

**EFFECT OF PROCESSING METHODS ON SOME NUTRIENTS, ANTINUTRIENTS
AND TOXIC SUBSTANCES IN *AMARANTHUS CRUENTUS*.**

^{1,*}Emmanuel O. Ogbadoyi, ^{1,4}Amanabo Musa, ²Johnson A. Oladiran, ³Matthew I.S. Ezenwa,
¹Funmilayo H. Akanya

¹Global Institute for Bioexploration/Department of Biochemistry, Federal University of
Technology, Minna, Nigeria

²Department of Crop Production, Federal University of Technology, Minna

³Department of Soil Science, Federal University of Technology, Minna

⁴Present address: Department of Biochemistry, Ibrahim Badamosi Babangida University, Lapai,
Niger State, Nigeria.

*Corresponding author: ogbadoyieo@gmail.com; Tel: +234 803 450 9296

ABSTRACT: The presence of antinutrients and toxic substances severely limits the nutritional benefits of vegetables. The objective of this study was to assess the effects of processing methods on some of these substances. Effects of boiling and sun drying on oxalate, cyanide and nitrate, vitamin C, β -carotene, and the mineral elements Fe, Cu, Mg, Na and K in *Amaranthus cruentus* were investigated. Both methods significantly ($p < 0.05$) reduced oxalate, cyanide and nitrate levels. Vitamin C content was significantly ($p < 0.05$) decreased. β -carotene level increased on boiling but was reduced in sundried vegetable. Boiling exceeding 5 minutes significantly ($p < 0.05$) reduced β -carotene level. The mineral elements decreased upon boiling but sun drying had no significant effect on their levels. We conclude that both methods are effective means of reducing the levels of antinutrients and toxic substances in *Amaranthus cruentus* to tolerable levels with boiling being a better method.

Key words: *Amaranthus cruentus*, cyanide, nitrate, oxalates, micronutrients, antinutrient

Practical Applications:

Many antinutrients (oxalate, phytate, etc) and toxic substances (cyanide, nitrate, phenols, etc) are present in many plants and vegetables. Vegetables are believed to be the most important source of nitrate in human nutrition. The nutritional quality of plants and vegetables are therefore severely limited by the presence of these substances. Cassava for example is known to contain high levels of cyanide, a respiratory poison. Consumption of vegetables in their fresh form which is believed to contain more micronutrients than processed vegetables becomes a major health concern because of the high levels of antinutrients and toxic substances that might be ingested with the associated health problems. Economically, this is a serious problem for vegetable farmers and grocery shop owners. The findings that boiling and sun drying reduce the levels of toxic substances and antinutrients to tolerable levels without dangerously compromising the micronutrients contents of vegetables are a plus for vegetable farmers.

INTRODUCTION

Amaranthus, commonly called “Alayyaho” in Hausa and “Tete” in Yoruba, is a widely distributed genus of short-lived herbs, occurring mostly in temperate and tropical regions. There are about 60 species of *Amaranthus* and several of them are cultivated as leafy vegetables, cereals or ornamental plants (Dhelli et al., 2006; He, 2002; Schippers, 2000).

Amaranthus cruentus is an herbaceous annual leafy vegetable that can be produced for fresh market in 4 - 6 weeks after planting. It can be produced all year round depending on the availability of water. This plant requires loamy to sandy loam soil for good yield and does well in soils with high organic matter content (Grubben, 1986). In Nigeria, amaranthus leaves combined with condiments are used to prepare sauce (Akubugwo *et al.*, 2007; Mepha *et al.*, 2007; Oke, 1983).

Amaranthus cruentus has a high nutritional value because of the high levels of vitamins, including β -carotene (precursor of vitamin A), vitamin B6, vitamin C, riboflavin, and folate, and dietary minerals including calcium, iron, magnesium, phosphorus, potassium, zinc, copper, and manganese (Makus and Davis, 1984; Sussan and Anne, 1988). This vegetable is also rich in lysine, an essential amino acid that is lacking in diets based on cereals and tubers (Schipper, 2000).

Despite these nutritional benefits, the vegetable is known to bioaccumulate various toxic substances and antinutrients that might undermine these nutritional benefits. These substances include alkaloids, phytate, cyanide, nitrates, and oxalates. Oxalate and phytate are known to chelate mineral elements (Ca^{2+} , Fe^{2+} , Na^+ , K^+ etc.) in the body making them unavailable to the body. Oxalate in combination with calcium leads to the formation of insoluble calcium oxalates which are precipitated and deposited in the kidney to form kidney stone (Prien, 1991). High level of nitrates in vegetables when ingested can be converted to nitrite which can lead to cancer and methemoglobinemia or blue-baby disease (Gupta *et al.*, 2000; Macrae, *et al.*, 1997; Oguchi *et al.*, 1996; Takebe and Yoneyame, 1997). Cyanide is a potent respiratory poison which exerts its ultimate lethal effect of histotoxic anoxia by binding to the active site of cytochrome oxidase, thereby stopping aerobic cell metabolism (Ames *et al.*, 1981, Ellenborn and Barcelonx, 1988).

It has been documented in that various processing methods reduce the levels of some of these toxic substances in vegetables (Ogbadoyi *et al.*, 2006). Considering the nutritional values of *Amaranthus cruentus* and the disease conditions associated with high levels of these inherent plant toxins, this study was designed to evaluate the effects of processing methods on the levels of cyanide, nitrate and oxalate with the hope that levels of these undesirable substances will be reduced to tolerable levels without compromising the nutritional benefits derivable from the vegetable.

MATERIALS AND METHODS

Amaranthus cruentus

Fresh samples of amaranthus (*Amaranthus cruentus*) was bought in three sets at different times from different locations namely, Maikunkele, Bosso and Chanchaga markets in Minna town, Nigeria.

