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Effect of Processing Methods on Some Micronutrients, Antinutrients and Toxic Substances in *Hibiscus sabdariffa*

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ABSTRACT
The nutritionists' interest in leaf vegetables including *Hibiscus sabdariffa* stems from their rich contents of essential amino acids, vitamins and minerals which are needed for normal metabolic activities of the body. Vegetables are also good sources of dietary fibres that are important for bowel movement. However, the presence of some inherent anti nutrients and toxic substances in vegetables has been a major obstacle in harnessing the full nutritional benefits. It is against this background that this research was conducted to determine the effect of some processing methods on the antinutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and some micronutrients which include vitamin C, β-carotene (provitamin A) and mineral elements (Fe, Mg, Zn, Na and K) in *Hibiscus sabdariffa*. The processing methods include boiling (vegetable leaves were boiled in distilled water for 5 and 10 min) and sun drying. Results obtained showed that the cyanide, nitrate and soluble contents in fresh vegetable sample are within the tolerable level and they can be well tolerated in the meals. However, the total oxalate content in the vegetable is high enough to induce oxalate toxicosis. All the processing methods significantly ($p<0.05$) reduced the antinutrients and toxic substances in *Hibiscus sabdariffa* except that the reduction in soluble and total oxalate with sun drying was not significant ($p>0.05$). Boiling methods reduced these toxic substances significantly ($p<0.05$) more than sun drying. The antinutrients and toxic substances generally decreased with boiling time. These post-harvest treatments also reduced vitamin C content significantly ($p<0.05$) in *Hibiscus sabdariffa*. Boiling method retained more of the vitamin compared to sun drying. β-carotene levels increased in the boiled vegetable leaves, while its content was reduced in sundried leaves. However, boiling beyond 5 min led to significant ($p<0.05$) reduction of β-carotene levels in the vegetable. Mineral elements (Fe, Cu, Mg, Na and K) decreased significantly ($p<0.05$) with boiling in *Hibiscus sabdariffa*; however sun drying had no significant effect on the mineral contents. The result concludes that moderate boiling significantly reduces the levels of antinutrients and toxic substances while still conserve some micronutrients in amounts sufficient to meet our dietary requirements.

Key words: Hibiscus sabdariffa, boiling, sun drying, micronutrients, antinutrients and toxic substances

INTRODUCTION
Roselle (*Hibiscus sabdariffa*) popularly called "Yakuwa" in Hausa belongs to the family of malvaceace and is a popular vegetable in Indonesia, India, West Africa and many tropical regions

(Tndall, 1986; Fbabatunde, 2003). The vegetable is widely grown in the North-Eastern and middle belt regions of Nigeria (Akanya *et al.*, 1997). This plant has been found to thrive on a wide range of soil conditions. It can perform satisfactorily on relatively infertile soils but for economic purposes, a soil well supplied with organic materials and essential nutrients is important in the productions (Tndall, 1986; Adanlawo and Ajibade, 2006). It can tolerate relatively high temperature throughout the growing and fruiting periods. The plant requires an optimum rainfall of approximately 45-50 cm distributed over a 90-120 day growing period (Tndall, 1986). In Nigeria, two botanical varieties were recognised, the red variety in which the calyx is used for the preparation of "sobo" drink and the green variety which calyx and leaves are used in stew and sauces (Duke, 1985; Syndenham, 1985; Adanlawo and Ajibade, 2006; Ojokoh, 2006). The leaves and calyx of the green variety are very rich in vitamin C and riboflavin with some major mineral elements (Babalola, 2000). This green variety are widely grown and consumed as leafy vegetable because of nutritive values among the North-Eastern and middle belt regions of Nigeria. Roselle has been shown to contain phytic acid, tannin and other phytotoxins, including glucoside such as delphinidin-3-monoglucosides and delphinidin which are toxic to animal and human tissue at high concentration (Morton, 1987; Ojokoh *et al.*, 2002). Tannins form complexes with protein (Goldstein and Swain, 1963). Phytic acid and oxalate chelates minerals and form complexes with proteins and thereby affects their nutritive value (Evans and Bandemer, 1967). Cyanogenic glucosides also found in this plant are an inhibitor of cytochrome oxidase enzyme (Aletor, 1993) and thereby cause respiratory paralysis.

Where this vegetable is used in meal preparation as soup or sausage, it has been subjected to different processing methods. However, to the best of our knowledge, the effect of some of these various post-harvest techniques on the levels of nutrients and toxic substances in the green variety of *Hibiscus sabdariffa* has not been evaluated. Against this back ground, this study was designed to evaluate the effect of some post-harvest handlings (5 and 10 min of boiling) and sun drying on toxic substances (cyanide and nitrate), anitnutrients (soluble and total oxalates) and micronutrients which include β-carotene (precursor of vitamin A), vitamin C and mineral elements (Fe, Cu, Mg, Na and K). This is aiming at identifying the best post-harvest treatments that will reduce the antinutrients and toxic substances to the barest minimum while retaining appreciable levels of some micronutrients.

MATERIALS AND METHODS

***Hibiscus sabdariffa*:** The fresh samples of roselle (*Hibiscus sabdariffa*) was obtained in three sets at different time from Maikunkele, Bosso and Chanchaga 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 of England.

