



Influence of sun drying and a combination of boiling and sun drying on the retention of nutrients and bioactive compounds in cowpea (*Vigna unguiculata* (L). Walp) leaves

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Abstract

The nutrients and bioactive compounds retention of cowpea (*Vigna unguiculata* (L). Walp) leaves subjected to the two traditional processing methods of sun drying and a combination of boiling and sun drying was investigated. Findings revealed that the retention of carbohydrates (92.72%), proteins (97.41%) and ash (92.39%) was significantly higher among samples that were subjected to sun drying alone, than samples subjected to boiling and sun drying. Considerable reduction in lipids content of sun dried samples (20.24%) and boiled and sundried samples (17.16%) were registered. Significant ($p < 0.05$) loss of bioactive compounds was registered when fresh leaves were subjected to the two processing methods. For example only 7.13% and 8% of β -carotene was retained in boiled and sun-dried samples and in sun dried samples, respectively. Insignificant effect on minerals was observed with more than 92% of Fe, Ca and Zn retained in sun dried and in boiled and sun dried leaves. The study demonstrated that subjecting cowpea leaves to sun drying and a combination of boiling and sun drying, leads to insignificant loss of carbohydrates and proteins but leads to the loss of bioactive compounds. The two processing techniques had insignificant effect on minerals contents. The study results show that drying could be considered for cowpeas preservation, which would contribute to ensuring all year availability of the vegetable.

Keywords: β -carotene, Vitamin C, Phenolics and traditional processing

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1. Introduction

Cowpeas (*Vigna unguiculata* (L.) Walp) leafy vegetables are nutritionally rich and are associated with a number of benefits including provision of essential nutrients and bioactive compounds such as carotenoids, flavonoids, vitamin C, proteins and minerals (UNICEF, WHO, World Bank Group, 2019) and aiding in digestion due to their high dietary fibre content (Enyiukwu et al., 2018). These vegetables are also superior to other leafy vegetables, since they grow in diverse environments including tropical and semi-arid, require minimal attention and mature within a short period of time of only three weeks (Maringa et al., 2020). This makes cowpea leaves accessible most of the year, and suitable alternative to majorly unaffordable protein rich foods like beef, chicken and eggs in low-income countries such as Uganda (Kiremire et al, 2010; and Van der Hoeven et al., 2013). These leafy vegetables serve as a major delicacy, in various traditional diets across Uganda, especially in the northern and eastern parts of the country (Rubaihayo, 1995). Fresh leafy cowpea vegetables are mainly consumed as accompaniments to main dishes or as a sauce, contributing to the nutrition, food security and well-being of the rural poor communities (Muchoki, 2007; and Shetty et al., 2013).

Good postharvest handling practices, processing and preservation techniques are key in maintaining the nutritional and physical quality of these leaves. These practices can minimize damages to the leaves and nutrient loss (Gupta et al., 2013). In Uganda, sun-drying and boiling are the major traditional processing methods used to prepare or to extend the shelf life of cowpea leaves. However, there is paucity of information on the effect of these traditional methods on the retention of nutrients and bioactive compounds in cowpea leaves. Therefore, the present study investigated the effects of traditional processing and preservation techniques, namely sun drying and a combination of boiling and sun drying, on nutrient and bioactive compounds retention in cowpea leaves.

2. Material and methods

2.1. Sample collection

Freshly harvested cowpea leaves were collected from farmers in *Budondo* sub-county, Jinja district in eastern Uganda. Budondo is at 0° 30' 56" north of the equator and 33° 9' 54" east, 87 km east of Kampala capital city. Samples were obtained from *Buyala A*, *Buwailamu* and *Kivubuka B* villages that are popular in the cultivation of cowpeas for leaf consumption. One variety of cowpeas with small sized tender leaves locally known as '*Empindi*' was selected because it was reported by farmers and key informants to be early maturing and fast cooking. The leaves were harvested at physiological maturity of three weeks after planting. Nine leaf bundles each weighing about 500 g were prepared and collected from each village. The bundles were placed in cool boxes and transported to the nutrition laboratory of the Department of Food Technology and Nutrition at Makerere University where they were stored at 20 °C in a refrigerator for one day for further analyses.

