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NUTRITIONAL EVALUATION OF FIVE AFRICAN INDIGENOUS VEGETABLES

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ABSTRACT

The promotion and consumption of indigenous vegetables could help mitigate food insecurity and alleviate malnutrition in developing countries. In this respect, 17 accessions (candidate breeding lines that have not yet officially been released) of five African indigenous vegetables: amaranth (*Amaranthus cruentus*), nightshade (*Solanum scabrum*), African eggplant (*Solanum aethiopicum*), jute mallow (*Corchorus olitorius*) and okra (*Abelmoschus callei*), previously selected for their superior agronomic and horticultural traits, were evaluated in Cameroon for minerals (Ca, Mg, K, P, Zn and Fe), proteins, and carotenoids content. Nutrient content differed significantly ($P<0.001$) between cultivars. Amaranth (especially line AM-NKgn) had the highest Ca, Mg, and Zn content in comparison to other genera. Nightshade had the highest K and Fe content. The highest K and Fe levels were found in nightshades BG24 and SS52, respectively. Nightshade had the highest level of protein, especially line BFS1. The highest amount of carotenoids was identified in the eggplant variety Oforiwa. The study revealed that these vegetables are important sources of some vital nutrients. Increased production and consumption of these nutrient-rich vegetables will help reduce the nutrition-related disorders in Africa.

Key words: African indigenous vegetables, variety evaluation, nutrient-rich vegetables, food and nutritional security

INTRODUCTION

Traditional vegetables are valuable sources of nutrients (Nesamvuni *et al*. 2001; Yang and Keding 2009), with some having important medicinal properties (Hilou *et al*. 2006). Vegetables contribute substantially to food security (Yiridoe and Anchirinah 2005). Overcoming food and nutritional insecurity among women, pregnant and lactating mothers, and children under five years of age, remains a challenge in many developing countries in sub-Saharan Africa (Andersen *et al*. 2003). In these countries, people's diets rely heavily on rice, potato and cassava, which are high in calories but deficient in essential micronutrients. Chronic undernutrition affects about 215 million people in sub-Saharan Africa, representing 43% of the population (FAO 1996). Deficiencies in iron, vitamin A and iodine are widespread, affecting about 300 million people every year, with many more at risk of experiencing these deficiencies (FAO 1997). These conditions are not acceptable, yet they are projected to become worse in the future. Indeed, the International Food Policy Research Institute predicted an 18% rise in the number of malnourished children in 2001-2020 (IFPRI 2001). It is

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anticipated that Africa will lose at least a cumulative US $ 4 billion to chronic diseases by 2015 (Abegunde *et al*. 2007).

In Cameroon, the prevalence of vitamin A deficiency and anemia in children below five years of age is high (39% and 68%, respectively), indicating poor health care and malnutrition (WHO 2008a; WHO 2009a). About 50% of the anemia in Cameroon is attributable to iron deficiency (Stolzfus 2003) while about 30% of the children below the age of five suffer from chronic malnutrition, 36% are stunted, 16% are underweight, and 7% are wasted (UNICEF 2009). About 45% of those aged 15 and above are overweight or obese (WHO 2009b). Annually, Cameroon loses more than US $ 187 million in gross domestic product (GDP) to vitamin and mineral deficiencies (UNICEF 2004; World Bank 2009). To alleviate this condition, efforts should be made to genetically improve and produce the underexploited and lesser-known indigenous vegetables as sources of nutrients (Hussain *et al*. 2011).

Indigenous vegetables have long been part of traditional diets in communities worldwide, yet many of these crops are underutilized and their nutritional value is unknown (Keatinge 2012). Their utilization could improve the cassava and maize based diet and thus reduce the chronic nutrient deficiencies, although their adverse effects are reported among the populations. Despite official statistics indicating a low consumption level of vegetables in Subsaharan Africa, it appears that traditional vegetables are usually consumed with the stable food in various forms. The bioavailability of their nutrient and minerals content has been little investigated. There is a need to optimize the nutrient content and other properties of traditional vegetables in the daily food of the population. Indeed, little effort has been made to assess the nutritional value of traditional African vegetables and the products from these vegetables are under-utilized in Africa. Improving the nutritional quality of indigenous vegetables should be a priority of crop research (Gockowski *et al*. 2003). Nutrient analysis allows for identification of nutritional characteristics of food. Evaluating the nutritional importance of indigenous vegetables can lead to a better understanding of the value of these plants (Pandey *et al*. 2006). For this purpose, we assessed the nutritional value and mineral content of 17 indigenous vegetable candidates for cultivars that were chosen through participatory variety selection for their superior agronomic and horticultural characteristics (AVRDC 2009; 2010; 2011a; 2011b). All have been proposed for registration in Cameroon's Official Catalogue of Species and Varieties. Some of them have been released in Tanzania (Ojiewo *et al*. 2010). The objective of this study is to provide information on the nutritional characteristics of selected "folong" or amaranth (*Amaranthus cruentus*), "bitetam" or okra (*Abelmoschus caillei*), ”tegue“ or jute mallow (*Corchorus olitorius*), ”zom“ or nightshade (*Solanum scabrum*) and ”zong“ or eggplant (*Solanum aethiopicum*) to increase the uptake/promotion of indigenous vegetables.