Sample preparation

Boiling: One hundred and fifty grams of fresh leaves of *Hibiscus sabdariffa* were weighed out in two 1000 cm^3 beakers containing 600 cm^3 of distilled water. Content of one beaker was boiled for 5 min while the content of the second beaker was boiled for 10 min. The level of antinutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and nutrients (β-carotene, vitamin C, Fe, Mg, Cu, Na and K) in the decoctions were determined. The levels of these compounds were also determined in leaves obtained after filtration.

Drying: The leaves of *Hibiscus sabdariffa* 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.

Chemical analysis: The soluble and total oxalates concentration in the samples were determined by titrimetric method of Oke (1966). Nitrate content in the test samples was determined by the colourimetric method (Sjoberg and Alanko, 1994). Alkaline picrate method was used to analyse the cyanide concentration (Ikediobi *et al.*, 1980). The mineral elements (Fe, Mg, Zn, Cu, Ca, Na and K) in samples were determined according to the method of Ezeonu *et al.* (2002). The ascorbic acid concentration was determined by 2, 6-dichlorophenol indophenols method (Jones and Hughes, 1983) while the estimation of β-carotene was done by ethanol and petroleum ether extraction method (Musa *et al.*, 2010).

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's Multiple Range Test (DMRT) was used for comparison of mean.

RESULTS

Cyanide content: Analysis of *Hibiscus sabdariffa* showed that the processing methods adopted significantly decreased the cyanide content of the vegetable ($p<0.05$). The cyanide profile in various processed sample of the vegetable were: Fresh sample (63.96 mg kg^{-1}), 5 min decoction (28.42 mg kg^{-1}), 10 min decoction (30.94 mg kg^{-1}), leaves boiled for 5 min (18.39 mg kg^{-1}), leaves boiled for 10 min (16.49 mg kg^{-1}) and sundried leaves (51.41 mg kg^{-1}). The amount of cyanide in 5 min decoction was not significantly different from 10 min decoction ($p>0.05$). There was also no significant difference between the amount cyanide in the leaves boiled 5 and 10 min. However, the amount cyanide in the decoctions was significantly higher than in the boiled leaves (Fig. 1). Sundrying of *Hibiscus sabdariffa* led to a significant decrease ($p<0.05$) in its cyanide content

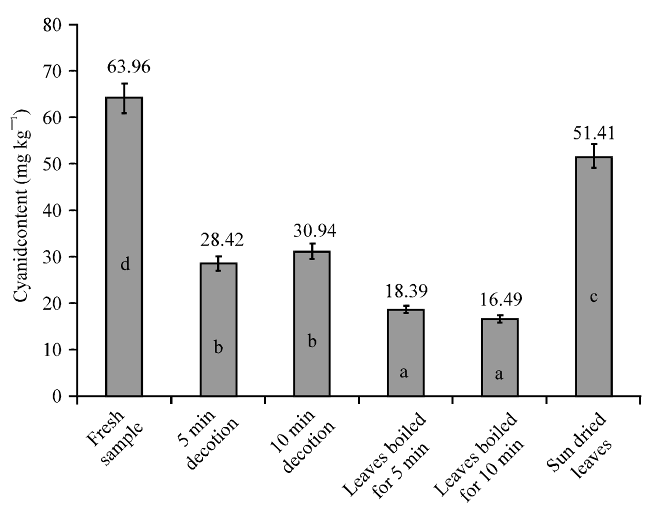

Fig. 1: Effect of processing methods on cyanide content in *Hibiscus sabdariffa*. Bars carrying the same letters are not significantly different ($p>0.05$)

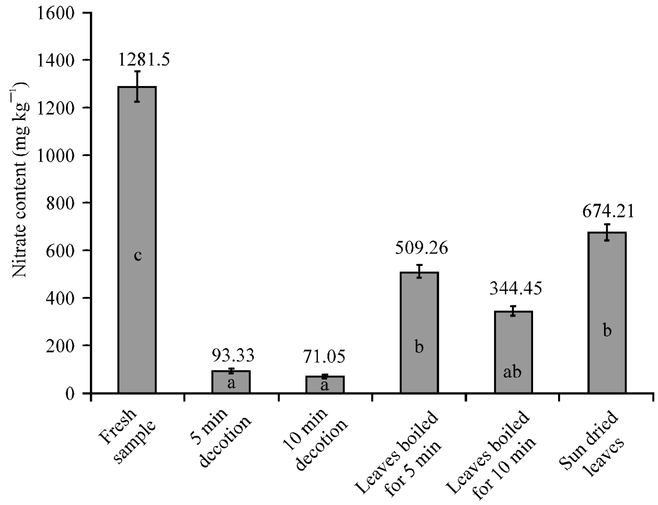

Fig. 2: Effect of processing methods on nitrate content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different (p>0.05)

(about 19.47%) compare with fresh sample. The amount of cyanide in sundried leaves was significantly (p<0.05) more than the cyanide found in the leaves boiled for 5 and 10 min and in 5 and 10 min decoction samples (Fig. 1).

