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# Effect of processing methods on some micronutrients, anti-nutrients and toxic substances in *Vernonia amygdalina* leaves

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**Abstract**
Studies were conducted to investigate the effect of processing methods on antinutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and some micronutrients, vitamin C, β-carotene (vitamin A precursor) and mineral elements (Fe, Cu, Mg, Na and K) in *Vernonia amygdalina*. The processing methods used were boiling and sun drying. Results obtained showed that the nitrate content (1347.22 mg/kg) in the fresh vegetable is within the tolerable level and can be well tolerated in our meal. The cyanide level (199.11 mg/kg) is close to the maximum tolerable level of 200 mg/kg fresh weight. The levels of soluble and total oxalates in the fresh samples (2.80 g/kg and 4.76 g/kg respectively), were high enough to induce toxicity in human. All processing methods adopted significantly ($p < 0.05$) reduced the anti-nutrients and toxic substances in the vegetable. Boiling methods reduced the anti-nutrients and toxic substances significantly ($p < 0.05$) more than sun drying. The anti-nutrients and toxic substances decreased with boiling time. The processing methods also decreased vitamin C content significantly ($p < 0.05$) in the vegetable. Boiling methods retained more of the vitamin compared to sun drying. β-carotene levels increased in boiled vegetable, while its content was reduced in sundried sample. However, boiling exceeding 5 minutes led to reduction of the provitamin A content. Mineral elements also decreased with boiling. However, sun drying had no significant effect on the mineral contents of the vegetable. In conclusion, moderate boiling significantly reduces the levels of antinutrients and toxic substances while still conserving most of the micronutrients in amounts sufficient to meet our dietary requirements.

**Keywords:** *Vernonia amygdalina*, anti-nutrients, toxic substances, micronutrients, boiling, sun drying, toxicity.

## INTRODUCTION

*Vernonia amygdalina* (bitter leaf-English) is a leafy vegetable that grows up to 5 m high, with abovate to oblanceolate leaves. This species is frequently found in gardens (Schippers, 2000) and commonly found in Nigeria, Cameroon, Gabon and Congo. *V. amygdalina* is generally raised by stem cutting, which are planted at an angle of 45° to obtain faster sprouting (Schippers, 2000). It is one of the leafy vegetables that can be used to alleviate the problem of micronutrient malnutrition, prominent in tropical Africa (Ejoh *et al.*, 2005). This leafy vegetable is relatively inexpensive, easily and quickly cooked and rich in several nutrients especially β-cartotene and vitamin C, which are essential for human health. The vegetable also provides some minerals such as iron, phosphorus, calcium, potassium (Oshodi, 1992).

Despite these huge nutritional benefits, *V. amygdalina* accumulates some secondary metabolites such as anti-nutrients and other toxic substance which affect health negatively and thereby underscore these nutritional values. For instance, high levels of cyanide cause respiratory poison (Ames *et al*., 1981; Ellenhoro and Bercelonx, 1988). Oxalate lead to the formation of kidney stone and oxalemia (Antia *et al*., 2006: Proph *et al*., 2006: Ogbadoyi *et al*., 2006), while nitrate is a culprit in cancer and methaemoglobinemia in man (Waclaw and Stefan, 2004; Anjana *et al*., 2007). In an attempt to harness the full nutritional benefits that

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abound in this leafy vegetable, the study was designed to determine the effect of various processing methods on the levels of its micronutrients, anti-nutrients and toxic substances. This is aimed at determining the processing method that will significantly reduce the phytotoxic constituents to the tolerable levels, and at the same time retaining the essential nutrients.

## MATERIALS AND METHODS

*Vernonia amygdalina*

The fresh samples of *Vernonia amygdalina* was bought in three sets at different time from Maikunkele, Bosso and Chanchanga markets in Minna town, Nigeria.

*Chemicals*

Except otherwise stated, all the chemicals used were of analytical grade and were purchased from BDH and Sigma Chemical Companies, both in England.

*Sample treatment*

*Cooking (boiling)*: A known weight **(**150 g) of fresh leaves of *V. amygdalina* were put in two beakers containing 600 $cm^3$ of distilled water. The content of one of the beakers was cooked for 5 minutes while the content of the second beaker was cooked for 10 minutes. The levels of phytotoxins (cyanide, nitrate, soluble and total oxalates), vitamins and mineral elements (β-carotene, vitamin C, Fe, Mg, Cu, Na and K) in the decoctions and in the cooked leaves were determined according to standard methods.

*Drying:* The leaves of *V. amygdalina* were weighed, spread in clean containers and sun-dried. The vegetables were turned occasionally in the container while in the sun until they started caking; an indication that they were properly dried. The dried samples were then used for the required analysis.

*Determination of anti-nutrients, mineral elements and vitamins*

Both the soluble and total oxalates in the fresh and processed samples were determined by titrimetric method described by Oke, (1966). The nitrate content in the test samples was determined by the colourimetric method described by Sjoberg and Alanko (1994). Alkaline picrate method described by Ikediobi *et al* (1980) was used to analyse the cyanide content in the test samples.

The mineral elements (Fe, Cu, Mg, Na and K) in the samples were determined according to the method of Ezeonu *et al* (2002). Briefly, the leaves of the vegetables (fresh and processed form) were oven-dried at 110$^{\circ}$C for 24 hours. After drying, they were ground into powder with pestle and mortar and 0.500 g of the ground dried samples were weighed into a boiling tube and 5.0 $cm^3$ of digestion mixture (comprising of concentrated perchloric acid and nitric acid in the ratio of 1:2) was added. The resulting mixtures were swirled and left in a fume cupboard over night. The samples were then digested at the temperature of 150$^{\circ}$C on a hot plate for 2 hours and or until frothing ceased. At the end of this period, the samples were then cooled for 10 minute after which 3.0 $cm^3$ of 6.0M HCl was added and further digested for another 1½ hour. After cooling, the contents of each tube was made up to 50 $cm^3$ with distilled deionised water in volumetric flask and later transferred into sample bottles. The sample were analysed for their mineral content of interest using atomic absorption spectrophotometer (Alpha 4A AAS) and flame photometer (Jenway PFP7) for Na and K only.

