Research Article

Nutritional value of grain and leafy Amaranth varieties grown in Tanzania

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ABSTRACT

Amaranth leaves and seeds are highly nutritious, but less is clearly known for the varieties grown in Tanzania. Grains, leaves (dry and fresh) and flower part of amaranth were analyzed for minerals (iron, zinc, copper and manganese), proximate (crude protein, crude fat, crude fibre and carbohydrate) and anti-nutrients (nitrate and oxalate) content. Minerals were significantly higher ($p<0.05$) in fresh leafy varieties performing 75.89 mg/100 g, 3.284 mg/100 g and 34.869 mg/100 g for *Amaranthus hypochondriacus* (Nafaka), *A. hypochondriacus* (Lishe njano) and *A. dubius* (White local) respectively, with iron being significantly higher in dried leaves (284.384 mg/1000 g) of *A. dubius* (Bwasi jekundu). Protein, Fat and Fibre content is significantly higher in grains of amaranths indicating Crude protein (15.787%) in *A. cruentus* (Bwasi kijani), Crude Fibre (13.040% and 13.163%) in White local and Bwasi jekundu respectively that are not significantly different ($p>0.05$) and Crude Fat (9.273%) in Bwasi jekundu. Total Carbohydrate (78.743%) is significantly higher in dried Bwasi kijani. Anti-nutrient contents were significantly higher in dried compared to fresh leaf varieties, grain and amaranth flowers. Oxalate ranging from 378.5 to 360.3 mg/100 g and are not significantly different ($p>0.05$) within varieties, nitrate (137.06 µg/g) is significantly higher in *A. hybridus* (Lishe nyeupe) of dried leaves compared to fresh, grains and amaranth flower. Bwasi jekundu appears to be the best variety as dried leaves have the highest iron, since micronutrients are of more significance in leaves of vegetables than macro nutrients.

Key words: Amaranths varieties, Nutrients content, Anti-nutrients content, Amaranth leaves, Amaranth grains

INTRODUCTION

The production and commercialization of indigenous African vegetables have been on the rise and continuous. The genus Amaranthus includes 50-60 species, cultivated for green leaves and grains, and a few wild species (Rai & Yadav, 2005). Amaranth is one of the oldest food crops in the world; evidence of its cultivation dates back to as far as 6700 BC (RSA, 2010). Amaranth is considered one of the most commonly produced and consumed indigenous vegetables on the African continent (Grubben, 2004). More than 100 different indigenous leafy vegetable species are identified in Africa; Amaranth is the most widely consumed. According to Myers (2004), amaranth is grown for its grains and leaves. Lack of nutrition security is reflected in malnutrition which has affected many Tanzanians in different forms. Amaranth has the potential to address the nutritional needs of non-vulnerable and vulnerable individuals because of its high content in essential fatty acids in grains and micronutrients such as iron, zinc, selenium, copper, and manganese in leaves which are required for normal physiological functioning of the body (Escudero *et al.,* 2006).

It is only said that amaranth is rich in certain nutrients, which has not been clear if all varieties grown in Tanzania have similar nutritional composition. However, nutrient variations in amaranth varieties grown in Tanzania have been less evidently documented. It is also known that consumers tend to remove the immature inflorescence part of the harvested amaranth leaves portion for consumption, thus there was a need to investigate whether the young flowering part of over matured amaranth leaves is less nutritious than the rest of the edible part in terms of the nutritional composition. It is also important to analyze anti-nutrient content because they lower bioavailability of micronutrients in the human body by binding them and preventing their absorption, this is due to saturation of the transport system and reduced absorption of the other nutrients caused by the anti-nutrients.

The main objective of this study was to analyze selected nutrients and anti-nutrient contents of different varieties of leafy amaranth and grain amaranth as an important step towards enhancing nutrient intake from amaranth-based dishes since Amaranths as an indigenous vegetable has a short production cycle, high yielding with good nutritional value and low cost of production which can therefore contribute to nutrition security once awareness of amaranth potential is created.

MATERIALS AND METHODS

Research design

The six varieties in local names and species names were identified by the Department of Crop Science and Production of Sokoine University of Agriculture (SUA). These varieties are

White local (*Amaranthus dubius*), Bwasi jekundu (*A. dubius*), Bwasi kijani (*A. cruentus*), Lishe nyeupe (*A. hybridus*), Lishe njano (*A. hypochondriacus*), and Nafaka (*A. hypochondriacus*) that are grown in different regions in Tanzania. The seed beds for growing amaranths were prepared in replicates for every variety. Sample collection involved the collection of fresh amaranth leaves, dry amaranth leaves, amaranth flowers (immature inflorescence), and amaranth grains which made amaranth to be analyzed into four treatments.