Nitrate content: Results obtained from analysis of *Hibiscus sabdariffa* showed that the nitrate content in fresh samples were higher than in any of the processed samples. The nitrate levels in fresh sample, 5 min decoction, 10 min decoction and leaves boiled for 5 min, leaves boiled for 10 min and sundried sample of the vegetable were 1281.50, 93.33, 71.05, 509.26, 344.45 and 647.21 mg kg^{-1}, respectively. The results showed that the nitrate content decreased significantly (p<0.05) in the all processed samples (Fig. 2). There was no significant difference in the residual nitrate content in leaves boiled for 5, 10 min and sundried sample. Both samples, however, contained significant (p<0.05) amount of the compound than the decoctions. Even though significant amount of nitrate was extract from boiled leaves, only small amount of the compound was found in their corresponding decoctions. The nitrate content in 5 min decoction was not significantly (p>0.05) different from that of 10 min decoction. However, numerically the former had more of the compound than the later (Fig. 2).

Soluble oxalate content: The analysis of this showed that the soluble oxalate content of fresh samples, leaves boiled for 5 min, leaves boiled 10 min and sundried leaves were 1.91, 0.19, 0.11 and 1.61 g kg^{-1}, respectively. The results revealed that sun drying had no significant (p>0.05) effect on the soluble oxalate content of the vegetable. Boiling methods of processing, however led to a significant (p<0.05) decreased of the antinutrient (Fig. 3). The residual soluble oxalate content in the two separately boiled leaves was not significantly different from each other.

Total oxalate content: The amount of total oxalate in fresh samples of the was 4.35 g kg^{-1} while the amount in 5 min decoction, 10 min decoction, sundried leaves and leaves boiled for 5 and 10 min were 0.79, 0.92, 3.95, 2.36 and 1.99 g kg^{-1}, respectively. Results obtained showed that boiling significantly (p<0.05) reduced the total oxalate content in the vegetable. Sun drying,

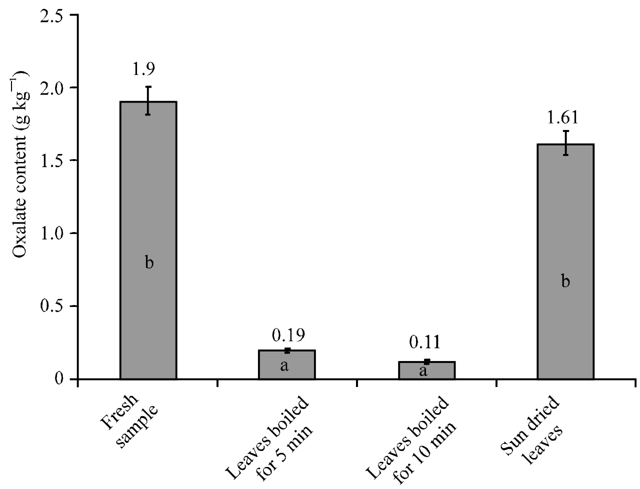

Fig. 3: Effect of processing methods on soluble oxalate content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different (p>0.05)

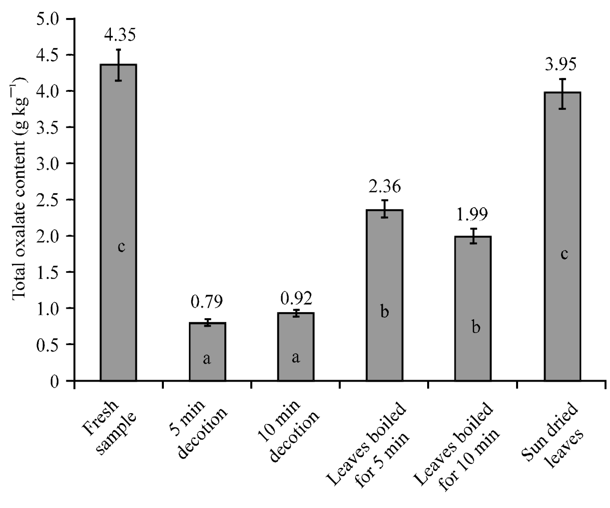

Fig. 4: Effect of processing methods on total oxalate content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different (p>0.05)

however, had no significant (p>0.05) effect on the total oxalate content of the vegetable. The two decoctions had the least contents of the antinutrient and their oxalate content was not significantly (p>0.05) different from each other. There was also no significant difference between the residual total oxalate in leaves boiled for 5 min from that of 10 min boiling (Fig. 4).

β-carotene content: Determination of β-carotene content in *Hibiscus sabdariffa* showed that the amount of β-carotene in the leaves of vegetable boiled for 5 min were in general greater than fresh and other processed samples. The β-carotene content in fresh sample, 5 min decoction, 10 min decoction and leaves boiled for 5 min, leaves boiled for 10 min and sundried leaves were 8772.00, 42.39, 78.00, 9407.67, 7213.00 and 5082.00 μg/100 g, respectively. The result also showed that sun drying significantly (p<0.05) decreases the β-carotene content to about 42.07%. Though the β-carotene in the leaves boiled 5 and 10 min were not significantly different from the levels in the fresh samples, leaves boiled for 5 min had higher amount of the provitamin than the fresh samples. The amount of β-carotene in the decoction samples were negligible when compared with the amount found in the boiled leaves sample (Fig. 5).