2.2. Sample preparation

The bundles were thoroughly washed under a stream of running water to remove foreign matter from the leaves and the stalks. The leaves were plucked off from the stalks by hand and sorted to remove wrinkled, bruised and bleached leaves. The sound fresh leaves were divided into three portions each weighing 300 g. One portion which acted as the control was kept in a refrigerator. The second portion was boiled in a saucepan (1:2, water to cowpea leaves) for 10 min simulating the procedure commonly practiced in households. The boiled leaves were then placed on clean metallic meshed trays and sundried at ambient temperatures 25-28 °C on a clean tarpaulin to constant weight for five days. The third portion of leaves was spread on pre-cleaned meshed metallic trays and also sun dried on a clean tarpaulin for five days. Dried samples were ground into powder using a blender (Oster Model SV, John Oster Mfg. Co., Milwaukee, WI, USA) and kept in air tight plastic containers at room temperature awaiting further analyses.

2.3. Nutrient analysis

2.3.1. Proximate composition analysis

Protein determination: Total crude protein content was determined using the Kjeldahl 984.13 method (AOAC, 2005). About 0.5 g each of the fresh and processed cowpea leaves were mixed with 10 mL of concentrated sulphuric acid and digested with a Kjeldahl digester (Model Bauchi 430). About 40 mL of water was added to

the digest and distilled using a Kjeldahl distillation unit (Model unit B-316). Liberated ammonia was collected in 20 mL boric acid with bromocresol green and methyl red indicators and titrated against 0.04 N sulphuric acid (H₂SO₄). Crude protein was determined by multiplying nitrogen content by a factor of 6.25.

Determination of carbohydrate: Carbohydrate content was determined by the phenol-sulphuric acid method (Dubois et al., 1956). One gram of sample was mixed with 5 mL of 2.5 N hydrochloric acid (HCl) and boiled in a water bath for 3 hours to hydrolyze the sugars. After cooling, a sufficient quantity of solid sodium carbonate was added until the effervescence ceased. The mixture was filtered and made up to the mark using distilled water in a 100 mL volumetric flask. Into a test tube, 5 mL of sample was pipetted and 1 mL of 5% phenol solution added. After shaking well, 5 mL of concentrated sulfuric acid (96%) was added after which the mixture was vortexed and then left to stand for 10 minutes. Absorbance of the sample was read at 490 nm using a spectrophotometer (Spectroquant Pharo® 300, EU). A standard curve was developed using glucose standards of varying concentration (0.01 to 0.1 mg/mL). The total amount of carbohydrate in the sample derived from glucose standard graph and expressed as g/100 g of the powdered cowpea leaves.

Lipid determination: The total lipid content was determined using the ether extraction method 920.39 (AOAC, 2005). Crude lipid was extracted from the three different cowpea leaves samples using 5 g for each sample of the extract in petroleum ether as a solvent and soxhlet extractor (Dijkstra Vereenigde BV, Lelystad, The Netherlands). After evaporation of the petroleum ether, the weight of the lipid obtained gave the crude lipid in the samples.

Ash determination: The inorganic matter (total ash) was determined using method 942.05 (AOAC, 2005). The organic matter of the three cowpea leaves samples was removed by heating them at 550°C overnight and the residue being the inorganic matter (ash).

$$\frac{\text{Weight of crucible and ash} - \text{weight of crucible}}{\text{Weight of crucible and sample} - \text{weight of crucible}} \times 100$$

Dietary fiber determination: The total dietary fiber content was determined using the method 978.10 (AOAC, 2005). Five grams of the three cowpea leaves samples including; one fresh form and two processed, were used to determine the fiber contents by acid digestion, filtration and base digestion. The resulting residues were eventually ignited at 550°C in a muffle furnace. Crude fiber content was expressed as a percentage lost on ashing, compared to the initial weight.

2.3.2. Bioactive compounds

β-carotene determination: The β-carotenoid content in the samples was determined according to the method described by Rodriguez-Amaya and Kimura (2004) with some modifications. One gram of the fresh or processed cowpea leaf sample was ground with 50 mL of acetone and the decanted liquid filtered in a 50 mL volumetric flask using glass wool. The filtrate was transferred to a 250 mL separating funnel to which 30 mL of petroleum ether was already added. Approximately, 250 mL of distilled water was added slowly to the mixture, letting it flow along the walls of the funnel. The two phases separated and the aqueous (lower) phase was discarded. The upper phase was washed four times with distilled water (250 mL each time) in order to remove any residual acetone. In the last washing, the lower phase was discarded as completely as possible, without discarding any of the upper phases. The petroleum ether phase was then collected in a volumetric flask (50 mL) while being passed through a small funnel containing anhydrous sodium sulphate (10 g) to remove residual water. The separatory funnel was washed with petroleum ether, collecting the washings in the volumetric flask while passing through the funnel with sodium sulphate. The solution was made up to the 50 mL mark using petroleum ether. Total carotenoids were determined by measuring absorbance at 470 nm against a blank sample using a Spectrophotometer (Spectroquant Pharo® 300, EU).

