EFFICACY OF BLANCHING TECHNIQUES AND SOLAR DRYING IN MAINTAINING THE QUALITY ATTRIBUTES OF COWPEA LEAVES

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Abstract

African indigenous vegetables are an excellent low cost source of nutrients in diets. Their availability is constrained by seasonality hence peaks and lows. The objective of this study was to investigate the effect of blanching and solar drying as means of dehydration on nutrient composition of cowpea (*Vigna unguiculata*) leaf vegetable. The blanched samples were subjected to hot water treatment for 2 minutes at 94^{0}C followed by cold water treatment at 8^{0}C for 2 minutes and then solar dried. One sample was blanched in pure water and another in salty water and the last sample was dried without blanching. The fresh and dehydrated samples were analyzed for selected proximate constituents, vitamins, minerals, anti-nutrients, colour change and sensory characteristics. Blanching and solar drying had little effect on most proximate and mineral elements. However, ascorbic acid, beta carotene and total phenolic content were most affected. Solar dried without blanching recorded the highest vitamin retention levels at 68.02% for beta carotene and 68.39% for ascorbic acid unlike blanching in pure water and solar drying at 55.58% for β_carotene and 21.08% for ascorbic acid and blanching in salty water and solar drying at 52.78% for beta carotene and 20.24% for ascorbic acid. In addition, solar drying without blanching recorded the highest retention total phenolic content at 149.91% exceeding the fresh sample by around 49.91%. However, blanching in pure water and solar drying and blanching in salty water and solar drying recorded retention levels of 62.58% and 65.79% of total phenolic content respectively. On the other hand, solar drying without blanching, blanching in pure water and solar drying and blanching in salty water and solar drying recorded a loss of 5.87%, 10.77% and 11.17% of oxalates and 37.22%, 69.98% and 58.7% of nitrates respectively from the fresh sample. Blanching and solar drying had a varied effect on the sensory quality. Cooked fresh, solar dried without blanching, blanched in pure water and solar dried and blanched in salty water and solar dried cowpea leaves recorded an average of 5.91, 4.91, 4.46 and 3.46 consumer rating respectively on a standard seven points hedonic scale. Solar drying without blanching was the simplest convenient technology for preserving nutrients, especially when cowpea leaves are abundantly available.

Keywords: Cowpea leaves; blanching; dehydration; nutrient retention; anti-nutrient elimination.

Introduction

African indigenous vegetables have played an immeasurable role in African nutritional requirements for decades (Smith and Eyzaguirre, 2007). The passage of culture together with preservation of sources of food from one generation to the next demonstrates the role these vegetables played in traditional food systems. That notwithstanding, these vegetables have grown to become strong economic and social pillar in recent years (Mwaura *et al*., 2013) since the growth of the

venture has benefited mainly women who have become financially uplifted hence maintaining descent families. The situation has been notable in the rural areas where these vegetables are produced and consumed in large quantities (Maundu, 1997). The concept has spilled to the middle and upper class citizens in most parts of the country (Irungu *et al.,* 2007) because of the scientific evidence suggesting that the vegetables are superior nutritionally. These vegetables have also been documented to counteracting emerging lifestyle diseases and disorders (Habwe *et al*., 2008; Smith and Eyzaguirre, 2007; Abukutsa-Onyango, 2003; Kimiywe *et al.,* 2007). Despite these positive aspects, notable anti-nutrient contents have been discussed (Muchoki *et al.,* 2010; Chikwendu *et al* 2014; Ajala 2009). In Kenya there are hundreds of species domesticated and/or wild (Irungu *et al.,* 2007; Otieno *et al.,* 2009). According to HCD report (2014), cowpea (*Vigna unguiculata*) is ranked as the 3rd most important vegetable among the African indigenous vegetables in production and consumption at 22% preceded by *Solanum* spp at 27% and *Cleome* spp at 23%.

The potential of cowpea leaves has not been maximized due to agronomic challenges and to a greater extent, postharvest handling limitations (Affognona *et al.,* 2014). It is estimated that postharvest losses contribute to about 50% (Masarirambi *et al.,* 2010) total losses in cowpea value chain. However, figures between 10–40%, and as high as 50–70% are regularly reported (FAO-World Bank, 2010). The losses are expressed as estimates since cowpea like the other African indigenous vegetables has not been comprehensively documented due to their informal marketing channels and small scale production over a vast area. According to Affognon *et al.,* (2014), the real magnitude of postharvest losses is not clearly known because of the inadequacies of loss assessment methodologies available. The high postharvest losses lead to wasted resources invested in production. To achieve food and nutrition security in Kenyan population especially among the rural population and urban poor, the estimated postharvest losses should be reduced to the bare minimum (FAO-World Bank, 2010). It is undisputed that there are other underlying economic problems such as poor transport network and distribution systems which contribute to postharvest losses (Shiundu and Oniang'o, 2007). Another underlying contributor to the high postharvest losses is the seasonality characterizing production of cowpeas, such that gluts are achieved during the wet season and scarcity during the dry season (Abukutsa-Onyango *et al*., 2006; Chavasit *et al.,* 2002).