Determination of nutrient contents amaranth

Minerals content determination

Leafy amaranth (both fresh and dry amaranth), flowering part, and grain amaranth were analyzed for the selected trace minerals (iron, zinc, copper, and manganese) using the atomic absorption spectrophotometer (Eslami *et al.*, 2007).

Proximate analysis

Determination of protein content

The Kjeldahl method (AOAC, 1990) was used for protein analysis, which is a standard method for determining total nitrogen in foods. This method is based on the assumption that a mixture of pure proteins will contain 16% nitrogen. Protein content was obtained by multiplying the percentage determined nitrogen by the appropriate factor which was 6.25.

Determination of fat content

The Soxhlet method was used to determine total fat (AOAC, 1990). Crude lipid was extracted with n-hexane in a soxhlet extractor which was fitted with a reflux condenser and a 250 mL round bottom flask containing 150 mL of petroleum ether.

Determination of fibre content

The crude fiber was determined by the Kirk and Sawyer (1991) method. Accordingly, 2 gm of the sample was defatted in boiled 200 cm^3 of 0.1275 M sulphuric acid solution for 30 minutes with constant agitation. The boiling mixture was poured into a Buckner funnel and washed with Acetone. Then, the residue was boiled in a 0.313 M sodium hydroxide solution for 30 minutes with constant stirring. The residue was mixed with boiling water followed by 1% hydrochloric acid, then washed with boiling water until free from acid. It was dried in an oven to a constant weight.

Determination of total carbohydrates

The percentage of total carbohydrates was calculated by the difference method of summing the percentage values of moisture, crude protein, ash, and crude fat and subtracting the sum from 100 (McDonald *et al.*, 1973).

Determination of anti-nutrient contents amaranth

Determination of oxalate content

The oxalate content was determined by heating 2.0 g of powdered sample in distilled water and 0.3 M HCl. The cold filtrate was treated with 2 to 3 drops of methyl red indicator and NH_4OH solution before heating the mixture to 100 °C. After cooling, the filtrate was heated further before the addition of 10 cm^3 of 10% $CaCl_2$ solution and allowed to stand overnight. After filtration, the precipitate formed was washed to remove traces of Ca^{2+} before dissolving in the H_2SO4 solution. The solution formed was brought to near boiling by heating before titrating with 0.05 M (potassium permanganate) $KMnO_4$ solution (AOAC, 1995; Daniel, 2003).

Determination of nitrates content

One gram of homogenized sample was weighed into a conical flask, and then 7 mL of distilled water and 0.25 mL of

Table 1: The mineral composition of six amaranth varieties with respect to grains, fresh leaves, dried leaves and flowering part (mg/100 g)

Varieties	Iron	Zinc	Copper	Manganese
Grains				
Lishe Nyeupe	21.628[t]	7.066[l]	0.662[j]	9.698[q]
Nafaka	33.750[r]	6.836[mn]	0.663[j]	7.997[s]
Lishe Njano	45.987[q]	6.857[mn]	0.664[j]	9.764[q]
White Local	33.578[r]	7.324[k]	0.660[j]	5.963[t]
Bwasi Kijani	27.844[s]	6.668[n]	0.667[j]	21.013[ef]
Bwasi Jekundu	21.349[t]	6.751[n]	0.981[i]	18.798[i]
Fresh leaves				
Lishe Nyeupe	60.021[k]	5.750[o]	2.066[c]	16.506[k]
Nafaka	75.884[i]	75.89[a]	1.318[h]	11.794[o]
Lishe Njano	93.258[g]	9.243[i]	3.284[a]	25.577[d]
White Local	78.250[h]	9.805[g]	2.251[b]	34.869[a]
Bwasi Kijani	55.598[l]	9.171[i]	1.698[e]	28.730[b]
Bwasi Jekundu	33.530[r]	19.187[b]	1.027[i]	9.264[r]
Dried leaves				
Lishe Nyeupe	225.838[d]	9.453[h]	0.976[i]	20.862[fg]
Nafaka	258.353[b]	15.355[c]	0.667[j]	21.091[e]
Lishe Njano	219.512[e]	10.741[f]	0.658[j]	20.818[g]
White Local	111.858[f]	8.391[j]	0.662[j]	11.546[p]
Bwasi Kijani	229.388[c]	13.024[e]	0.985[i]	20.719[g]
Bwasi Jekundu	284.384[a]	13.532[d]	0.642[j]	20.287[h]
Flowering part				
Lishe Nyeupe	46.908[p]	5.559[p]	1.500[g]	12.972[n]
Nafaka	51.171[m]	7.318[k]	1.573[f]	13.886[l]
Lishe Njano	66.862[j]	10.593[f]	2.074[c]	18.483[j]
White Local	48.547[o]	5.024[q]	1.485[g]	13.450[m]
Bwasi Kijani	50.358[n]	7.026[lm]	1.540[fg]	13.923[l]
Bwasi Jekundu	59.549[k]	9.324[hi]	1.831[d]	26.440[c]

