

Effect of Cooking and Sun Drying On Micronutrients, Antinutrients and Toxic Substances in *Corchorus Olitorius* (Jute Mallow)

Amanabo Musa^{1,2*} and Emmanuel O. Ogbadoyi²

¹Department of Biochemistry, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria

²Department of Biochemistry/Global Institute for Bioexploration, Federal University of Technology, Minna, Nigeria

Abstract

Leafy vegetables generally contain some intrinsic phytotoxins that affect human health negatively at high concentrations. The presence of these toxins which is believed to protect the plant from their preys has severely limited the nutritional potential of vegetables. The reason that, this research was conducted to determine the effect of cooking (fresh leaves of the vegetable were cook or boiled for 5 and 10 minutes) and sun drying on antinutrients (soluble and total oxalates), toxic substance (cyanide and nitrate) and some micronutrients which include vitamin C, β -carotene (provitamin A) and mineral elements (Fe, Mg, Cu, Na and K) in *Corchorus olitorius*. Results obtained showed that cooking and sun drying significantly ($p < 0.05$) reduced the antinutrients and toxic substances in *Corchorus olitorius* except that the reduction in cyanide and total oxalate concentrations with sun drying were not significant ($p > 0.05$). *Corchorus olitorius* is an excellent source of β -carotene, vitamin C and some mineral elements. However, both treatments reduce vitamin C concentration significantly ($p < 0.05$). β -carotene concentration increased in the cooked *Corchorus olitorius* leaves, while its concentration was reduced in sundried leaves. However, cooking exceeding 5 minutes led to significant ($p < 0.05$) reduction in β -carotene concentration in the vegetables. Mineral elements (Fe, Cu, Mg, Na and K) in the *Corchorus olitorius* decreased significantly with cooking, whereas sun drying had no significant effect on the mineral concentrations. The results conclude that moderate cooking reduce the phytotoxins to the tolerable levels without compromising the nutritional values of the vegetable.

Introduction

The genus *Corchorus* consists of 50 - 60 species, of which about 30 are found in Africa. The plant is mainly known for its fibre product, jute and for its leafy vegetables [1]. Several species of *Corchorus* are used as vegetable, of which *Corchorus olitorius* is most frequently cultivated. *Corchorus olitorius* called jews mallow or jute mallow in English, ayoyo in Hausa and ewedu in Yoruba is popular as vegetable in both dry or semi-arid regions and in the humid areas of Africa. The plant prefers light (sandy), medium (loamy) and heavy (clay) soils. This vegetable does well in acid, neutral and basic (alkaline) soils [2]. *Corchorus olitorius* is extremely consumed as a health vegetable in Japan, because it contains abundant carotenoids, vitamin B₁, B₂, C and E, and minerals. The dark-green leaves of *Corchorus olitorius* have varying proportion of Ca, Fe, β -carotene, vitamin C, fibre and protein required for health [1]. Despite these huge nutritional benefits, *Corchorus olitorius* like other leafy vegetables, bioaccumulates various antinutrients and toxic substance which has negative effect on health at high concentration and thereby underscore the derivable nutritional benefits. For instance high concentrations of cyanide cause respiratory poison [3,4]. Oxalate lead to the formation of kidney stone and oxalemia [5-8], while nitrate causes cancer and methaemoglobinemia in man [9-12]. In order to harness the maximum nutritional benefit from this commonly consumed leafy vegetable, the research is designed to determine the effect of two different cooking times (5 and 10 minutes of cooking) and sun drying on the concentrations of some plant toxins and micronutrients. This is with the view of determining the treatment methods that would significantly reduce the phytotoxins to the tolerable levels without compromising the derivable nutritional benefit of *Corchorus olitorius*.

Materials and Methods

Corchorus olitorius

The fresh samples of *Corchorus olitorius*, was obtained from three different markets in Minna town namely, Maikunkele, Bosso and Chanchaga.

Preparation of sample

Cooking: 150 g of fresh leaves of *Corchorus olitorius* were weighed out in two 1000 cm³ beakers containing 600 cm³ of distilled water. Content of one beaker was cooked for 5 minutes while the content of the second beaker was cooked for 10 minutes. The level of antinutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and micronutrients (β -carotene, vitamin C, Fe, Mg, Cu, Na and K) in the decoctions and cooked leaves were determined.

Drying: the leaves of *Corchorus olitorius* were weighed, spread in clean containers and dried in the sun. The leaves 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.

Analytical procedure

The soluble and total oxalates concentrations in the fresh and processed *Corchorus olitorius* was determined by titrimetric method [13]. Nitrate content in the test samples was determined by the colorimetric method [14]. Alkaline picrate method was used to analyse the cyanide concentration [15]. The mineral elements (Fe, Mg, Cu,

*Corresponding author: Amanabo Musa, Department of Biochemistry, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria, Tel: + 234-803-488-4031; E-mail: musaamanabo@gmail.com

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Na and K) in samples were determined according to the method of Ezeonu et al. [16]. The ascorbic acid concentration was determined by 2, 6-dichlorophenol indophenols method [17] while the estimation of β -carotene was done by ethanol and petroleum ether extraction method [18]. Each parameter in the fresh and processed samples was determined in triplicates.