To leverage the postharvest losses, other methods such as improving and lengthening shelf life and optimization of production have been proposed (Chavasit *et al.,* 2002). Some of the methods that should be employed include value addition, packaging and streamlining supply and marketing systems. The solution to the economic challenges that contribute to postharvest losses need concerted efforts of the government and NGOs and value chain managers. Success of these strategies ensures near continuous availability of cowpea vegetables and other African indigenous vegetables throughout the year regardless of production seasonality. In addition, farmers' welfare and livelihoods will be improved through the continuous stream of income which will be realized (Adebooye and Opadode, 2004 as cited by Habwe *et al*., 2008). Reduction in the losses will ultimately benefit consumers as well because of stable product prices and continuous availability.

Drying as a means of dehydration has been the most common form of postharvest preservation in traditional systems to supplement indigenous vegetables during the dry seasons (Fellows, 2009). This was

attributed to the ease in carrying out and managing the processes which didn't require specialized skills. Dehydration is achieved through several techniques including solar drying, shade drying, open air drying, oven drying and freeze drying. However, whichever method used, the amount of minerals and nutrients is reduced (Gupta *et al.,* 2013; Muthoka *et al.,* 2007; Frias *et al.,* 2010). The extent of reduction is dependent on the specific technique used. For instance, sun drying technique has been documented to lead to a greater loss in vitamins than shade drying and solar drying (Muthoka *et al.,* 2007; Ndawula *et al.,* 2004). Apart from volatilization and vaporization, blanching has been cited as one of the cause of the high loss in minerals and vitamins in withered vegetables and fruits due to leaching and effects of heat on chemical degradation (Muchoki *et al.,* 2007, Tannenbaum, 1976). Optimization of blanching and dehydration methods can lead to establishment of cost effective practice in postharvest management of cowpea leaves that leads to quality products. The objective of the study was to evaluate the efficacy of two blanching techniques and solar drying in maintaining the physical and nutritional quality of cowpea leaves.

Materials and Methods

Preparation: One local cowpea accession (sura mbaya) superior in terms of consumer acceptability and yield was grown at the University of Nairobi Field Station for two consecutive seasons, season 1 being the short rains and season 2 being the long rains. The leaves of the accession were harvested seven weeks after planting because at this stage, production for dual purpose of cowpea is at its optimal point (Inaizumi *et al.,* 1999). The harvested vegetables were separated into four samples; fresh, solar drying without blanching, blanching in pure water and solar drying and blanching in salty water and solar drying. The salt content used equaled 10% of the weight of the vegetable and a ratio of 1:4 (vegetable to water) w/v basis. For example, five hundred grams of fresh sample was blanched in 2000 mL of hot water dissolved with 50 grams of salt. The leaves were blanched for 2 minutes at temperatures of 94^0C followed by cooling in 8^0C water for 2 minutes. The leaves were then dehydrated in a solar drier until the leaves became brittle when felt in the hand then the leaves were sealed in an air tight polythene bags waiting analysis.

Moisture content: Moisture content was determined according to A.O.A.C. methods (A.O.A.C. 1990). Dry moisture dishes were placed in a desiccator and their weight recorded (W_0). One (1g) of the dry sample was weighed and transferred to the dry moisture dishes and weighed (W_1). The samples were transferred to a heated oven at 105^0C for 3 hours. This time coincides with the time when a constant weight is achieved. The dry samples and the moisture dishes were weighed after cooling in a desiccator (W_2).

Moisture content was calculated using from the following formula;

$$\frac{(W1 - W2)}{(W2 - W0)} * 100\%$$

Ash content: Moisture content was determined according to A.O.A.C. methods (A.O.A.C. 1990). A clean dry crucible was weighed (W0). One gram (1g) of the dried sample was weighed and put in the crucible and the total weight taken as (W1). The samples in the crucibles were charred on a mantle until it turned black (carbonisation) and no smoke was being produced. The charred sample was transferred to a furnace at 550^0C for 3 hours. The samples were allowed to cool in a desiccator and their weight measured (W2).

The ash content was determined in percentage as follows;

$$\frac{(W2 - W0)}{(W1 - W0)} * 100\%$$

Minerals: Minerals were analysed according to A.O.A.C. methods (A.O.A.C. 1990). One gram of the sample was charred in the oven for 30 minutes then put in a muffle furnace at 550°C for 3 hours to ash. The ash was allowed to cool and dissolved with 10ml of 1N hydrochloric acid. The mixture was then filtered and diluted with 100ml of distilled water. The absorbance of the solution was measured by atomic absorption spectroscopy. The minerals analysed included; potassium, calcium, iron, zinc, manganese because these minerals represent macro and micro elements that play an important role in human body (Achikanu *et al.,* 2013)

Crude protein content: Protein was determined using the semi micro Kjeldal method (A.O.A.C. 1990). One gram (1g) of sample was weighed into a digestion flask together with a combined catalyst of 5 g potassium sulphate and 0.5 g of copper sulphate and 15 mL of sulphuric acid. The mixture was heated in a fume hood till the digest colour turned blue signifying the end of the digestion process. The digest was cooled, transferred to 100 mL volumetric flask and topped up to the mark with deionized water. A blank digestion with the catalyst was also made. Ten mL of diluted digest was transferred into a distilling flask and washed with distilled water. Fifteen mL of 40% NaOH was added and washed with distilled water. Distillation was done to a volume of about 60 mL which was titrated using 0.02 N HCL to an orange colour of the mixed indicator, which signified the end point.