Vitamin C content: Results obtained from analysis of vitamin C content in *Hibiscus sabdariffa* clearly showed that the concentration of the vitamin significantly ($p<0.05$) decreased in all the processed samples. The amount of vitamin C in fresh sample was 27.44 mg/100 g while the levels in 5 min decoction, 10 min decoction and leaves boiled for 5 min, leaves boiled for 10 min and sundried leaves were 0.81, 1.30, 14.51, 9.67 and 9.40 mg/100 g, respectively. The percentage losses recorded in leaves boiled for 5 and 10 min were 47.51 and 64.76%, respectively (Fig. 6). The 2.95

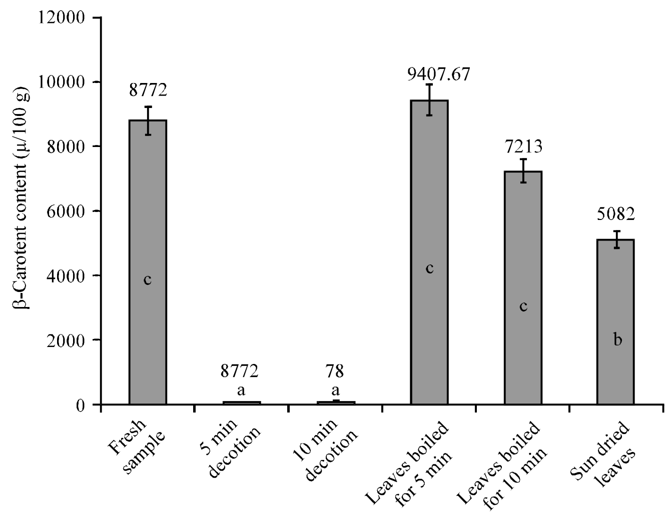

Fig. 5: Effect of processing methods on β-carotene content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different ($p>0.05$)

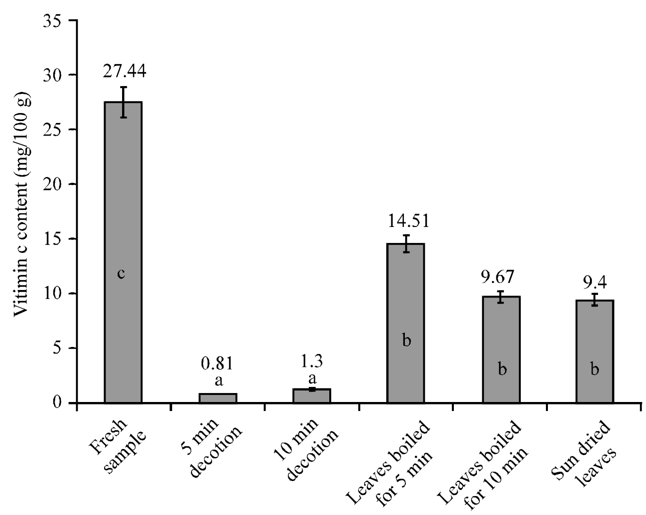

Fig. 6: Effect of processing methods on Vitamin C content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different ($p>0.05$)

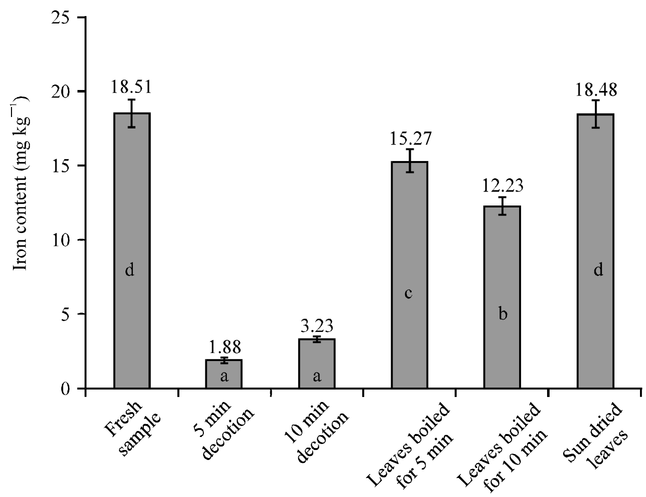

Fig. 7: Effect of processing methods on iron content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different (p>0.05)

and 4.74% of vitamin found in 5 and 10 min decoctions were negligible compared with great losses observed in the boiled leaves. The vitamin C content in sundried leaves of vegetable was significantly (p<0.05) lower than in the fresh samples. The percentage lost recorded in sundried sample was about 65.74% for the vegetable. The residual vitamin C in sundried sample, leaves boiled for 5 and 10 min were not significantly different from each other.

Iron content: Results obtained showed that sun drying had no significant (p>0.05) effect on the Fe content of vegetable. The Fe content in fresh sample, 5, 10 min decoction and leaves boiled for 5 min, leaves boiled for 10 min and sundried leaves of vegetable were 18.51, 1.88, 3.23, 15.27, 12.23 and 18.48 mg kg^{-1}, respectively (Fig. 7). Fe contents of vegetable reduced significantly (p<0.05) in leaves boiled for 5 and 10 min. The residual Fe in leaves boiled for 5 min was significantly higher when compared with leaves boiled for 10 min. Least amount of the mineral was found in 5 and 10 min decoctions (Fig. 7).