Statistical analysis

Analysis of variance (ANOVA) was carried out using statistical package Minitab to determine variation between treatments. The DUNCAN's Multiple Range Test (DMRT) was used for comparison of mean.

Results

Cyanide concentration

Results obtained from the analysis of cyanide concentration in the processed samples of *Corchorus olitorius* showed that the cyanide content in fresh sample, 5 minutes decoction, 10 minutes decoction, leaves cooked for 5 minutes, leaves cooked for 10 minutes and sundried leaves were 147.77 mg/kg, 71.24 mg/kg, 80.63 mg/kg, 40.60 mg/kg, 31.89 mg/kg and 128.00 mg/kg, respectively. Data analysis indicated that sun drying had no significant ($p > 0.05$) effect on the cyanide concentration in the *Corchorus olitorius*. However, the two cooking periods led to a significant ($p < 0.05$) reduction of cyanide concentration (Figure 1). The amount of cyanide in leaves cooked 5 minutes was not significantly different from those cooked for 10 minutes. The residual cyanide in cooked leaves was significantly ($p < 0.05$) lower than the cyanide concentration in the decoction samples. The cyanogenic glycoside concentration in 5 and 10 minutes decoctions were also not significantly different from each other.

Nitrate concentration

Nitrate profile of the various processed samples of *Corchorus olitorius* were: fresh samples (3107.37 mg/kg), 5 minutes decoction (257.25 mg/kg), 10 minutes decoction (187.03 mg/kg), leaves cooked for 5 minutes (433.29 mg/kg), leaves cooked for 10 minutes (371.29 mg/kg) and sun dried leaves (1135.29 mg/kg). The results showed that

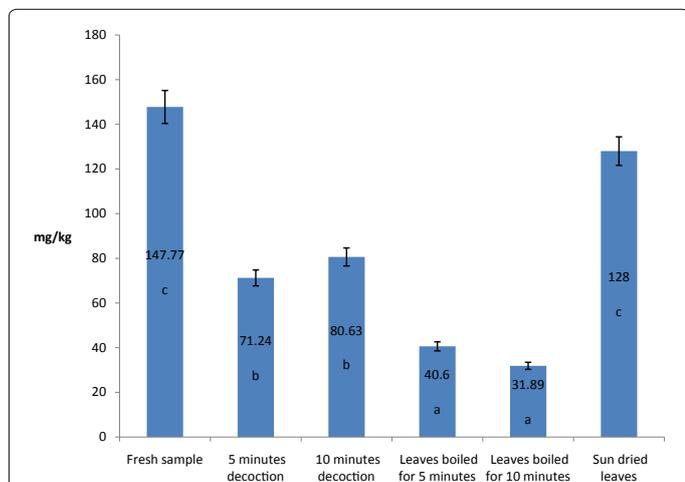


Figure 1: Effect of processing methods on cyanide content in *Corchorus olitorius*. Bars carrying the same letter are not significantly different ($p > 0.05$).

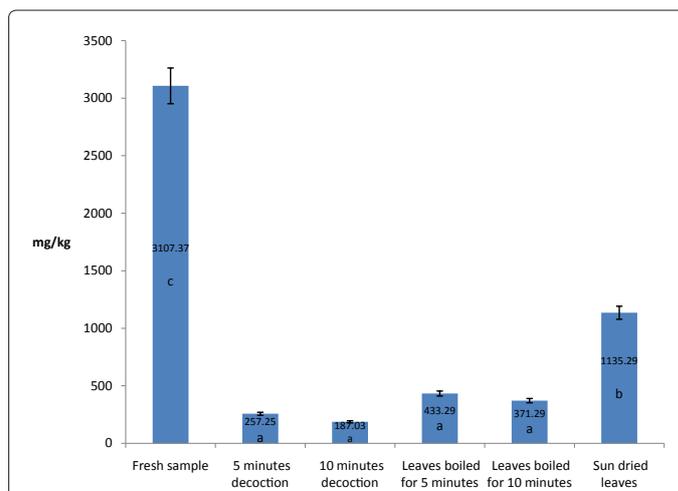


Figure 2: Effect of cooking and sun drying on nitrate content in *Corchorus olitorius*. Bars carrying the same letter are not significantly different ($p > 0.05$).

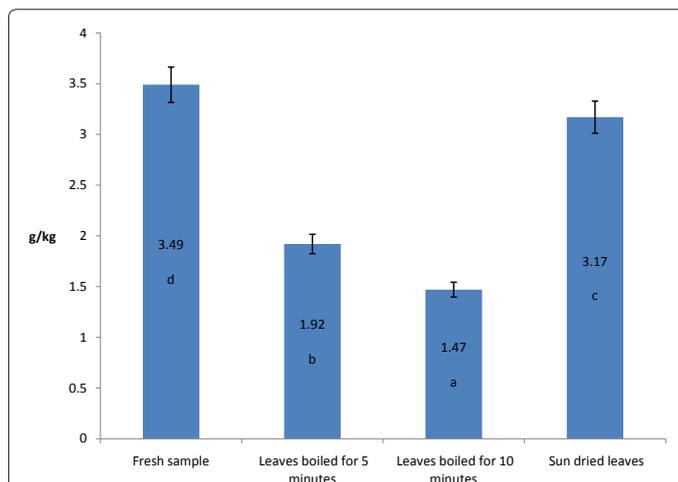


Figure 3: Effect of cooking and sun drying on soluble oxalate content in *Corchorus olitorius*. Bars carrying the same letter are not significantly different ($p > 0.05$).

nitrate concentration decreased significantly ($p < 0.05$) in all processed samples. The nitrate concentration in 5 minutes decoction, 10 minutes decoction, and leaves boiled for 5 and 10 minutes were not significantly ($p > 0.05$) different from each other. Sun dried leaves however, had significant ($p < 0.05$) amount of the compound than any of the processed samples (Figure 2).