Sample processing

Boiling

150g of fresh leaves of *Amaranthus cruentus* were weighed out in two 1000cm³ beakers containing 600cm³ of distilled water. The content of one beaker was boiled for 5 minutes while the content of the second beaker was boiled for 10 minutes. The decoctions were decanted to separate them from the residue and both were kept for analysis.

Drying

The leaves of *Amaranthus cruentus* were weighed, spread in clean containers and dried in the sun. The vegetables were turned occasionally in the container while in the sun until they were properly dried as indicated by caking. The dried samples were then used for the required analysis.

Analysis of processed samples

Processed samples were analysed for their levels of oxalate, nitrate, cyanide, and mineral elements (Fe, Cu, Mg, Na and K).

Cyanide

Alkaline picrate method of Ikedobi *et al.* (1980) was used to analyse the cyanide content in the test samples.

Nitrate

The nitrate content in the test samples was determined by the colourimetric method as described by Sjoberg and Alanka (1994).

Oxalate

Both soluble and total oxalates in the fresh and processed samples were determined by titrimetric method of Oke (1966).

 β -carotene

β -carotene was determined by ethanol and petroleum ether extraction method as described briefly below. 2.0 grammes of Na_2SO_4 was added to 10.0g of vegetable leaves and ground in mortar. The ground vegetables were extracted with 100cm³ of hot 95% ethanol for 30 minutes in hot water bath. The extract obtained was filtered and measured. Water was added to the extract to bring the percentage of the ethanol extract to 85%. The 85% ethanol extract was cooled in a cold water bath for some minutes. After cooling, the ethanol extract was put inside separating funnel and 30cm³ of petroleum ether was added and the mixture shaken. The separating flask was clamped to the retort stand for some time to allow the solution to settle down into layers. The bottom layer containing ethanol was collected into the beaker while the top layer of the petroleum ether was stored in 250cm³ conical flask. The ethanol layer in the beaker was re-extracted twice with 10cm³ of petroleum ether. The ether layers of re-extraction was added to the original petroleum extract in the conical flask and re-extracted with 50cm³ of 85% ethanol in order to remove any xanthophylls which may be present. The top petroleum ether layer which contained β -carotene was collected, measured and the volume noted.

Lastly, the optical density (OD) of the final petroleum ether extract was determined at the wave length of 450nm with spectrophotometer using petroleum ether as blank. The concentration of β -carotene was calculated thus:

$$A = E\% \times C \times l$$

Where A = absorbance of the sample

E% = extinction coefficient of β -carotene

l = path length (usually 1.0cm).

Ascorbic acid

The ascorbic acid content in the samples was determined by 2, 6-dichlorophenol indophenol method of Eleri and Hughes (1983). Briefly, 2.0 grammes of samples of fresh and processed leaves of the vegetables were weighed separately into mortar and 15cm³ of metaphosphoric acid/acetic acid mixture added to the vegetable in the mortar and ground with pieces of glass. The extract obtained was decanted and filtered into 100cm³ volumetric flask. This extraction was repeated with another 10cm³ of metaphosphoric acid/acetic acid mixtures and finally the residues were washed with distilled water. Both the second extract and washed solution were added to the first extract in the 100cm³ volumetric flask and the volumes made up to mark with distilled water. The prepared indophenol was standardized with 5.0cm³ of freshly prepared standard ascorbic acid. 5.0cm³ of the filtered aliquots of the sample was then titrated against the standardized indophenol and the end point was reached when a faint permanent pink colour was observed. The titre value obtained was used to calculate the actual concentration of ascorbic acid present in the samples.

Fe, Cu, Mg, Na, and K

Mineral elements (Fe, Cu, Mg, Na and K) in samples were determined according to the method of Ezeonu *et al.* (2002). The levels of Fe, Cu, and Mg were determined using atomic absorption spectrophotometer (Alpha 4A AAS) while the levels of Na and K were determined using flame photometer (Jenway PFP7).

Statistical Analysis

Analysis of variance (ANOVA) was carried out using statistical package Minitab to determine variation between treatments (effect of different processing methods). The DUNCAN Multiple Range Test (DMRT) was used for comparison of means.

RESULTS

Cyanide levels

The results showed that the cyanide content in *Amaranthus cruentus* samples processed using different methods were generally lower than that in the fresh samples. The cyanide levels in fresh samples, 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 minutes, leaves boiled for 10 minutes and sun dried leaves were 88.51mg/kg, 47.01mg/kg, 55.81mg/kg, 26.88mg/kg, 21.26mg/kg and 44.36mg/kg respectively (Figure 1). Cyanide content decreased significantly ($p < 0.05$) in all processed samples. 5 and 10 minutes decoctions were not significantly different ($p > 0.05$) in their cyanide content. There was also no significant difference between the residual cyanide in leaves boiled 5 minutes and 10 minutes. However, the amount of cyanide in the boiled leaves was significantly ($p < 0.05$) lower than levels found in the decoctions. Sun drying of the vegetable led to a significant decrease ($p < 0.05$) in its cyanide content (50.11 %) compared with the fresh sample. The amount of cyanide in sundried vegetable was significantly ($p < 0.05$) higher than those found in leaves boiled for 5 and 10 minutes. The cyanide content in sundried leaves was not statistically different when compared with cyanide levels in the decoctions (Figure 1).

