

Vitamin C (Ascorbic Acid)

Table 4 shows the ascorbic acid content of the leafy vegetable (21.41 ± 1.32mg/ 100g DW). Achinewhu *et al.* (1995) reported that on fresh weight basis, the ascorbic acid content of common Nigerian leafy vegetables ranged from 18.0 – 98.8 mg/100g, indicating the leaves have ascorbic content within this range. The result of this analysis is a pointer that the leafy vegetable could be an important dietary source of ascorbic acid. However, since ascorbic acid is a water-soluble vitamin, much of it could be lost during excessive washing or during processing especially cooking, thus extra measures should be taken during processing to avoid loss of this vital micronutrient. Considering the positive effect of Vitamin C on mineral bioavailability, other sources of this vitamin such as "*Sobo*" should be taken together with diet prepared from the leafy vegetable. For better iron absorption, vitamin C to iron molar ratio should be between 2:1 and 4:1 (Lynch and Stoltzfus, 2003). Thus, *A. viridis* leaves have low ratio indicating that for proper utilisation of the leaves iron, other promoters such as meat or other vitamin C sources are imperative.

Nutritional significance of food material is usually compared with RDA values as this will entail its nutrient richness. As shown in Table 4, the analysed *A. viridis* leaves could be a good mineral supplement particularly potassium, magnesium and microelements. However, the plant is deficient in phosphorus and zinc. The finding was in agreement with the report of Afolayan and Jimoh (2009) in which the contribution of the vegetables to the RDAs for Zn and P was < 15%. Thus, food based on this leafy vegetable ought to be supplement with these elements preferably other vegetables rich in these elements such as *Moringa oliefera*.

Antinutritive Content of A. viridis leaves

Table 5 presents the result of antinutritive factors in the analysed leafy vegetable. The phytate content of *A. viridis* is 1,326.92 ± 16.57 mg/100gDW which is high compared to 1,214 mg/100g reported for *Tribulus terrestris* leaves (Hassan *et al*., 2007). High amount of phytate was also reported in some leafy vegetables such as *Tralinum triangulare* (2341.1 mg/100g), *V. amygdalina* (1466.7 mg/100g) and *Basella alba* (2030.8 mg/100g) (Akindahunsi and Oboh, 1999; Oboh *et al.*, 2005). The phytate content in the leaves was within the range of 0.1 – 6% reported in food items (Mohammed *et al*., 2002).

Generally, variation in phytate content between vegetables could be attributed to differences in variety, climatic conditions and soil types (Bhandari and Kawabata, 2004). High phytate content in the sample leaves indicate that the consumption of these leaves could decrease the bioavailability of minerals, especially Ca, Mg, Fe, and Zn (Agte *et al.,* 1999; Oatway *et al.,* 2001; Anyum *et al.,* 2002; Bhandari and Kawabata, 2004). Phytic acid intakes of 4 – 9 mg/100g DM was reported to decrease Fe absorption by 4 – 5 fold in human (Hurrel *et al.*, 1992). Protein and starch solubility digestion and absorption was also reported to be affected by phytate. Nevertheless, phytate was known to be an anti-carcinogen that protects against colon cancer and it is known to be a potent antioxidant that inhibits Fenton reactions leading to lipid peroxidation and inhibition of polyphenol oxidase (Agte *et al.,* 1999).

The analysed leafy vegetable has total oxalate content of 202.50 ± 6.50 mg/100g, which is low compared to 0.6% - 15.1% reported in some edible

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leafy vegetables (Badifu, 2001). Presence of oxalates in food causes irritation in the mouth and interfere with absorption of divalent minerals particularly calcium by forming insoluble salts with them (Hassan and Umar, 2004). Consumption of oxalates may also result in kidney disease (Hassan *et al.,* 2007). However, the level of oxalate in these leaves is not a major concern for normal healthy person as toxic level for humans was set as 2 – 5 g (Hassan and Umar, 2004).

Tannins content in the *A. viridis* leaves reported in this study was high (> 7.5%). Tannins are complex water-soluble phenolic compounds; and apart from their astringency which invests them with certain dietary attraction, their main nutritional significance derives from their ability to complex with and precipitate proteins. Tannins are also known to inhibit the activities of such enzymes as trypsin, chymotrypsin, amylase and lipase and to interfere with iron absorption and growth (Essien *et al.,* 1993; Umaru *et al*., 2007).