The ascorbic acid content in the samples was determined by 2, 6-dichlorophenol indophenols method of Eleri and Hughes (1983). Briefly, 2.0 g of the fresh and processed samples were weighed separately into a mortar and 15 $cm^3$ of metaphosphoric acid/acetic acid mixture added. This was ground with pieces of glasses. The extract obtained was decanted and filtered into 100 $cm^3$ volumetric flask. This process was repeated one more time. Both the second extract and washed solution were added to the first extract in the 100 $cm^3$ volumetric flask and the volumes made up to the marked level with distilled water. The prepared indophenol was standardized with 5.0 $cm^3$ of freshly prepared standard ascorbic acid. Thereafter, 5.0 $cm^3$ of the filtered aliquots of the sample was then titrated against the standard 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. Furthermore, β-carotene was determined by ethanol and petroleum ether extraction method. Briefly, 2.0 g of $Na_2SO_4$ was added to 10.0 g of vegetable leaves and ground in mortar. The ground vegetables were extracted with 100 $cm^3$ of hot 95% ethanol for 30 minutes in hot water bath. The extract obtained was filtered and the volume measured. Water was added to the extract to bring the percentage of the ethanol extract to 85% after which the solution was cooled in a cold water bath for some minutes. After cooling, the ethanol extract was placed in the separating funnel and 30 $cm^3$ of petroleum ether added and shaken. The bottom layer containing ethanol was collected into the beaker while the top layer of the petroleum ether was stored in the conical flask. The ethanol layer in the beaker was re-extracted twice with 10 $cm^3$ of petroleum ether. The ether layers of was added to the intial petroleum extract in the conical flask and re-extracted with 50 $cm^3$ of 85% ethanol in order to remove any xanthophylls which may be present. The volume of petroleum ether layer containing β-carotene was noted. Lastly, the optical density (OD) of the final petroleum ether extract was read at the wave length of 450 nm with spectrophotometer using petroleum ether as blank.

The concentration of β-carotene was calculated from the expression:

$$A = E^{\circ} \times C \times l$$

Where: A = absorbance of the sample

$E^{\circ}$ = extinction coefficient of β-carotene

l = path length (usually 1.0cm).

*Statistical analysis*

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

**RESULTS**

The analysis of *V. amygdalina* showed that fresh samples had higher cyanide content than any of the processed samples In specific terms, the cyanide contents in fresh sample, 5 minutes decoction, 10 minutes decoction, 5 minutes boiling, 10 minutes boiling and sun-drying were 199.11 mg/kg, 51.45 mg/kg, 55.06 mg/kg, 62.16 mg/kg, 54.44 mg/kg and 107.49 mg/kg respectively. The cyanide levels in 5 minutes decoction, 10 minutes decoction, and 5 and 10 minutes boiling were not significantly different from each other (Figure 1). However, sun-dried vegetable leaves had a significantly ($p < 0.05$) higher amount of the cyanide than the leaves that were boiled for 5 and 10 minutes (Figure 1).

Various processing techniques significantly ($p<0.05$) reduced the nitrate levels of the vegetables. The nitrate content in sun-dried sample was significantly more ($p < 0.05$) than in any other processed samples. The residual nitrate in leaves boiled for 5 minutes was not significantly different from those boiled for 10 minutes (Figure 2). In this processed vegetable samples, only small amount of nitrate were found in the water extracts when compared with the amount of the compound extracted from the boiled leaves. Decoctions had the least amount of nitrate compared to the other processed samples (Figure 2).

The soluble oxalate content of *V. amygdalina* decreased significantly ($p < 0.05$) with the processing methods used. The residual soluble oxalate in sun-dried sample leaves boiled for 5 and 10 minutes were not significantly different ($p > 0.05$) from each other (Figure 3).

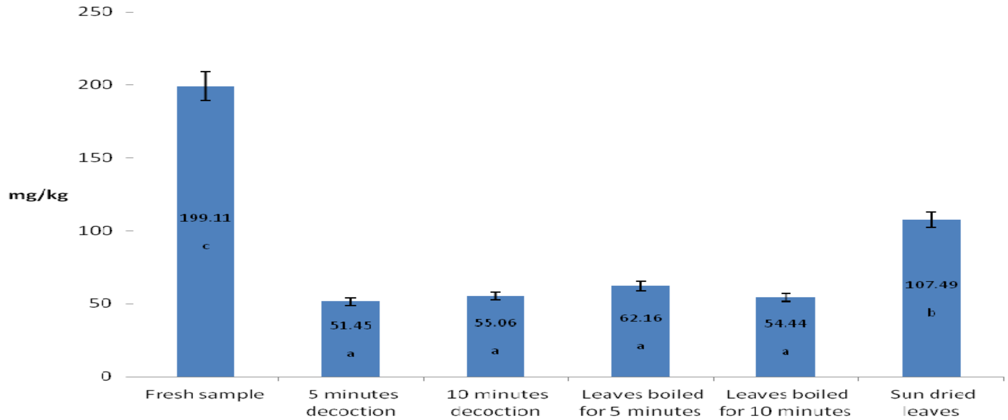


**Figure 1: Effect of processing methods on cyanide content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different (p > 0.05).**