Soluble oxalate concentration

Determination of soluble oxalate content in *Corchorus olitorius* showed that the oxalate concentration in the vegetable decreased significantly ($p < 0.05$) in all the processed samples. The amount of soluble oxalate in fresh (unprocessed) sample in *Corchorus olitorius* was 3.49 g/kg, however, with sun drying, 5 and 10 minutes of cooking it decreased to 3.17 g/kg, 1.92 g/kg and 1.47 g/kg, respectively. The residual soluble oxalate in leaves cooked for 5 minutes was significantly ($p < 0.05$) higher than in the leaves cooked for 10 minutes. However, the residual soluble oxalate from the two separately cooked leaves was significantly lower than in the sun dried leaves (Figure 3).

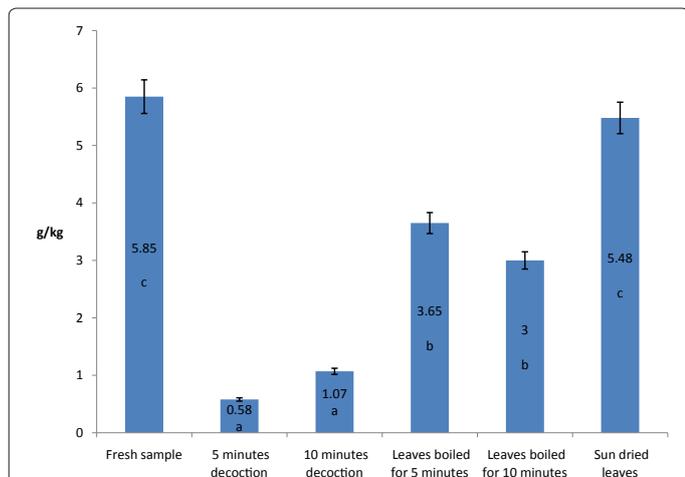


Figure 4: Effect of cooking and sun drying on total oxalate content in *Corchorus olitorius*. Bars carrying the same letter are not significantly different ($p > 0.05$).

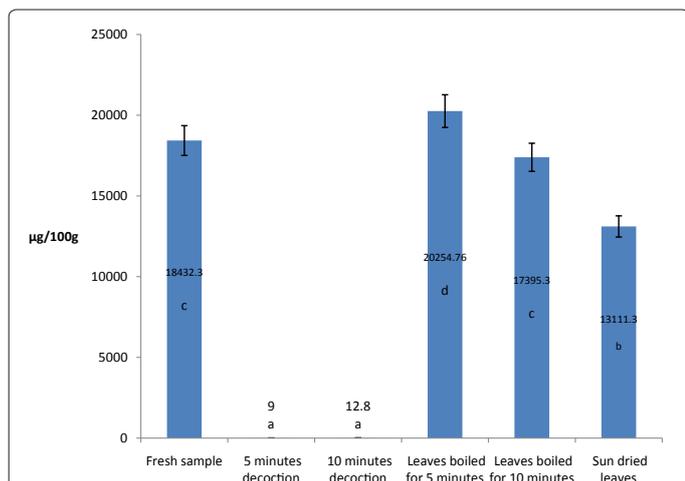


Figure 5: Effect of cooking and sun drying on β-carotene content in *Corchorus olitorius*. Bars carrying the same letter are not significantly different ($p > 0.05$).

Total oxalate concentration

Analysis of total oxalate concentration in *Corchorus olitorius* showed that sun drying had no significant ($p > 0.05$) effect on the total oxalate content. Cooking, however, significantly ($p < 0.05$) reduced total oxalate concentration in the *Corchorus olitorius*. The concentration of total oxalate in raw and processed samples of *Corchorus olitorius* were; fresh sample (5.85 g/kg), 5 minutes decoction (0.58 g/kg), 10 minutes decoction (1.07 g/kg), leaves cooked for 5 minutes (3.65 g/kg), leaves cooked for 10 minutes (3.00 g/kg) and sundried leaves (5.48 g/kg). The total oxalate in leaves cooked for 5 minutes was not significantly ($p > 0.05$) different from those of the leaves cooked for 10 minutes. The two decoctions had the least concentration of total oxalate, but their oxalate concentrations were not significantly different from each other (Figure 4).

