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Nutritional diversity of leafy amaranth species grown in Kenya

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ABSTRACT
Objectives: Despite the availability of many species of amaranth in Kenya, there is inadequate information on their nutritional diversity and how they can be best used in mitigation of malnutrition. Hence, this study was aimed at investigating the nutritional diversity of five leafy amaranth species grown in Kenya.
Methodology and results: Amaranth vegetables were harvested 5-6 weeks after planting. They were analyzed for their nutritional and phytochemical content using standard methods. Moisture content was lowest in *A.cruentus* (79.29±1.26%). *A.cruentus* had the highest protein (4.37 ±0.02%).The fat content of *A.hybridus* (2.53±0.06%) and *A.hypochodriacus* (2.63±0.11%) was significantly higher than the other species. The crude fibre content (3.01±0.29%) was similar in all the species. *A.dubius* had the highest calcium (336.47±0.9mg/100g) and iron (18.64±0.23mg/100g) while *A.cruentus* was highest in zinc content (1.67±0.03mg/100g).The total phenols content was highest in *A.cruentus* (3.59±0.01GAE/100mg).Catechins were highest in *A.cruentus* (7.15±0.63CE/100mg) while quercetin was highest in *A.cruentus* (14.28±0.86QE/100mg).
Conclusion and application of results: More than 50% of the Kenyan population live below the poverty line and lack access to adequate food. The food available food is of poor nutritional value, this causes malnutrition and other nutritional disorders. There is therefore a need to identify nutrient-rich foods that can be produced inexpensively to meet the nutrient requirements of everyone and especially the vulnerable groups, such as pregnant women, children and the elderly. Amaranth is drought tolerant, grows fast and is easily cultivated. This study indicates that the Amaranth species found in Kenya are a good source of key nutrients, which can be used in mitigation of malnutrition. *A.dubius* is a superior source of calcium and iron and can help curb the micronutrient deficiencies in Kenya, while *A.cruentus* is a superior source of protein and phytochemicals which are important in reducing the risk of chronic diseases which are so rampant in Kenya today.
Key words: *A. dubius, A. hybridus* and *A. cruentus, A. albus* and *A. hypochondriacus. Nutrients.*

INTRODUCTION

Amaranth is the collective name for the genus *Amaranthus* (family *Amaranthaceae*). It is one of the oldest food crops in the world with evidence of cultivation dating back to over 6000 years in Puebla, Mexico (Itúrbide and Gispert, 1994). The genus *Amaranthus* has received considerable attention in many countries because of the high nutritional value of some species that are important sources of food, as either vegetable or grain (Srivastava, 2011). The grain and vegetable types can be differentiated but often both the grain and leaves are utilized (Saunders and Becker, 1984; Tucker, 1986). *Amaranthus* species can produce a crop of edible leaves within two weeks for up to six months (National research council of Washington 1984). Among the species commonly found in Kenya are, *A. dubius* and *Amaranthus hybridus,* which is grown as vegetables while *Amaranthus Cruentus* is grown as grain and *A. hypochondriacus* is dual purpose.(Figure 1 a,b,c,and d)

Figure 1 (a) *A.cruentus*

(b) *A.hypochondriacus*

(c) A.albus

d) A.dubius

Amaranth is highly nutritious, cheap to produce and easily adapts to the environment in which it grows (Wambugu, and Muthamia, 2009). It is drought tolerant and has the earliest maturity period in the cereal class ranging between 45 days to 75 days (Jacob 2005). Therefore, increased production of this crop has the potential to contribute to improved food and nutritional security among vulnerable communities. In Kenyan rural areas, amaranth is largely grown by women, thus providing them with a degree of financial independence and better nutrition (IPGRI, 2003). The volumes of production and trade in vegetable amaranth have increased over the last few years in response to the growing urban vegetable demand (Onyango and Imungi, 2007). Today, vegetable amaranth is found in many supermarkets and green groceries in the urban centres. More than 90% of the supply to these outlets is from farms that are within the environs of the urban centres (Onyango *et al*, 2008). There are many cultivars of leafy amaranth in cultivation in Kenya but it is not known which of these has the highest nutritional value. As such it is of interest to map out the nutritional diversity of the different species of amaranth found in Kenya as a criterion for deciding its production, consumption and marketing.

MATERIALS AND METHODS

Research design: An experimental plot of about ¼ acre was acquired at the Jomo Kenyatta University Agriculture and Technology research farm for planting the vegetables. The seeds of the five amaranth species were planted in blocks of 3 m by 3m and spacing of 30cm by 10cm between vegetables. No artificial fertilizers were used but farm yard manure was applied at planting. Irrigation was undertaken every 3 days using overhead sprinklers while weeding was carried out weekly. Leaves of each of the vegetables were harvested between 5-6 weeks after planting. They were then cleaned by removing all adhering dirt, fibrous leaves and damaged parts.

