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Nutritional Evaluation of Five Species of Grain Amaranth – An Underutilized Crop

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Abstract: Variation in the proximate and mineral compositions of twenty nine accessions of grain amaranth (*Amaranthus*), belonging to five species: *Amaranthus caudatus, A. cruentus, A. hybrid, A. hypochondriacus* and *A. hybridus* were evaluated. Results showed that significant ($p < 0.05$) differences were observed in the proximate and mineral compositions among all the species evaluated. *Amaranthus caudatus* had the highest levels of crude fibre (4.04 g/100g), sodium (8.95 mg/kg), phosphorus (5765.64 mg/kg), magnesium (2219.15 mg/kg) and aluminum (111.09 mg/kg) contents. *Amaranthus cruentus* had the highest levels of crude fat (8.68 g/100g), zinc (59.49 mg/kg), copper (6.62 mg/kg), manganese (136.44 mg/kg) and calcium (1642.45 mg/kg). *Amaranthus hybridus* had the highest levels of protein (17.89 g/100g) and starch (38.01 g/100g). Phosphorus was the most abundant mineral present, followed by potassium and magnesium; while selenium was the least abundant mineral element present. The grain amaranth species have higher protein, crude fibre, starch and essential minerals than commonly consumed cereals and hold promise as a healthy alternative to these cereals and their products.

Keywords: Amaranth, minerals, proximate analysis, species variation.

INTRODUCTION

Malnutrition remains one of the public health problems among preschool children contributing to more than half of deaths in children worldwide. (FAO Canada, 2002). Child malnutrition was associated with 54% of deaths in children in developing countries in 2001 (WHO, 2013a; Muller *et al*., 2005). Protein-energy malnutrition (PEM), first described in the 1920s, is observed most frequently in developing countries but has been described with increasing frequency in hospitalized and chronically ill children in the United States (Hendricks *et al.*, 1995). In addition to PEM, children may be affected by micronutrient deficiencies, which also has a detrimental effect on growth and development. The most common and clinically significant micronutrient deficiencies in children and childbearing women throughout the world include deficiencies of iron, iodine, zinc, and vitamin A and are estimated to affect as many as two billion people (Aphane *et al.*, 2002).

Although fortification programs have helped diminish deficiencies of iodine and vitamin A in individuals in the United States, these deficiencies remain a significant cause of morbidity in developing countries, whereas deficiencies of vitamin C, B, and D have improved in recent years. Micronutrient deficiencies and protein and calorie deficiencies must be addressed for optimal growth and development to be attained in these individuals. Three broad strategies, namely, supplementation through high-dose capsules, food fortification, and food diversification are explored worldwide for combating nutrient deficiency, especially among children. (Aphane *et al*., 2002). Current treatment for children involves the use of special formulated food which is expensive and not sustainable in the long term (Jed, 2005). Food diversification is the more sustainable long-term strategy to address nutrient deficiency. Although foods of animal origin are the best sources of vitamin A, protein and some minerals these food items are expensive and often out of economic reach

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of poor households. Exploration of underutilized nutrient-rich foods that can be produced inexpensively to meet the nutrient requirements for these vulnerable groups would be one of the possible interventions in reducing malnutrition.

Amaranth, a pseudocereal, is recognized as the grain of the future and has received considerable attention in many countries because of its exceptional nutritional quality of some species that are important sources of food, as either vegetable or grain (Srivastava, 2011). Amaranth can be consumed by persons who are not gluten tolerant such as babies up to six months or those who suffer from celiac disease (Alvarez-Jubete *et al*., 2009)