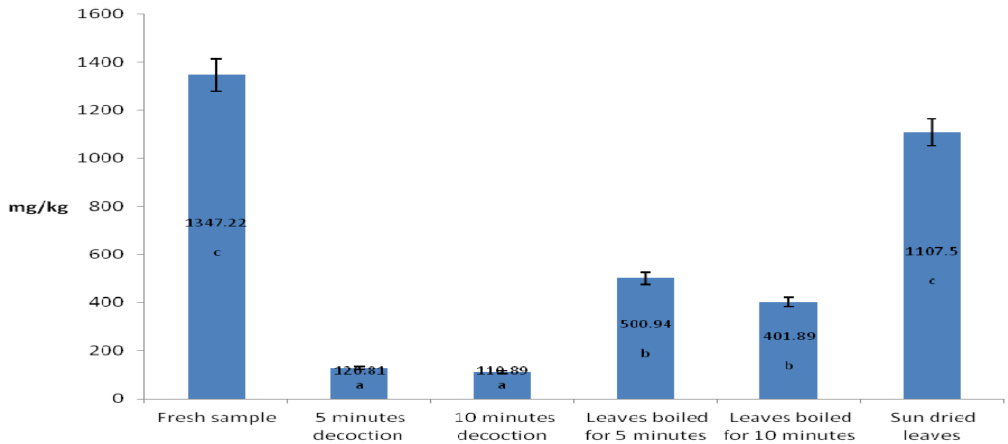


**Figure 2: Effect of processing methods on nitrate content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different (p > 0.05).**

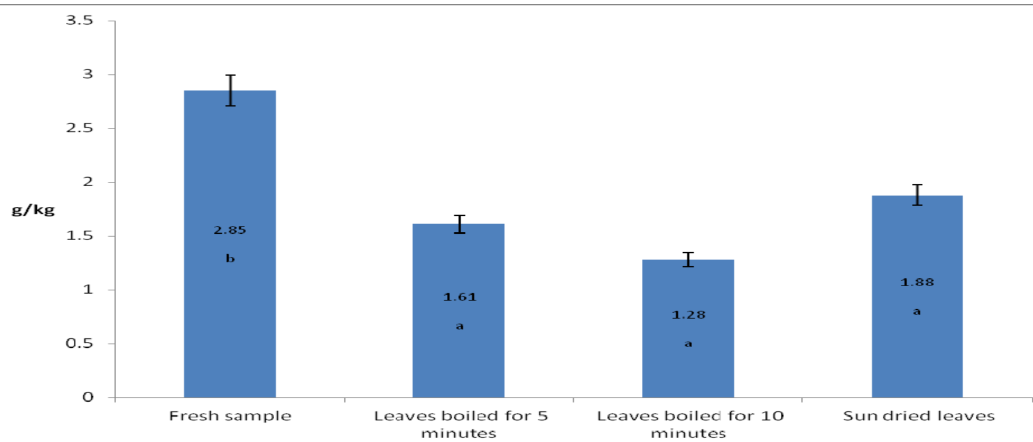


**Figure 3: Effect of processing methods on soluble oxalate content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different (p > 0.05).**

The concentration of total oxalate in the fresh was the highest compared to the other processed samples (Figure 4). Although, the residual total oxalate content in the leaves boiled for 5 and 10 minutes were not significantly different from each other, the former appear to contain more oxalate than the later. Furthermore, the oxalate levels in the boiled samples were significantly lower than that in the sun-dried leaves (Figure 4).

Data analysis indicated that sun-drying significantly ($p < 0.05$) decreased the β-carotene content of the vegetable (to about 40.22%). The β-carotene content in the vegetable leaves boiled for 5 minutes was significantly ($p < 0.05$) higher than in fresh sample and in the leaves boiled for 10 minutes. Even though the provitamin content in fresh sample was not significantly different from the level in the leaves boiled for 10 minutes, numerically, the former had more of the caroteniods than the later. Negligible amount of the β-carotene were found in the decoctions (Figure 5).

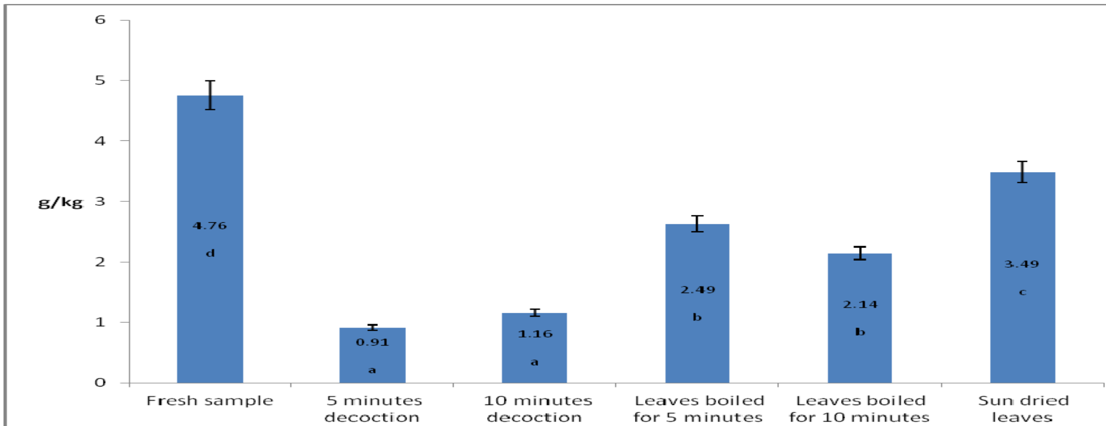


**Figure 4: Effect of processing methods on total oxalate content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different ($p > 0.05$).**