MATERIALS AND METHODS

Plant materials

Seventeen breeding lines of five indigenous vegetables were evaluated, including two amaranths (AM-NKgn and AC-NL originated from Cameroon), four jute mallows (Aziga and Bafia originated from Cameroon, IP2 and UG originated from Tanzania), six nightshades (BFS1 and SS52 originated from Cameroon; BG14, BG24 and TZSMN55-3 originated from Tanzania; MW25 from Kenya), one okra (PI496946 originated from Benin) and four African eggplants (AB2, DB3 and Oforiwa originated from Ghana; N13 originated from Tanzania). The plant parts used for the analysis were leaves for the leafy vegetables (amaranth, nightshade and jute mallow) and fruits for the fruiting vegetables (okra and eggplant).

Sample preparation

The selected indigenous vegetables were grown in 2010 at AVRDC's experimental farm at Nkolbisson (altitude: 755 m above sea level, 3°51'N 11°27'E), Yaoundé Cameroon in the dry (December-March) and rainy (July-October) seasons. Samples of each vegetable type were collected at maturity and brought to the laboratory. The samples were washed under running water and oven-dried at 60 °C. The dried material obtained was ground to a fine powder and stored in polythene bags. Two powdered samples per genotype were used in all the analyses.

Nutritional composition

Total nitrogen (N) was determined from a wet acid digest (Buondonno *et al*. 1995) of 300 mg of sample by colorimetric analysis (Anderson and Ingram 1993). Crude protein was calculated by multiplying the total N value by a factor of 6.25 and expressed in % (Dieter and Whitaker 1984). Eggplant total carotenoids content was determined using the Harvest Plus screening method (Delia *et al.* 2004). 5-7 g of fresh eggplant was weighed and extracted with cold acetone using a mortar and pestle. The resulting extract was filtered and partitioned to petroleum ether. The resulting upper phase was collected through anhydrous sodium sulfate to remove residual water. The absorbance was read at 450 nm and the total carotenoids content was calculated. Total chlorophylls ($\mu g \cdot 100\ g^{-1}$ fresh weight) and carotenoids ($\mu g \cdot 100\ g^{-1}$ fresh weight) content in leaf samples were determined by macerating the sample in 80% acetone, centrifuging and reading the absorbance of the supernatant at the indicated wavelengths (Lichttenthaler 1987).

Determination of mineral content

The mineral content (Ca, Mg, K, P, Zn and Fe) was estimated by dry ashing 500 mg of sample in a muffle furnace. The ash was dissolved in an acid mix of HCl/HNO_3 and analyzed using the atomic absorption spectrophotometer (Jones and Case 1990). Ca, Mg, K and P were expressed in % of Dry Weight and Zn and Fe in $\mu g \cdot g^{-1}$ Dry Weight.

Data analysis

Data consisting of nutrient content of selected cultivars was submitted to the analysis of variance using the Statistical Analysis System (SAS Institute 2006). Data analyses were performed following the one-way linear statistical model:

$Y_i = \mu + \beta_i + \varepsilon_i$,

where Y_i is the average value of the dependent variable for the i^{th} cultivar; μ is the overall mean; β_j and ε_i correspond, respectively to, cultivars and the accepted random error. All measurements were performed in n = 2 replicates. Means were compared using the Least Significant Difference (LSD) at P=0.05.

RESULTS

Highly significant differences were found between accessions, while season had no effect on the nutrient composition of the selected cultivars for the measured parameters.

Nutrient composition of the studied cultivars

Macronutrient and crude protein content

The macronutrient and crude protein contents of the selected cultivars are given in Tab. 1. Highly significant ($P<0.0001$) differences were observed for all the variables between the cultivars, except for P ($P<0.05$). Amaranth AM-NKgn recorded the highest Ca and Mg content, while nightshades BG24 and TZSMN55-3 had the highest levels of K. Nightshade BFS1 contained the highest level of total N (6.11 ± 0.636%; data not shown) and crude protein.