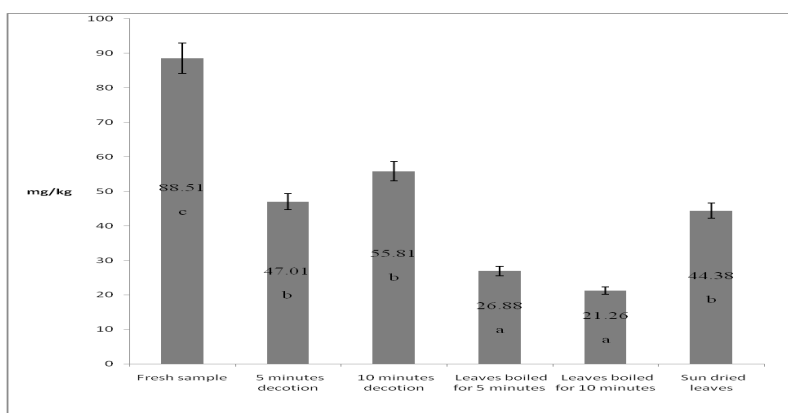


Figure 1: Effect of processing method on cyanide content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

Nitrate Level

The nitrate profile in the various processed samples of *Amaranthus cruentus* were: fresh sample (4335.21mg/kg); 5 minutes decoction (356.67mg/kg); 10 minutes decoction (269.67mg/kg); leaves boiled for 5 minutes (2304.63mg/kg); leaves boiled for 10 minutes (1560.24mg/kg) and sundried leaves (2009.26mg/kg). These results showed that the processing methods led to a significant ($p < 0.05$) reduction of nitrate content of the vegetable.

The results also indicated that increasing time of boiling significantly reduced the nitrate content of the vegetable, as there was more residual nitrate in leaves boiled for 5 minutes when compared with that boiled for 10 minutes (Figure 2). Though more nitrate was extracted from leaves boiled for 10 minutes when compared with the leaves boiled for 5 minutes, 5 minutes decoction had more nitrate content than 10 minutes decoction. The residual nitrate found in leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from nitrate content in sundried leaves.

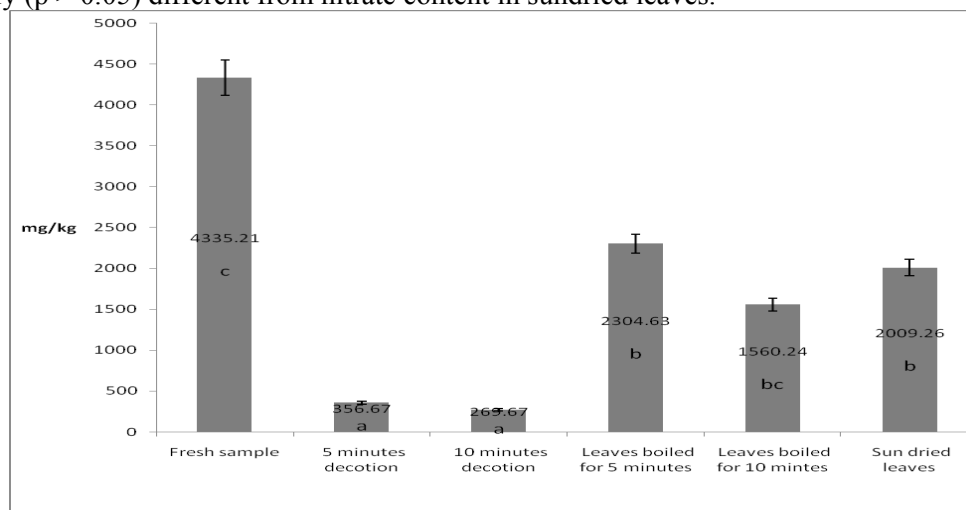


Figure 2: Effect of processing methods on nitrate content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

Soluble Oxalate Level

Soluble oxalate content reduced significantly ($p < 0.05$) in the processed samples. The soluble oxalate content in fresh sample was 4.02g/kg while those of processed samples were: leaves boiled 5 minutes (2.60g/kg), leaves boiled for 10 minutes (2.03mg/kg) and sundried leaves (3.15g/kg). The residual soluble oxalate content in sundried leaves was significantly ($p < 0.05$) higher than that of leaves boiled for 10 minutes but not significantly different from the leaves boiled for 5 minutes. The soluble oxalate content in leaves boiled for 5 minutes was also not significantly different ($p > 0.05$) from those leaves boiled for 10 minutes (Figure 3). With boiling methods of processing, soluble oxalate were not determined in the decoctions, since the oxalate extracted into boiling water is termed the total oxalate (consisting of soluble and insoluble oxalate).

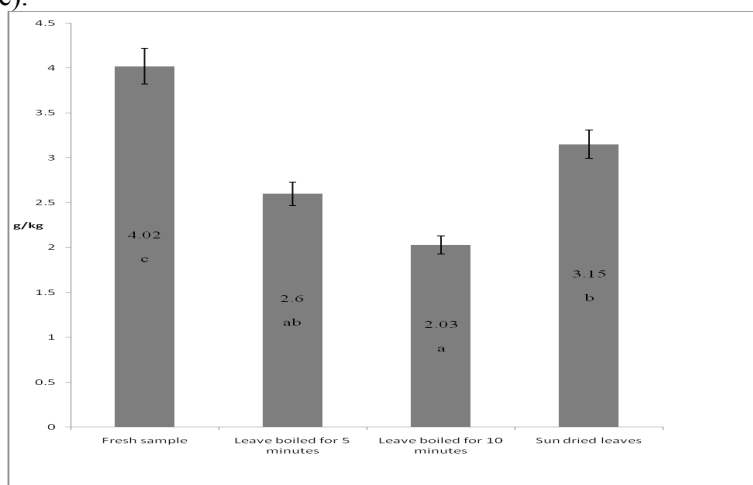


Figure 3: Effect of processing methods on soluble oxalate content in *amaranthus cruentus*. bars carrying the same letters are not significantly different ($p > 0.05$).

Total Oxalate Level

The total oxalate content in various processed samples of *Amaranthus cruentus* were: fresh sample (7.90g/kg), 5 minutes decoction (0.87g/kg), 10 minutes decoction (1.04g/kg), leaves boiled for 5 minutes (5.89g/kg), leaves boiled for 10 minutes (5.37g/kg) and sundried leaves (6.49g/kg). The total oxalate content decreased significantly ($p < 0.05$) in all the processed samples (Figure 4). The total oxalate content was least in the decoctions. The oxalate contents in the 5 and 10 minutes decoctions were not significantly different from each other. The oxalate content in sundried leaves was significantly ($p < 0.05$) higher than residual total oxalate in leaves boiled for 10 minutes, but it was not significantly different from the residual total oxalate content in leaves boiled for 5 minutes.