β-carotene concentration

The amount of β-carotene in the processed samples of *Corchorus olitorius* were: fresh sample (18432.30 µg/100 g), 5 minutes decoction (9.00 µg/100 g), 10 minutes decoction (12.80 µg/100 g), leaves

cooked for 5 minutes (20254.76 µg/100 g), leaves cooked 10 minutes (17395.30 µg/100 g) and sun dried leaves (13111.30 µg/100 g). Data analysis showed that while 5 minutes of cooking significantly ($p < 0.05$) increased the β-carotene concentration in the *Corchorus olitorius*, sun drying significantly ($p < 0.05$) decrease its content. The percentage reduction of β-carotene caused by solar drying was about 28.87%. The amount of β-carotene in leaves cooked for 10 minutes was not significantly different from level in fresh sample (Figure 5). It is also pertinent to note that negligible amount of the β-carotene were found in decoctions.

Vitamin C concentration

The vitamin C concentration in *Corchorus olitorius* decreased significantly ($p < 0.05$) in all the processed samples. The amount of vitamin C in the processed samples of *Corchorus olitorius* were: fresh sample (78.90 mg/100 g), 5 minutes decoction (0.92 mg/100 g), 10 minutes decoction (1.01 mg/100 g), leaves cooked for 5 minutes (15.89 mg/100 g), leaves cooked for 10 minutes (11.60 mg/100 g) and sun dried leaves (13.69 mg/100 g). The percentage losses of the vitamin in leaves cooked for 5 and 10 minutes were 79.86% and 85.30%, respectively. Only negligible amount of the vitamin was found in 5 minutes (1.28 %) and 10 minutes (1.16%) decoctions. The percentage losses of the vitamin recorded in sun dried sample was about 82.35 %. Residual vitamin C in sun dried leaves, leaves cooked for 5 and 10 minutes were not significantly different from each other (Figure 6).

Iron concentration

The Fe concentration in the various processed samples of *Corchorus olitorius* were: fresh sample (26.03 mg/kg), 5 minutes decoction (6.37 mg/kg), 10 minutes decoction (9.54 mg/kg), leaves cooked for 5 minutes (16.63 mg/kg), leaves cooked for 10 minutes (11.81 mg/kg) and sundried leaves (25.98 mg/kg). The results obtained showed that sun drying had no significant effect on the Fe content in the *Corchorus olitorius*. However, 5 and 10 minutes of cooking significantly decreased ($p < 0.05$) the Fe content of *Corchorus olitorius* (Figure 7). The Fe concentration in the leaves cooked for 5 minutes was significantly ($p < 0.05$) higher than in the leaves cooked for 10 minutes. The amount of the mineral element in 10 minutes decoction was not significantly different from the amount in 5 minutes decoction and in leaves cooked for 10 minutes. However the later is significantly higher in the Fe concentration than the former.

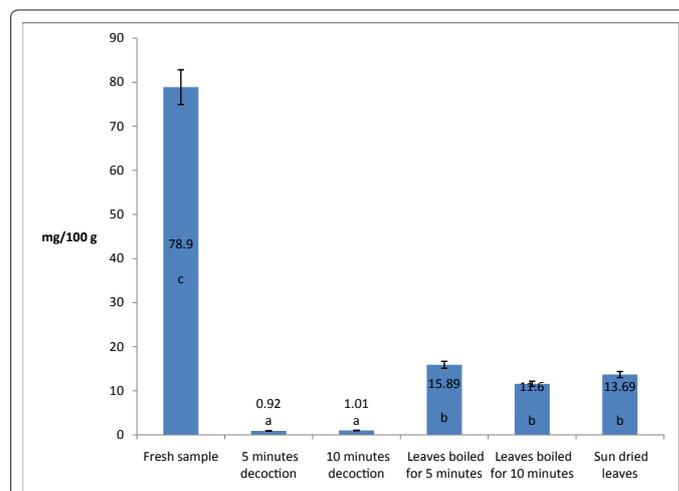
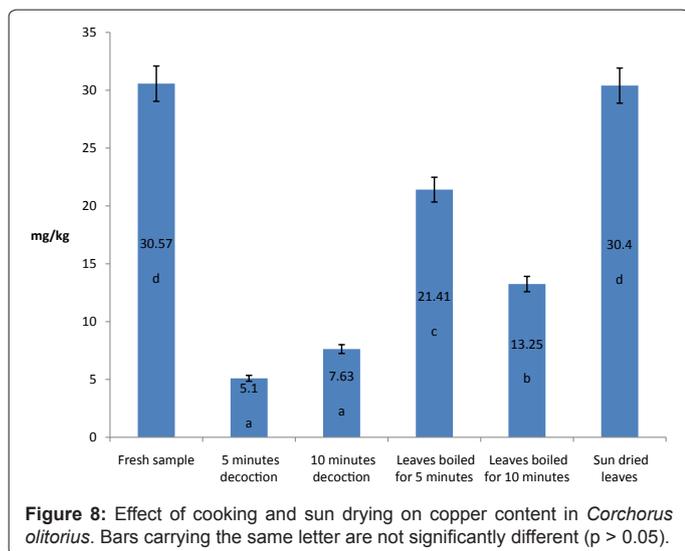
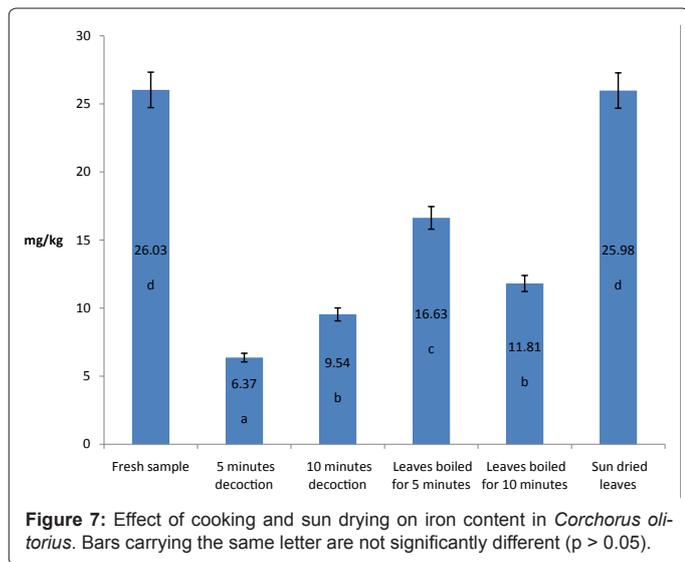