Proximate composition: Moisture was determined according to AOAC methods specification 950 46, method 925.10-32.10.03 (AOAC, 1995). Results were reported on the wet weight basis. Protein was determined using the semi-micro kjeldahl method, specification 950.46, method 20.87-37.1.22 (AOAC, 1995). Fat Determination was done using the soxhlet method 920.85-32.1.13, (AOAC, 1995). Crude fibre was determined according to method 920.86.32.1.15 (AOAC, 1995). Ash content was determined by incinerating in a muffle furnace (AOAC, 1995) method 923.03-32.1.05. The atomic absorption spectrophotometer (AAS) method was applied to determine iron calcium and zinc content (AOAC, 1995).

Determination of phytochemicals

Solvent extraction: Initial ethanol extraction was applied for the fresh vegetables. Fifty grams of the fresh leaves were put in a flask was covered with 500ml methanol and allowed to stand for 48 - 72 h. It was then filtered through Whatman filter paper No. 1 and distilled using rotary evaporator (Bibby Sterilin Ltd, RE 100B, UK) at 60°C until ethanol- free liquid was obtained. The resulting extracts were then subsequently labelled as ethanol extracts and preserved at 5°C in airtight bottles until further use (Alanis *et al*., 2005).

Total phenolic assay: Total phenolic content in the vegetables was estimated spectrophotometrically using Folin Ciocalteu reagent, as described by Spanos and Wrolstad (1990) with slight modification, using Gallic acid as a standard. One millilitre of ethanolic extract was transferred into a test tube and mixed with 5ml of distilled water. To each sample 0.5ml of 0.2N (v/v) Folin-Ciocalteu reagent was added and mixed. After 5min, 1.5ml of 5% Na_2CO_3 was added to the reaction mixture and allowed to stand for 60 min. The absorbance was read at 765nm. The absorbance values were converted to total phenolic and were expressed in milligrams equivalents of Gallic acid per grams of the sample. Standard curves were established using various concentrations of Gallic acid in 95% ethanol.

Catechin and Quercetin Assay: The calorimetric aluminium chloride method was used. One (1) ml of ethanolic extract was added to 4ml of water and 0.3 ml of 5% sodium nitrite was then added. After 2 minutes 0.3ml of 10% aluminium chloride was added and allowed to stand for 6 minutes, 2ml of 1M sodium hydroxide was then added and the solution topped up with 10ml distilled water. The absorbance was read at 415nm against catechin and quercitin standards.

Data Analysis: The data obtained was subjected to one way analysis of variance (ANOVA), SAS statistical package. Significantly different means were separated by

Duncan's multiple range tests. Results were given at 5% significance levels.

RESULTS AND DISCUSSION

Proximate composition: The proximate composition of the five species is shown in Table 1. There were significant inter-species differences in moisture, protein, ash, and fat content contents but not in the crude fibre. All the species had considerably high moisture content ranging between (79.29-82.52%). *A cruentus* exhibited significantly lower moisture content and significantly higher protein content than the other species. Protein values ranged from (2.3-4.37%). Asibey and Tayie (1999). (reported lower values of 2.1% in *Amaranth incarvutus*, while Kwenin and Dzomeku (2011), found similar values (4.46%) in *A.cruentus.* The protein content of *A. cruentus* (4.37%) is considerably higher than other vegetables consumed in Kenya. For example, Hanif *et al.* (2006*)* found crude protein content ranging from 0.9% to 2.1% in cauliflower, carrot, cabbage, lettuce, spinach. Uusiki *et al* (2010) reported 3% protein in pumpkin leaves. Hence, amaranth vegetables can be an important source of dietary protein especially to the poor who cannot afford animal protein. The fat content of *A. hybridus* (2.53±0.%) and *A. hypochodriacus* (2.63±0.11%) was significantly higher than the other species, but these values are lower compared to the fat content reported for black nightshade (8 mg/100g) by Gqaza *et al* 2013. The ash content ranged from (1.21-3.3.0%), which is comparable to that of *Amaranth incarvutus* (1.4%) as documented by Asibey and Tayie (1999). The crude fibre content ranged from 2.31 to 3.01, and is higher than the figure that was reported by Funke, (2011) of (0.77 %). However, these values are in the same range as those of *Corchorus olitorius* (Jute mallow), (2.10 %) and C. *ochroleuca* (Slender leaf) (1.2 %). (Mibei, 2011).Children, adults, pregnant and lactating mothers require 19-25, 21-38, 28 and 29g, of dietary fibre respectively (National academy of sciences, 2001). Consumption of 100 grams of fresh amaranth could contribute 15% of the recommended daily allowance. Crude fibre is important in reducing the risk of colon cancer, constipation, diabetes and reducing absorption of cholesterol (Ishida *et al*., 2000).