The hydrocyanic acid (HCN) content in the sample is 13.07 ± 2.38 mg/100g DW. Badifu (2001) reported HCN content in some raw leaves such as *Celosia argentea* (20 mg/100g) *Tralinum triangulare* (75 mg/100g) and *Celosia laxa* (30 mg/100g). Consumption of high levels of cyanide is associated with a serious health problem, spastic paraparetis known as *Konzo.* In Nigeria, a neurological disease known as Tropical Ataxic Neuropathy (TAN) was also linked to consumption of high level of cyanide in cassava–based diet (Hassan and Umar, 2004). The HCN level in the studied leafy vegetable is within the permissible range for human consumption. Only plants with more than 200 mg of HCN equivalent per 100 mg fresh weight are considered dangerous (Betancur-Ancona *et al*., 2008). This shows that leaves are safe for consumption as far as HCN is concerned.

The concentration of nitrate in the sample is 25.35 ± 2.74 mg/100g, below the acceptable daily intake (ADI) of 3.7mg/kg body weight equivalent to 220mg for 60kg person (Hassan and Umar, 2004). Furthermore, boiling was reported to reduce nitrate to the level of about 60 – 70% as observed in vegetables. Fytianos and Zarogiannis (1999) reported that spinach contains high nitrate concentrations (1000 – 3000 ppm) while as high as 6000 ppm has been reported in lettuce. Cabbage contains nitrate at concentrations ranging from several hundreds to over 1000 ppm. Studies have indicated that nitrates generally cause methaemoglobinaemia in young infants, but not in adults. However when reduced to nitric oxide it plays an important role in the body as it provides host defence against numerous micro-organisms (Benjamin, 2000).

Bioavailability Prediction of Ca, Zn and Fe

To predict the bioavailability of some divalent elements especially Ca, Fe and Zn, antinutrients to nutrients ratios were calculated and presented in Table 6. The estimation of the phytate-to-mineral molar ratio is a valuable tool in predicting the inhibitory effect of phytate on the bioavailability of minerals. The [Ca][phytate]/[Zn] ratio in *A. viridis* (0.28) was above the 0.5mol/kg critical level, thus indicating significant effect of phytate on zinc bioavailability (Umar, 2005). In the case of zinc, [phytate]/[Zn] ratio above 1.5:1 may inhibit Zn availability (Frontela *et al.*, 2008). Based on this ratio, *A. viridis* have [phytate]/[Zn] ratio above the critical ratio indicating poor zinc bioavailability. Furthermore, [Ca][Phytate]/[Zn] was found to be a better measure of zinc bioavailability than [phytate]/[Zn] ratio. Like [phytate]/[Zn] ratio, *A. viridis* have higher ratio compared to the critical ratio.

The [Phytate]/[Fe] in *A. viridis* leaves is 0.27 below the critical value of < 0.4, above which impaired iron bioavailability (Mitchikpe *et al*., 2008). For calcium, [Phytate]/[Ca] ratios in *A. viridis* (0.73) is above the critical level of 0.24:1 (Frontela *et al.*, 2008) signifying poor calcium bioavailability due to phytate.

From the result, it was observed that [oxalate]/[Ca] ratio in *A. viridis* (2.39) and [oxalate]/[(Ca+Mg)] ratio (0.06) in the sample are below the critical level of 2.5 known to impair calcium bioavailability (Umar, 2005).

CONCLUSIONS

The results presented herein indicated that the *A. viridis* leaves analysed have a great potential as sources of food particularly considering their protein and amino acid profile, thus can be used in narrowing the amino acid and other nutrients supply deficits that are prevalent in many developing countries. Furthermore, considering the ash content, this signals the potential of the leafy vegetable as a source of important minerals needed by the body. The minerals analysis of the sampled plants indicated that it is rich in most mineral elements with high predicted bioavailability for calcium and iron, but that of zinc is low. However, since the analysed vegetables are consumed when cooked which reduces the level of antinutritive factors, it is expected to further enhance the bioavailability of the minerals elements.

