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COMPOSITIONAL ATTRIBUTES OF THE LEAVES OF SOME INDIGENOUS AFRICAN LEAFY VEGETABLES COMMONLY CONSUMED IN KENYA

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Abstract

The nutritional potential of the leaves of four African leafy vegetables namely; Corchorus olitorius (Jute mallow), Crotalaria ochroleuca (Slender leaf), Solanum scabrum (Black nightshade) and Cleome gynandra (Spider plant) were assessed by determining the proximate and mineral compositions. Results indicated that there was no significant difference in crude protein content of the vegetables. Crude fiber (2.1±0.5%), ascorbic acid (153.7±7. 75mg/100g) and magnesium (56.5±0.75mg/100g) contents of C. olitorius were significantly higher than the other vegetable samples (P<0.05). However, C. gynandra was significantly higher in ash (11.2±0.49%) whereas, S. scabrum was lower in dry weight basis (12.8±0.14%) as well as vitamin C content (62.6±4.57mg/100) compared to the other three vegetables. The vitamin C and beta carotene contents of C. gynandra (104.3±6.68, 8.73±0.42 mg/100g) and C. olitorius (153.7±7.75, 7.70±0.54 mg/100g) respectively were significantly higher compared to S. scabrum and C. ochroleuca. Additionally, the fat and carbohydrate content of the ALVs was low below1.5%. Drying and cooking of the ALVs on the other hand, lead to significant loss of the nutrients especially vitamin C. As well, there was no significant difference in the composition of minerals, vitamin C and beta carotene between the shade and solar dried vegetables P<0.05. The established superior nutritional composition of these ALVs highlighted their usefulness and should therefore be used to disapprove the misconception that ALVs have inferior dietary value.

Key words. Indigenous, African leafy vegetables, proximate, mineral composition.

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1. INTRODUCTION

African Leafy Vegetables (ALVs) are indigenous or traditional vegetables whose leaves, young shoots and flowers are consumed. They are indispensable constituents of human diets and have provided food and nutritional security to various communities in Africa therefore forming a significant part of the traditional diets (Grubben and Denton, 2004). They represent cheap but quality nutrition for large parts of the population in both rural and urban areas (Chweya and Eyzaguirre, 1999).

However, ALVs have an advantage of possessing desirable agronomic and organoleptic traits. They are often easier to grow, resistant to pests and diseases, and are quite acceptable to local tastes. Their production and consumption have been neglected and some ALVs are at risk of extinction as they are being replaced by high-yielding exotic varieties (Aphane *et al.*, 2002 and Adedoyin and Taylor, 2000). This is because information on their chemical composition tends to be anecdotal and abound in literature (Okeno *et al.*, 2003).

Kenya is experiencing a decline in the consumption of these vegetables and may eventually result in loss of this biodiversity (Abukutsa-Onyango, 2003). When an indigenous variety is lost, it can never be recovered; therefore, there is an urgent need for intervention to avoid such a situation.

Malnutrition due to nutritionally inadequate diets is one of the major concerns in Kenya and many other developing countries. Many people are undernourished, (especially children being weaned and pregnant and lactating mothers) and nutrient-deficiency diseases such as night blindness, scurvy and rickets are common in rural areas and slums.

Several ALVs have been used for prophylactic and therapeutic purposes by rural communities

(Ayodele, 2005). Keeping in view the importance of the valuable indigenous vegetables**,** the present study was undertaken with the objectives of evaluating the proximate and chemical composition of leaves of four different species of ALVs commonly consumed in Kenya. This information will highlight the potential usefulness of these ALVs to alleviate widespread food insecurity.

2. MATERIALS AND METHODS

2.1. Reagents

Petroleum ether, ammonium sulphate, sodium hydroxide, methylene blue, sodium bicarbonate, anhydrous sodium sulphate, 2, 6-dichloroindophenol (DCIP), methanol, hydrochloric acid were purchased from Fluka (Sigma Aldrich, Switzerland). All these chemicals and reagents were of analytical grade.