Table 1: Proximate composition of the amaranth vegetables (%)

	A.albus	*A.hybridus*	*A.cruentus*	*A.dubius*	*A.hypochondriacus*
Moisture	81.29^{a} ± 0.45	81.52^{a}±0.26	79.29^{b}± 1.26	82.53^{a}± 0.16	82.44^{a}± 0.60
Protein	2.35^{d}± 0.06	3.34^{b} ±0.06	4.37^{a} ±0.02	2.74^{c} ±0.06	3.34^{b} ±0.09
Fat	1.59^{b} ±0.03	2.53^{a} ±0.06	1.62^{b} ± 0.03	1.88^{b} ± 0.07	2.63^{a} ± 0.11
Ash	2.35^{b} ± 0.13	2.23^{b} ±0.34	1.52^{c}± 0.02	3.30^{a} ±0.04	1.21^{c} ±0.13
Crude fibre	2.31^{a} ± 0.23	2.85 ^{a}± 0.55	3.01^{a}± 0.29	2.53 ^{a} ± 0.17	2.49^{a}± 0.09
Carbohydrates	10.11^{a}±1.00	7.53^{b}±0.23	10.19^{a}±0.64	7.02^{b}±0.12	7.89^{b}±043

Values are given as means of three replicates ± SEM. Means with different small letters within a row are significantly different (P < 0.05). SEM= Standard error of the mean

Minerals composition: This study revealed significant inter-species differences in the mineral levels (Table 2). *A. dubius* was found to have the highest levels of iron (18.63±0.23 mg/100g) and calcium (336.47±0.99mg/100g). While *A.hypochondriacus* recorded the lowest iron and calcium contents of (9.55±0.15 mg/100g) and (131.06±3.14mg/100g) respectively. Values of iron obtained in this study agree with findings of Onyango (2010) who reported iron content in *A. hypochrondicus* as (16 ± 3 /mg100g). Raja *et al*. (1997) reported iron contents of 13.43 mg per 100 g in amaranth sold in Dar es Salaam, while Srivastava (2011) reported a range of (12.23-14.55mg/100g) iron in other *Amaranth* species the iron contents are high as compared to some vegetables consumed in Kenya. For example, the iron contents of spinach (*Spinacia oleracea*) is about 1.7 mg per 100 g edible portion (FAO, 2004) while Hanif *et al* 2006 documented 1.4mg/100g and

1.1mg/100g of iron in carrot and lettuce respectively. Iron is especially important to women of reproductive age, pregnant women and young children who are vulnerable to iron deficiency anaemia. The daily iron requirements for children range between 7-15mg/day and women of reproductive age require 15-18mg/day while pregnant women require 27 mg/day (National academic press 2001). Thus, consumption of 100g of amount of amaranth leaves from the species *A. dubius* would meet 100% of the daily requirements if the iron is highly bioavailable. The levels of zinc ranged from (1.36-1.67mg/100g) which is lower than the values obtained by (i) Raja *et al*. (1997) who reported values of 4.08 mg/100 g for amaranth collected in various markets in Dar es Salaam; and (ii) Onyango (2010), who obtained values of up to 6.3mg/100g in *A. hypochrondiacus* sold in various supermarkets in Kenya. However, these values are higher than those recorded by Mibei (2011) in *Cleome gynandra* (spider plant) (0.1mg/100g). Jaarsvelda (2006) also recorded lower values of zinc 0.75mg/100g and 0.42 mg/100g in *Curcurbita muschata* (pumpkin leaves) and in *Vigna unguiculata* (cowpeas leaves) respectively. Since an adult requires 8-13mg/ day of zinc, consumption of 100g of amaranth vegetable from *A.cruentus* species would contribute to 10% of the daily requirements. Zinc is necessary for a wide range of biochemical, immunological and clinical functions and is present in all body tissues and fluids (Ma G *et al* 2005). These biochemical functions of zinc are responsible for its unique role for growth and development. *A.dubius* had the highest calcium content (336.47±0.99mg/100g). Calcium was considerably high in all the five species, compared to other vegetables. For example, Hanif *et al* (2006) found 76 mg/100g in spinach and 52mg/100g in cabbage, and Mibei (2011) reported a calcium content of 94.1mg/100g in spider plant. Calcium is essential for the full activity of many enzymes such as nitric oxide synthase, protein phosphatases, and adenylate kinase and is required as a component of the human diet. Chronic calcium deficiency contributes to a reduction in bone mass and the development of osteoporosis. RDA is 1000mg/day for adults aged 19-50years (The council for responsible nutrition, 2002).Consumption of 100 grams of amaranth would contribute to 30% of recommended calcium intake.