%Nitrogen = (V1- V2) * N * F * 100/ (V * 100/S)

Where: V1 is the titre for sample in mL, V2 is titre for blank in mL; N= normality of standard HCL (0.02); F= factor of standard HCL solution; V= volume of diluted digest taken for distillation (10 mL); S= weight of sample taken for distillation (1 g);

% protein= %nitrogen* protein factor (6.25)

Crude fibre: Crude fibre was determined using Weende method involving acid hydrolysis (Van-Soest, 1973). Two grams of the sample was weighed (W0). Two hundred millilitre of 1.25% sulphuric acid was added to the sample and boiled for 1 hour. The sample was filtered through a glass wool and the residue boiled in 1.25% sodium hydroxide for 1 hour. The residue was then filtered and washed with hot water followed by 1.25% hydrochloric acid, alcohol, petroleum ether and diethyl ether in that order. The residue was dried in a desiccator for 30 minutes, weighed (W1) and transferred to a furnace at 550^0C for 1 hour and weighed (W2).

Crude fibre was calculated and expressed as a percentage as follows;

$$\frac{W1 - W2}{W0} * 100\%$$

Beta carotenes: Beta carotene content was analysed using column chromatography and UV Spectrophotometer. Acetone and petroleum ether extraction method was used as described by Rodriguez-Amaya and Kimura, (2004). Five hundred milligrams (500mg) of the dried sample was weighed, chopped finely and placed in a mortar with about 10 mL of acetone. The sample was thoroughly ground and the acetone extract transferred into 100 mL volumetric flask. The residue was extracted again with 10 mL acetone and the extract added to the contents of the volumetric flask. The extraction with acetone continued until the residue no longer gave colour. The combined extract was made to a volume of

100 mL with acetone. Twenty five millilitres of the extract was evaporated to dryness using a rotary evaporator. The residue was then dissolved with 10 mL petroleum ether and the solution injected into a chromatographic column which was eluted with petroleum ether and beta carotene collected in a flask. The beta carotene elute was made to a volume of 25 mL with petroleum ether and the absorbance read at 440 nm in a UV-Vis spectrophotometer (Shimadzu model UV – 1601 PC, Kyoto, Japan). Beta carotene standards were prepared to make a calibration curve.

Ascorbic acid: The ascorbic acid content in the samples was determined by HPLC method according to Vikram *et al.,* (2005). Eight hundred milligrams (800mg) of sample was weighed and extracted with 0.8% metaphosphoric acid. The solution was made to 20 mL of juice and centrifuged at 10000 rpm for 10 minutes at 4^0C. The supernatant was filtered and diluted with 10 mL of 0.8% metaphosphoric acid. The mixture was then passed through 0.45 µm syringe filter and 20 µL injected into the HPLC machine. Various concentrations of ascorbic acid standards were made to make a calibration curve. HPLC analysis was done using Shimdzu UV-VIS detector at a wavelength of 266 nm. The HPLC conditions were as follows; Mobile phase: 0.8% metaphosphoric acid, Column: C18, Oven temperature: 25^0C, Flow rate: 1.0 mL/min, injection volume: 20µL.

Nitrates: The nitrate content in the test samples was determined by the calorimetric method using salicylic acid according to Cataldo *et al.,* (1975). A hundred milligrams (100mg) of dried sample were weighed and put in a test tube and 10 mL of hot (90-95^0C) distilled water added. The closed tubes were placed in a water bath at 80^0C for 30 minutes and shaken. The samples were then cooled and centrifuged at 4500 rpm for 10 minutes. The supernatant was decanted and weighed to determine the exact volume of extract. Chlorophyll in leaf extract was removed by adding 0.5g magnesium carbonate ($MgCO_{3)}$ and centrifuged again. An aliquot of 0.2 ml of the filtrate was pippeted into a 50 ml beaker and 0.8 ml of 5% (w/v) salicylic acid in sulphuric acid was added and mixed thoroughly. The mixture was then allowed to stand for 20 min at ambient temperatures. Nineteen millilitres of 2N sodium hydroxide was added and the mixture allowed to cool for 30 min. The absorbance was read at 410 nm against a common blank using UV-Vis spectrophotometer (Shimadzu model UV – 1601 PC, Kyoto, Japan). The nitrate content was determined from a standard curve and expressed in mg/100 g.