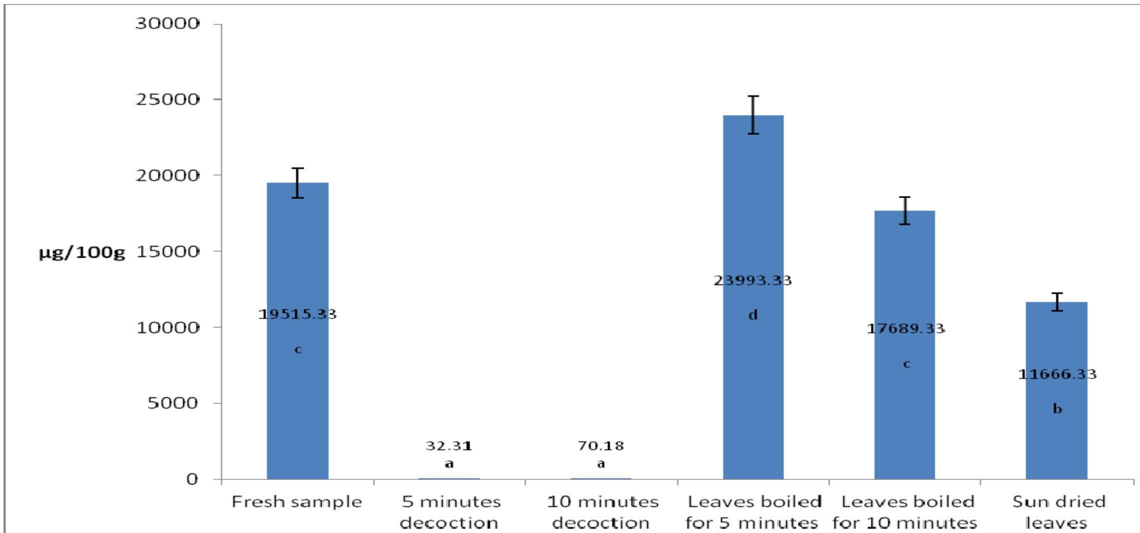


**Figure 5: Effect of processing methods on β-carotene content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different ($p > 0.05$).**

The vitamin C content in the fresh leaves sample of the vegetable was significantly ($p < 0.05$) higher than in all the other processed samples. The percentage loss of the vitamin in the leaves boiled for 5 and 10 minutes were 55.60% and 69.65% respectively. The percentage loss of vitamin C in the sun-dried vegetable was 62.52%. The amount of vitamin C in sundried leaves and leaves boiled for 10 minutes were not significantly ($p > 0.05$) different from each other. Negligible amount of the vitamin were also found in the decoction samples (Figure 6).

Results obtained from the analysis of Fe content in *Vernonia amygdalina* indicated that solar drying had no significant ($p > 0.05$) effect on the mineral content of vegetable. However, boiling of the vegetable significantly reduced the Fe content. Furthermore, the Fe content in the leaves boiled for 5 minutes was not significantly different ($p > 0.05$) from that of 10 minutes and fresh sample. However, the amount of mineral in the fresh sample was significantly ($p < 0.05$) higher than in the leaves boiled for 10 minutes (Figure 7). The 5 and 10 minutes decoctions had the least content of the mineral and their values were not significantly different from each other.

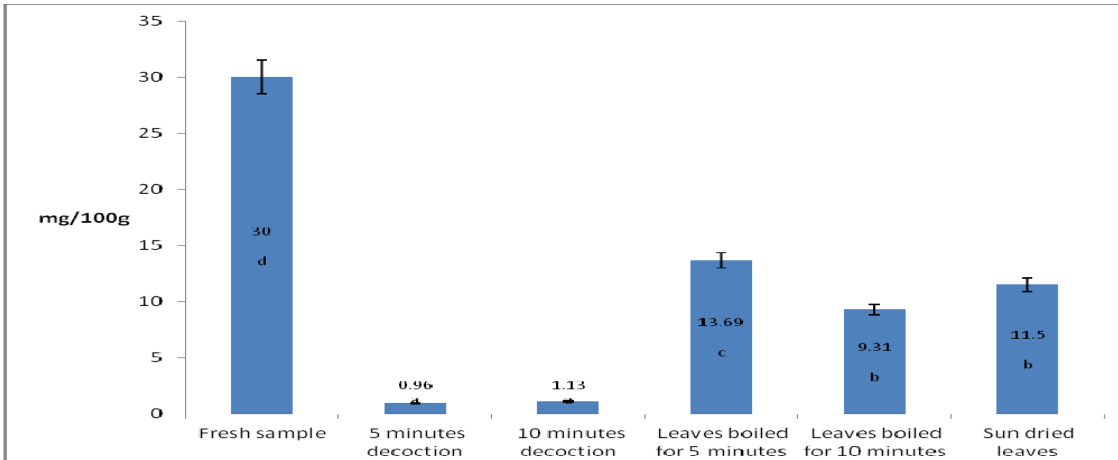


**Figure 5: Effect of processing methods on vitamin C content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different ($p > 0.05$).**