Copper content: The amount of Cu in the various processed samples of the studied vegetable were as follows: fresh sample (26.67 mg kg^{-1}), 5 min decoction (1.97 mg kg^{-1}), 10 min decoction (2.72 mg kg^{-1}), leaves boiled for 5 min (20.72 mg kg^{-1}), leaves boiled for 10 min (16.70 mg kg^{-1}) and sundried leaves (26.65 mg kg^{-1}). The results obtained showed that sun drying had no significant effect (p>0.05) on the mineral content of vegetable. However, 5 and 10 min boiling significantly (p<0.05) reduced the Cu content of the vegetable. The residual Cu in leaves boiled for 5 min was significantly (p<0.05) higher than in the leaves boiled for 10 min. The two decoction samples had the least amount of the mineral compared to other processed samples (Fig. 8).

Magnesium content: Results obtained from the determination of Mg content in *Hibiscus sabdariffa* also showed that the Mg content in fresh sample (21.69 mg kg^{-1}) of the vegetable was not significantly different (p>0.05) from that of sundried sample (21.68 m kg^{-1}). But with 5 and 10 min boiling the mineral content decreased significantly (p<0.05) to 14.45 and 13.21 mg kg^{-1}, respectively. The Mg content in 5 and 10 min boiled leaves were not significant

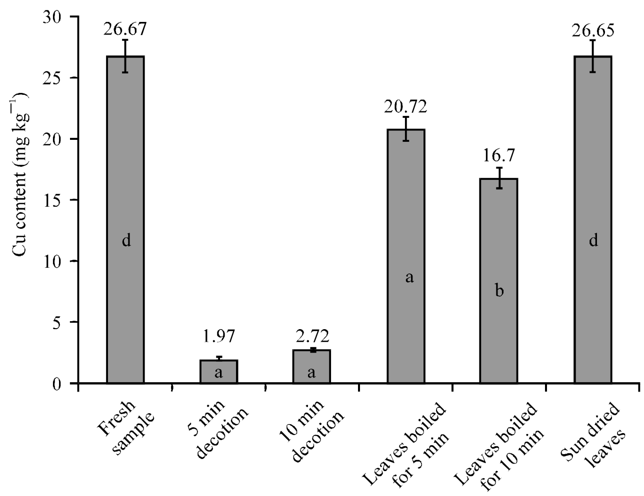

Fig. 8: Effect of processing methods on copper content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different ($p>0.05$)

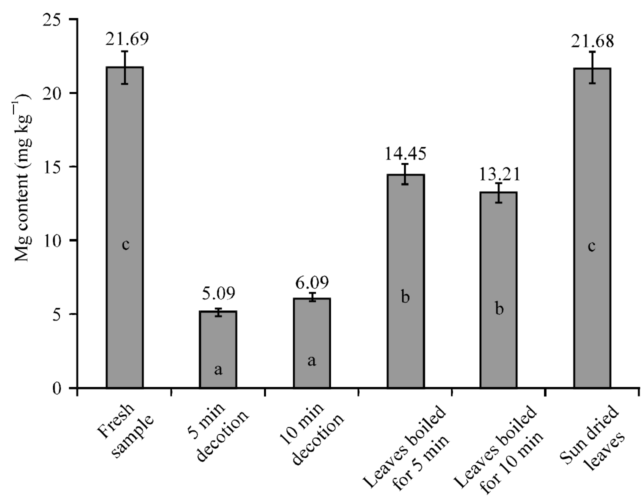

Fig. 9: Effect of processing methods on magnesium content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different ($p>0.05$)

different ($p>0.05$) from each other. The mineral content in the 5 min decoction (5.09 mg kg^{-1}) and 10 min decoction (6.09 mg kg^{-1}) were also not significantly different ($p>0.05$), however, their Mg content were significantly ($p<0.05$) lower than in other processed samples (Fig. 9).

Sodium content: Analysis of the vegetable also showed that the Na content in fresh sample (6.11 mg kg^{-1}) of the vegetable was not significantly different ($p>0.05$) from that of sundried sample (5.70 mg kg^{-1}). However, with 5 and 10 min boiling the, mineral content decreased significantly ($p<0.05$) to 3.68 and 3.17 mg kg^{-1}, respectively. The Na content in 5 and 10 min boiled leaves were not significantly different from each other. The Na content in 5 min decoction (2.11 mg kg^{-1}) and 10 min decoction (2.61 mg kg^{-1}) were also not significantly different from each other, but the levels of the mineral was significantly ($p<0.05$) lower in these samples than in other processed samples (Fig. 10).

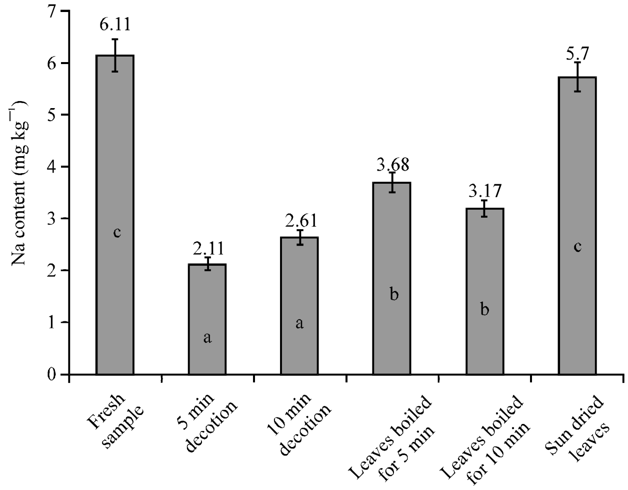

Fig. 10: Effect of processing methods on sodium content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different ($p>0.05$)