Oxalates: Analysis was done by HPLC method as suggested by Yu *et al.*, (2002). Fifty milligrams (50mg) of dried sample was homogenized in 5 mL of 0.5N HCL. The homogenate was heated at 80^0C for 10 minutes with intermittent shaking. To the homogenate, distilled water was added up to a volume of 25 mL. The solution was centrifuged at 10000 rpm for 10 minutes. About 1 mL of supernatant was passed through a micro filter (0.45µm) before HPLC analysis. Standards were prepared at varying concentrations for quantification. HPLC analysis was done using Shimadzu UV-VIS detector, Hypsil C18 column (5µM, 4.6 mm *250 mm) equipped waters 550 was used as the static phase at 221 nm. The conditions for HPLC; Mobile phase: 0.01 N H_2SO_4, Column: C18, Oven temperature: 25^0C, Flow rate: 0.6 mL min^{-1}.

Total phenolic content: One gram (1g) of the dry sample was crushed and weighed into a 250 mL conical flask and about 50 mL methanol added. The flask was closed securely using parafilm and covered with aluminum foil. The samples were put in a shaker and shaken for about 3 hours. They were then kept in the dark and left to extract for 72 hours.

Thereafter, the samples were filtered through Whatman No. 4 filter paper and the filtrate concentrated to dryness using a rotary evaporator, then re-dissolved in 12.5 mL of methanol and kept frozen to await analysis.

Total Phenolics content was estimated by a calorimetric assay based on the procedure described by Escarpa and Gonzalez (2001) with slight modifications. A 100 µL aliquot of the extracted sample was added to 500 µL of 0.2N Folin-Ciocalteu reagent and 6 mL of distilled water. After mixing the contents for 1 minute, 4 mL of saturated sodium carbonate (Na_2CO_2) was added. Samples were left to stand at room temperature for 90 minutes and absorbance measurements taken at 725 nm using a UV-VIS 1800 Shimadzu spectrophotometer (Shimadzu, Kyoto, Japan). Gallic acid was used as a reference standard and the results expressed as milligram Gallic acid equivalents (mg GAE) per 100 g extract in dry weight basis.

Sensory evaluation: Sensory analyses were performed on the dried and fresh vegetables. The vegetable samples were evaluated for general appearance (colour), aroma, texture, tenderness, taste/flavour, mouthfeel and general acceptability using untrained panelists, familiar with the taste of cooked cowpea leaves. The evaluation was based on a standard seven points hedonic scale (where 1 = dislike extremely and 7 = like extremely). Two hundred and fifty grams (250g) of the fresh and 28g of the dried cowpea leaves which are equivalent to 250g of fresh sample were boiled in a stainless steel pot for 32 minutes till the leaves were tender. The samples were then removed, excess water drained and fried using the following procedure. Forty grams of finely chopped onions were weighed into an aluminum pot with 25 mL vegetable cooking oil (Rina vegetable cooking oil, Kapa Oil Refineries Ltd, Kenya). The pot was heated until the onions turned golden brown then 95g of finely chopped tomatoes were added. Six grams of salt (Kensalt, Salt Manufacturers Kenya Ltd) was also added. When a paste of the ingredients had formed, the drained sample was added and thoroughly mixed and allowed to simmer for 10 minutes. The vegetables were served hot to the panelists with an accompaniment for *ugali* (a maize meal paste) as it is consumed locally.The samples served had been coded with 4-digit random number to maintain panellist neutrality. Mineral water was given to the panellists to rinse their mouths after every sample. The number of panellists involved in the study was 29 for season1 and 31 for season 2 familiar with cowpea recipe and consumption.

Colour change evaluation: Leaf colour was measured when fresh, after blanching and after drying to determine the effect of processing on the colour of the product. The colour of the leaf surface was measured using a potable colour meter that was calibrated with a white and black standard tile. The L*, a* and b* coordinates were recorded and, a* and b* values converted to hue angle (H°) according to Mc Lellan, *et al.,* (1995). The dried samples were dipped in hot water for two minutes before the color is measured to allow rehydration.

Hue angle (H°) = arctan (b/a) (for +a and +b values)

= arctan (b/a) + 180 (for -a and +b values)

= arctan (b/a) + 180 (for -a and –b values)

Hue angle distribution is as shown below;

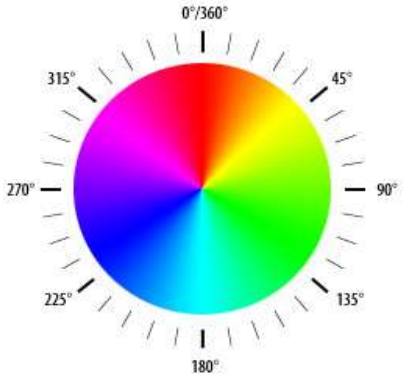

Fig.1: Hue angle distribution (in degrees). Courtesy (www.huevaluechroma.com/012.php)

Statistical analysis: Data was analyzed using Genstat statistical package 15th edition. The treatments were subjected to by Analysis of Variance (ANOVA) and means separated by Least Significance Difference (LSD) at P ≤ 0.05 and Fishers protected.