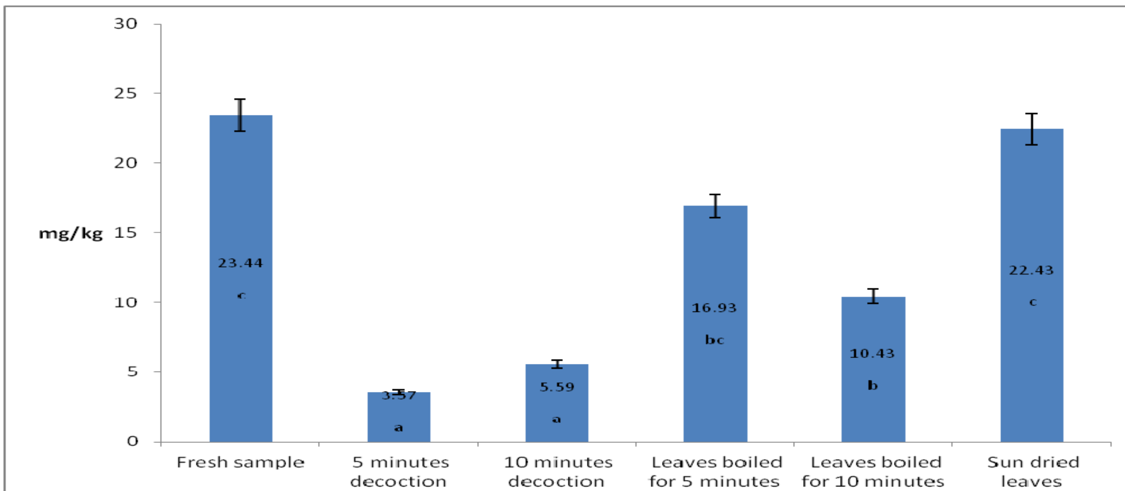


**Figure 7: Effect of processing methods on iron content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different ($p > 0.05$).**

Analysis of Cu content in the vegetable showed that 5 and 10 minutes of boiling significantly ($p < 0.05$) reduced the mineral content. Sun-drying, however, had no significant ($p > 0.05$) effect on the mineral content of the vegetable. The residual Cu in the leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from each other. The level of the element in 5 and 10 minutes decoctions were not significantly different from each other, even though 10 minutes decoction had more of the mineral element. The 5 and 10 minutes decoctions were significantly ($p < 0.05$) lower in the mineral content than in all other processed samples (Figure 8).

Boiling of the vegetable leaves for 5 and 10 minutes significantly reduced ($p < 0.05$) the magnesium content (Figure 9). Sun-drying however, had no significant effect ($p > 0.05$) on the mineral content of the vegetable. The residual Mg in the leaves boiled for 5 and 10 minutes were not significantly different from each other. The levels of magnesium in the 5 and 10 minutes decoctions were also not significantly different from each other, even though that of 10 minutes decoction had more of magnesium. Boiling for 5 and 10 minutes produced significantly lower ($p < 0.05$) magnesium content than in all other processed samples (Figure 9).

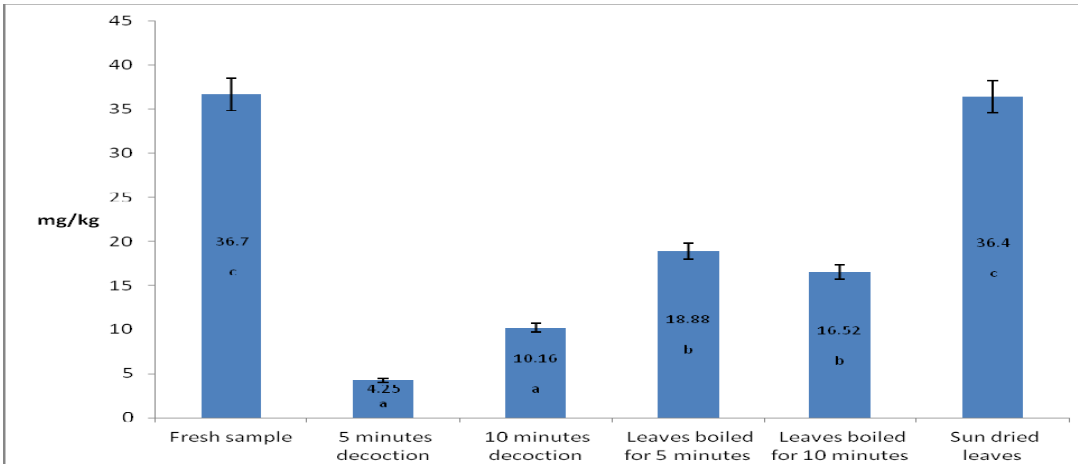


**Figure 8: Effect of processing methods on copper content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different (p > 0.05).**

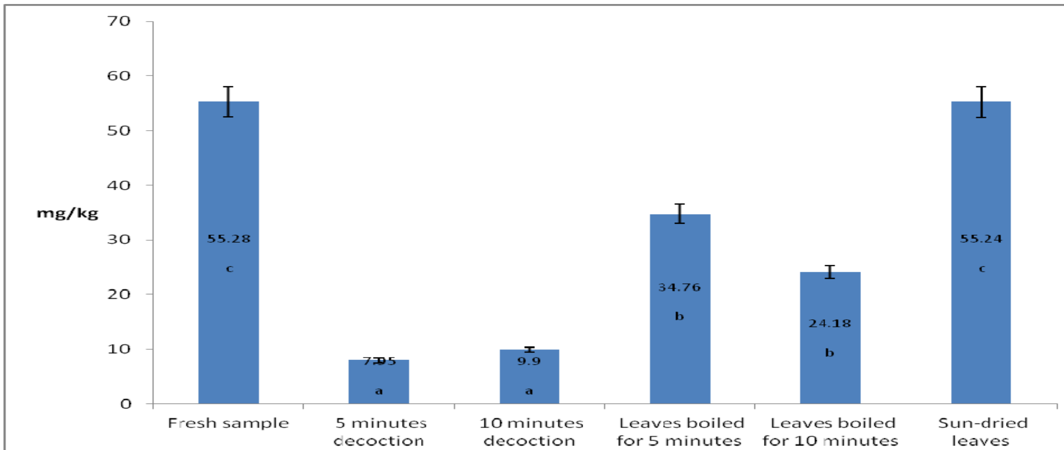


**Fig 9: Effect of processing methods on magnesium content in Vernonia amygdalina. Bars carrying the same letter are notsignificantly different (p > 0.05).**