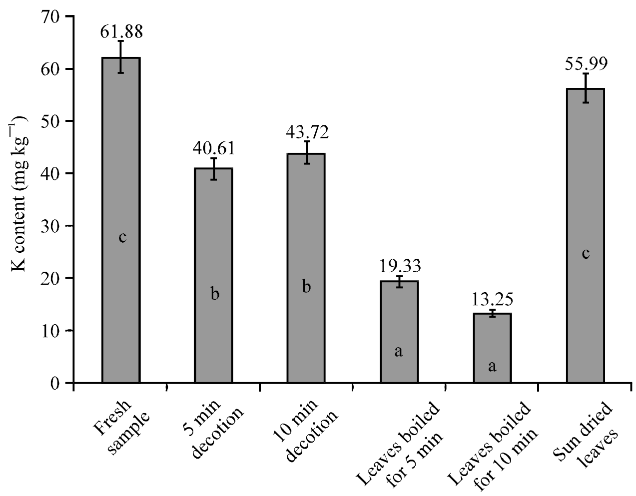

Fig. 11: Effect of processing methods on potassium content in *Hibiscus sabdariffa*. Bars carrying the same leter are not significantly different ($p>0.05$)

Potassium content: The amount of K in the various processed samples of *Hibiscus sabdariffa* were as follows: fresh sample (61.88 mg kg^{-1}), 5 min decoction (40.61 mg kg^{-1}), 10 min decoction (43.72 mg kg^{-1}), leaves boiled for 5 min (19.33 mg kg^{-1}), leaves boiled for 10 min (13.25 mg kg^{-1}) and sundried leaves (55.99 mg kg^{-1}). The results showed that sun drying had no significant ($p<0.05$) effect on the mineral content of vegetable. However, 5 and 10 min boiling significantly ($p<0.05$) reduced the K content of the vegetable. The residual K in leaves boiled for 5 and 10 min were not significantly different from each. The K content in these boiled leaves was significantly ($p < 0.05$) lower than in their corresponding decoctions. The mineral content in the two water extracts were not significantly different from each other (Fig. 11).

DISCUSSION

The nutritionists' interest in some leaf vegetables including *Hibiscus sabdariffa* stems from their rich contents of essential amino acids, vitamins and minerals which are needed for normal metabolic activities of the body. Vegetables are also good sources of dietary fibres that are important for bowel movement. However, the presence of some inherent anti nutrients and toxic substances in vegetables has been a major obstacle in harnessing the full nutritional benefits, hence the need to determine the various post-harvest treatments on some toxic substances, antinutrients and nutrients in this vegetable.

The observed higher cyanide content in the fresh samples of the different vegetables studied compared to their corresponding processed samples, agrees with the submission of Oboh (2005), McDonald *et al.* (2006) and Ojiako and Igwe (2008) that various food processing methods will reduce cyanide content in *Americana* leaves, plants and cassava leaves, respectively. In the current study, there was a significantly higher level of cyanide in 5 and 10 min decoctions than in the corresponding boiled leaves of *Hibiscus sabdariffa*. This observation is an indication that boiling of vegetables in water and discarding the water used in boiling would greatly reduce the cyanogenic glycoside content in the vegetables. This finding is in line with the reports of Aganga and Tshwenyane (2003) and Ogbadoyi *et al.* (2006). These authors independently observed that boiling of the vegetables in water rupture 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 in the vegetable during sun drying may be attributed to the volatile nature of cyanide and could have been dissipated during sun drying. This observation is in agreement with the finding of Richard (1991) and Aganga and Tshwenyane (2003) to the effect that cyanides are volatile compounds and can be dissipated while drying. The recorded significant amount of this respiratory poison in sundried sample compared to the levels found in the leaves boiled for 5 and 10 min indicated that boiling may be a good choice in cyanide reduction than sundrying. The reason may be attributed to the fact that boiling led to break down of the plant cell wall which permit the leakage of cell content (Aganga and Tshwenyane, 2003; Ogbadoyi *et al.*, 2006) while sundrying is a mere gradual evaporation processes. Cyanide content of fresh samples of this vegetable is lower than permissible level of 200 mg kg^{-1} fresh weight of vegetables or forages (Everist, 1981; Richard, 1991) and can well be tolerated if the vegetable is use in meal preparation. Interestingly, the various processing methods used, significantly reduced the cyanide content in the vegetables.

The significantly higher nitrate content in fresh sample of *Hibiscus sabdariffa* compared to the processed samples is in line with the findings of Bakr and Gawish (1997), Mozolewski and Stefan (2004), Anjana and Muhammad (2006) and Anjana *et al.* (2007) who reported that various heat treatments such as boiling/cooking and drying significantly reduced the nitrate content of the vegetables compared to fresh samples. Similarly, there is observed general higher nitrate content in 5 min decoctions than 10 min decoctions. The observation that the leaf residues boiled for 10 min contained less nitrate, suggests that the nitrate may have been degraded or converted to other compound with increased heating time. The observation is in agreement with the submission of Mozolewski and Stefan (2004) who showed that heat treatment can degrade nitrate into another compounds. The higher levels of nitrate in sundried samples compared to the levels found in the leaves boiled for 5 and 10 min further shows the superiority of boiling over sun drying. Vegetables may be classified as high or low nitrate content. Vegetables with nitrate levels of 1000-4000 mg kg^{-1} are classified as high nitrate content (http://www.inchem.org/pages/jecfa.html)