Figure 6: Effect of cooking and sun drying on vitamin C content in *Corchorus olitorius*. Bars carrying the same letter are not significantly different ($p > 0.05$).



Copper concentration

Analysis of Cu in the processed samples of *Corchorus olitorius* showed that 5 and 10 minutes of cooking significantly ($p < 0.05$) reduced the Cu concentration in the vegetable. Sun drying, however, had no significant effect on the mineral content in *Corchorus olitorius*. The amount of Cu in fresh sample of the vegetable was 30.57 mg/kg while the levels in 5 minutes decoction, 10 minutes decoction, and leaves cooked for 5 minutes, leaves cooked for 10 minutes and sun dried leaves were 5.10 mg/kg, 7.63 mg/kg, 21.41 mg/kg, 13.25 mg/kg and 30.40 mg/kg, respectively. The concentration of Cu in the leaves cooked for 5 minutes was significantly ($p < 0.05$) higher than in the leaves cooked for 10 minutes. The 10 minutes decoction had more of the mineral element than the 5 minutes decoction. The Cu content in the decoction samples were significantly ($p < 0.05$) lower than in all other processed samples (Figure 8).

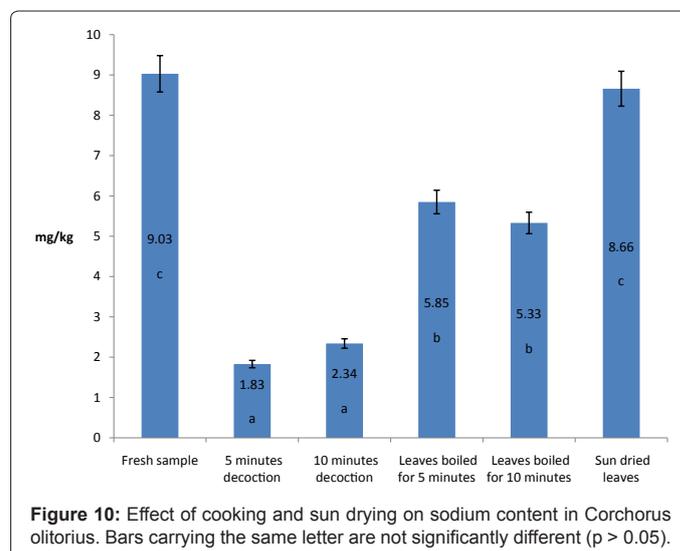
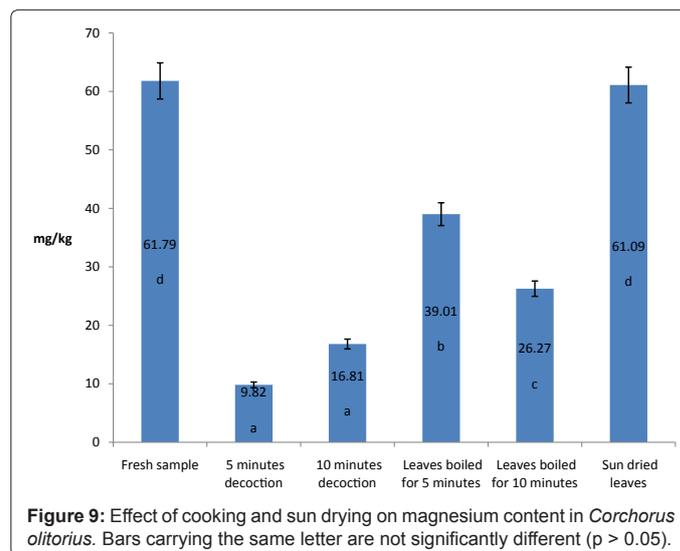
Magnesium concentration