Boiling the vegetable leaves for 5 and 10 minutes significantly ($p < 0.05$) reduced the sodium content (Figure 10). Sun-drying, however, had no significant effect on the mineral content of the vegetable. The residual Na in the leaves boiled for 5 and 10 minutes were not significantly different from each other. The level of mineral in 5 and 10 minutes decoctions were also not significantly different from each other, though the 10 minutes decoction had more of sodium. The sodium content of the 5 and 10 minutes decoctions were significantly ($p < 0.05$) lower than in all other processed samples (Figure 10).

Sun-drying did not produce any significant effect ($p > 0.05$) on the potassium content of the vegetable (Figure 11). However, boiling for 5 and 10 minutes significantly reduced ($p < 0.05$) the potassium content of the vegetable. The amount of potassium in the 5 and 10 minutes decoction as well as vegetable leaves boiled for 5 and 10 minutes were not significantly different ($p > 0.05$) from each other (Figure 11).

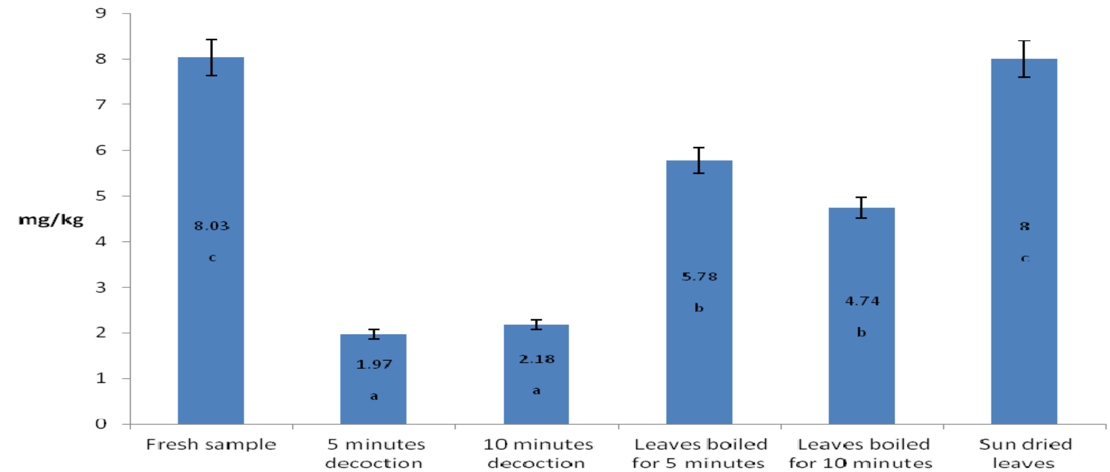


**Figure 10: Effect of processing methods on sodium content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different (p > 0.05).**

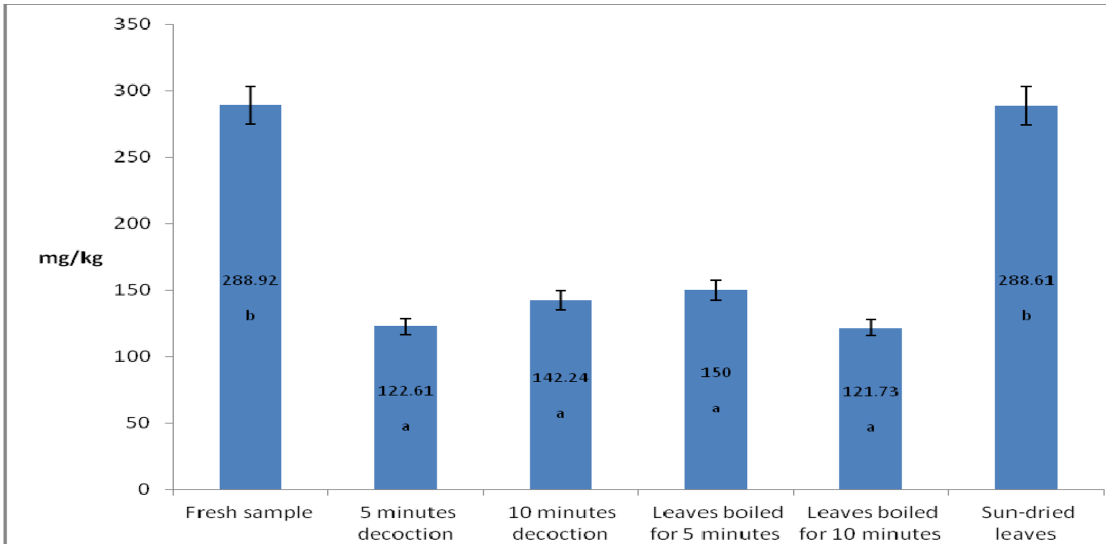


**Figure 11: Effect of processing methods on potassium content in *Vernonia amygdalina*. Bars carrying the same letter are not significantly different (p > 0.05).**