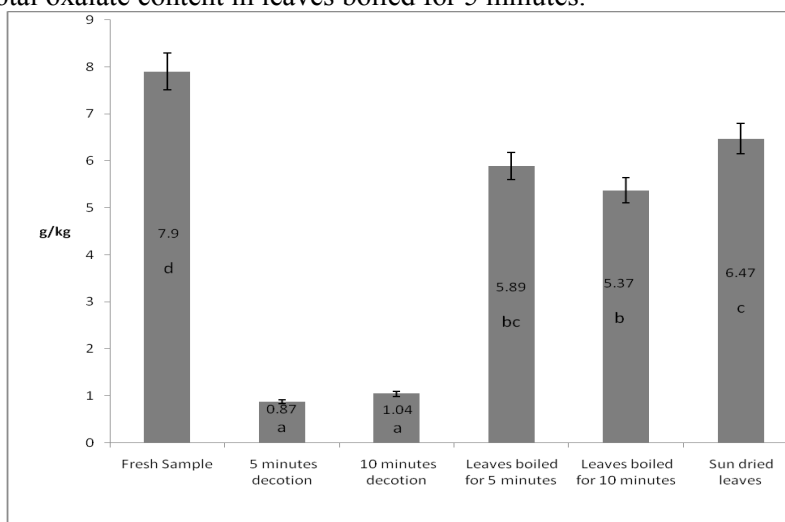


Figure: 4: Effect of processing methods on total oxalate content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

β -carotene Level

Analysis of β -carotene content showed that the amount of β -carotene in the leaves boiled for 5 minutes was higher than in fresh and other processed samples. The β -carotene content in fresh and processed samples of *Amaranthus cruentus* were: fresh sample (11956.80 μ g/100g), 5 minutes decoction (12.70 μ g/100g), 10 minutes decoction (16.00 μ g/100g), leaves boiled for 5 minutes (14725.90 μ g/100g), leaves boiled for 10 minutes (9970.30 μ g/100g) and sundried leaves (8020.00 μ g/100g). Analysis of the data showed that sundrying significantly ($p < 0.05$) reduced the β -carotene content of the vegetable (Figure 5). The percentage reduction of the provitamin brought by solar radiation is 32.93%. With boiling, only leaves boiled for 10 minutes led to a significant reduction of β -carotene of vegetable. Leaves boiled for 5 minutes although, not significantly different from fresh sample, contain more of the provitamin than the fresh sample. The 5 and 10 minutes decoctions were least in β -carotene content (Figure 5).

Vitamin C Level

The vitamin C content in different processed samples of *Amaranthus cruentus* were: fresh sample (69.35mg/100g), 5 minutes decoction (0.92mg/100g), 10 minutes decoction (1.14mg/100g), leaves boiled for 5 minutes (19.22mg/100g), leaves boiled for 10 minutes (14.40mg/100g) and sundried leaves (11.74mg/100g). The vitamin content was reduced significantly ($p < 0.05$) in all processed samples. The percentage losses of the vitamin in leaves boiled for 5 and 10 minutes were 72.30% and 79.20% respectively. Leaves boiled for 5 minutes had significant ($p < 0.05$) higher amount of vitamin C than the leaves boiled for 10 minutes. Only 1.33% and 1.64% were found in 5 and 10 minutes decoction respectively.

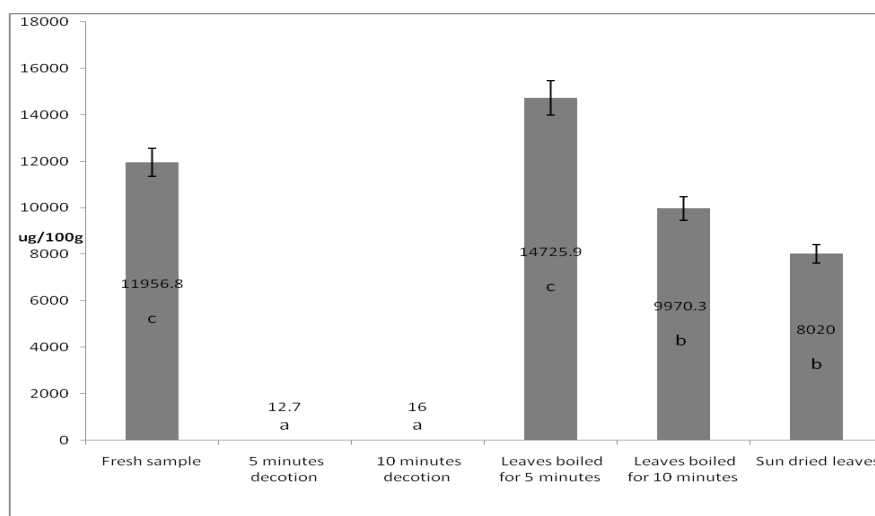


Figure 5: Effect of processing methods on β -carotene content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

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Sun drying significantly reduced ($p < 0.05$) the vitamin content of the vegetable. This processing method resulted in a greater loss of the vitamin (about 83.07% was recorded). Although, there was no significant difference in residual vitamin content in leaves boiled for 10 minutes from the levels in sundried leaves, the later retained less amount of vitamin (Figure 6).