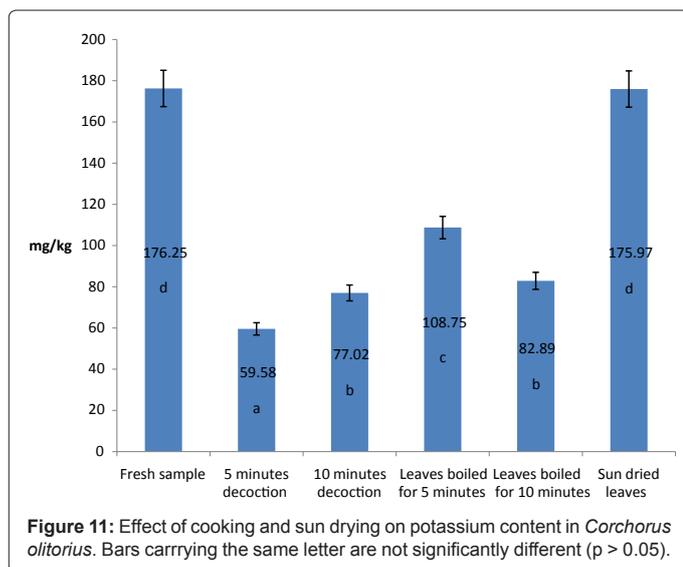
Results obtained from the determination of Mg content in the *Corchorus olitorius* showed that the mineral element concentration in

fresh sample (61.79 mg/kg) was not significantly different ($p > 0.05$) from that of sun dried sample (61.09 mg/kg). However, 5 and 10 minutes of cooking significantly decreased ($p < 0.05$) the Mg concentration to 9.82 mg/kg and 16.81 mg/kg, respectively. The Mg concentrations in 5 and 10 minutes cooked leaves were significantly the same ($p > 0.05$). The Mg concentration in 5 minutes decoction (9.82 mg/kg) and 10 minutes decoction (16.81 mg/kg) were also not significantly different ($p > 0.05$) from each other. Their Mg content was significantly ($p < 0.05$) lower than in other processed samples (Figure 9).

Sodium concentration

The amount of Na in the various processed samples of the *Corchorus olitorius* were as follows: fresh sample (9.03 mg/kg), 5 minutes decoction (1.83 mg/kg), 10 minutes decoction (2.34 mg/kg), leaves cooked for 5 minutes (5.85 mg/kg), leaves cooked for 10 minutes (5.33 mg/kg) and sun dried leaves (8.66 mg/kg). The results obtained clearly showed that sun drying had no significant effect ($p > 0.05$) on the Na concentration in *Corchorus olitorius*. However 5 and 10 minutes of cooking significantly reduced the Na concentration in the vegetable. The residual concentration Na in leaves cooked for 5 and 10 minutes





was significantly the same. The Na concentration in 5 and 10 minutes decoctions were least compared to other processed samples. The Na concentration in the decoctions was not significantly different from each other (Figure 10).

Potassium concentration

Results obtained from the analysis of K content in *Corchorus olitorius* showed that the concentration of the element in fresh sample (176.25 mg/kg) was significantly the same ($p > 0.05$) as that of sundried sample (175.97 mg/kg). However, 5 and 10 minutes of cooking significantly decreased ($p < 0.05$) the Na concentration from 176.25 mg/kg to 108.75 mg/kg and 82.89 mg/kg, respectively. The K concentration in the leaves cooked for 5 and 10 minutes was not significantly different from each other. The mineral element content in 5 minutes decoction (59.58 mg/kg) and 10 minutes decoction (77.02 mg/kg) was also not significantly different from each other. The K concentration in the decoctions and cooked leaves was significantly the same, except that leaves cooked for 5 minutes had significant ($p < 0.05$) higher concentration of K than 5 minutes decoction (Figure 11).

Discussion

The observed higher cyanide concentration in the fresh sample of *Corchorus olitorius* compared to the corresponding processed samples, agrees with the submission of [19-21] that various food processing methods reduce cyanide content in *Americana* leaves, plants and cassava leaves, respectively. In the current study there was a significantly higher concentration of cyanide in 5 and 10 minutes decoctions than in the corresponding cooked leaves in *Corchorus olitorius*. This observation may entail that cooking the leaves of *Corchorus olitorius* in water and discarding the water used in cooking would greatly reduce the cyanogenic glycoside concentration in the vegetables. This observation is in agreement with the earlier reports [8,22]. These authors separately observed that boiling of the vegetables in water break the cell walls and can then cause the leakage of the cell contents including the antinutrients and toxic substances. The observed low concentrations of cyanide in decoctions and residual leaves compared to higher concentrations of cyanide in the fresh sample of *Corchorus olitorius* implies that cyanide may be volatile and, or some may likely be destroyed during cooking. The much decrease

in cyanide concentrations in *Corchorus olitorius* during sun drying can be attributed to the volatile nature of cyanide and could likely be dissipated during sun drying. This observation corroborates the earlier findings of [22,23]. The recorded significant amount of this respiratory poison in sundried leaves compared to the levels found in the leaves cooked for 5 and 10 minutes indicates that cooking may be superior in cyanide reduction than sun drying. The reason may be attributed to the fact that boiling leads to break down of the plant cell wall which allows for the leakage of cell contents [8,22] while sun drying is a mere gradual evaporation process. The concentration of cyanide in the fresh sample of *Corchorus olitorius* is lower than maximum permissible level of 200 mg/kg fresh weight of vegetables or forages [23,24]. The insinuation of the results is that the cyanide concentration in the fresh and processed samples of *Corchorus olitorius* may not be high enough to induce toxicity in man.