The absorbance of the sample was taken at 450 nm using a Spectrophotometer (Spectroquant Pharo® 300, EU) and the β-carotene content calculated using the formula below:

$$\beta\text{-carotene } (\mu\text{g/g}) = \frac{\text{Absorbance} \times \text{Total volume} \times 10^{-4}}{\text{Sample weight} \times 2592 \times 12}$$

Analysis of vitamin C content: Determination of vitamin C was done using the 2, 6-dichloroindophenol (DCPIP) method according to the AOAC method 967.21 (AOAC, 2005). Five grams of the fresh or processed cowpea leaf sample were macerated with solvent of 3% (w/v) meta-phosphoric acid and 8% (v/v) glacial acetic acid and transferred to a 50 mL volumetric flask to which more solvent was added up to the mark. The mixture was shaken vigorously and 5 mL pipetted out into conical flasks. The solution was titrated against standard DCPIP until a gross pink which was stable for one minute. The ascorbic acid content was then obtained by calculation using the formula below:

$$\text{Ascorbic acid (mg/100 mL)} = \frac{\text{Net titer} \times \text{Conc. of DCPIP} \times \text{Total volume} \times 100}{\text{Volume pipetted} \times \text{Sample weight}}$$

Total phytates content determination: Phytic acid content was determined using the colorimetric method according to procedures developed by Harland and Oberleas (1986) and slightly modified by Sarkiyayi and Agar (2010). About 1 g of sample was macerated in a mortar and pestle to extract phytic acid using 100 mL of 2.4 M hydrochloric acid (HCl) mixed with 0.1 M sodium chloride. The clear supernatant of filtrate of the extract was diluted 10 times by transferring it into a 100 mL volumetric flask and making up to the mark using distilled water. Thereafter, 1 mL of clear solution was further diluted 10 times with distilled water. Three milliliters of the diluted sample were mixed with 1 mL of Wade reagent (0.03% FeCl₃·6H₂O + 0.3% sulfosalicylic acid; 27308, Sigma-Aldrich Laborchemikalien GmbH), thoroughly vortexed at 3000 rpm and centrifuged for 10 min (Fischer scientific 225, fisher scientific co, st Louis, MO, USA). A series of calibration standards containing 0, 1.12, 2.24, 3.36, 5.6, 7.84 and 11.2 mg/mL were prepared from sodium salt (molecular weight = 660.04 g). Absorbance of color reaction products for both samples and standards was read at 500 nm on a spectrophotometer (Spectroquant Pharo® 300, EU).

Extraction and analysis of phenolics and flavonoids: Phenolics and flavonoids were extracted using the method described by Singleton *et al.* (1999) with slight modification. Five grams of fresh or processed cowpea samples were extracted using 50 mL of (80% methanol: 20 mL of water solution (v/v) and placed in falcon tubes. The falcon tubes containing the mixture were suspended in ultrasonic water (Bransonic series, M.2800-E; Branson Ultrasonics, Co, Danbury, CT, USA) and subjected to ultrasonic treatment for approximately 20 min at room temperature to allow extraction to take place. The extracts were then cooled in a freezer for 10 minutes at 4 °C and there after centrifuged at 3000 × g for 10 min using a centrifuge (Fischer scientific 225, fisher scientific co, St Louis, MO, USA). The supernatant was removed from the mixture and collected into a separate tube and stored at 4 °C. The remaining mixtures were further reextracted under the conditions previously described to ensure efficient extraction. The two supernatants were poured into an airtight container and stored in a freezer at 4 °C to be used in the determination of total phenolics content and total flavonoids content.