2.2. Plant material

The target vegetables seeds were collected from Kenya Agricultural Research Institute (KARI) gene bank and some from Prof. Abukutsa, JKUAT and planted in JKUAT experimental farm. Planting was done in rows and farm yard manure was used. After 8-12 weeks, fresh vegetable leaves were harvested, washed properly with tap water and rinsed with sterile distilled water. Sample leaves were divided into two. Some leaves were shade dried at room temperature to constant weight over a period of 5-9 days, while others were solar dried. The dried leaves were then subsequently ground into fine powder. The prepared samples were stored at room temperature in airtight sterile containers protected from sunlight awaiting further treatment (Junaid *et al.,* 2006). The other portion was analyzed while fresh.

2.3. Chemical analysis

Chemical composition of the ALV leaves was determined using the AOAC methods (2000) as described by Indrayan *et al.* (2005). The moisture content of the ALV leaves was determined using the air oven drying method using a known weight of the sample at 105 °C until a constant weight was obtained. The loss of weight was regarded as a measure of moisture content. For determination of ash content, 10 g of each sample was weighed into a crucible. The crucible was first heated on a heating mantle till all the material was completely charred, followed by incineration in a muffle furnace at 550 ^{0}C for 3 -5 hours. It was then cooled in a desiccator and weighed (ash became white or greyish white). Weight of ash gave the ash content. Crude fat content was determined by extracting 2g of moisture free sample with petroleum ether (b.p 40-60 ^{0}C) in a Soxhlet extractor; petroleum ether was then evaporated in vacuum evaporator. Increase in weighed of beaker gave the crude fat. Determination of crude protein was done using semi micro Kjeldahl method which involved the digestion of a given weight of the sample with concentrated H_2SO_4 and catalyst to convert any organic nitrogen to ammonium sulphate, $(NH_4)_2SO_4$, in solution followed by the decomposition of $(NH_4)_2SO_4$ with NaOH. The ammonia liberated was distilled into 5% boric acid. The nitrogen from ammonia was deduced from titration of the trapped ammonia with 0.05N HCl using methylene red and methylene blue (double indicator solution) indicators. Percentage crude protein was calculated using nitrogen-to-protein conversion factor of 6.25. Crude fibre was obtained from the loss in weight on ignition of dried residue remaining after digestion of fat-free samples with 1.25% each of H_2SO_4 and NaOH solutions under specified condition. Carbohydrate content was determined by subtracting the total ash, crude fat, crude protein and crude fibre contents from the total dry matter.

2.4. Mineral Composition

The total ash obtained after dry-ashing at 550^{o}C was boiled with 10 mL of 20% hydrochloric acid in a beaker and then filtered into a 100 mL standard flask. It was then made up to the mark with de-ionized water. The minerals Na, Ca and K were determined from the resulting solution using emission flame photometer (Model A A-6200, Shimadzu, Corp., Kyoto, Japan), while Mg, Fe, Zn, Mn

and Cu were determined using atomic absorption spectrophotometer (Model A A-6200, Shimadzu, Corp., Kyoto, Japan) using standard methods.

2.5. Fatty acid composition

The extracted fat was dissolved in 4mL hexane, transferred to a conical flask and evaporated on a hot plate. Four mL of 95% methanolic HCl solution was then added and heating was done under reflux for 1½ hours. It was then cooled under tap water. Methyl esters were extracted by transferring the solution into a separating funnel and 4ml of hexane added. The funnel contents were placed on a shaker and shaken vigorously at room temperature and let to stand (Shaker Model KS 250 basic, Germany). The hexane layer was collected and the aqueous layer was returned and extraction repeated one more time. The hexane fractions were combined and washed with 3-4 portions of distilled water to remove acid. Anhydrous sodium sulphate was added in sufficient quantities to remove water. The filtrate was concentrated using nitrogen gas to about 0.5ml and the sample was injected into the GC. The standards were also injected and the procedure was repeated for all the samples (AOAC. 2000).