Table 2: Mineral composition of the amaranth vegetables in WWB

	A.albus	*A.hybridus*	*A.cruentus*	*A.dubius*	*A.hypochondriacus*
Calcium	235.19^{b}±0.89	198.48^{c}±5.08	222.69^{b}±1.75	336.47^{a}± 0.99	131.06^{d}± 3.14
Zinc	1.40^{a}± 0.03	0.892^{c}±0.35	1.67^{a} ± 0.03	0.60^{c}± 0.05	1.36 ^{a} ±0.04
Iron	11.42^{b}± 0.10	10.57^{c}± 0.06	11.61^{b} ± 0.30	18.64^{a}±0.23	9.55^{d} ±0.15

Values are given as means of three replicates ± SEM. Means with different small letters within a row are significantly different (*P* < 0.05). SEM= Standard error of the mean

Phytochemical composition: Phytochemicals are bioactive non-nutrient plant compounds in plant foods. Table 3 shows that *A cruentus* had significantly high levels of all the three phytochemicals compared to all other species, while *A hypochrondicus* had significantly (p<0.05) low amounts of total phenols and *A dubius* had lowest quercitin.

Table 3: Phytochemical composition of the amaranth vegetables in GAE, CE, and QE mg/100g

	A.albus	*A.cruentus*	*A.dubius*	*A.hybridus*	*A.hypochondriacus*
Total phenols (TP)	2.24^{b}± 0.07	3.59^{ab}± 0.01	2.22^{b} ± 0.19	2.77^{a}± 0.02	1.68^{c}±0.001
Catechins	5.55^{a} ±0.18	7.15^{a}± 0.63	3.75^{b}±0.39	6.05^{a} ±0.10	3.63^{b}±0.2
Quercetin	12.55^{a}±1.04	14.28^{a}± 0.86	4.69^{b}± 0.45	13.76^{a}±1.16	6.5^{b}± 0.71

Values are given as means of three replicates ± SEM. Means with different small letters within a row are significantly different (*P* < 0.05). SEM= Standard error of the mean, GAE =Gallic acid equivalent, CE= Catechin equivalent, QE = Quercetin equivalent

Total phenolics (TP) ranged from 1.68 - 3.59GAEmg/100g.*A.hypochondriacus* had the lowest total phenols (1.68±0.001mg/100g). The values of total phenols in *A hybridus* were much lower than those reported by Nana *et al* (2000) who indicated a value of 8.30 ± 0.52 GAE/100g in *A. hybridus*. The quercitin contents of *A.cruentus* (14.28±0.86QE/100g) and *A.hybridus* (13.76±1.16 (QEmg/100g) were higher than those reported for these species (2.90 ± 0.25 QEmg/100g and 4.33±0.27 QE /100 g respectively) by Nana *et al* (2000). These differences may be due to differences in soils, climate or environmental stresses. Nevertheless, amaranth contains higher quercetin than some commonly consumed vegetables. For example Bhagwat *et al* (2011), recorded values of 0.04-1.05, 1.05-3.26 and 0.07-4.5 QE/100g quercetin in cabbage, broccoli, and kale respectively. Catechin contents were lowest, in *A.dubius* (3.75+ 0.39 CE/100g) and *A. hypochondriacus* (3.63+0.2 CE/100g). Phytochemicals such as phenolic compounds and flavonoids possess strong antioxidant properties and have been implicated in the prevention of cancer and cardiovascular disease, diabetes and aging (Hertog *et al* 1992, Adeoye *et al* 2005). Intake of phytochemicals such as flavonoids reduces the risk of coronary artery disease (Hertog *et al* 1992) Flavonoids have also been reported to have medicinal properties such as antimicrobial and antioxidant properties (Stephen *et al.,* 2009).

CONCLUSION

This study indicates that the Amaranth species found in Kenya are a good source of key nutrients. The species exhibited significant differences in their nutrient composition. According to this study, *A. dubius* is the most preferred species in terms of its nutrient composition, whereas *A.cruentus* is the second most preferred *A. cruentus* had the highest protein. *A.dubius* is not only a superior source of iron and calcium than the other amaranth species but is also superior to other green vegetables grown in Kenya. *A. cruentus* is a good source of zinc. These species could serve as potential sources of nutrients for alleviation of problems associated with micronutrient deficiency in Kenya. *A.cruentus* had the highest total phenols, quercetin, and catechin. Consumption of this species could potentially reduce the risk of chronic diseases which are so rampant in Kenya today. The data generated from this study provides an important insight on the differences in nutrition content of various amaranth species. This is important in identification of the best sources of various nutrients especially in nutritional interventions. Therefore the production, utilization and conservation of amaranth through educational programs and market linkages to communities should be promoted.

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