(Anjana *et al.*, 2007). It follows therefore that the vegetable studied, with nitrate levels of 1281.50 mg kg^{-1} is a high nitrate vegetable. However, this value of nitrate in vegetable is less than the acceptable daily intake (ADI) of 3.65 mg kg^{-1} for 60 kg body weight (219.00 mg day^{-1}) if 100 g samples are consumed per day. This finding thus indicated that inclusion of the vegetable in our meal preparation may not likely to cause any health problem relating to nitrate toxicity such as methaemoglobinaemia and cancers (Galler, 1997; Mozolewski and Stefan, 2004; Onyesom and Okoh, 2006; Anjana *et al.*, 2007). The observed higher soluble and total oxalates content in the fresh samples of the vegetable compared with processed samples is in harmony with the observation of Bakr and Gawish, (1997) and Adeboye and Babajide (2007) who have reported that various food processing methods reduce oxalate content in plants. The significant higher oxalates level in the fresh vegetable sample than in the boiled leaves agrees with reports of Ogbadoyi *et al.* (2006), Antia *et al.* (2006), Adeboye and Babajide (2007) and Ojiako and Igwe (2008) which show that proper boiling/cooking of vegetables before consumption significantly reduced the oxalate content. The elevated soluble and total oxalate content in sundried sample than in 5 and 10 min boiled leaves further supports that boiling, as processing methods is more effective in reducing the antinutrient content in the vegetable than sun drying method.

From the results obtained the soluble oxalate content in the fresh vegetable sample is within the permissible level of 250 mg/100 g fresh sample (Oguchi *et al.*, 1996). However, the total oxalate content of 4.35 g kg^{-1} (435.00 mg/100 g) in the fresh vegetable was more than the permissible level of 250 mg/100 g fresh weight as reported by Oguchi *et al.* (1996). The results thus reveal that regular consumption of fresh raw samples of the vegetables without proper processing could deliver toxic levels of the antinutrient into the body with attendant health problems of oxalate toxicosis. Which may ultimately results to hypocalcaemia, kidney stone and reduced bioavailability of the minerals to the body (Nakata, 2003; Miyazaki *et al.*, 2003; Okon and Akpanyung, 2005; Antia *et al.*, 2006; Prohp *et al.*, 2006). Interestingly the processing methods used (especially boiling) significantly reduced the total oxalate content of the vegetable to the tolerable level. However, the boiling water must be discarded (Bakr and Gawish, 1997; Ogbadoyi *et al.*, 2006).

The observed higher β-carotene content in leaves boiled for 5 min than those boiled for 10 min and fresh samples of the vegetables is in accordance with the report of USDA (1998) that moderate cooking increases the availability of β-carotene in the vegetable; 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 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 min decoctions compared to amount of the compound in the fresh and boiled vegetables justifies the non- hydrosoluble nature of β-carotene (Olaofe, 1992; George, 1999; Iqbal *et al.*, 2004; Ejoh *et al.*, 2005; Rickman *et al.*, 2007).

The significantly lower levels of β-carotene in sundried sample compared with the fresh sample agrees with the report of Ejoh *et al.* (2005) that various food processing methods affect the level of pro-vitamin A content. 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 easily by molecular oxygen during sun drying to a compound with no β-carotene activity (Rickman *et al.*, 2007). Rickman *et al.* (2007) further stressed that the isomerisation of the naturally predominant all-trans carotenoids to cis conformations could as well decrease the β-carotene of the vegetable during sun drying. The higher levels of β-carotene in boiled vegetables than in the sundried samples implies that moderate boiling/cooking is superior in conserving and improving the availability of β-carotene than sun drying (USDA, 1998; Ejoh *et al.*, 2005; Rickman *et al.*, 2007). This observation, thereby strengthen the earlier submission that boiling as a processing method may be superior to sun drying in conserving nutrients. The fresh leaves of the vegetable can provide over and above the recommended adult daily allowance of 900 μg vitamin A (George, 1999; Akanya, 2004). Leaves boiled for 5 min had more β-carotene. This is in agreement with the earlier reports that moderate cooking improves the availability of the provitamin in the vegetable (USDA, 1998; Ejoh *et al.*, 2005; Rickman *et al.*, 2007). Sundried vegetable sample had β-carotene content lower than the normal recommended adult daily allowance of 900 μg vitamin A (5400 μg of β-carotene). The implication of the results is that sun drying which is the most common method of processing vegetables in the rural areas to take care of glut cannot retain enough β-carotene in *Hibiscus sabdariffa* meet the normal adult recommended daily allowance.