Total flavonoids content was determined using the colorimetric assay as described by Muanda *et al.* (2011) with some modification. A 250 μL aliquot of the methanol extract was added to a 25 mL volumetric flask containing 1 mL of distilled water and 75 μL of sodium nitrite (5% w/v) and mixed. After 5 min, 75 μL of aluminum chloride (10% w/v) was added. Five hundred micro liters of sodium hydroxide (1 M) was added to the mixture immediately after which the solution was diluted by adding 2.5 mL of distilled water and mixed thoroughly. Absorbance of the mixture was determined at 510 nm against a blank that contained distilled water instead of sample. Using quercetin standard, a calibration curve was constructed within the concentration range 0.025-0.225 mg/mL (R² = 0.999). The total flavonoid content of the samples was expressed as milligram quercetin equivalents per gram (mg QE/g) of cowpea leaf.

The total phenolics content of cowpea leaves was determined using the folin-ciocalteu colorimetric method as described by Singleton *et al.* (1999) with some modifications. About 100 μL of the diluted sample extract (1:10 of the leaf sample to water (v/v)) was pipetted into a test tube covered with aluminum foil and topped up to 0.5 mL with double distilled water. Then 0.25 mL of folin-ciocalteu reagent (1N) was added followed by 1.25 mL of sodium carbonate (20% w/v) and the mixture homogenized using a vortex at 1500 rpm for 1 min. The mixture was then incubated at room temperature for 40 min to allow for color development. Color absorbance was measured at 725 nm (Genezys 10-uv-spectrophotometer, thermo Electron Corporation, Madison WI, USA) against methanol as the blank. Gallic acid was used as a standard for plotting a calibration curve with varying concentrations (0.02-0.125 mg/mL). The total phenolics contents were determined and expressed as milligram gallic acid equivalent (mg GAE/100 g) of the cowpea leaf.

2.3.3. Mineral content determination

For mineral content determination, the leafy vegetable samples were digested using nitric/sulphuric acid (1:1 v/v) mixtures (AOAC, 2006). The atomic absorption spectroscopy method 975.03B as described by Fungo *et al.* (2015), was used to determine calcium (Ca) at a wavelength of 624 nm and zinc (Zn) contents at a wavelength of 430 nm while iron (Fe) at a wavelength of 510 nm was determined using the atomic absorption spectroscopy methods 999.11 (AOAC, 2006), and phosphorous (P) at a wavelength of 315 nm content determined using the gravimetric method 966.01 (AOAC, 2006). Both atomic absorption spectrophotometer (model AAS model, SP9) and calorimeter (model DSC-2010—TA Instruments) were calibrated against the standard curves that were obtained after instrument calibration for each corresponding pure mineral of iron, zinc, calcium and phosphorous.

2.4. Statistical analysis

The data obtained were analyzed using XLSTAT software (version 2012. 10.7.01 Addinsoft, Paris, France). The means for nutrient and bioactive concentration of the fresh, sun dried and a combination of boiling and sun drying of the leafy vegetables were calculated. The results were expressed as means \pm standard deviations. A one-way ANOVA was performed and means separated using Tukey's test at $p = 0.05$.

3. Results

3.1. Proximate composition of fresh and processed cowpea leaves

The retention of carbohydrates (92.72%), proteins (97.41%) and ash (92.39%) were significantly ($p < 0.05$) higher in sun dried samples than in boiled and sun dried samples (Table 1). Furthermore, considerable reduction in total lipids content of the sun-dried samples (20.24%) and boiled and sun dried samples (17.16%) were registered.

Treatment	Carbohydrates	Proteins	Dietary fiber	Ash	Lipids
Fresh (control)	33.78 ^b \pm 1.64	23.09 ^b \pm 8.04	18.23 ^a \pm 2.93	10.92 ^b \pm 0.06	7.81 ^a \pm 0.06
Sun dried	31.32 ^a \pm 8.66	22.43 ^a \pm 7.41	15.20 ^b \pm 2.59	10.09 ^a \pm 1.80	1.57 ^b \pm 0.01
Retention (%)	92.72	97.41	83.38	92.39	20.24
Boiled + Sun dried	28.27 ^a \pm 3.57	18.25 ^{a, b} \pm 3.55	13.16 ^c \pm 4.45	9.10 ^c \pm 0.22	1.34 ^c \pm 0.03
Retention (%)	83.43	79.03	72.19	83.34	17.16

Note: Values with the same superscript in the same column are not significantly different while those with different superscripts are significantly different from each other ($p < 0.05$).