Values are expressed as mean (n=3); Values with different superscripts down the column are significantly different from each other at p<0.05

4% NaOH were added. The content in the flask was warmed at 80 °C for 25 minutes with occasional shaking. The resulting solution was filtered into a 100 mL volumetric flask and then diluted to the mark. 2 mL of aliquot was taken into the test tube cooled in ice then 0.5 mL of 5% Ag_2SO_4 solution was added followed by 3.5 mL of 98% H_2SO_4 and 0.5 mL of 5% Phenol solution. The solution was allowed to stand for 20 minutes with occasional shaking. 5 mL of Toluene was added and then shaken for 5 minutes. The aqueous layer was discarded and the supernatant was washed twice with 10 mL portions of distilled water by shaking for 2 minutes each time that aqueous layer was discarded. The organic phase was shaken with 10 mL of 10% Na_2CO_3. The washed organic phase was read for absorbance at 407 nm (Gaya & Alimi, 2000).

Statistical analysis

The data generated from each sample was subjected to statistical analysis using two-way analysis of variance (two-way ANOVA) tests and the difference in mean was compared using Duncan's new Multiple Range test ($p \leq 0.05$) (Duncan, 1955). This was done to test for differences in nutrient contents among the test varieties and the test treatments.

RESULTS AND DISCUSSION

Mineral composition of amaranths

Table 1 shows the results of minerals contents (mg/100 g) of six amaranth varieties, for each variety in grains, dried leaves, fresh leaves, and flowering part of amaranth. The results showed that iron was generally high in all varieties of dried leaves of amaranth ranging from 111.858 to 284.384 mg/100 g. Zinc appeared high in fresh leaves of amaranth ranging from 5.750 to 75.89 mg/100 g. Manganese was high in fresh leaves of amaranth (9.264 - 34.869 mg/100 g), and copper was high in fresh leaves (1.027 - 3.284 mg/100 g). Zinc, copper, and manganese appeared to be high in Nafaka (*A. hypochondriacus*) with 75.89 mg/100 g, Lishe njano (*A. hypochondriacus*) with 3.284 mg/100 g and White local (*A. dubius*) with 34.869 mg/100 g varieties of the fresh leaves of amaranth respectively.

These results are supported by a study conducted by Makobo *et al.* (2010) which showed the levels of manganese, copper, and zinc were high in fresh amaranth and decreased in dried amaranth. Iron concentration increased in dried

Table 2: Proximate composition of six amaranth varieties with respect to grains, fresh leaves, dried leaves and flowering part (%)