Amaranth of the genus *Amaranthus* belongs to the family *Amaranthacea* and consists of nearly 60 species. (Anjali *et al*., 2013; Kalac *et al*., 2000). Amaranth is characterized by great diversity of species and wide spectrum of adaptability to diverse environmental conditions with earliest maturity period in the pseudo- and cereal classes (Anjali *et al*., 2013; Wambugu, 2009; Jacob, 2005). *Amaranthus cruentus*, *A. hypochondriacus* and *A. caudatus* are the essential grain species cultivated for human and animal consumption (Teutonico *et al*., 1985). The amaranth grain is high in minerals such as calcium, potassium, phosphorus, as well as dietary fiber (Taylor *et al*., 2014). Amaranth has lysine-rich high protein grains and forms a good source of essential amino acids (Akin-Idowu *et al*., 2013 and Mota *et al*., 2016). These dual-purpose plants supply not only nutritious grains but also tasty, leafy vegetables consumed all over the world, as both human food and animal feed. The leaves of amaranth constitute an inexpensive and rich source of protein, carotenoids, vitamin C, dietary fibre, calcium, iron, zinc, magnesium and phosphorus (Shukla *et al*., 2006; Ozbucak *et al*., 2007). Amaranth protect against several disorders such as defective vision, respiratory infections, recurrent colds, retarded growth, functional sterility, bleeding tendencies, leucorrhoea, and premature ageing (Bakhru, 2007). Due to its nutritional potential, amaranth presents an interesting alternative in order to increase the range of plants used for nutrition.

Amaranth nutritional values are likely to vary due to influences of environment, genotype and adaptation to specific agro-ecological area under which the plant genotypes have evolved and are adapted (Makobo *et al*., 2010). Information on nutritional variation among the species is essential for efficient utilization of plant genetic resources. This study therefore evaluated the proximate and mineral composition of 29 accessions of amaranth belonging to five species.

MATERIALS AND METHODS

Twenty nine accessions of *Amaranthus* belonging to five species: *A. caudatus, A. cruentus, A. hybrid, A. hypochondriacus* and *A. hybridus* were used in this study (Table 1). Twenty seven of the accessions were obtained from the USDA-ARS North Central Regional Plant Introduction Station (NCRPIS) in Ames, USA; and two were obtained from the National Horticultural Research Institute (NIHORT) germplasm, Ibadan, Nigeria. They were planted in the experimental field of NIHORT in three replicates in a randomized complete block design.

Sample preparation

Seeds of the twenty nine grain amaranth accessions were harvested at maturity, dried and milled into flour to obtain a homogenous particle size and made to pass through a 40-mesh screen. The milled samples were stored in airtight containers and kept at 4°C prior to analysis.

Chemical Analysis

Moisture, ash, crude fat and crude fibre were analyzed following the methods of the Association of Official Analytical Chemists (AOAC, 2000). The nitrogen content was estimated by Kjeldhal method based on the assumption that plant proteins contain 16% nitrogen and protein content was calculated using the formula (protein = N x 6.25). Starch and sugar were determined by the methods of Dubois *et al*., (1956) and McCready, (1970).

Mineral elements were determined using an Inductively Coupled Plasma Atomic Emission Spectrometry (ICPAES) according to the method of Hwang *et al*., (2009).

Statistical analysis

All chemical analyses were carried out in duplicate. Data was analysed by one-way analysis of variance (ANOVA) of SAS (Statistical Analysis Software version 9.1). Significant difference comparisons were done using Duncan's multiple range test and statistical significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Proximate Composition

Results of the proximate composition of five amaranth species are presented in Table 2. Significant ($p < 0.05$) difference was observed in the proximate composition of all the five amaranth species studied.

The moisture content ranged from 9.30 – 11.54 g/100g. *Amaranthus hypochondriacus* had the highest level and is significantly ($p < 0.05$) higher than values obtained in the other species. The moisture content obtained in this study is in agreement with values (10.69 – 12.22 g/100g and 11.40 – 12.07 g/100g) obtained in some grain amaranth species (Kachiguma *et al*., 2015; Repo-Carrasco-Valencia *et al*., 2010). They are comparable to values obtained in major cereals such as wheat (13.30 g/100g) (Ahmed *et al*., 2012; Becker *et al*., 1981); maize (9.20 – 10.91 g/100g) (Ullah *et al*., 2010); rice (15.50 g/100g) oat (14.00 g/100g), sorghum (14.50 g/100g) (McKevith, 2004); and pseudocereals like acha (12.73 g/100g), quinoa (11.32 g/100g) and buckwheat (11.60 g/100g) (Becker *et al*., 1981; Enyisi *et al*., 2014). The moisture contents obtained in this study are also similar to 9.20 g/100g obtained for cowpea (Arawande *et al*., 2010). Moisture content is the most important property affecting stability of the grain during storage (Chelowski, 1991). The moisture content obtained in this study is within the recommended range of 9.00 – 12.00 g/100g for long term storage of flour and seed viability for up to seven years (Singh *et al*., 2005; O'Brien *et al*., 2008). Low moisture content is a good attribute of food samples, as it extends shelf life of the final product. On the other hand, food with high moisture content encourages microbial growth, hence reduces storage stability which result in food spoilage.