3.2. Minerals composition of fresh and traditionally processed cowpea leaves

The mineral contents of fresh samples were not significantly different from the contents registered in the samples subjected to the traditional processing techniques (Table 2). The boiled and sun dried cowpea leaves samples registered a higher retention of all minerals concentration (except for phosphorous which was 182.01 mg/100 g) than samples that were subjected to sun drying alone.

3.3. Bioactive compounds composition of fresh and traditionally processed cowpea leaves

Fresh cowpea leaves registered significantly ($p < 0.05$) higher contents of β -carotene (20.6 μ g/100 g), vitamin C (182.32 mg/100 g), phenolics (195.47 mg/100 g) and flavonoids (23.56 OE /100 g) than the contents registered in the two traditionally processed samples (Table 3). Significant losses of bioactive compounds were registered when cowpea leaves were subjected to the two drying techniques. The samples that were subjected to sun drying and the combination of boiling and sun drying techniques, retained β -carotene contents of 1.65 μ g/100

g and 1.47 $\mu\text{g}/100\text{ g}$ respectively, vitamin C contents of 12.60 mg/100 g and 9.13 mg/100 g, phenolics content of 85.50 GAE/100 g and 25.52 GAE/100 g and flavonoids content of 4.56 QE/100 g and 3.97 QE/100 g.

Minerals contents (mg/100 g)	Treatment		
	Fresh	Sun-dried	Boiled + sun-dried
Fe	79.32 ^a \pm 2.01	74.81 ^a \pm 0.27	77.38 ^a \pm 2.95
Retention (%)		94.31	97.55
Zn	8.06 ^a \pm 0.65	7.90 ^a \pm 1.37	8.02 ^a \pm 0.16
Retention (%)		98.01	99.50
P	191.25 ^a \pm 2.04	182.01 ^a \pm 1.56	180.69 ^a \pm 3.29
Retention (%)		95.17	94.47
Ca (g/100 g)	2.08 ^a \pm 0.45	1.92 ^a \pm 1.61	2.01 ^a \pm 0.20
Retention (%)		92.30	96.63

Note: Values with the same superscript in the rows are not significantly different while those with different superscripts are significantly different from each other ($p < 0.05$).

Bioactive compounds contents (mg/100 g)	Treatment		
	Fresh	Sun-dried	Boiled + sun-dried
β -carotene ($\mu\text{g}/100\text{ g}$)	20.60 ^a \pm 1.64	1.65 ^b \pm 0.59	1.47 ^b \pm 1.24
Retention (%)		8.00	7.13
Vitamin C	182.36 ^a \pm 03.34	12.60 ^b \pm 10.34	9.13 ^c \pm 02.96
Retention (%)		6.90	5.0
Phenolics (GAE/100 g)	199.05 ^a \pm 4.89	85.50 ^b \pm 2.36	25.52 ^c \pm 3.55
Retention (%)		42.96	12.83
Phytates	11.03 ^a \pm 0.65	5.90 ^b \pm 1.37	2.02 ^c \pm 0.16
Retention (%)		53.50	18.32
Flavonoids (QE/100 g)	23.56 ^a \pm 2.34	4.56 ^b \pm 0.21	3.97 ^c \pm 0.03
Retention (%)		19.36	16.86

Note: Values with the same superscript in the rows are not significantly different while those with different superscripts are significantly different from each other ($p < 0.05$).

Generally, more bioactive compounds were retained in the sun dried samples than samples that were subjected to the boiling and sun drying. Processing of cowpea leaves with traditional processing techniques

significantly ($p < 0.05$) reduced anti-nutrients in the leaves. A combination of boiling and-sun drying method, resulted in products with the least phytates (2.02 mg/100 g) and phenolics (25.52 GAE/100 g) contents.