The higher concentration of nitrate in fresh sample of *Corchorus olitorius* compared to the treated samples is in harmony with the findings of [10,12,25,26] who reported that various heat treatments such as cooking and drying significantly reduced the nitrate concentration in the vegetables compared to fresh samples. Similarly there is observed general higher nitrate content in 5 minutes decoctions than 10 minutes decoctions. The observation that the leaves residue cooked for 10 minutes had less concentration of nitrate suggested that the nitrate may have been degraded or converted to other compound with increased heating time. The observation is in accord with the submission of Waclaw and Stefan [10] who demonstrated that heat treatment can degrade nitrate into another compounds. The significantly higher amount of nitrate in sun dried leaves compared to the concentrations found in the leaves cooked for 5 and 10 minutes further shows the superiority of cooking over sun drying. Vegetables may be classified as high or low nitrate content. Vegetables with nitrate levels of 1000-4000 mg/kg are classified as high nitrate content [12,27]. It follows therefore that *Corchorus olitorius*, with nitrate levels 3107.37 mg/kg is a high nitrate vegetable. Values of nitrate in fresh sample of *Corchorus olitorius* is more than the acceptable daily intake (ADI) of 3.65 mg/kg for 60 kg body weight (219.00 mg/day) if 100 g samples are consumed per day. The implication of the verdict is that regular consumption of raw (unprocessed) samples of *Corchorus olitorius* may likely over load the body with nitrate with attendant health problems of methaemoglobinaemia and cancers [9-12]. Fortunately, the processing methods adopted greatly reduced the nitrate concentration in *Corchorus olitorius* to the acceptable levels.

There are higher soluble and total oxalates concentration in the fresh leaves of *Corchorus olitorius* compared with processed samples. This is in harmony with the observation of Abakr and Ragaa [25] and Adeboye and Babajide [28], who have reported that various food processing methods reduce oxalate content in plants. The higher oxalates concentration in the fresh sample of *Corchorus olitorius* than in the cooked leaves agrees with reports of Antia et al. [6], Ogbadoyi et al. [8], Ojiako and Igwe [21] and Adeboye and Babajide [28], which show that proper boiling/cooking of vegetables before consumption significantly reduced the oxalate concentration. The higher soluble and total oxalates concentration in sun dried sample than in 5 and 10 minutes cooked leaves further supports that cooking, as processing method is more effective in reducing the antinutrient content in *Corchorus olitorius* than sun drying.

The soluble and total oxalate concentrations are 3.49 g/kg and 5.85 g/kg, respectively in fresh leaves of *Corchorus olitorius* are more than the permissible level of 250 mg/100 g fresh [29]. Thus regular

consumption of fresh raw sample of *Corchorus olitorius* without proper treatment could lead to ingestion of toxic levels of the antinutrient into the body, with attendant health problems of hypocalcaemia, kidney stone and electrolyte imbalance [5-7,30-32]. Our current finding revealed that only cooking reduced the soluble oxalate concentration in *Corchorus olitorius* to the tolerable level and significantly reduced the total oxalate, but sun drying could not. It therefore suggested that sun drying as a method of processing may not be the appropriate method for reduction of oxalate content in *Corchorus olitorius* to satisfactory levels.

The observed higher β -carotene concentration in leaves cooked for 5 minutes than those cooked for 10 minutes and fresh sample in *Corchorus olitorius* is in accordance with the report of USDA [33], that moderate cooking increases the availability of β -carotene in the vegetables; as 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 [34]. Further stressed that the release of protein-bound β -carotenes and loss of soluble solids that arise during boiling may also contribute to the observed increase in the provitamin A concentration. The negligible amount of the β -carotene found in 5 and 10 minutes decoctions compared to higher amount of the compound in the fresh and boiled vegetables justifies the hydrophobic nature of β -carotene [34-37].

The level of β -carotene was significantly lower in sundried sample compared with the fresh sample in the vegetable. This observation agrees with the report of Ejoh et al. [37], 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 which can be oxidized by molecular oxygen during sun drying to a compound with no β -carotene activity [34]. Further stressed that, the isomerisation of the naturally predominant all-trans carotenoids to cis conformations could as well reduce the β -carotene content in the vegetable during sun drying. The significantly higher concentrations of β -carotene in cooked *Corchorus olitorius* than in the sun dried sample suggest that moderate cooking is better in conserving and improving the availability of β -carotene than sun drying [33,34,37]. This observation, thereby strengthen the earlier submission that boiling as a processing method may be better to sun drying. The fresh leaves of *Corchorus olitorius* can provide over and above of the adult recommended daily allowance of 900 μ g vitamin A [35,38]. 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 [33,34,37]. Sun drying which significantly decreased the β -carotene content in *Corchorus olitorius*; still provide sample with residual β -carotene more than the normal recommended adult daily allowance of 900 μ g vitamin A. The results thus revealed that sun drying which is the most common method of processing in the rural areas can still retain enough β -carotene concentration in *Corchorus olitorius* to meet the normal adult recommended daily allowance. Moderate cooking (especially 5 minutes cooking), however increased the provitamin when compared with fresh samples. Thus adopting any of the processing methods for *Corchorus olitorius* may not require pharmaceutical supplements for a healthy individual to meet the normal recommended daily allowance of vitamin A.