Results

Proximate analysis: Moisture content, ash, crude fibre and crude proteins were analysed. There was no significant difference ($p<0.05$) in ash content for the four treatments. However, crude fibre and crude protein content showed some varied levels of significance ($p<0.05$). Fresh leaves consistently recorded the highest contents of crude fibre and protein at 15.81% and 35.51% for season 1 and 15.99% and 35.53% for season 2 respectively closely followed by solar drying without blanching, blanching in pure water and solar drying and blanching in salty water and solar drying in that order. However, there was no consistency in significance for the samples blanched in pure water and solar dried and blanched in salty water and solar dried. The moisture content was used to express the contents in dry matter basis.

Beta carotene, ascorbic acid and total phenolic content: Two water soluble vitamins (beta carotene and ascorbic acid) present in large quantities in vegetables were chosen together with total phenolic content, a phytochemical important for its antioxidant activity. Generally, there was high significant difference ($p<0.05$) between the fresh sample and the dehydrated ones, whether blanched or not. Solar drying without blanching recorded the highest vitamin retention levels at 68.02% for β_carotene and 68.39% for ascorbic acid. On the other hand, blanching in pure water and solar drying and blanching in salty water and solar drying recorded a retention level of 55.58% for beta carotene and 21.08% for vitamin C and 52.78% beta carotene and 20.24% ascorbic acid respectively. In terms of total phenolic content, solar drying without blanching recorded the highest retention at 149.91% which surpassed the fresh sample by 49.91%. However, blanching in pure water and solar drying and blanching in salty water and solar drying recorded lower retention levels of total phenolic content at 62.58% and 65.79% respectively.

Mineral elements: Although mineral elements were lost during processing, the losses were not significantly different ($p<0.05$) among all the treatments. However, high amounts of the minerals were generally reported in the vegetable. The highest amounts of minerals were present in the fresh sample at 34204ppm, 26048ppm, 598.3ppm, 152.3ppm and 719.8ppm for potassium, calcium, iron, zinc and manganese respectively for season 1.

Anti-nutrient components: Nitrates and oxalates are important components in vegetables that determine the digestibility and toxicity of vegetables when consumed. Anti-nutrients also influence the availability and digestibility of other nutrients in the gut. Oxalates were found to be higher in the vegetable and among the treatments. For instance, the fresh samples had an average of 3400mg/100g oxalates in dry weight basis. Solar drying without blanching, blanching in

pure water and solar drying and blanching in salty water and solar drying recorded an average of loss of 5.87%, 10.77% and 11.17% oxalate content respectively. The highest amount of nitrate content was found in fresh leaves, season 1 at 82.81 mg/100g dry weight basis. Solar drying, blanching in pure water and solar drying, blanching in salty water and solar drying recorded the biggest loss of 37.22%, 69.98% and 58.7% respectively between the seasons.

Table 1: Levels of selected proximate of fresh and processed cowpea leaves expressed in dry matter basis, Season 1.

Treatments	Proximate contents (%)			
	Moisture Content	Ash	Crude fibre	Crude Protein Content
Fresh leaves	86.57±0.03^{a}	12.41±0.16^{a}	15.81±0.43^{a}	35.51±0.23^{a}
Solar drying without blanching	12.07±0.10^{b}	12.01±0.12^{a}	15.89±0.18^{a}	35.02±0.05^{b}
Blanching in pure water and solar drying	11.69±0.46^{b}	11.52±0.26^{a}	14.70±0.18^{b}	31.86±0.12^{c}
Blanching in salty water and solar drying	11.92±0.25^{b}	11.87±0.25^{a}	13.69±0.35^{c}	30.94±0.05^{d}
Means	30.56	11.95	15.02	33.334
LSD (5%)	0.875	0.674	0.992	0.4327

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Table 2: Levels of selected proximate of fresh and processed cowpea leaves expressed in dry matter basis, Season 2.

Treatments	Proximate contents (%)			
	Moisture Content	Ash	Crude fibre	Crude Protein Content
Fresh leaves	86.79±0.04^{a}	12.33±0.35^{a}	15.99±0.10^{a}	35.53±0.13^{a}
Solar drying without blanching	10.98±0.12^{c}	12.00±0.18^{a}	16.05±0.14^{a}	34.93±0.16^{b}
Blanching in pure water and solar drying	11.92±0.17^{b}	11.61±0.27^{a}	14.35±0.6^{ab}	31.75±0.21^{a}
Blanching in salty water and solar drying	12.01±0.27^{b}	11.87±0.12^{a}	13.72±0.28^{b}	30.95±0.10^{d}
Means	30.423	11.95	15.02	33.288
LSD (5%)	0.5601	0.801	1.135	0.5074

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Colour change (hue angles) during processing: Colour of fresh leaves and those taken immediately after blanching did not show any significant difference ($p<0.05$). However, after dehydration, there was significant difference among the treatments with blanching in salty water and solar drying maintaining the closest colour to the fresh samples at 136.3^0 and 139^0 for the two seasons, respectively, followed by solar drying without blanching at around 131^0 and blanching in pure water and solar drying at around 123^0.