Ash content is an index of mineral content in a plant material (Idris *et al*., 2011). The ash content obtained in this study ranged from 3.14 – 4.94 g/100g. *Amaranthus hybrid* had the highest ash content, this was significantly ($p < 0.05$) higher than levels obtained in other species. The moisture content is similar to 3.10 – 3.20 g/100g obtained for four Amaranth species (*A cruentus, A hypochondriacus, A caudatus and A hybridus*) (Leon-Camacho *et al*., 2001), and comparable to 3.00 g/100g obtained for cowpea (David *et al*., 2015). The ash content obtained in this study is higher than 1.10 – 2.95 g/100g obtained for maize and maize products (Enyisi *et al*., 2014); 1.96 – 2.32 g/100g obtained for maize (Ndukwe *et al*., 2015) and 1.40 – 3.30 g/100g reported for maize (Maziya-Dixon *et al*., 2000). Values obtained in this study are also higher than 1.80, 1.59 and 2.60 g/100g obtained for wheat, buckwheat and quinoa, respectively; (Berghofer *et al*., 2007) and 2.25 g/100g obtained for acha (Oburuoga *et al*., 2012).

Proteins are an abundant component in all cells and almost all except storage proteins are important for biological functions and cell structure (Nielsen, 2003). Plant foods that provide more than 12.00 g/100g of its calorific value from protein are considered a good source of protein (Ali, 2009). Protein content obtained in this study ranged from 13.82 to 17.89 g/100g with highest value observed in *A. hybridus*, this was significantly ($p < 0.05$) higher than levels obtained for the other species. All five species can be considered to be important sources of dietary protein. Values obtained in this study are similar to 15.50 – 17.10 g/100g obtained for *A. cruentus, A. caudatus, A. hypochondriachus and A. hybridus* (Berganza *et al*., 2003) and comparable to 18.30 g/100g obtained for some grain amaranth accessions (Kachiguma *et al*., 2015). The protein content (14.25 g/100g) obtained for *A. caudatus* in this study is similar to 14.19 g/100g obtained for *A. caudatus* (Emire *et al*., 2012), higher than 9.41 g/100g and 10.23 g/100g obtained for wheat flour (David *et al*., 2015) and also 4.50 – 9.87 g/100g obtained for maize and maize products (Enyisi *et al*., 2014). The protein content obtained in this study is also higher than 8.38 g/100g obtained for Acha (*Digitaria exilis*), (Oburuoga *et al*., 2012), but lower than 24.53 g/100g obtained for cowpea (David *et al*., 2015). Protein content obtained for *A. hybridus* (17.89 g/100g) and *A. cruentus* (15.81 g/100g) are higher than value obtained for wheat (13.50 to 14.50 g/100g), maize (10.60 to 13.80 g/100g), barley (10.00 to 14.90 g/100g) and oats (12.40 to 12.90 g/100g) (Adeyeye *et al*., 1992). Belitz *et al*., (2009) obtained protein content of 11.30 g/100g in wheat; 8.80 g/100g in corn; 10.80 g/100g in oats and 7.70 g/100g in rice, these are lower than values obtained in this study. Ullah *et al*., (2010) reported that the crude protein contents in some varieties of maize ranged from 7.71 to 14.60 g/100g, these are lower than values obtained for *A. hybrid, A. hybridus* and *A. cruentus* in this study.