The significantly lower levels of vitamin C in cooked samples compared to fresh sample in *Corchorus olitorius* is in line with earlier reports [34,35,37,39]. The authors attributed the losses of the vitamin to the thermo sensitive, labile and hydrophilic nature of vitamin C. The higher percentage losses of vitamin C in the leaves cooked for 10

minutes compared to those cooked for 5 minutes is in line with the recommendation of [25,34,40] 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 *Corchorus olitorius* despite the higher percentage losses observed in the cooked leaves justifies the labile and thermo sensitive properties of vitamin C [34,35,37,39]. Significant losses of the vitamin in sundried sample may be probably due to oxidation of the vitamin which is one of the biochemical changes caused by the intrinsic enzymes (vitamin C oxidase and peroxidase) found together with the vitamin. Wilting is one of the factors that could be responsible for the vitamin losses during sun drying [39,41-43]. The vitamin C concentration in the fresh *Corchorus olitorius* is 78.9 mg/100 g. From the results obtained in this study, *Corchorus olitorius* could supply enough vitamin C to the adult recommended daily allowance of 60 mg [35,39] if 100 g of the samples are consumed. Unfortunately, the *Corchorus olitorius* accumulates 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 decreased the vitamin C concentration less than the recommended daily allowance of 60 mg [35,39]. Among the treatment methods adopted, 5 minutes cooking retained and conserved more of the vitamin in *Corchorus olitorius* leaves than other treatment methods, even though the vitamin concentration was lower than the recommended daily allowance. Considering the vital roles of vitamin C in human nutrition 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 contents in the cooked leaves compared with the fresh leaves of *Corchorus olitorius* is in accordance with the earlier findings [19,25,44-46] that various conventional food processing techniques (blanching, cooking) cause a significant decrease in the mineral element concentrations in the vegetables. This observation however, contradicts the results of [47] that the minerals in the vegetables are not affected by cooking the leaves of the vegetables. Losses of the mineral elements during cooking were attributed to the discharge of the cell content including minerals during cooking [25].

The higher levels of the minerals in the leaves cooked for 5 minutes compared with those cooked for 10 minutes, harmonized with the generally higher concentration of the minerals in the 10 minutes than 5 minutes decoctions, agrees with the report of [25]. These authors concluded that the amount of minerals lost in the vegetable during cooking increases with cooking time.

The insignificant effect of sun drying on Fe, Cu, Mg, Na and K concentrations in *Corchorus olitorius* observed in this present study is in line with the finding of Chweya and Nameus [47] who has reported that the mineral elements in the vegetables were not significantly affected by sun drying. 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 general non-volatile substances.

The concentration of Fe in the fresh leaves of *Corchorus olitorius* is 26.03 mg/kg. This vegetable contains an appreciable amount of the mineral and it therefore implies that adequate intake of fresh and sun dried leaves of the vegetable can provide the body more than the recommended daily intake of 18 mg/day of Fe for normal adult [48]. Cooked leaves of *Corchorus olitorius* could only meet the

recommended daily intake of this mineral element that is involved in cellular metabolism if the decoctions are retained. Since controlled cooking and discarding the decoctions is one of the effective ways of reducing some of the plant toxins safe levels [8], supplementation of mineral with fruits and pharmaceuticals products become necessary.

The concentrations of the Cu in fresh, dried and leaves cooked for 5 minutes could meet the range of the recommended daily allowance of 1.5 - 3.0 mg/day of Cu [48], if 100 g of samples were consumed. However, with leaves cooked for 10 minutes, the decoction must be included in the meal preparation otherwise the residual Cu cannot meet adult recommended dietary allowance.

The Mg concentration of 61.69 mg/kg in fresh *Corchorus olitorius* is lower than the normal adult recommended daily allowance of 350 mg of Mg/day [35]. The results indicated that the Mg content in fresh *Corchorus olitorius* is low, with processed samples even lower. The inference of this observation is that total dependency on *Corchorus olitorius* to provide this important cofactor of enzymes involved in cell respiration, glycolysis and transmembrane transporter [48,49] may lead to the deficiency of the mineral. To prevent this condition, there is a need to balance up the nutrient concentrations 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 [35].

Similarly the Na concentration of 9.03 mg/kg in fresh *Corchorus olitorius* is low when compared with values found in the in available literature. Fortunately, this element required for maintenance of fluid balance and normal osmotic pressure in the body for cellular activities [48,50,51] is added in almost every home in food preparations as condiments to taste in the form of sodium chloride or table salt [35,50,52]. This practice will complement the low concentration of Na in *Corchorus olitorius* and its losses during processing.

The concentration of K in fresh *Corchorus olitorius* is 176.25 mg/kg. This result revealed that the vegetable contained an appreciable amount of the element responsible for maintaining fluid and acid-base and regulation of nerve transmission. Thus, *Corchorus olitorius* could be considered as excellent sources of K [53]. 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 decoction in order to reduce some of the plant toxins to an appreciable safe level [8], supplementation of the mineral with fruits and whole grains may be necessary.

Conclusion

The concentrations of nitrate, soluble and total oxalates in the fresh sample of *Corchorus olitorius* are higher than the permissible levels. The negative health problems associated with high intake of these phytotoxins in the vegetable can be averted through cooking and sun drying. With moderate cooking (especially 5 minutes cooking) being the preferred method, since it reduce the plant toxins to tolerable levels without compromising the nutritional potential of *Corchorus olitorius*.

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