DISCUSSION

The observed higher levels of cyanide, nitrate, soluble oxalate, total oxalate, β-carotene (except in leaves boiled for 5 minutes where the β-carotene levels was elevated), vitamin C and mineral elements (Fe, Cu, Mg, Na and K) in the fresh samples of the different vegetables studied compared to their corresponding processed samples, agreed with the submission of several authors (Aster-Damas, 1975; Augustine *et al*., 1981; Olaofe, 1992; Abakr and Ragaa, 1996; USDA, 1998; George, 1999; Shahnaz *et al*., 2003; Waclaw and Stefan, 2004; Oboh, 2005; Anjana and Muhammad, 2006; McDonald, 2006; Anjana *et al*., 2007; Rickman *et al*., 2007; Ojiako and Igwe, 2008). These authors reported that various food processing methods reduced the nutrients, anti-nutrients and toxic substances in vegetables. In the current study, boiling of *V. amygdalina* leaves significantly decreased the amounts of anti-nutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and vitamin C and mineral elements (Fe, Cu, Mg, Na and K). This observation is in agreement with the reports of Olaofe (1992), Abakr and Ragaa (1996), George (1999), Aganga and Tshwenyane (2003), Ejoh *et al.* (2005), Ogbadoyi *et al.* (2006) and Rickman *et al.* (2007). These authors independently observed that boiling of the vegetables in water rupture the cell walls and subsequently cause the leaching of the cell contents including the anti-nutrients, toxic substances and some micronutrients. Waclaw and Stefan (2004) further stressed that degradation of nitrate by heat to other compound(s) can as well reduce the nitrate content during boiling. Loss of vitamin C during boiling in addition to leaching, was attributed to the thermo sensitive, labile and hydrophilic nature of the vitamin (Olaofe, 1992); George, 1999; Ejoh *et al.* 2005; Rickman *et al.* 2007). The higher β-carotene content in leaves boiled for 5 minutes than those boiled for 10 minutes and fresh samples of the vegetable is in accordance with the report of USDA, (1998) that moderate cooking increases the availability of β-carotene in the vegetables; it helps in breaking down the plant cell walls of the vegetable, and that repeated cooking at high temperature however, destroys some of the provitamins. Rickman *et al*. (2007) further added that loss of soluble solids and the release of protein-bound β-carotenes that occur during boiling may equally contribute to the increase in the provitamin content in the present study. The negligible amount of the β-carotene found in the 5 and 10 minutes decoctions compared to high amount in the fresh and boiled vegetables justifies the hydrophobic nature of β-carotene (Olaofe, 1992; George, 1999; Khalid *et al*., 2004; Ejoh *et al*., 2005; Rickman *et al*., 2007).

The higher content of the nutrients, anti-nutrients and toxic substances in the leaves boiled for 5 minutes when compared to those boiled for 10 minutes is in accordance with the findings of Mathook and Imungi (1994), Abakr and Ragaa (1996), Rickman *et al*. (2007) that the amount of anti-nutrients and nutrients lost in vegetables increases with cooking time.

The significant decrease in cyanide, nitrate, soluble and total oxalates, vitamin C and β-carotene concentrations during sun drying of vegetables in this study is in accordance with the reports of previous researchers (Fafunso and Basir, 1976; Addo, 1983; Keshinro and Ketiku, 1985; Richard, 1991; Olaofe, 1992; Abakr and Ragaa, 1996; Aganga and Tshwenyane, 2003; Ejoh *et al*., 2005; Anjana and Muhammad, 2006; Anjana *et al*., 2007; Rickman *et al*., 2007) to the effect that solar drying reduced the levels of anti-nutrients and vitamins in plants. Reduction of cyanide during sun drying is due to volatile nature of the compound and can be dissipated while drying (Richard, 1991; Aganga and Tshwenyane, 2003), while that of β-carotene is the oxidation of conjugated double bonds by molecular oxygen and isomerisation of the naturally predominant all-trans carotenoids to cis conformations (Rickman *et al*., 2007). Similarly wilting and oxidation of the vitamin C which is one of the biochemical changes caused by the inherent enzymes (vitamin C oxidase and peroxidase) found alongside the vitamin could be accountable for the vitamin C losses during sun drying (Fafunso and Basir, 1976; Addo, 1983; Keshinro and Ketiku, 1983; Olaofe, 1992). 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 findings of Chweya and Nameus (1997) who reported 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 mere gradual evaporation process which does not involve leaching. It should also be noted that minerals are generally non-volatile substances.

The significant amount of cyanide, nitrate, soluble and total oxalate, in sun-dried samples compared to the levels found in the leaves boiled for 5 and 10 minutes indicated that boiling may be superior in the reduction of these compounds than sun drying. The reason may be attributed to the fact that boiling lead to the break down of the plant cell wall which permit the leakage of cell content (Aganga and Tshwenyane, 2003; Ogbadoyi *et al*., 2006) while sun drying is a mere gradual evaporation process. Similarly, the higher levels of β-carotene and vitamin C in boiled vegetables compared to the sundried samples implies that moderate boiling or cooking is superior in conserving these micronutrients than sun drying (USDA, 1998; Ejoh *et al*., 2005; Rickman *et al*., 2007). This observation further supports the earlier submission that boiling as a processing method is superior to sun drying.

Cyanide content in the fresh vegetable sample is relatively higher. The value of the cyanide in the vegetable is close to maximum permissible level of 200 mg/kg fresh weight of vegetables or forages (Everist, 1981; Richard, 1991). The implication of these results is that regular consumption of unprocessed leaves of these vegetables as it is done in ethno-medical practices may likely deliver toxic levels of the compound to the body. Should this happen, disease conditions associated with cyanide overload such as hypoxia, flushing, headache, tachynea, dizziness, respiratory depression which progresses rapidly to coma seizure are likely to occur (Ames *et al*. 1981; Ellenhoro and Barcelonx, 1988). Interestingly, the various processing methods used, significantly reduced the cyanide content in the vegetable. Sun drying is not effective compared to boiling. This finding may therefore suggest that boiling method of processing may be preferred for vegetable processing to sun drying with regard to cyanide content.