Fat content ranged from 4.85 to 8.68 g/100g, this is similar to values (7.71 to 8.13 g/100g) obtained for *A. cruentus, A. hypochondriacus, A. edulis* (Becker *et al*., 1981); 6.31 – 7.56 g/100g obtained for *A. caudatus* (Repo-Carrasco-Valencia *et al*., 2010) and 7.49 g/100g obtained for *A. caudatus* (Emire *et al*., 2012). *Amaranthus cruentus* had the highest fat content (8.68 g/100g), this is not in agreement with value (1.62 g/100g) obtained for *A. cruentus* (Muriuki *et al*., 2014). The fat contents obtained in this study are higher than values (2.50 g/100g and 1.33 g/100g) obtained for wheat (Becker *et al*., 1981; David *et al*. 2015); 2.17 – 4.43 g/100g obtained for maize (Enyisi *et al*., 2014) and 2.04 g/100g obtained for acha (Oburuoga *et al*., 2012). The fat contents obtained in this study are also higher than 1.00 g/100g obtained for cowpea (David *et al*., 2015).

Crude fibre content ranged from 1.89 – 4.04 g/100g, with *A. caudatus* having significantly ($p < 0.05$) higher level than the other species. The crude fibre content obtained in this study is comparable to 2.68 – 6.73 g/100g obtained for *A. caudatus* and 3.44 – 5.34 g/100g obtained for *A. cruentus* and *A. hypochondriacus* (Repo-Carrasco-Valencia *et al*., 2010). The crude fibre content obtained in this study is also comparable to 3.21 g/100g obtained for cowpea (David *et al*., 2015) and 2.60 g/100g obtained for wheat (Becker *et al*., 1981). Enyisi *et al*., (2014) obtained a wide range of values (2.10 to 26.77 g/100g) for crude fibre in some *Amaranthus* species, this is much higher than values obtained in this study. Crude fibre is important in reducing the risk of colon cancer, constipation, diabetes and reducing absorption of cholesterol (Ishida *et al*., 2000). Pseudocereals contain relatively high amounts of dietary fibre which improves lipid metabolism and takes part in the prevention of LDL-C oxidation (Gorinstein *et al*., 1998). Children, adults, pregnant and lactating mothers require about 19-25, 21-38, 28 and 29 g of dietary fibre; respectively (National Academy of Sciences, 2001). Consumption of 100g of grain amaranth could therefore contribute 14 g/100g of the recommended daily allowance.

Total Starch contents in this study ranged from 29.05 - 38.01 g/100g. These are comparable to 22.00 – 45.00 g/100g obtained in pulse grain (Hoover *et al*., 2010) but lower than 67.30 g/100g obtained in *A. cruentus*, 48.00 - 69.00 g/100g obtained in some amaranth species (Becker *et al*., 1981 and Bressani, 1994) and 61.40 g/100g obtained in amaranth (Alvarez-Jubete *et al*., 2009). Total starch contents obtained in this study are lower than 69.00 g/100g obtained in Quinoa, 67.20 g/100g obtained in Buckwheat and 61.00 g/100g obtained in wheat (Bonafaccia *et al*., 2003; Souci *et al*., 1993). Starch contents obtained in quinoa (64.20 g/100g), buckwheat (58.90 g/100g) and wheat (63.00 g/100g) (Alvarez-Jubete *et al*., 2009) is also higher than values obtained in this study.

Mineral Content

The result of the mineral composition of the five grain amaranth species is shown in Table 3. All the mineral elements differed significantly ($p<0.05$) among the five species evaluated. *Amaranthus caudatus* had the highest levels of sodium (8.95 mg/kg), phosphorus (5765.64 mg/kg), magnesium (2219.15 mg/kg) and aluminum (111.09 mg/kg) contents. *Amaranthus cruentus* had the highest levels of zinc (59.49 mg/kg), copper (6.62 mg/kg), manganese (136.44 mg/kg) and calcium (1642.45 mg/kg) contents. *Amaranthus hypochondriacus* had the highest levels of Iron (149.71 mg/kg) and Potassium (5362.44 mg/kg) contents; while *A. hybrid* had the highest level of selenium (0.82 mg/kg) content. Phosphorus was the most abundant mineral element present, followed by potassium and magnesium. Similar result was observed for some amaranth species, maize varieties, millet and quinoa in which phosphorus was the most abundant element followed by potassium and then magnesium (Becker *et al*., 1981, Enyisi *et al*., 2014; Oshodi *et al*., 1999). Minerals such as manganese, zinc, copper, sodium and selenium were present in low amounts; with selenium being the least abundant mineral element present.