4. Discussion

4.1. Proximate composition

The results obtained for proteins, carbohydrates, dietary fiber, total ash and lipids in the present study fall in the range of findings reported by Kirakou *et al.* (2017), Muchoki *et al.* (2007), Chikwendu *et al.* (2014), Kasangi *et al.* (2010) and Owade *et al.* (2019). For instance, a range of 28-42 (g/100 g) in fresh cowpea leaves and a range of 29.09-39.24 (g/100 g) for sun dried cowpea leaves, for proteins has been documented elsewhere among edible cowpea leaves grown in Nairobi city, Kenya (Nekesa, 2016), rural areas of Nigeria (Chikwendu *et al.*, 2014) and Northern settings of Ivory Coast (Oulai *et al.*, 2015). Furthermore, a range of lipid contents of 9.00-10.26 42 (g/100 g) in fresh cow pea leaves (Nekesa, 2016; Oulai *et al.*, 2015; and Kirakou *et al.*, 2017) and a range of 4.33-12.92 (g/100 g) in boiled cowpea leaves (Aathira *et al.*, 2017; Kirakou *et al.*, 2017; and Kasangi *et al.*, 2010) have been documented previously. On the other hand, in the present study, it was also observed that the contents of carbohydrates, proteins and ash in cowpeas leaves, were the least affected by the two traditional processing methods, although boiled and sun dried samples lost considerably higher contents of carbohydrates and proteins than samples that were subjected to only sun drying. The losses in proteins for the solar dried and boiled samples may be attributed to the leaching of water soluble proteins, when samples were subjected to boiling and denaturation of heat sensitive proteins during the drying process. Several scholars Singh *et al.* (2003), Njoroge *et al.* (2015) and Kirakou *et al.* (2017), have documented evidence among sun dried African leafy vegetables, relating loss of proteins with loss of water soluble nitrogen containing compounds such as free amino acids, nucleic acids and nucleotides during blanching. This is evident because the boiled and sun dried samples in the present study recorded the highest loss in protein content compared to the non-boiled samples.

In addition, any form of heating including sun drying of leafy vegetables has been associated with reduction in both proteins and carbohydrates, possibly due to the cross-link Maillards reaction between proteins and carbohydrates. Maillards reactions are directly dependent on the temperature and time of drying and boiling and is greatly amplified by long exposure to high heat such as sun drying (Hardy *et al.*, 1999). The importance of soluble reducing sugars have been demonstrated by several scholars and Edith *et al.* (2018) as major promoters of Maillard reactions, as well as intermediary compounds from the sugar degradation reactions, such as carbonyl compounds. Delgado-Andrade *et al.* (2007) further documented how carbohydrates reduction is directly correlated with concentration of furosine, hydroxymethylfurfural and carboxymethyllysine in food systems and the thermal treatment applied in food. Generally, the high carbohydrate composition of the two samples that were subjected to sun drying and a combination of boiling and sun drying, presents cowpea as a better and superior vegetable to amaranths with 12.11% carbohydrate (Afolabi *et al.*, 2012). This indicates that cowpea leaves can be better carbohydrates suppliers in the diets than many leafy vegetables. Then again, carbohydrates provided by the cowpea leaves have been documented to have low glycemic index (FAO, 2016). Therefore, consumption of these leaves can provide carbohydrates, that when broken down, are converted to glucose which is released into the blood stream thus improving the insulin sensitivity and metabolism and reducing the health related risks of diabetes and cardio vascular diseases in the body (Phillips *et al.*, 1998; and Enyiukwu *et al.*, 2018).

It was also observed that more than 70% of either dietary fiber and ash contents and about 20% of lipids content, were retained in the cowpea leaves that were subjected to the two methods. The boiled and sun dried samples recorded higher losses of crude fiber than samples that were subjected to only sun drying, which could be as a result of leaching of the water soluble components of the crude fiber. The dietary fiber content of the fresh cowpea leaves in the current study compare well with the Nigerian cowpea leaves findings of Enyiukwu *et al.* (2018) who reported a value of 19.46% and 15.33% crude fiber registered among the Ivorian cowpea leaves reported by Oulai *et al.* (2016). However, Jethwani *et al.* (2015) reported higher results of 25% dietary fiber content of cowpea leaf powder in India, a cheap nutritional supplement for the vulnerable population. The difference in fiber contents in the present study with findings of Jethwani *et al.* (2015), could be attributed to the age and genetic variation and post-harvest handling of the leafy vegetables (Fungo *et al.*, 2019).