2.6. Vitamin C analysis

The amount of vitamin C in a sample was determined by redox titration using the reaction between ascorbic acid in the sample and 2, 6-dichloroindophenol (DCIP) titration method according to AOAC methods (2000) as described by Ranganna (2001). TCA reagent is prepared by dissolving 10g of TCA in 100 mL of distilled water. Standard ascorbic acid 1mg/ml is then prepared. The DCIP solution was prepared by dissolving 0.250 g of 2, 6-dichloroindophenol in about 500 mL of water. Sodium bicarbonate (0.21 g) was then added and dissolved. The resulting solution was finally diluted to 1 L with distilled water to make approximate concentration of 250 mg DCIP/L. Five grams of the sample was accurately weighed and ground in a mortar with acid washed sand using a suitable volume of TCA. It is then transferred into a 100mL volumetric flask and made up to the mark with the TCA reagent. It is then immediately filtered through a fluted filter paper. Ten mL of sample (0.05mg/ml) was pipetted into a 100mL conical flask. Two mL of the sulfuric acid mixture and about 25 mL of distilled water was then added to the flask. The flask was swirled to mix the solution. A 50-mL buret was filled with the DCIP solution which was then used to titrate the sample solution until a permanent light red or pink color appeared. The volume of DCIP needed to oxidize all of the ascorbic acid was recorded and the procedure was repeated. A blank determination was also carried out with TCA. The ascorbic acid content was calculated using the dye factor, determined by the titration of the standard ascorbic acid solution with DCPIP dye using the balanced equation for the oxidation-reduction reaction between ascorbic acid and DCIP.

Vitamin C content (mg/100g) = (A – B) x C x V/v x 100/w

Where:
A = Volume in mL of the Indophenol solution used for sample titration
B = Volume in mL of the indophenol solution used for sample blank titration
C = Mass in mg of ascorbic acid equivalent to 1.0mL of indophenol standard solution
V = Volume of the sample after toping up (100ml)
v = Volume of the sample taken for titration (10ml)
w = Weight in g of sample taken for sample preparation

2.7. Beta carotene

Approximately 2 g of fresh material is weighed accurately. It is then placed in a motor with about 10ml of acetone and ground thoroughly. The acetone extract is then transferred to a 100 mL volumetric flask and the residue extracted again with 10 mL of acetone and transferred to the volumetric flask. The extraction with acetone is repeated until the residue no longer gives color to acetone. The combined extract is

made to the 100mL mark. Twenty five mL of the extract is evaporated to dryness on a rotary evaporator and the residue dissolved in about 1 mL of petroleum ether. The solution is introduced into chromatographic column and eluted with petroleum ether. The beta-carotene is then collected in a flask. Beta-carotene goes through the column as a yellow pigment very quickly. The beta-carotene eluate to a volume in the 25mL volumetric flask with petroleum ether. Five solutions of standard pure beta-carotene with concentrations between 0.5µg/mL and 2.5µg/mL are prepared from a stock solution containing 2.5µg/mL. The absorbance values of the solution are determined at 440 nm using UV-vis spectrophotometer (UV mini 1240 model, Shimadzu Corp., Kyoto, Japan) and plotted against their corresponding concentration to give a standard curve (AOAC. 2000.

2.8. Data analysis

The data was presented as mean ± standard deviation of three replicates. The proximate composition and mineral data obtained from this study were subjected to one-way analysis of variance (ANOVA) at 5% level of confidence using SAS software.