The significantly lower levels of vitamin C in the boiled vegetable leaves compared to fresh ones is in line with the report of the Olaofe (1992), George (1999), Ejoh *et al.* (2005) and Rickman *et al.* (2007). 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 min compared to those boiled for 5 min is in accordance with the verdict of Mathooko 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 min decoctions in the vegetable despite the higher percentage losses observed in the boiled leaves confirmed the labile and thermo sensitive properties of vitamin C (Olaofe, 1992; George, 1999; Ejoh *et al.*, 2005; Rickman *et al.*, 2007). Significant losses of the vitamin in sundried sample in the vegetable may be probably due to oxidation of the vitamin which is one of the biochemical changes caused by the inherent enzymes (vitamin C oxidase and peroxidase) found alongside the vitamin. Wilting is one of the factors that could be accountable for the vitamin losses during sun drying (Fafunso and Bassir, 1976; Addo, 1983; Keshinro and Ketiku, 1983; Olaofe, 1992). Because of the higher percentage losses of vitamin C in sundried samples, sun drying may not be a good method of processing that will conserves the vitamin content of the vegetables (Olaofe, 1992). The levels of vitamin C in the fresh vegetable sample is 27.44 mg/100 g, this value is far less than the recommended daily allowance of 60mg per 100 g of vitamin C (Olaofe, 1992; George, 1999). With processed samples even lower. These results may therefore suggest that this vegetable is not an excellent source of vitamin C as report by Babalola (2000). Thus complete dependency on this vegetable as a dietary sources may led vitamin C to deficiency disease. Considering the pivotal roles of this water soluble vitamin in human health, pharmaceutical supplementation of the vitamin will be necessary to augment its low level in this vegetable and 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 contents in the boiled leaves compared with the fresh sample of the vegetable is in line with the findings of Astier-Dumas (1975), Augustin *et al.* (1981), Bakr and Gawish (1997), Alvi *et al.* (2003) and Oboh (2005) that various conventional food processing techniques (blanching, cooking) cause a significant decrease in the mineral content of the vegetables. This observation however, contradicts the results of Chweya and Mnzava (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 (Bakr and Gawish, 1997).

The generally higher levels of the minerals in the leaves boiled for 5 min compared with those boiled for 10 min, coupled with the higher level of the minerals in the 10 min than 5 min decoctions, agrees with the report of Bakr and Gawish (1997) These authors concluded that the amount of minerals lost in the vegetable during cooking increases with cooking time.

Sun drying had no significant affect on the mineral (Fe, Cu, Mg, Na and K) contents in the studied vegetable. This observation is in line with the finding of Chweya and Mnzava (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 mere gradual evaporation process which does not involve leaching. It should also be noted that minerals are general nonvolatile substances.

The Fe content in the fresh sample of *Hibiscus sabdariffa* is 18.51 mg kg^{-1}. Comparing these values with the available literature, the vegetable contain an appreciable amount of the mineral. Adequate intake of the vegetables could provide the body with the recommended daily intake of 18mg/day of Fe for normal adult (Tietz *et al*., 1994). Sundried sample of the vegetable could also provide the body with daily recommended intake of the mineral. From the results obtained, boiled samples 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 safe levels (Ogbadoyi *et al*., 2006) supplementation of mineral with fruits and pharmaceuticals products become necessary. The results obtained indicated that *Hibiscus sabdariffa* is a good source of this important element that is involved in normal carbohydrate and lipid metabolism (Hambidge *et al*., 1987).

The concentrations of the Cu in the vegetable samples (fresh and dried samples and leaves boiled for 5 and 10 min) could furnish the body with the recommended range of daily allowance of 1.5-3.0 mg/day of Cu (Tietz *et al*., 1994) if 100 g of samples were consumed.

The value of 21.69 mg kg^{-1} of Mg obtained in the fresh sample of the vegetable is lower than the levels reported in the available literature on some leafy vegetables. For example, 3700 mg kg^{-1} was reported for *Amaranthus hybridus* and 3259 mg kg^{-1} for *Corchorus olitorius* (Osuntogun *et al*., 2004), 860 mg kg^{-1} for *Cleome gynandra* (Chweya and Mnzava, 1997), 550 mg kg^{-1} for spinach (George, 1999) and 266.80 mg kg^{-1} for *Cnidoscolus acontifolus* (Oboh, 2005). The results obtained indicated that the Mg content in fresh sample of the vegetable is low, with processed samples even lower. Thus the vegetable is not likely to supply the mineral to meet the recommended daily allowance of 350 mg of Mg/day for normal adult (George, 1999). The implication of this observation is that complete dependency on this vegetable 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).

Similarly the Na (6.11 mg kg^{-1}) and K (61.88 mg kg^{-1}) contents in fresh vegetable leaves is low when compared with values found in the in available literature. Interestingly, sodium an, essential element require for maintenance of fluid balance and normal osmotic pressure in the body for cellular activities (Wayne and Dale, 1989; Tietz *et al*., 1994; Aliyu and Morufu, 2006) is added in almost every home in the food preparations as condiments to taste in the form of NaCl or table salt

(Pyke, 1979; Wayne and Dale, 1989; George, 1999). With potassium, fruits and pharmaceutical supplement may be necessary to augment low level of mineral in the vegetable and its losses during processing.

CONCLUSION

The leaves of *Hibiscus sabdariffa* (green variety) from the data, reveals that it contain low levels of the analysed phytotoxins except for total oxalate whose concentrations exceed the tolerable levels. The various post-harvest handlings reduce the antinutrients and toxic substances to the tolerable levels except sun drying. Though the vegetable is low in vitamin C content, the **β**-carotene and other micronutrients are high enough to alleviate micronutrients problem which is prominent in African countries. Among the processing method adopted, 5 min of boiling reduce antinutrients and toxic substances significantly with higher retention of most micronutrients and thus should be preferred over others.

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