Micronutrient, total chlorophyll, and total carotenoid content

The mean contents of micronutrients, total chlorophylls and total carotenoids in the selected cultivars are presented in Tab. 2. Highly significant ($P<0.0001$) differences characterized micronutrient contents between the cultivars. Amaranth AM-NKgn was found to contain the highest level of Zn while nightshade SS52 contained the highest level of Fe. Highest total carotenoid was found in eggplant Oforiwa.

DISCUSSION

This study was initiated to investigate the nutrient contents of selected indigenous vegetables. Results from this study showed highly significant differences in the nutrient content of the selected vegetables. Leafy vegetables had higher content of minerals than fruit vegetables. These findings are important considering the prevalence of mineral deficiency problems in sub-Saharan Africa. Thus, selection of indigenous vegetables varieties should go beyond yield, diseases resistance and horticultural traits to include nutrient content. Promoting

Table 1. Macronutrients and crude protein content in selected indigenous vegetable accessions

Crop	Accession (country of origin)	Macronutrients and protein content (%)				
		Ca	Mg	K	P	Protein
African eggplant (*Solanum aethiopicum*)	AB2 (G)*	0.17±0.0	0.19±0.0	2.15±0.01	0.26±0.00	10.16±0.29
	DB3 (G)	0.18±0.0	0.2±0.0	1.84±0.04	0.23±0.00	9.4±0.44
	N13 (T)	0.15±0.0	0.19±0.0	1.62±0.00	0.28±0.00	9.5±0.06
	OFORIWA (G)	0.16±0.0	0.21±0.0	2.19±0.00	0.29±0.00	10.7±0.16
Amaranth (*Amaranthus cruentus*)	AC-NL (C)	1.77±0.1	1.17±0.1	4.89±0.88	0.53±0.11	23.02±3.27
	AM-NKgn (C)	2.69±0.4	1.53±0.1	5.36±0.14	0.42±0.01	26.78±1.81
Jute mallow (*Corchorus olitorius*)	Aziga (C)	1.15±0.1	0.29±0.0	3.28±0.17	0.51±0.06	21.91±0.239
	Bafia (C)	1.33±0.07	0.35±0.0	3.08±0.20	0.51±0.05	23.35±0.540
	IP2 (T)	1.27±0.01	0.48±0.01	3.42±0.28	0.46±0.04	31.15±2.783
	UG (T)	1.33±0.03	0.41±0.00	3.47±0.18	0.49±0.02	24.82±0.663
Nightshade (*Solanum scabrum*)	BFS1 (C)	1.46±0.01	0.50±0.02	5.48±0.32	0.54±0.07	38.18±3.975
	BG14 (T)	1.31±0.06	0.55±0.00	4.38±0.29	0.47±0.06	34.45±3.236
	BG24 (T)	1.20±0172	0.49±0.04	5.89±0.41	0.46±0.05	33.02±4.891
	MW25 (K)	1.49±0.05	0.50±0.03	5.77±0.62	0.40±0.00	34.5±4.209
	SS52 (C)	1.28±0.11	0.49±0.03	5.41±0.23	0.43±0.03	34.06±2.76
	TZSMN55-3 (T)	1.28±0.08	0.48±0.04	5.86±0.29	0.47±0.05	36.81±3.946
Okra (*Abelmoschus callei*)	PI496946 (B)	1.01	0.54±0.03	2.73±0.00	0.46±0.00	20.48±2.76
LSD $_{0.05}$		0.47	0.2	1.2	0.17	9.37

*C – Cameroon, T – Tanzania, G – Ghana, K – Kenya, B – Benin

Table 2. Micronutrients, total chlorophylls and total carotenoids content in selected indigenous vegetable cultivars