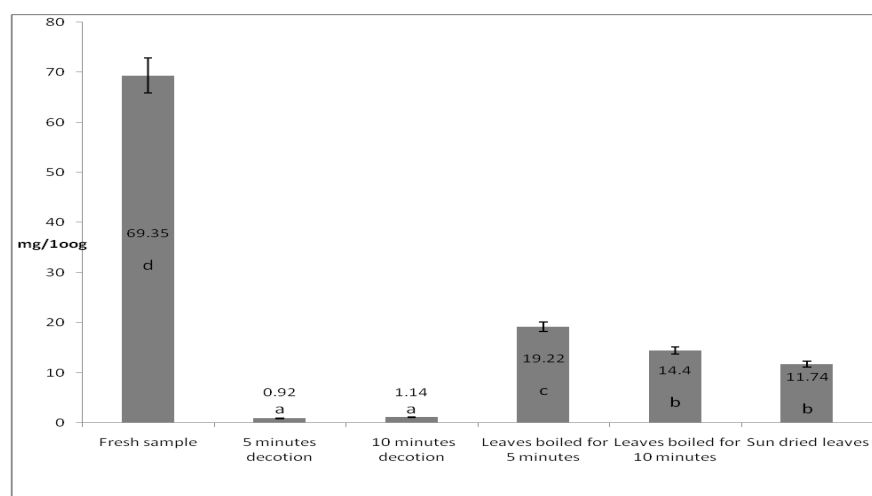


Figure 6: Effect of processing methods on vitamin c content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

Mineral elements

Boiling significantly ($p < 0.05$) reduced the levels of all the mineral elements analysed but sun drying had no significant ($p > 0.05$) effect. The details are shown in Figures 7.1-7.5.

DISCUSSION

The observed higher cyanide content in the fresh sample of *Amaranthus cruentus* compared to processed samples, agrees with the submissions of McDonald (2006), Oboh (2005), and Ojiako (2008) that various food processing methods reduce cyanide content in *Americana* leaves, plants in general, and cassava leaves. In the current study, there was a significantly higher level of cyanide in 5 and 10 minutes decoctions than in the corresponding leaves left upon decanting the decoctions. It therefore follows that boiling of vegetables in water and discarding the water used in boiling would greatly reduce the cyanogenic glycoside content in the vegetable. This observation is in accordance with the reports of Aganga and Tshwenyane, (2003) and Ogbadoyi et al. (2006).

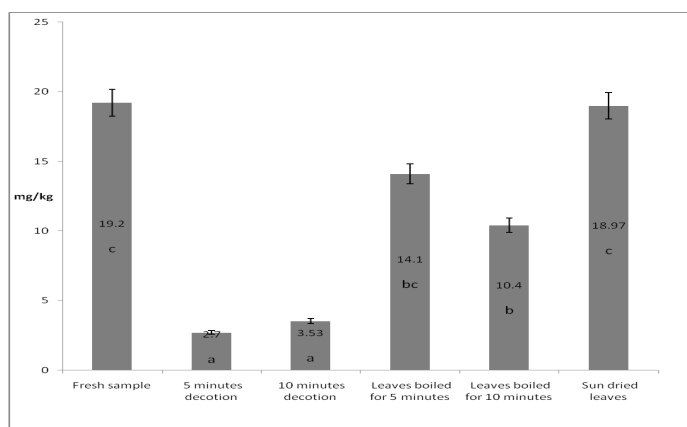


Figure 7.1: Effect of processing methods on iron content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

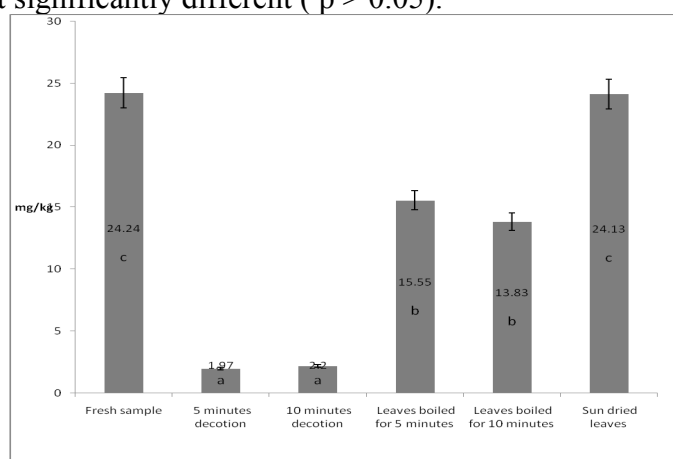


Figure 7.2: Effect processing methods on copper content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

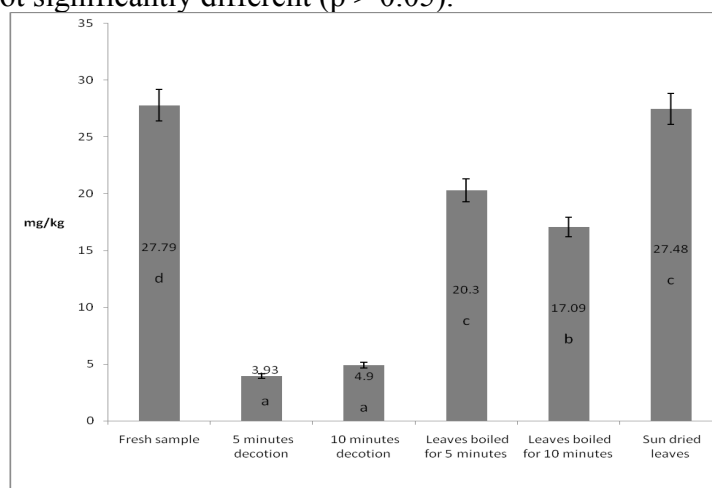


Figure 7.3: Effect of processing methods on magnesium content in *amaranthus cruentus*. bars with the same letter are not significantly different ($p > 0.05$).