Iron contents ranged from 102.04 to 149.71 mg/kg. *Amaranthus hypochondriacus* had significantly ($p<0.05$) higher values than the other species. The iron contents obtained in *A. cruentus* (117.94 mg/kg) and *A. hypochondriacus* (149.70 mg/kg) are not in agreement with values 174.00 mg/kg obtained for *A. cruentus* and 106.00 mg/kg obtained for *A. hypochondriacus* (Becker *et al*., 1981). Results of this study are higher than 84.20 mg/kg and 31.00 mg/kg obtained for *A. edulis* and wheat, respectively (Becker *et al*., 1981). Kachiguma *et al*., (2015) reported that the iron contents of some grain amaranth accessions ranged from 36.10 to 225.10 mg/kg, these are either similar to or higher than values obtained for the five amaranth species in this study. The iron content obtained in some maize varieties ranged from 38.02 – 56.14 mg/kg (Ullah *et al*., 2010) and 18.00 mg/kg (Hassan *et al*., 2009); these are lower than results obtained in this study. The iron content obtained in all the grain amaranth species studied is higher than the recommended human dietary intake of 15 mg, (Lenntech, 2013), and the suggested supplementation in pregnant women of 30 - 60 mg iron/day, (World Health Organization 2013), indicating that all species are good sources of dietary iron.

The zinc contents ranged from 42.20 - 59.49 mg/kg with highest level observed in *A. cruentus*, this is significantly ($p<0.05$) higher than values obtained in the other species. *Amaranthus hypochondriacus* with zinc content of 46.02 mg/kg was higher than value 38.30 to 38.70 mg/kg reported for *A. hypochondriacus* (Czerwinski *et al*., 2004), and also 37.00 to 40.00 mg/kg obtained for *A. edulis* (Becker *et al*., 1981). Kachiguma *et al*., (2015) reported that the zinc content in some grain amaranth accessions ranged from 5.30 - 12.00 mg/kg, this is not in agreement with values obtained in this study. The zinc contents obtained in this study are higher than 29.00 mg/kg obtained in wheat, 33.00 mg/kg in oatmeal, 18.00 mg/kg in rice, 21.00 mg/kg in barley, 30.00 mg/kg in rye; (McKevith, 2004 and Holland *et al*., 1998); 27.20 mg/kg in mungbean and 5.00 – 37.05 mg/kg in maize (Hassan *et al*., 2009; Ullah *et al*., 2010). The zinc contents obtained in this study are also higher than 41.70 mg/kg obtained in acha (Oburuoga *et al*., 2012). Consumption of grain amaranth can help in the stabilization of the immune function and reduction in complications from disease especially in patients whose immune systems have been compromised.

Copper ranged from 3.37 - 6.62 mg/kg with highest value obtained in *A. cruentus*, this is twice the value obtained in *A. hypochondriacus*. The value observed in *A. hypochondriacus* (3.37 mg/kg) is not in agreement with 8.10 - 8.30 mg/kg obtained for *A. hypochondriacus* (Czerwinski *et al*., 2004). The copper content obtained in this study is lower than 7.90 - 13.20 mg/kg obtained for some amaranth species (Becker *et al*., 1981) and 11.02 - 14.25 mg/kg obtained for some maize varieties (Ullah *et al*., 2010). It is however higher than 2.21 – 2.36 mg/kg obtained for some maize varieties (Feli *et al*., 2005).

The sodium content ranged from 0.00 - 8.95 mg/kg. Sodium was not detected in *A. hybridus*, this is not in agreement with report of Akubugwo *et al*., (2007) in which 7.43 mg/kg was obtained in *A. hybridus*. *Amaranthus caudatus* had the highest sodium content and is significantly ($p < 0.05$) higher than values obtained for the other species. *Amaranthus caudatus* had three times the value obtained in *A. hybrid*, six times the value obtained in *A. cruentus* and nine times the value obtained in *A. hypochondriacus*. The sodium contents obtained in this study are lower than values obtained in wheat (30.00 mg/kg), rice (40.00 mg/kg), barley (30.00 mg/kg), oats (90.00 mg/kg), rye (10.00 mg/kg), sorghum (70.00 mg/kg) and millet (50.00 mg/kg) (McKevith, 2004, Holland *et al*., 1998). The sodium contents reported for two maize varieties ranged from 15 – 18 mg/kg (Hassan *et al*., 2009), this is higher than values obtained in this study.