Crop	Accession (country of origin)	Fe (µg·g^{-1} DW)	Zn (µg·g^{-1}DW)	Chlorophyll (µg·100 g^{-1} FW)	Carotenoids (µg·100g^{-1} FW)
African eggplant (*Solanum aethiopicum*)	AB2 (G)*	39.74±0.0	10.64±0.004	2.71±0.0	537.12±0.0
	DB3 (G)	33.44±0.099	7.63±0.005	1.95±0.0	299.39±0.0
	N13 (T)	39.42±0.561	7.88±0.001	2.25±0.0	286.25±0.0
	Oforiwa (G)	38.61±0.049	9.09±0.038	2.22±0.0	624.54±0.0
Amaranth (*Amaranthus cruentus*)	AC-NL (C)	205.71±21.07	57.93±17.07	284.88±7.2	104.16±4.18
	AM-NKgn (C)	200.58±15.3	102.57±2.589	225.38±7.4	77.49±5.01
Jute mallow (*Corchorus olitorius*)	Aziga (C)	177.28±58.78	21.54±3.029	349±84	140.93±52.3
	Bafia (C)	151.56±2.06	25.74±5	369.25±52.5	151.49±30.2
	IP2 (T)	195.062±46.75	37.045±3.77	61.1±0.0	131.3±20.09
	UG (T)	220.09±42	28.92±1.52	425.95±212.1	174.56±43.7
Nightshade (*Solanum scabrum*)	BFS1 (C)	182.05±9.65	39.70±4.55	312.81±8.1	119.41±4.81
	BG14 (T)	248.91±15.66	39.21±1.41	227.25±33.6	85.3±20.64
	BG24 (T)	266.52±55.36	39.37±0.13	258.83±6.6	91±2.71
	MW25 (K)	147.37±1.69	41.82±1.56	292.29±0.7	100.81±2.89
	SS52 (C)	387.93±13.61	38.33±0.96	238.78±36.2	82.28±13.39
	TZSMN55-3 (T)	184.45±2.64	38.90±3.07	273.74±3	91.67±1.33
Okra (*Abelmoschus callei*)	PI496946 (B)	42.25±42	38.66±1.52	17.88±0.0	9.07±0.0
LSD $_{0.05}$		95.00	17.2	103.7	112.7

*C – Cameroon, T – Tanzania, G – Ghana, K – Kenya, B - Benin the consumption of indigenous vegetables is an important priority for *in situ* conservation (Gockowski *et al*. 2003).

Results from this study indicate that amaranth AM-NKgn (selected in Cameroon) contains the highest levels of Ca, Mg and Zn. In fact, the level of Zn in amaranth AM-NKgn is nearly two times greater than the Zn level of amaranth AC-NL, and almost three to four times greater than the Zn levels of jute mallow, nightshade and okra cultivars. Odhav et al. (2007) found similar concentrations of Ca (2.36%) and Mg (1.31%) in *Amaranthus hybridus*, a species close to *A. cruentus*. While the Ca level in nightshade cultivars in this study was similar to the finding of Odhav *et al*. (2007) in *S. nigrum*, the Mg content was almost twice higher; 0.48 to 0.55% as compared to 0.277 and 0.247%, respectively (Odhav *et al.* 2007; Akubugwo *et al*. 2007a). Zn content of 40.8 $\mu g \cdot g^{-1}$ was reported in amaranths collected in various markets in Dar es Salaam, whereas 40.2 ± 1.5 $\mu g \cdot g^{-1}$ of Zn were found in *A. hybridus* sampled from different regions in South Africa (Raja *et al*. 1997; Van der Walt *et al*. 2009), which are comparable to the Zn content in AC-NL and considerably lower than Zn content in AM-NKgn. Despite the high Zn content in AM-NKgn, which makes it a good source of Zn, this value is lower than the Zn level found by Odhav *et al*. (2007) and Aletor *et al*. (2002) – 180 $\mu g \cdot g^{-1}$ and 251 $\mu g \cdot g^{-1}$ in *A. hybridus* in South Africa and Nigeria, respectively). People with HIV have the highest levels of zinc deficiency (Baum *et al*. 2003). Although the rate of new HIV infection has decreased, the total number of people living with HIV continues to rise (UNAIDS 2010), and sub-Saharan Africa still bears an inordinate share of the global HIV burden. Promoting production and consumption of amaranth high in Zn will help to alleviate health problems associated with Zn deficiency.