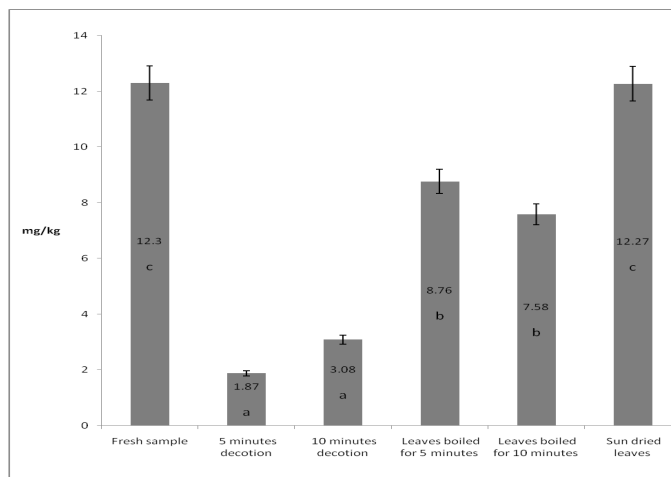


Figure 7.4: Effect of processing methods on sodium content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

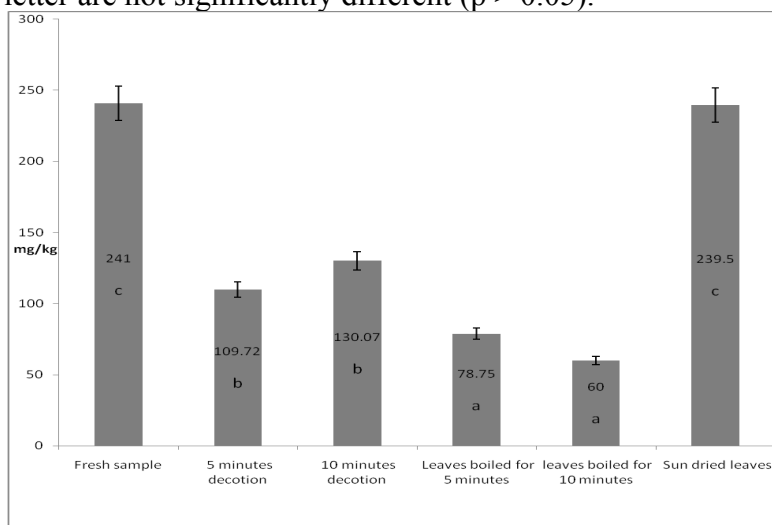


Figure 7.5: Effect of processing methods on potassium content in *amaranthus cruentus*. bars carrying the same letter are not significantly different ($p > 0.05$).

These authors independently observed that boiling of vegetables in water ruptures the cell walls and can subsequently cause the leaching of the cell contents including the antinutrients and toxic substances. The significant decrease in cyanide concentrations during sun drying may be attributed to the volatile nature of cyanide which may have been dissipated during sun drying. This observation is in agreement with the finding of Aganga and Tshwenyane, (2003), Richard, (1991) that cyanides are volatile compounds and can be dissipated while drying. The recorded significant amount of this respiratory poison in sundried samples compared to the levels found in the leaves boiled for 5 and 10 minutes suggests that boiling may be superior in cyanide reduction than sun drying. It may well be attributed to the leakage of cell content as explained above (Aganga and Tshwenyane, 2003; Ogbadoyi *et al.*, 2006) while sun drying is a gradual evaporation process. Cyanide content of fresh sample of the vegetable which is 88.51mg/kg is lower than the highest acceptable or maximum permissible level of 200mg/kg fresh weight of vegetables or forages (Everist, 1981; Richard, 1991).

The implication of these results is that consumption of unprocessed leaves of the vegetable as in ethnomedical practices may not likely deliver toxic levels of the compound to the body. Interestingly, the residual cyanide in the various processed samples had lower cyanide content than the fresh sample. Sun drying is less effective when compared to boiling. This finding may therefore suggest that boiling may be preferred for vegetable processing to sun drying with regard to cyanide content in vegetables; however the water used in boiling must be discarded before using the vegetables for meals.

The significantly higher nitrate content in the fresh sample compared to the processed samples is in line with the findings of Abakr and Ragaa (1996), Anjana *et al.* (2007), Anjana and Muhammed (2006), Waclaw and Stefan (2004), who reported that various heat treatments such as boiling or cooking and drying significantly reduced nitrate content of vegetables. The level of nitrate in 5 minutes decoction was higher than that in 10 minutes decoction. The observed less nitrate level in the leaf residues obtained from 10 minutes of boiling suggests that the nitrate may have been degraded or converted to other compounds with increased heating time as has been reported by Waclaw and Stefan (2004). The significantly higher amount of nitrate in sundried samples compared to the levels found in the leaves boiled for 5 and 10 minutes further shows the superiority of boiling over sun drying. Vegetables with nitrate levels of 1000 – 4000mg/kg are classified as high nitrate content (Anjana *et al.*, 2007). It follows therefore that the *Amaranthus cruentus*, with nitrate level of 4335.21mg/kg is a high nitrate containing vegetable. The nitrate content in fresh sample of *Amaranthus cruentus* is more than the acceptable daily intake (ADI) of 3.65mg/kg for 60kg body weight (219.00mg/day) if 100g samples are consumed per day. The implication of the finding is that regular consumption of raw (unprocessed) samples of the vegetable may likely overload the body with nitrate with attendant health problems of methaemoglobinaemia and cancers (Anjana *et al.*, 2007; Galler, 1997; Oyesom and Okoh, 2006; Waclaw and Stefan, 2004). Fortunately, the processing methods adopted greatly reduced the nitrate content of the vegetable to the acceptable levels.

The observed higher levels of soluble and total oxalates in the fresh sample compared with the levels in processed samples is in harmony with the observation of Abakr and Ragaa (1996), and Adeboye and Babajide (2007) who have reported that various food processing methods reduce oxalate content in plants. The significantly higher levels of oxalate in the fresh *Amaranthus cruentus* leaves than in the boiled leaves agrees with reports of Adeboye and Babajide (2007), Antia *et al.* (2006), Ogbadoyi *et al.* (2006), and Ojiako and Igwe (2008) which showed that proper boiling/cooking of vegetables before consumption significantly reduced the intake of oxalate. The levels of soluble and total oxalates were more elevated in sundried sample than in 5 and 10 minutes boiled leaves, reinforcing the fact that boiling, as a processing method is more effective in reducing the antinutrient content in the vegetable than sun drying method.