Table 3: Levels of beta carotene vitamins, ascorbic acid and total phenolic content of fresh and processed cowpea leaves expressed in dry matter basis, season 1.

Treatments	Antioxidants		
	β_carotene (mg/100g)	Ascorbic acid (mg/100g)	Total Phenolic Content (GAE mg/100g)
Fresh leaves	36.4±0.39[a]	201.6±0.42[a]	4664±58.07[b]
Solar drying without blanching	24.76±0.03[b]	137.9±0.31[b]	6974±101.32[a]
Blanching in pure water and solar drying	20.23±0.07[c]	42.5±1.17[c]	2911±105.84[c]
Blanching in salty water and solar drying	19.21±0.04[d]	40.8±0.30[c]	3061±118.17[c]
Means	25.152	105.7	4402
LSD (5%)	0.6476	2.149	321.2

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Table 4: Levels of beta carotene vitamins, ascorbic acid and total phenolic content of fresh and processed cowpea leaves expressed in dry matter basis, season 2.

Treatments	Antioxidants		
	β_carotene (mg/100g)	Ascorbic acid (mg/100g)	Total Phenolic Content (GAE mg/100g)
Fresh leaves	36.32±0.66[a]	206.9±0.52[a]	4715±6.05[b]
Solar drying without blanching	24.83±0.02[b]	137.2±0.32[b]	6716±130.56[a]
Blanching in pure water and solar drying	20.35±0.22[c]	41±0.13[c]	2724±119.98[c]
Blanching in salty water and solar drying	19.47±0.01[c]	40.1±0.24[c]	2972±43.91[c]
Means	25.24	106.3	4282
LSD (5%)	1.136	1.09	298

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Table 5: Levels of selected mineral elements of fresh and processed cowpea leaves expressed in dry matter basis, season 1.

Treatments	Mineral contents (PPM)				
	K	Ca	Fe	Zn	Mn
Fresh leaves	34204±1497[a]	26048±1392[a]	598.3±116.5[a]	152.3±19.9[a]	719.8±78.57[a]
Solar drying without blanching	33717±1595[a]	25105±908[a]	584.2±114.7[a]	144.5±21.33[a]	710.7±76.2[a]
Blanching in pure water and solar drying	32317±1790[a]	24671±853[a]	576.9±115.7[a]	139.6±20.66[a]	702.1±75.84[a]
Blanching in salty water and solar drying	32039±1698[a]	24345±872[a]	563.2±111.1[a]	137±18.16[a]	697.8±74.68[a]
Means	33069	25042	581	143	708
LSD (5%)	5376.9	3362.2	373.4	65.4	248.9

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Table 6: Levels of selected mineral elements of fresh and processed cowpea leaves expressed in dry matter basis, season 2.

Treatments	Mineral contents (PPM)				
	K	Ca	Fe	Zn	Mn
Fresh leaves	34149±1562[a]	25416±1071[a]	554.7±106.7[a]	156.4±19.07[a]	721.5±67.36[a]
Solar drying without blanching	33577±1428[a]	25010±1024[a]	549.7±105.5[a]	151.2±18.1[a]	713.8±68.24[a]
Blanching in pure water and solar drying	32871±1374[a]	24636±1201[a]	542.4±104.4[a]	144.8±17.65[a]	706.6±66.15[a]
Blanching in salty water and solar drying	36018±1937[a]	24547±1174[a]	537±101.9[a]	142.7±17.57[a]	702.2±65.68[a]
Means	34154	24903	546	148.8	711
LSD (5%)	5186.8	3650.9	341.2	59.06	218.1

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Sensory quality analysis: The sensory parameters evaluated after cooking the cowpea leaves subjected to different treatments included; general appearance/colour, aroma, texture, taste/flavor, mouth-feel and general acceptability. During both seasons, fresh samples recorded the highest average rating at 5.91 for season 1 and 5.94 for season 2 followed by solar dried without blanching at 4.91 for season 1 and 5 for season 2. Blanching in pure water and solar drying recorded a rating of 4.46 for season 1 and 4.51 for season 2, and blanching in salty water and solar drying sample at 3.46 for season 1 and 3.57 for season 2 as shown in Tables 9 and 10.

Table 7: Levels of selected anti-nutrients of fresh and processed cowpea leaves expressed in dry matter basis.

Treatments	Anti-nutrients (mg/100g)			
	Nitrates		Oxalates	
	Seasons 1	2	1	2
Fresh leaves	82.81±0.19[a]	81.39±0.54[a]	3395±37.97[a]	3400±48.86[a]
Solar drying without blanching	51.99±1.27[b]	52.65±0.44[b]	3196±33.24[b]	3212±14.38[b]
Blanching in pure water and solar drying	24.86±0.75[d]	26.71±0.14[d]	3030±45.98[c]	3096±76[bc]
Blanching in salty water and solar drying	36.12±0.28[c]	34.2±0.67[c]	3016±23.23[c]	2979±31.74[c]
Means	48.95	48.74	3159	3172
LSD (5%)	2.464	1.595	117.6	157.9

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Table 8: Changes in colour (hue angle) of fresh, blanched and dehydrated cowpea leaves expressed in degrees.