Results from this study demonstrate that nightshade, especially SS52, has the highest level of iron compared with jute mallow UG and amaranth AC-NL. The levels of iron found in amaranth and African eggplant are similar to these reported by Weinberger and Msuya (2004) of 229.5 $\mu g \cdot g^{-1}$ in amaranth and 24.5 $\mu g \cdot g^{-1}$ in African eggplant from Singida district in Tanzania. Odhav *et al*. (2007) also reported a high level of Fe in *S. nigrum* (up to 850 $\mu g \cdot g^{-1}$) and *A. hybridus* (210 $\mu g \cdot g^{-1}$). The Fe content found in nightshade in this study is higher than 130 $\mu g \cdot g^{-1}$ reported by Akubugwo *et al*. (2007a) and 145.5 $\mu g \cdot g^{-1}$ reported by Weinberger and Msuya (2004). The Fe content of jute mallow is comparable to 228 $\mu g \cdot g^{-1}$ reported in *C. olitorius* leaves (Ndlovu and Afolayan 2008). Hence, the high value of iron in these vegetables makes them a potential source of iron for vulnerable groups such as children under five and pregnant and lactating women. There is a high prevalence of anemia in pregnant women (48.2% and 57% in Southeast Asia and Africa, respectively, compared with 25.1% in Europe) (WHO 2008b). Iron deficiency anemia is responsible for 20% of neonatal mortality and 10% of maternal mortality, or about 800 000 deaths, representing 2.4% of annual global deaths from disease (Black *et al*. 2003). The consumption of nightshade can thus help reduce the mortality due to anemia among pregnant women and children in developing countries.

Levels of crude protein found in the three leafy vegetables in this study are within the range of 20.48 - 41.66% reported by Ponka *et al*. (2005), with nightshade containing the highest amount. The level of crude protein in all jute mallow, nightshade and amaranth cultivars is far higher than 16.2 ± 3.3% reported by Ndlovu and Afolayan (2008) in *C. olitorius*, 24.9 ± 0.02% reported in *S. nigrum* by Akubugwo *et al*. (2007a) and 17.92% reported in *A. hybridus* by Akubugwo *et al*. (2007b). These leafy vegetables can play a significant role in providing cheap and affordable protein for rural communities. Pregnant and lactating mothers require 71 g of protein daily (FND 2005). Assuming complete protein absorption, 100 g DWB of nightshade, amaranth and jute mallow leaves would respectively contribute for about 49.5, 35.0 and 35.0% of the daily protein requirement of these pregnant and lactating mothers.

This study revealed that African eggplant contained the highest level of total carotenoids, at least two times greater than any other vegetable evaluated. The level of total carotenoids in eggplant from this study is far higher than the 4.8 μg·100 g^{-1} reported by El-Qudah (2008) in *S. melongena*. However, the level of total carotenoids in jute mallow is comparable to the 126 μg·100 g^{-1} reported by El-Qudah (2008). In Africa, about 30% of all preschool children are affected by vitamin A deficiency and in some countries this figure can reach more than 60% (Standing Committee on Nutrition 2004). The introduction of carotenoid-rich African eggplant in the diet of children in Africa could help alleviate vitamin A deficiency.

The vegetable production in sub-Saharan Africa is underdeveloped and has not improved much over the past 40 years; vegetable consumption in the region remains extremely low. There have been numerous health projects in sub-Saharan Africa and elsewhere in the developing world to address micronutrient deficiency from a medical perspective (Mason *et al*. 2004). These programs involve the prescription and distribution of vitamin and mineral supplements, which usually have to be imported (Hillocks 2011). An alternative or complementary approach is to promote the inclusion of high quality food crops in the farming system to enrich the diet with essential vitamins and minerals (Bouis 2000; Underwood 2000). Agricultural solutions to the problem of micronutrient deficiencies have the additional advantage of fostering community self-reliance; they are sustainable in the absence of external funding and offer the opportunity for enhanced income by marketing surplus production (Hillocks 2011). A dietary approach, rather than the medicinal (supplementing pills) approach, is the most economical and sustainable way to correct micronutrient deficiencies (Ali and Tsou 2000). The indigenous vegetables targeted in this study are well known in sub-Saharan Africa, and the adoption, widespread cultivation, and consumption of these nutrient-rich crops will help tackle malnutrition problems.

CONCLUSION

The present study revealed that the selected African indigenous vegetables are a good source of nutrients (Ca, Mg, K, P, N, Zn, Fe, protein and carotenoids). These crops can be consumed together with starchy staples as part of a balanced diet, and help to alleviate some nutrient deficiencies. Investigating the bioavailability of the nutrient and minerals content of traditional vegetables together with the optimization of their properties and nutritional values in the daily food of the population will lead to higher demand, wider cultivation, and increased supply. The projection of Sub Saharan Africa as regards life expectancy and food security, are quite depressing and challenging. Obtaining information and promoting knowledge about high functional value of selected nutrient-rich indigenous vegetables could potentially address some challenges. Increasing the production of indigenous vegetables and informing people how to prepare vegetables to gain maximum nutritional value will help ensure low-cost nutrients reach vulnerable populations and enhance food and nutritional security.

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