Varieties	Moisture	*CP	*CF	Lipid	Ash	*CHO
Grains						
Lishe Nyeupe	9.643[j]	14.753[cd]	6.557[b]	8.473[bc]	2.373[d]	51.640[h]
Nafaka	9.640[j]	15.280[b]	3.903[d]	8.447[c]	2.147[e]	56.677[f]
Lishe Njano	10.503[i]	14.530[d]	2.520[f]	8.933[ab]	2.740[b]	58.257[e]
White Local	9.397[j]	14.743[cd]	13.040[a]	7.923[d]	2.473[cd]	39.387[i]
Bwasi Kijani	10.130[i]	15.787[a]	4.867[c]	8.510[bc]	2.920[a]	52.923[g]
Bwasi Jekundu	9.483[j]	14.980[c]	13.163[a]	9.273[a]	2.380[d]	37.557[j]
Fresh leaves						
Lishe Nyeupe	86.523[a]	4.420[i]	1.757[ij]	1.470[j]	2.737[b]	1.337[no]
Nafaka	86.513[a]	3.837[j]	1.963[hi]	1.697[j]	1.913[f]	2.113[m]
Lishe Njano	86.203[ab]	3.613[jk]	1.313[l]	4.530[g]	2.653[bc]	0.373[P]
White Local	85.917[bc]	4.247[i]	1.490[kl]	2.433[i]	1.323[g]	3.100[kl]
Bwasi Kijani	85.597[cd]	4.153[i]	1.623[jk]	2.320[i]	1.403[g]	3.283[k]
Bwasi Jekundu	85.350[d]	5.240[g]	2.297[fg]	2.617[i]	1.420[g]	0.780[op]
Dried leaves						
Lishe Nyeupe	9.270[jk]	4.827[h]	1.877[hi]	1.713[j]	2.460[cd]	77.977[b]
Nafaka	10.217[i]	3.510[k]	1.907[hi]	4.540[g]	1.863[f]	76.053[c]
Lishe Njano	8.937[k]	3.543[k]	2.933[e]	4.843[g]	2.557[bcd]	74.253[d]
White Local	9.343[j]	4.163[i]	2.130[gh]	6.767[e]	1.843[f]	75.833[c]
Bwasi Kijani	8.507[l]	5.770[f]	1.563[jk]	2.387[i]	1.467[g]	78.743[a]
Bwasi Jekundu	11.367[h]	4.713[h]	2.487[f]	2.357[i]	2.473[cd]	74.123[d]
Flowering part						
Lishe Nyeupe	82.793[e]	4.800[h]	2.870[e]	1.637[j]	2.630[bc]	2.400[lm]
Nafaka	81.993[f]	4.263[i]	5.057[c]	0.470[k]	2.127[e]	1.027[nop]
Lishe Njano	82.233[f]	3.430[k]	1.557[jk]	5.370[f]	2.530[cd]	3.320[k]
White Local	78.413[g]	5.603[f]	2.543[f]	6.767[e]	1.843[f]	2.287[m]
Bwasi Kijani	82.127[f]	6.230[e]	2.043[h]	2.450[i]	1.500[g]	3.607[k]
Bwasi Jekundu	82.133[f]	5.657[f]	2.097[gh]	3.537[h]	2.403[d]	1.683[mn]

Values are expressed as mean (n=3); Values with different superscripts down the column are significantly different from each other at p<0.05;
*CHO: Carbohydrate; * CF: Crude fibre; *CP: Crude protein

leaves, the study by Joshi and Mehta (2010) on the effect of dehydration of iron content also supports the findings of this study as well.

Proximate Composition of Amaranth Varieties and Treatments

Table 2 shows the proximate levels in six amaranth varieties, for each variety in its grains, dried leaves, fresh leaves, and flowering part of amaranth. The values are expressed in percentage (%). Crude protein, crude fibre, and crude fat (lipid) were significantly high ($p<0.05$) in grain amaranth performing in a range of (14.530 - 15.787%), (2.520 - 13.040%), and (7.923 - 9.273%) respectively. Ash was also high in amaranth grains ranging from 2.373 to 2.920%, moisture content was significantly high in fresh leaves of amaranth ranging from 85.350 to 86.523%, and total carbohydrates were found high in dried leaves of amaranth ranging from 74.123 to 78.743%. Therefore, the results showed that grains were significantly high in crude protein (especially Bwasi kijani variety), lipids (especially Bwasi jekundu variety), and crude fibre (especially White local variety). Whereas carbohydrates were significantly high in dried leaves of amaranth (especially Bwasi kijani variety) as shown in Table 2. The study conducted by Mnkeni *et al.* (2007) on the nutritional quality of vegetables and seeds from different accessions had shown that there were significant differences between the vegetables from the different accessions of amaranthus which supports the findings of this study.