The soluble and total oxalate levels of 4.02g/kg and 7.90g/kg respectively in fresh sample of *Amaranthus cruentus* are above the permissible levels of 250mg/100g fresh weight (Oguchi *et al.*, 1996). It therefore means that regular consumption of fresh raw samples of the vegetable without proper processing could deliver toxic levels of the antinutrient into the body with attendant health problems of oxalate toxicosis. This may ultimately result to hypocalcaemia (Antia *et al.*, 2006; Mandel, 1996; Nakata, 2003; Shingeru *et al.*, 2003), formation of kidney stone (Aletor and Omodara, 1994; Fabola, 1990; Nakata, 2003, Proph *et al.*, 2006; Sealy *et al.*, 1990) and reduced bioavailability of the minerals to the body (Aletor and Omodara, 1994; Hodgking *et al.*, 1968; Okon and Akpanyung, 2005; Sandberg *et al.*, 1996). Our current study has shown that only boiling method of processing reduced the soluble oxalate of the vegetable to the tolerable levels. Sun drying could not reduce the total oxalate to within the acceptable levels of not more than 250mg/100g. This implies that sun drying alone may be unable to reduce the oxalate content to acceptable levels.

β -carotene content in leaves boiled for 5 minutes was higher than those boiled for 10 minutes and fresh samples of the vegetable.

This is in line with the report of USDA, (1998) that moderate cooking increases the availability of β -carotene in the vegetables as a result of breakdown of plant cell walls of the vegetable. Rickman *et al.* (2007) further added that loss of soluble solids and the release of protein-bound β -carotenes that occurred during boiling may equally contribute to the observed increase in the provitamin content. The negligible amount of the β -carotene found in 5 and 10 minutes decoctions compared to the amount of the compound in the fresh and boiled vegetables justifies the non- hydrosoluble nature of provitamin (Ejoh *et al.*, 2005; George, 1999; Khalid *et al.*, 2004; Olaofe, 1992; Rickman *et al.*, 2007).

The levels of β -carotene were significantly lower in sundried samples compared with the fresh samples. This observation agrees with the report of Eioh *et al.* (2005) that various food processing methods affect the level of pro-vitamin. The reason for the significant reduction of the β -carotene might be due to the presence of conjugate double bonds in β -carotene, which can be oxidized by molecular oxygen during sun drying to a compound with no β -carotene activity (Rickman *et al.*, 2007). These authors further stressed that the isomerisation of the naturally predominant all-trans carotenoids to cis conformations could as well reduce the β -carotene of the vegetables during sun drying. The higher levels of β -carotene in boiled leaves than in the sundried samples implies that moderate boiling/cooking is superior in conserving and improving the availability of β -carotene than sun drying (Ejoh *et al.*, 2005; USDA, 1998; Rickman *et al.*, 2007). This observation strengthens the earlier submission that boiling as a processing method may be superior to sun drying. The fresh leaves contained over and above the recommended adult daily allowance of 900 μ g vitamin A (Akanya, 2004; George, 1999). Leaves boiled for 5 minutes had more β -carotene. This is in agreement with the earlier reports that moderate cooking improves the availability of the provitamin in the vegetable (Ejoh *et al.*, 2005; Rickman *et al.*, 2007; USDA, 1998). Sun drying significantly decreased the β -carotene content of the vegetable and still provided residual β -carotene (5400 μ g β -carotene) more than the recommended adult daily allowance of 900 μ g vitamin A. Moderate boiling/cooking, especially 5 minutes boiling, however improves the availability of the provitamin when compared with fresh samples. Thus adopting any of the processing methods or both for the vegetables may be sufficient such that there may be no need for pharmaceutical supplements for a healthy individual to meet the normal recommended daily allowance.

In line with available information (George 1999; Olaofe, 1992; Ejoh *et al.* 2005; Rickman *et al.* 2007), the levels of vitamin C in the boiled samples were significantly lower than those of fresh samples. The authors attributed the losses of the vitamin to the thermo sensitive, labile and hydrosoluble nature of the compound. The higher percentage losses of vitamin C in leaves boiled for 10 minutes compared to those boiled for 5 minutes is in accordance with the report of Abakr and Ragaa (1996), Mathook and Imungi (1994), and Rickman *et al.* (2007) that the amount of ascorbic acid lost increases with cooking time. Negligible amount of vitamin C found in the 5 and 10 minutes decoctions in all the vegetables despite the higher percentage losses observed in the boiled leaves confirmed the labile and thermo sensitive properties of vitamin C (George, 1999; Ejoh *et al.*, 2005; Olaofe, 1992; Rickman *et al.*, 2007). Activities of the inherent enzymes (vitamin C oxidase and peroxidase) found alongside the vitamin may be a contributory factor to the significant losses of the vitamin. Wilting is another factor that could be responsible for the vitamin losses during sundrying (Addo, 1983; Fafunso and Bassir, 1976; Keshinro and Ketiku, 1983; Olaofe, 1992). Sun drying appears to be a poor method of processing owing to the higher percentage losses of vitamin C in sundried samples. The level of vitamin C in the fresh sample is 69.35mg/100g which is enough to supply the vitamin above the recommended daily allowance of 60mg (George, 1999; Olaofe, 1992) if 100g of the samples are consumed. Unfortunately, the vegetable contained toxic levels of some antinutrients and toxic substances that need to be reduced to tolerable level through various food processing methods. However, the processing methods used in this study decreased the vitamin C content to less than the recommended daily allowance of 60mg.

Among the processing methods adopted, 5 minutes boiling retained and conserved more of the vitamin in the vegetable leaves than other processing methods, even though the vitamin content was lower than the recommended daily allowance. Considering the pivotal roles of this water soluble vitamin in human health and the associated diseases resulting from its deficiency, pharmaceutical supplementation of the vitamin will be necessary to augment its losses during the various food processing methods. This will enable the body to meet the dietary requirement of the vitamin.