Treatments	Colour change (hue angles)					
	FRESH		AFTER BLANCHING		AFTER DRYING	
	Seasons 1	2	1	2	1	2
Solar drying without blanching	151.2[a]	155.6[a]	*	*	130.3[a]	131.5[a]
Blanching in pure water and solar drying	151.2[a]	155.6[a]	154.9[a]	154.1[a]	122.9[b]	124.6[b]
Blanching in salty water and solar drying	151.2[a]	155.6[a]	154.5[a]	155.4[a]	136.3[a]	139.2[c]
Means	151.25	155.6	154.71	154.7	129.8	131.8
LSD (5%)	3.064	9.36	3.801	7.57	6.73	5.76

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Discussions

The richness of food stuff is measured by the quantities of nutrients it provides. The higher the nutrient content the more it's considered high quality. The results obtained for crude proteins, crude fibre and total ash in this study were in the same range with results from Muthoka, *et al.*, (2007), Chikwendu, *et al.*, 2014 and Kasangi, *et al.*, (2010). The significant losses ($p<0.05$) in crude proteins for the solar dried and blanched samples can be as a result of leaching of water soluble proteins and denaturation of heat sensitive proteins. Njoroge, *et al.*, (2015) suggested that the slight loss in crude protein could probably be due to loss of water soluble nitrogen-containing compounds in African indigenous vegetables such as free amino acids, nucleic acids and nucleotides during blanching. This is evident because the blanched samples recorded the highest loss in crude protein content compared to the non-blanched samples. Crude protein content was least for samples blanched in salty water and solar dried (at 30.95%) and

highest for the fresh samples (at 35.53%). Although total ash slightly varied among the treatments, there was no significant differences ($p<0.05$). This could be as a result of minimal loss in mineral elements which constitute the ash content. On the other hand, crude fibre showed significant differences ($p<0.05$) among the treatments, with fresh samples having the highest percentage of crude fibre content and samples blanched in salty water and solar dried having the least. The blanched samples recorded some losses in crude fibre which could be as a result of losses of the water soluble components of the crude fibre.

Table 9: Hedonic scores for sensory quality attributes of fresh and processed cowpea leaves, season 1.

Treatments	Sensory attributes							Mean
	General appearance	Aroma	Texture	Tenderness	Taste	Mouth feel	General acceptability	
Fresh leaves	5.6	5.4	5.2	6.4	6.2	6.2	6.4	5.91
Solar drying without blanching	5	5.4	4.4	5	5	4.6	5	4.91
Blanching in pure water and solar drying	5.6	5.2	3.8	4	4.2	4	4.4	4.46
Blanching in salty water and solar drying	4.2	3	3.2	3.4	4	3.2	3.2	3.46
Mean	5.1	4.75	4.15	4.7	4.85	4.5	4.75	
LSD (5%)	1.87	1.87	2.36	2.28	2.16	2.29	2.1	

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Table 10: Hedonic scores for sensory quality attributes of fresh and processed cowpea leaves, Season 2.

Treatments	Sensory attributes							Mean
	General appearance	Aroma	Texture	Tenderness	Taste	Mouth feel	General acceptability	
Fresh leaves	6	5.8	5	6.2	6.4	6	6.2	5.94
Solar drying without blanching	5.2	5.2	4.8	4.8	5.2	4.6	5.2	5
Blanching in pure water and solar drying	5.4	5.4	3.8	4.2	4	4.2	4.6	4.51
Blanching in salty water and solar drying	4.4	3.2	3	3.2	4.4	3.4	3.4	3.57
Mean	5.25	4.9	4.15	4.6	5	4.55	4.85	
LSD (5%)	1.91	1.89	2.21	2.19	2.18	2.23	1.96	

*All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different ($P < 0.05$).

Water soluble vitamins are very important in human diets. They are important in improving immunity and supporting physiological processes and scavenging for free radicals (Gareth *et al*., 1998 and FAO, 1995). ß-carotene is the principal precursor of vitamin A, which is involved in vision, cell differentiation, synthesis of glycoproteins,

mucus secretion from the epithelial cells, and overall growth and development of bones (Guerra–Vargas *et al*., 2001). Relatively high levels of β_carotene and ascorbic acid were recorded in the vegetable, however losses as a result of processing were significantly different ($p<0.05$) from the fresh leaves. Solar drying without blanching, blanching in pure water and solar drying, blanching in salty water and solar drying retained on average 68.02%, 55.58% and 52.78% of β_carotene, and 68.39%, 21.08% and 20.24% of ascorbic acid, respectively, relative to the fresh leaves. Aruna *et al*., (1999) explained the loss of β_carotene to be due to non-oxidative changes involving cis-trans isomerization, epoxide formation or heat degradation of tissues or oxidative changes on exposure to light and oxygen. The losses in β_carotene and ascorbic acid tallied with results from Singh *et al.,* (2003), Oboh *et al.,* (2004) and Gupta *et al.,* (2013). Gupta *et al.,* (2008) explained that ascorbic acid is heat labile, sensitive to light, oxygen and oxidizing agents. The extent of loss of β_carotene was low compared to that of ascorbic acid because of the insolubility of beta carotene in water. The loss in ascorbic acid could have resulted from leaching during blanching, the processing temperatures or due to enzymatic and chemical degradation. Negi and Roy (2000) came to a conclusion that during blanching, vitamin losses are as a result of thermal degradation, diffusion and leaching.