Also, the lipids content in fresh cowpea leaves, from the present study were in the range of the findings reported by Chikwendu *et al.* (2014) and Jethwani *et al.* (2015) who reported 9% fat content in fresh cowpea

leaves. The reduction in lipids contents among samples subjected to the two processing techniques may be due to, lipid molecules reacting with non-lipid materials including: water, proteins, carbohydrates, enzymes, salts, vitamins, and pro- and antioxidants (Karel *et al.*, 1975). Then again, basic groups in proteins may catalyze aldol condensation of carbonyls produced from lipid oxidation, resulting in the formation of brown pigments causing significant nutritional losses. On the other hand, due to the generally low level of crude lipids in the cowpea vegetable leaves of the current study, they can be considered appropriate for consumption by individuals need to avoid weight gain or reduce weight.

4.2. Mineral contents

The processing of leafy vegetables traditionally has minimal effect on the mineral concentration. The slight decrease of the mineral content in the sampled leaves subjected to both sun drying and boiling and sun drying techniques, could be attributed to leaching of minerals during boiling process (Bolanle *et al.*, 2004). During sun drying and boiling, cell walls rupture leading to the leaching of minerals. The findings in the current study were in agreement with the findings of Owade *et al.* (2019) who reported a range of 66-75 mg/100 g for iron, 5.33-12.91 mg/100 g for zinc and 24.3-24.6 mg/100 g calcium in cowpea leaves that were boiled and dried implying that the two processing methods result in loss of valuable minerals.

4.3. Bioactive compounds

Fresh cowpea leafy vegetables are rich in bioactive compounds including β carotene, vitamin C, flavonoids, phytates and phenolics. However, these compounds are unstable when subjected to sun drying and boiling due to oxidation (Oulai *et al.*, 2016). Oxidation occurs as a result of cutting the leafy vegetables during preparation which allows the exposure of the inner tissues to oxygen and light, leading to isomerization of bioactive compounds such as β -carotene from the all-trans form to the cis form that is less available biologically (Gayathri *et al.*, 2004; and Mduma, 2010). For this reason, there is a remarkably higher concentration of bioactive compounds in fresh form of the vegetables than in the sun-dried and the boiled then sun dried leaves.

In the current study, processing of cowpea leaves had a significant effect on flavonoid and phytate contents and the values of the sun-dried (4.56 QE/100 g, 7.90 mg/100 g) and boiling with sun-drying (3.97 QE/100 g, 2.02 mg/100 g) were remarkably lower than the values observed in the fresh leaves. These results are in agreement with the findings of Afolayan and Jimoh (2009), Chikwendu *et al.* (2014) and Jethwani *et al.* (2015) who reported a marked reduction in the content of flavonoids from 26.72 QE/100 g (fresh) to 3.77 QE/100 g (boiled) and for phytate from 18 mg/100 g (fresh) to 1.42 mg/100 g (boiled) contents, in leafy vegetables that were subjected to both boiling and sun drying. Boiling of cowpea leaves significantly reduces the phytate concentration through the rupturing of the plant cell walls leading to the leaching of the phytic acid into the boiling water (Hemmige *et al.*, 2017). However, contradicting literature indicates that sun drying does not significantly reduce phytate content in the leafy vegetables (Yadav and Sehgal, 2003; and Chen *et al.*, 2015) hence more research is needed to resolve this.

Given the importance of having adequate daily intake of essential bioactive compounds to human health especially among children and females of child bearing age, consumption of cowpea leaves can be a great source for the different essential bioactive compounds (Merrell, 2017). β -carotene is a precursor of vitamin A, an important nutrient that can only be obtained through diet since it cannot be synthesized by the human body (Oruch and Pryme, 2012). On the other hand, vitamin C is essential for a number of physiological processes for the humans such as formation of the protein used for making the skin, as well as aiding in the absorption of iron to strengthen teeth (Devaki and Raveendran, 2017). Phenolics are important as they reduce the free radicals in our bodies hence reducing on the cancer incidents (Shi *et al.*, 2005) and flavonoids which when consumed in diets are associated with lowering the risk of chronic diseases such as cancer and cardiovascular diseases (Hoeijmakers, 2001).

5. Conclusion

The two traditional drying and preservation techniques of cowpea were found to lead to significant loss of bioactive compounds of β carotene, vitamin C, flavonoids and phenolics but did not significantly affect the mineral of cowpea leaves. Dried cowpea leaves are a potential source of proteins, carbohydrates and minerals, therefore cowpea preservation using traditional drying processes can contribute to facilitating all year vegetable availability.

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Ethical review

This study does not involve any human or animal testing.

Conflicts of interest

The authors declare no conflict of interest.

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