Manganese content ranged from 63.55 - 136.40 mg/kg with highest value observed in *A. cruentus*, this was significantly higher than values obtained in all the other species. *Amaranthus cruentus* had twice the amount obtained in *A. caudatus*. Values obtained in this study are higher than 15.90 - 45.90 mg/kg obtained in amaranth species (Becker *et al*., 1981) and 31.50 - 31.70 mg/kg obtained for *A. hypochondriacus* (Czerwinski, 2004).

Potassium was observed to be the second most abundant element in this study and ranged from 4281.00 to 5362.00 mg/kg with highest content observed in *A. hypochondriacus*. The potassium content is comparable to 2900.00 – 5800.00 mg/kg obtained for some amaranth species, higher than 3700.00 mg/kg obtained for wheat (Becker *et al*., 1981) and 93.00 – 108.00 mg/kg obtained for two varieties of maize (Hassan *et al*., 2009). The potassium contents in this study are also higher than 2700.00 mg/kg reported for barley, 4100.00 mg/kg for rye, 3400.00 mg/kg obtained in wheat, 1500.00 mg/kg obtained in rice, 3500.00 mg/kg obtained in oatmeal, 3700.00 mg/kg obtained in miller (McKevith, 2004; Holland *et al*., 1998) and 2915.00 – 3471.00 mg/kg obtained for some maize varieties (Ullah *et al*., 2010). The potassium contents obtained in some maize varieties ranged from 3400.00 – 3600.00 mg/kg and 3710.00 – 3930.00 mg/kg (Feli *et al*., 2005; Hussaini *et al*., 2008); this is much lower than values obtained in this study.

Phosphorus was observed to be the most abundant mineral present and ranged from 4481.79 - 5765.64 mg/kg. Highest value was observed in *A. caudatus*, and this was significantly ($p<0.05$) higher than values obtained in the other species. Phosphorus contents in this study are higher than 3330.00 mg/kg obtained for wheat; 4340.00 mg/kg obtained for rice (Azeke *et al*., 2011) and 4410.00 – 4580.00 mg/kg obtained for three sorghum cultivars (Nour *et al*., 2010). They are higher than that of Castor bean oilseed (2650.00 mg/kg) and melon oilseed (2800.00 mg/kg) (Enujiugha *et al*., 2003). The phosphorus contents in this study were also comparable to values reported for five species of rice (5200.00 – 5400.00 mg/kg) (Oko *et al*., 2011).

Calcium contents ranged from 1115.90 - 1642.45 mg/kg with highest value observed in *A. cruentus*, this is significantly higher than values obtained in the other species. The calcium content is lower than 1700.0 - 2150.0 mg/kg obtained in some amaranth species (Becker *et al*., 1981), lower than 10046.0 mg/kg and higher than 783 mg/kg obtained in some grain amaranth accessions (Kachiguma *et al*., 2015). The calcium content obtained in this study is much higher than 380.00 mg/kg obtained in wheat, 510.00 mg/kg in rice, 520.00 mg/kg in oatmeal, 200.00 mg/kg in barley, 32.00 mg/kg in rye and 400.00 mg/kg in millet (McKevith, 2004; Holland *et al*., 1998). The calcium contents were also higher than values obtained for acha (67.00 mg/kg) and mungbean (353.00 mg/kg) (Oburuoga *et al*., 2012). The high calcium content can meet the recommended daily intake of 1000 mg (Lenntech, 2013) and the suggested supplementation in pregnant women of 1500 - 2000 mg calcium/day (WHOb, 2013). The results indicate that the species are good dietary sources of calcium.

Magnesium contents ranged from 1760.23 - 2219.15 mg/kg with highest level observed for *A caudatus*, this is significantly ($p<0.05$) higher than values obtained in the other species. Values obtained in this study are not in agreement with value (973.80 mg/kg) obtained for some grain amaranth accessions (Kachiguma *et al*., 2015), but are comparable to 2300.00 – 3360.00 mg/kg obtained for some amaranth species (Becker *et al*., 1981). The magnesium content in this study is higher than 1200.00 mg/kg obtained in wheat, 1100.00 mg/kg in rice, 1100.00 mg/kg in oatmeal, 650.00 mg/kg in barley and 920.00 mg/kg in rye (McKevith, 2004; Holland *et al*., 1998). The magnesium content of some maize varieties ranged from 985.20 – 1625.00 mg/kg, 1060.00 – 1130.00 mg/kg (Ullah *et al*., 2010, Feli *et al*., 2005; Hussaini *et al*., 2008). These are much lower than results obtained in this study.