African indigenous vegetables have been documented to contain substantial amounts of vitamins and other phytochemicals (Habwe *et al*., 2008; Smith and Eyzaguirre, 2007; FAO, 1995; Abukutsa-Onyango, 2003). Like vitamins, Phenolics have been found to have strong antioxidant activity. Meyer *et al.,* (1998) stated that the antioxidant activities of phenolics in different vegetables markedly vary due to the differences in the phenolic compound structures primarily related to their hydroxylation and methylation patterns. Total phenolic content in the treatment which was solar dried without blanching increased by 149.9% for season 1 and 142.2% for season 2. This can be attributed to concentration of phenolics in the dehydrated vegetable (Zoro *et al.,* 2015). The increase in the phenolic content of the dehydrated leaves was comparable with results from Oboh *et al.,* (2004) and Zoro *et al.,* (2015). On the other hand, blanched samples recorded a significant decrease ($p<0.05$) in phenolic content compared to the fresh and solar dried ones. Blanching in pure water and solar drying recorded a retention capacity of 37.4%, whereas blanching in salty water and solar drying recorded a decrease of 34.2%. This loss can be attributed to diffusion and leaching (Negi and Roy 2000).

Macro and micro nutrients are important constituents of vegetables. Although there were decrease in all the mineral contents analysed after processing, the losses were not significant ($p<0.05$) when compared with fresh vegetables. This can be attributed to the fact that mineral elements are embedded in cell structures, and are hard to remove hence the lowered solubility in water.

Most plant species contain nutritional stress factors also known as anti-nutrients that increase the loss of essential nutrients from the body. Their presence interferes with the metabolism of absorbed essential nutrients therefore, decreasing the digestion of food. Reduction of these anti-nutrients in vegetables increases the bioavailability of nutrients hence improvement in quality of vegetable. The common anti-nutrients in vegetables include nitrates and nitrites, oxalates, cyanogenic glycosides, glucosinolates, tannins and saponins (Teutonico and Knorr 1984). In this study, there were significant differences ($p<0.05$) in nitrate and oxalate contents among the treatments. Generally, the fresh sample exhibited the highest levels of both the anti-nutrients followed by the solar dried, salty

water blanching and solar drying and blanching in pure water and solar drying treatments. These results are consistent with the results from Muchoki *et al*., (2010). The oxalate content in the blanched samples did not show any significant differences ($p<0.05$). The loss in the anti-nutrients can be as a result of leaching and volatilization since both are water soluble.

Colour is the first physical impression that determines the acceptability of a product to consumers. Processing interferes with colour, either positively or negatively depending on the treatment. In this case colour change was tracked from the fresh vegetables, after blanching and after dehydration as explained in the procedure. Chlorophyll is the major component contributing to the green colour in cowpeas and other green leaves. There was no significant difference ($p<0.05$) in colour between the fresh and blanched samples. However, there were significant differences ($p<0.05$) between the first two stages (fresh sample and blanched sample) and the last stage (dehydrated sample). The colour of the vegetables changed from dark green (151-155^0) in the fresh and blanched samples to pale green at 131.5^0, 124.6^0 and 139.2^0 for fresh leaves, solar dried leaves, leaves blanched in pure water and solar dried and leaves blanched in salty water and solar dried, respectively. The slight loss in colour can be attributed to the loss in chlorophyll because of leaching and chlorophyll forming pheophytins being broken down (Rodoni *et al.,* 1997).

Processing of any food whether through dehydration or blanching is expected to produce some changes in the sensory qualities of the product. Bunger *et al.,* (2003) stated that use of salts during blanching is a process that modifies the sensory characteristics improving colour, increasing external crispness and internal softness. As presented in Tables 7 and 8, fresh leaves scored the highest average score of all the sensory attributes in the hedonic scale followed by solar dried leaves, leaves blanched in pure water and solar dried and leaves blanched in salty water and solar dried.

Conclusion

The results of the present study indicate that solar drying without blanching was the better option for preserving cowpea vegetables. This is because, the loss of ascorbic acid and beta carotene is minimal compared to the other techniques which in addition had high rating by the sensory panelists. Due to its simplicity, this is a convenient option for preservation of the vegetables to enhance longevity, shelf life and quality. However, value addition through dehydration led to reduced nutrient contents, especially, ascorbic acid and beta carotene. The loss of the other nutrient elements a part from the vitamins was minimal.

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