Table 1: Proximate Composition of *Amaranthus viridis* Leaves

Parameter	Concentration (% DW)*
Moisture Content‡	87.67 ± 1.45
Ash	21.05 ± 0.30
Crude Protein	35.11 ± 0.33
Crude Lipid	5.26 ± 0.30
Crude Fibre	14.04 ± 0.35
Available Carbohydrate	24.54 ± 0.71
Calorific Value (kcal/100g)*	530.34 ± 0.01

The data are mean value ± standard error of three replicates.
‡Value expressed as % wet weight
DW = Dry weight

Table 2: Amino acids Composition of *Amaranthus viridis Leaves*

Amino acid	**Concentration (g//100 Protein)**
Lysine (Lys)*	3.65 ± 0.09
Histidine (His)	2.00 ± 0.05
Arginine (Arg)	4.37 ± 0.11
Aspartic acid (Asp)	8.78 ± 0.23
Threonine (Thr)*	4.22 ± 0.11
Serine (Ser)	1.95 ± 0.05
Glutamic acid (Glu)	9.02 ± 0.23
Proline (Pro)	2.31 ± 0.06
Glycine (Gly)	3.34 ± 0.09
Alanine (Ala)	4.12 ± 0.11
Cysteine (Cys)	0.92 ± 0.04
Valine (Val)*	3.99 ± 0.10
Methionine (Met)*	0.95 ± 0.02
Isoleucine (Ile)*	4.13 ± 0.11
Leucine(Leu)*	7.81 ± 0.20
Tyrosine (Tyr)	3.39 ± 0.09
Phenylalanine (Phe)*	3.89 ± 0.10

** Essential Amino Acid*
The data are mean value ± standard error of two replicates.

Table 3: Amino acid score for *Amaranthus viridis* Leaves

Amino acid	Amount (g/100g protein)	*WHO Ideal Protein		Amino acid Score**	
		Children	Adult	Children	Adult
Lys	3.65	5.8	1.6	63	228
Thr	4.22	3.4	0.9	124	469
Met + Cys	1.87	2.5	1.7	75	110
Val	3.99	3.5	1.3	114	307
Ile	4.13	2.8	1.3	148	318
Leu	7.81	6.6	1.9	118	411
Phe + Tyr	7.28	6.3	1.9	116	383
His	2.00	1.9	1.6	105	125

*WHO/FAO/UNU, 1985. `** Amino acid score= [(% Amino Acid)/ Ideal] x 100

Table 4: Minerals and Vitamin C (Ascorbic Acid) Contents of *Amaranthus viridis Leaves*

Mineral	Available quantity (mg/100g DW)
K	2,391.67 ± 79.49
Na	26.67 ± 8.69
Ca	110.67 ±15.51
Mg	403.13 ± 34.27
P	17.20 ± 1.22
Fe	419.00 ±68.81
Mn	19.53 ± 2.31
Cu	2.87± 1.23
Zn	1.30 ± 0.70
Ni	ND
Cr	1.53 ± 0.57
Co	0.33 ± 0.09
Vitamin C*	21.41 ± 1.32 (173.64)
Vitamin C/Fe‡	0.03

The data are mean value ± standard error of three replicates.
**Values are mean value ± standard error of four replicates reported on fresh weight basis. Values in parenthesis are the corresponding dry weight equivalent. DW = dry weight. ‡Molar ratio*

Table 5: Anti-nutritive Content of *Amaranthus viridis Leaves*.

Anti-nutritive Factor	Concentration (mg/100 g Dry weight)*
Phytate	1,326.92 ± 16.57
Total Oxalate	202.50 ± 6.50
Soluble Oxalate	97.50 ± 3.75
Tannin	7,530.21 ± 5.21
Cyanide	13.07 ± 2.38
Nitrate	25.35 ± 2.74

** The data are mean value ± standard error of three replicates.*
Values within a row with different superscript are significantly ($p < 0.05$) different.

Table 6: Antinutrients to Nutrients Molar Ratios of *Amaranthus viridis Leaves*.

Parameter	Ratio	Critical Value
[Oxalate]/[Ca]	2.39	2.5*
[Oxalate]/[Ca + Mg]	0.06	2.5*
[Ca][Phytate]/[Zn]	0.28	0.5mol/kg*
[Phytate]/[Zn]	100.52	1.5**
[Phytate]/[Fe]	0.27	0.4‡
[Phytate]/[Ca]	0.73	0.24**

Sorce: *Umar, 2005; **Frontela *et al*., 2008; ‡Mitchikpe *et al.,* 2008

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