The observed significantly lower Fe, Cu, Mg, Na and K levels in the boiled leaves compared with the fresh samples of the vegetable is in accordance with the submissions of Abakr and Ragaa (1996), Astler-Dumas (1975), Augustine *et al.* (1981), Oboh (2005), Shahnaz *et al.* (2003) that various conventional food processing techniques (blanching, cooking) cause a significant decrease in the mineral content of vegetables. This observation however, contradicts the results of Chweya and Nameus (1997) that the minerals in the vegetables are not affected by cooking/boiling the leaves of the vegetables. Losses of the mineral elements during boiling/cooking were attributed to the leaching of the cell content including minerals during cooking (Abakr and Ragaa, 1996).

Sun drying had no significant effect on the mineral (Fe, Cu, Mg, Na and K) contents in the studied vegetables. This observation is in line with the finding of Chweya and Nameus (1997) who have shown that the mineral elements in the vegetables were not significantly affected by sun drying the vegetables. The reason for the observation may be that sun drying is a gradual evaporation process which does not involve leaching. It should also be noted that minerals are generally non volatile substances.

The amount of Fe in the fresh sample was 19.20mg/kg. Comparing the value with available literature, the vegetable contains an appreciable amount of the mineral. Adequate intake of the vegetable could provide the body with the recommended daily intake of 18mg/day of Fe for normal adult (Tietz *et al.*, 1994). Sundried samples of the vegetables could also furnish the body with daily recommended intake of the mineral, since sun drying had no significant effect on the mineral content of the vegetable (Chweya and Nameus, 1997). Boiled sample of the vegetable could only meet the recommended daily intake of this important mineral involved in cellular metabolism if the water used in boiling (decoctions) is retained. Since controlled boiling and discarding the water used in boiling is one of the effective ways of reducing some of the plant toxins to safe levels (Ogbadoyi *et al.*, 2006), supplementation of mineral with fruits and nutraceuticals becomes necessary.

The concentrations of the Cu in fresh sample, dried sample and leaves boiled for 5 minutes could meet the range of the recommended daily allowance of 1.5 - 3.0mg/day of Cu (Tietz *et al.*, 1994), if 100g of samples were consumed. However, leaves boiled for 10 minutes, could only meet the range of the recommended daily allowance of the mineral if the water used in boiling is included in the meal preparation. But since it is necessary to discard the decoctions in order to remove an appreciable amount of some of the plant toxins (Ogbadoyi *et al.*, 2006); fruits and pharmaceutical supplements may be necessary if the vegetable is to be boiled for 10 minutes.

The Mg content of 27.78mg/kg in the fresh sample of the vegetable is lower than the levels reported in the available literature on some leafy vegetables. For example, 3700mg/kg was reported for *Amaranthus cruentus* and 3259mg/kg for *Corchorus olitorius* (Bolanle *et al.*, 2004), 860mg/kg for *Cleome gynandra* (Chweya and Nameus, 1997), 550mg/kg for spinach (George, 1999) and 266.80mg/kg for *Cnidocolus acontifolus* (Oboh, 2005). The results obtained indicated that the Mg content in fresh samples of the vegetable is low, with processed samples even lower. Thus the vegetables are not likely to supply the mineral to meet the recommended daily allowance of 350mg of Mg/day for normal adult (George, 1999). The implication of this observation is that complete dependency on the vegetables to provide this important cofactor of enzymes involved in cell respiration, glycolysis and transmembrane transporter (Ryan, 1991; Tietz *et al.*, 1994) may lead to the deficiency of the mineral. To avoid this condition, there is a need to balance up the nutrient contents of the soil, to improve the Mg uptake by the plants or by the inclusion of cereals and nuts, which are rich in Mg in our diets as supplements (George, 1999).

The 12.30mg/kg obtained for Na in *Amaranthus cruentus* in this study fall far below those reported in available literature. Values of the mineral reported by authors are: 336.00mg/kg for Cleome gynandra (Chweya and Nameus, 1997), 325.50mg/kg for *Cnidoscolus acontifolus* (Obboh, 2005), 42.30mg/kg for *Ipomoea batatas* (Antia et al., 2006), 966.60mg/kg and 481.90mg/kg for red and green of *Hibiscus sabdariffa* respectively (Adanlawo and Ajibade, 2006), 390mg/kg for *Hibiscus sabdariffa* and 300mg/kg for *Corchorus olitorius* (Aliyu and Morufu, 2006). Low level of the mineral is found in the vegetables when compared with values in the available literatures, thus complete dependency on the vegetable as a major source of the mineral may not meet the body's need. Interestingly, this important mineral, essential for maintenance of fluid balance and normal osmotic pressure in the body for cellular activities (Aliyu and Morufu, 2006; Tietz et al., 1994; Wayne and Dale, 1989) is added in almost every home in the food preparations as condiments to taste in the form of NaCl or table salt (George, 1999; Magmus, 1979; Wayne and Dale, 1989). This supplementation with sodium chloride will compensate for the low levels of the mineral in analysed vegetables.

The K content found in the studied vegetable is 241.88mg/kg. This result revealed that the analysed vegetable contained an appreciable quantity of K in the fresh samples. Thus, the vegetable could be regarded as excellent sources of the mineral. However, during cooking, significant amount of the mineral was leached into the boiling water. Discarding the decoctions may lead to significant loss of the minerals and thus supplementation of the mineral with fruits and whole grains may be necessary.

Conclusion

Our current findings indicate that *Amaranthus cruentus* is a good source of β -carotene (precursor of vitamin A), vitamin C and some essential mineral elements. The level of cyanide in the fresh sample of the vegetable is within the tolerable limit. However, the nitrate and oxalate levels in the fresh sample of the vegetable are high enough to induce toxicity in humans. With careful selection of good choice of processing method, the nutritional potential of this commonly consumed leafy vegetable can be fully harnessed. In this present study, we recommend boiling (especially 5 minutes of boiling) over sun drying as a choice of processing method, as this method significantly reduces the plant toxins and conserves more nutrients.

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