Anti-nutrient composition of amaranth varieties and treatments

Table 3 shows the anti-nutrient contents (nitrate and oxalate) in six amaranth varieties with respect to grains, dried leaves, fresh leaves, and flowering part of amaranth. The results showed that oxalate was significantly high at ($p<0.05$) in all six varieties of the dried amaranth leaves ranging from 360.3 to 378.5 mg/100 g compared to grains, fresh leaves and flowering part of amaranth. Oxalate content within six varieties of dried amaranth leaves did not show a significant difference in their levels. Nitrate content was seen to be high in dried amaranth leaves which show significant differences within varieties ranging from 115.23 to 137.06 μg/g. Other varieties did not show significant differences in nitrate content among different treatments such as Lishe njano grain (119.15 μg/g), Bwasi kijani fresh leaves (118.41 μg/g), White local dried leaves (118.81 μg/g) and Bwasi kijani flower (119.05 μg/g). With these findings, dried amaranth was seen to contain high levels of anti-nutrients (oxalate and nitrate) as shown in Table 1. This is supported by the study conducted by Joshi and Mehta (2010) on effect of dehydration on the nutritive value of drumstick leaves, whereby oxalate content increased from 101 mg/100 g in fresh leaves to 430 mg/100 g in sundried leaves.

Table 3: Anti-nutrient contents of six amaranth varieties with respect to grains, fresh leaves, dried leaves and amaranth flower

Varieties	Nitrate(μg/g)	Oxalate (mg/100 g)
Grains		
Lishe Nyeupe	92.44[l]	108.0[j]
Nafaka	96.00[k]	111.6[ij]
Lishe Njano	119.15[e]	98.8[jk]
White Local	113.14[gh]	90.3[jk]
Bwasi Kijani	101.56[j]	77.9[k]
Bwasi Jekundu	98.10[k]	115.6[ij]
Fresh leaves		
Lishe Nyeupe	117.34[ef]	230.0[d]
Nafaka	122.14[cd]	298.9[b]
Lishe Njano	103.07[ij]	189.3[ef]
White Local	112.66[gh]	270.6[c]
Bwasi Kijani	118.41[e]	175.3[f]
Bwasi Jekundu	115.30[fg]	177.8[f]
Dried leaves		
Lishe Nyeupe	137.06[a]	378.5[a]
Nafaka	127.26[b]	360.8[a]
Lishe Njano	123.47[c]	368.8[a]
White Local	118.81[e]	371.8[a]
Bwasi Kijani	119.70[de]	360.3[a]
Bwasi Jekundu	115.23[fg]	364.5[a]
Flowering part		
Lishe Nyeupe	112.18[h]	209.9[de]
Nafaka	122.14[cd]	136.6[hi]
Lishe Njano	127.78[b]	235.7[d]
White Local	105.45[i]	149.9[gh]
Bwasi Kijani	119.05[e]	170.4[fg]
Bwasi Jekundu	114.44[gh]	229.1[d]

Values are expressed as mean (n=3); Values with different superscripts down the column are significantly different from each other at $p<0.05$.

CONCLUSIONS

It is believed that the results of this study will help to stimulate the consumption or utilization of amaranth as a good source of nutrients needed in combating nutritional deficiencies according to the nutritional needs of individuals towards reducing malnutrition cases and enhancing nutrition security. The study has shown that drying of the amaranth leaves results in the concentration of nutrient iron although anti-nutrients become high too, which is disadvantageous as it lowers the bioavailability of the micronutrients like minerals in the body. On the other hand, since dehydration is one of the most possible strategies for the preservation of green leafy vegetables, on the requirement of certain nutrients such as iron due to its quality of iron content that will increase blood levels then the dried amaranth can be used for supplementation but with a cooking method of discarding water after boiling the dried leaves. This can lower anti-nutrient content so as to minimize its effect of lowering nutrients bioavailability. The common practice of discarding amaranth flowers when preparing amaranth leafy

vegetables don't appear to be supported since the study has shown that the nutrient composition is not so far different from the fresh leaves. When the vegetative stage ends and flowering begins, subsequent harvests are lower in nutritional quality, so at this harvesting stage in case of obtaining this kind of amaranth, it is recommended not to discard the flower heads of amaranth as it will contribute into the nutritive value of the harvest instead of removing and making them less.

RECOMMENDATIONS

The best identified Amaranthus varieties from this study can serve as good starting materials for plant breeders to come up with more desired plant lines composed of more different nutrients widening its potential in nutrition security. Also, amaranth grain can serve as a good option in the fortification of staples like maize flour, sorghum flour, and wheat, which are nutritionally low in protein and other essential nutrients. The findings of the study have shown that iron content is high in dried amaranth leaves making it best to supplement with iron and meet the iron needs/requirements of the body. Zinc, copper, and manganese contents are high in fresh amaranth leaves making them of nutritional importance to cover the required levels in the body on consumption. Proximate levels of crude fat, crude fibre, and crude protein are high in grains of amaranth.

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