The levels of nitrate (1347.22mg/kg) in the fresh *Vernonia amygdalina* is less than the acceptable daily intake (ADI) of 3.65mg/kg for 60 kg body weight (219.00mg/day) if 100 g samples are consumed per day notwithstanding the lower values in the processed samples. The implication of the finding is that the nitrate content of this vegetable is not enough to cause nitrate toxicity if included in the diets (Anjana *et al*., 2007). The soluble oxalate content in the fresh vegetable samples was higher than the permissible level of 250 mg/100 g fresh sample (Oguchi *et al*., 1996). Therefore, regular consumption of fresh raw samples of the vegetable without proper processing could deliver toxic levels of the anti-nutrient into the body with attendant health problems of oxalate toxicosis. This may lead to hypocalcaemia (Shingeru *et al*., 2003; Antia *et al*., 2006), formation of kidney stone (Nakata, 2003, Proph *et al*., 2006) and reduced bioavailability of some minerals to the body (Sandberg *et al*., 1996; Okon and Akpanyung, 2005). However, all the processing methods studied significantly reduced the soluble and oxalates content of the vegetable to tolerable levels, except that the total oxalate content in sundried sample was still more than the accepted tolerable level. These results further strengthen the earlier submission that boiling is superior in the reduction of phytotoxins to sun drying.

The fresh leaves of the vegetables contained over and above the recommended adult daily allowance of 900 µg of vitamin A (George, 1999; Akanya, 2004). Leaves boiled for 5 minutes had more β-carotene. Although, sun drying significantly decreased the β-carotene content in the vegetable, the residual β-carotene content in sun-dried leaves can meet adult recommended daily allowance. The implication of the results is that sun drying which is the most common method of processing in the rural areas during glut may still retain enough β-carotene to meet the normal adult recommended daily allowance. From the results obtained in this study, the fresh sample of the vegetable could not supply enough vitamin C that can meet up with the recommended daily allowance of 60 mg (Olaofe, 1992; George, 1999) if 100 g of the samples are consumed. Thus, this vegetable is not an excellent source of this water soluble vitamin. Considering the pivotal roles of this water soluble vitamin in human health and the associated diseases, pharmaceutical supplementation of the vitamin will be necessary to augment its low level in the vegetable and losses during the various food processing methods. This will enable the body to meet the dietary requirement of the vitamin.

Comparing the value of Fe in the studied vegetable with the values in the available literatures, *V. amygdalina* leaves contained an appreciable amount of the mineral. Adequate intake of the vegetable could provide the body with the recommended daily intake of 18 mg/day of Fe for normal adult (Tietz *et al*., 1994). Sundried sample of the vegetable 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). From present study, boiled sample of the vegetable could meet the recommended daily intake of this important mineral that is 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), fruits and pharmaceuticals products may be required as a supplement to augment the lost of Fe during boiling. The findings in the present study indicate that the vegetable is an excellent source of iron. Iron is involved in normal carbohydrate and lipid metabolism (Hambidge *et al*., 1987).

The concentrations of the Cu in fresh sample and processed leaves were high enough to meet the range of the recommended daily allowance of 1.5 - 3.0 mg/day of Cu (Tietz *et al*., 1994), if 100 g of samples were consumed.

The Mg content in fresh sample (55.28mg/kg) of *Vernonia amygdalina* is low and even lower when they are processed. Thus, the vegetable is not likely to supply enough of the mineral needed to meet up with the recommended daily allowance of 350 mg of Mg/day for normal adult (George, 1999). The implication of this is that complete dependence on the vegetable to provide this important cofactor of enzymes involved in cell respiration, glycolysis and transmembrane transporter (Ryan, 1991; Tietz *et al*., 1994) may consequently result in the deficiency of the mineral. To avoid this condition, there is the 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 value of 8.03 mg/kg obtained for Na in the vegetable in this study is far below those reported in literatures (Chweya and Nameus, 1997; Oboh, 2005; Antia *et al*., 2006; Adanlawo and Ajibade, 2006; Aliyu and Morufu, 2006). Thus, complete dependence on the studied vegetables as a major source of the mineral may not meet up the body's need. Interestingly, this important mineral, essential for maintenance of fluid balance and normal osmotic pressure in the body (Wayne and Dale, 1989; Titz *et al*., 1994; Aliyu and Morufu, 2006) is added in almost every food preparations as condiments to taste in the form of NaCl or table salt (Magmus Pyke, 1979; Wayne and Dale, 1989; George, 1999). This supplementation with sodium chloride will compensate for the low levels of the mineral in analysed vegetables.

The K content of the fresh vegetable sample is 288.92mg/kg. This result revealed that *V. amygdalina* contained an appreciable quantity of the element. Thus, the vegetable could be an excellent sources of the mineral (Oyenuga and Fetuga, 1975). 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. Since it is necessary to discard the water used in boiling in order to reduce some of the anti-nutrients in the vegetable (Ogbadoyi *et al*., 2006), supplementation of the mineral with fruits and whole grains may be necessary.

## CONCLUSION

The concentration of nitrate in the fresh vegetable sample is within the acceptable levels, while those of cyanide and oxalates are higher enough to induce toxicity in man. However, the various processing methods used significantly reduced their concentrations to tolerable levels except that the total content in sun dried sample was till high enough to cause some nutritional problems. *Vernonia amygdalina* is an excellent source of micronutrients. With carefull selection of good choice of processing method, the nutritional benefits of this vegetable can be fully explored. In this present study, boiling (especially 5 minutes of boiling) is recommended over sun drying as a better choice of processing method, since the method significantly reduces the plant toxins and conserves more micronutrients.

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