Selenium is an essential micronutrient for humans and animals with antioxidant, anti-cancer and anti-viral effects (Lyons *et al*., 2003). Selenium was the least abundant element present and ranged from 0.23 - 0.82 mg/kg. Highest value was observed in *A. hybrid* and this was significantly (p<0.05) higher than values observed in the other species. The value obtained in *A. hybrid* was three and half times the value obtained in *A. caudatus*, *A. hypochondriacus* and *A. hybridus*. Selenium content of grains or cereals vary depending on the selenium content of the soil and is responsible for the wide range of values (Graham *et al*., 2005). *Amaranthus hypochondriacus* having selenium content of 0.27 mg/kg is similar to values (0.22 - 0.26 mg/kg) obtained in *A. hypochondriacus* (Czerwinski 2004). The selenium content obtained in *A. hybrid* and *A. cruentus* in this study are higher than 0.43 mg/kg and 0.66 mg/kg obtained in wheat and barley, respectively (Cordain, 1999). They are also higher than values (0.04 mg/kg) obtained in maize and (0.10 - 0.13 mg/kg) obtained in rice (Cordain, 1999). The selenium contents obtained in this study are higher than 0.06 mg/kg obtained in wheat, 0.10 mg/kg in rice; 0.03 mg/kg in oatmeal and 0.01 mg/kg in barley (McKevith, 2004; Holland *et al*., 1998).

CONCLUSION

Results of this study indicate that the grain amaranth species vary greatly in terms of proximate and mineral compositions. This variability observed is due to both genetic and environmental factors which may influence the individual chemical composition of the grain. Some amaranth species have higher nutritional compositions than conventional cereals such as wheat, rice, rye, barley, millet, sorghum, acha, oatmeal and maize. These species can provide essential minerals, protein and energy requirements to the daily diet of vulnerable groups in rural communities. Thus, nutrient variation observed will be useful in designing strategies that maximize the utilization of amaranth germplasm.

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Table 1. Species and accessions of grain amaranth used in this study and their passport data.

Species	Accession Number	Accession code	Origin	Plant name	Seed colour
Amaranthus caudatus	1	P1 490458	Bolivia	LSK 38	Cream+black
	2	PI 511679	Argentina	RRC 551	Cream
	3	PI 553073	United States, New Jersey	LOVE-LIES-BLESSING	Pink
	4	P1 642741	Bolivia	Oscar Blanco	Cream
Amaranthus cruentus	5	PI 477913	Mexico	RRC 1011	Cream
	6	PI 511719	Guatemala	Niqua, alegria, chang	Cream
	7	PI 515959	United states, Montana	Montana-3	Cream
	8	PI 538319	United states, Pennsylvania	K266	Cream
	9	PI 590992	China	TIBET	Cream
	10	P1 604666	United states, Pennsylvania	RRC 1027	Cream
	11	PI 641047	Nigeria, Oyo	CEN/IB/97/AMA008	Cream
	12	PI 641045	Nigeria, Oyo	CEN/IB/97/AMA005	Cream
Amaranthus hybrid	13	PI 538325	United states, Pennylsyvania	K593	Cream
	14	PI 538326	United States, Pennysylvania	D70-1	Cream
	15	PI 538327	United States, Pennysylvania	DI36-1	Cream
	16	Ames 1974	Nigeria	RRC 18C	Normal green, with pink veins and margin
	17	Ames 2256	Nigeria	SP 12C	Normal green, with pink veins and margin
	18	Ames 5644	Nigeria	RRC 1044	Cream
	19	Ames 5647	Nigeria	RRC 1047	Normal green, with pink veins and margin
Amaranthus hypochondriacus	20	PI 337611	Uganda	P 373	Cream
	21	PI 511731	Mexico	RRC 646	Cream
	22	PI 558499	United States, Nebraska	PLAINSMAN	Cream
	23	PI 590991	China, Shanxi	ZHEN PING	Gold
	24	PI 615696	India, Himachal Pradesh	Amapurna	Cream
	25	P1 619250	United States, Pennsylvania	K 116	Gold
	26	PI 633596	Nepal	Jumla	Cream
	27	Ames 1972	Nigeria	RRC 18A	Cream
Amaranthus hybridus	28	NH 84/444-4	Nigeria	NH Purple	Cream
	29	NAC 3	Nigeria	NH Green	Cream

Table 2. Proximate Composition of five grain Amaranth species (g/100g)

Species	Moisture	Ash	Protein	Starch	Sugar	Fat	Crude fibre
A. caudatus	10.85c ± 0.05	3.66d ± 0.08	14.25c ± 0.18	29.36d ± 0.11	1.63b ± 0.04	8.18b ± 0.05	4.04a ± 0.10
A. cruentus	11.17b ± 0.08	3.14e ± 0.04	15.81b ± 0.05	31.21c ± 0.09	1.66b ± 0.03	8.68a ± 0.05	3.48b ± 0.05
A. hybrid	10.01d ± 0.04	4.94a ± 0.05	15.78b ± 0.11	29.05e ± 0.08	1.18c ± 0.03	5.92d ± 0.08	1.89e ± 0.07
A. hypochondriacus	11.54a ± 0.06	4.20c ± 0.04	13.82d ± 0.10	37.65b ± 0.06	1.95a ± 0.04	4.85e ± 0.04	3.25c ± 0.06
A. hybridus	9.30e ± 0.19	4.40b ± 0.09	17.89a ± 0.27	38.01a ± 0.11	1.62b ± 0.03	7.46c ± 0.13	2.33d ± 0.06
Max	11.54	4.94	17.89	38.01	1.95	8.68	4.04
Min	9.30	3.14	13.82	29.05	1.18	4.85	1.89

Data are presented as mean ± Standard error of mean
Values in the same column having the same letter are not significantly different at P < 0.05.

Table 3. Mineral Content (mg/kg) of five grain Amaranth species

Species	Fe	Zn	Cu	Na	Mn	K	P	Ca	Mg	Al	Se
A. caudatus	144.14b ± 0.27	43.19c ± 0.39	4.14c ± 0.10	8.95a ± 0.14	63.55e ± 0.66	5137.57b ± 62.50	5765.64a ± 65.56	1287.77c ±29.08	2219.15a ± 1.49	111.09a ± 1.01	0.24b ± 0.02
A. cruentus	117.94c ± 0.39	59.49a ± 1.46	6.62a ± 0.12	1.39c ± 0.02	136.44a ± 0.46	4281.06d ± 73.55	4618.77c ± 17.32	1642.45a ± 5.22	2035.24b ± 19.93	47.55d ± 0.11	0.78a ± 0.01
A. hybrid	102.04d ± 1.29	47.19b ± 0.40	4.64b ± 0.20	2.57b ± 0.18	87.13d ± 0.10	4742.75c ± 38.43	5383.15b ± 34.28	1620.52a ± 8.38	2193.16a ± 4.89	86.59c ± 0.48	0.82a ± 0.01
A. hypochondriacus	149.71a ± 2.95	46.02b ± 0.48	3.37d ± 0.02	0.97d ± 0.03	100.84b ± 0.12	5362.34a ± 19.31	5381.46b ± 18.31	1392.09b ± 4.33	2199.70a ± 2.69	110.19a ± 0.99	0.27b ± 0.016
A. hybridus	145.94a ± 0.74	42.20c ± 0.05	4.50c ± 0.05	ND	94.05c ± 0.27	5172.61b ± 28.29	4481.79d ± 3.03	1115.90d ± 2.11	1760.23c ± 3.78	94.98b ± 1.28	0.23b ± 0.013
Max	149.71	59.49	6.62	8.95	136.44	5362.34	5765.64	1642.45	2219.15	111.09	0.82
Min	102.04	42.20	3.37	ND	63.55	4281.06	4481.79	1115.90	1760.23	47.55	0.23

Data are presented as mean ± Standard Error
Values in the same column having the same letter are not significantly different at P < 0.05.
ND = Not detected