3. RESULTS AND DISCUSSION

3.1. Proximate composition

The nutrient values of the food are part of the dry matter portion which is the material remaining after removal of water. The ALV leaves demonstrated low dry matter value in all species ranging between 12.8–18.2 % (Table 1). *Solanum scabrum* had significantly ($P < 0.05$) lower dry matter content (12.8±0.14 % WWB) as compared to *C. ochroleuca*, *C. olitorius* and *C. gynandra* with (15.1±1.38, 16.8±0.17 and 18.2±0.20 %), respectively. *Corchorus olitorius* recorded significantly higher crude fiber content (2.1±0.50 % DWB) compared to other vegetables ($P < 0.05$). However, *C. olitorius* and *C. ochroleuca* had significantly higher ($P < 0.05$) composition of total fat, 1.4±0.27% DWB and 1.0±0.33% DWB, respectively, as compared to *C. gynandra* and *S. scabrum* with less than 1.0% total fat. Protein was significantly higher ($P < 0.05$) in *C. olitorius* (3.7±0.62% DWB) but there was no significant difference between the protein contents of *C. ochroleuca*, *C. gynandra* and *S. scabrum* ($P > 0.05$). Besides, the mean values indicated that, the ALV leaves had significantly low fat, carbohydrate and fiber contents.

Generally, the mean values indicate that the leaves had significantly low fat as compared to protein content. *Cleome gynandra* was also significantly ($P < 0.05$) rich in the amount of total ash (11.2±0.49% DWB) as compared to the other three vegetables. This is a reflection of the total inorganic matter present in these vegetables. It may also indicate that they possess some minerals which are essential for good health.

Table 1. Proximate composition of the edible leaves of African leafy vegetables

	Percentage composition on DWB				
Parameter	***C. olitorius***	***C. ochroleuca***	***C. gynandra***	***S. scabrum***	***LSD***
Dry matter (WWB)	16.8^{a}±0.17	15.1^{b}±1.38	18.2^{a}±0.20	12.8^{c}±0.14	0.065
Ash	8.3^{b}±0.08	9.2^{b}±0.06	11.2^{a}±0.49	8.8^{b}±0.10	0.023
Protein	3.7^{a}±0.62	2.6^{b}±0.46	2.6^{b}±0.25	2.4^{b}±0.22	0.038
Fiber	2.1^{a}±0.50	1.2^{b}±0.37	0.8^{c}±0.28	0.6^{c}±0.36	0.035
Fat	1.4^{a}±0.27	1.0^{a}±0.33	0.8^{b}±0.09	0.7^{b}±0.07	0.020
Carbohydrate	1.3^{b}±0.01	1.1^{b}±0.02	2.8^{a}±0.93	0.3^{c}±0.00	0.010
Total organic matter	91.7^{a}±0.13	90.8^{a}±0.11	88.8^{b}±0.85	91.2^{a}±0.17	0.081

Values are given as means of three replicates ± SEM. Means with different superscript letters within a row are significantly different ($P < 0.05$). SEM= Standard error of the mean. LSD= Least significant difference.

3.2. Minerals

Eight elements were assayed in all the ALVs and their composition apparently revealed relatively high concentrations of calcium, magnesium and potassium (Table 2). The mineral contents of fresh ALVs did not vary significantly ($P > 0.05$) with that of the dried ALVs. As well, the mineral contents of fresh, shade and solar dried vegetables were significantly higher than that of cooked ALVs on DWB. Apparently, cooking of the vegetables led to an average loss of over 50% in some minerals. This might be mainly because of the solubility of some of the minerals during cooking. *Corchorus olitorius* and *C. ochroleuca* on the other hand, had significantly higher iron contents (22.2±0.15 mg/100g and 13.6±0.52 mg/100g DWB, respectively) as compared to *C. gynandra* and *S. scabrum* ($P < 0.05$). Other mineral elements detected in reasonable amounts were zinc, sodium and manganese. Magnesium content of the leaves is a component of chlorophyll and it is an important mineral element in connection with ischemic heart disease and calcium metabolism in bones (Ishida *et al.*, 2000). Calcium plays an important role in bone formation. It is noteworthy that, although the Ca content in these ALV leaves was relatively high, its availability to the human body needs be investigated. This is because Oke (1996) observed that calcium bioavailability could be lower than expected due to its usual occurrence as insoluble oxalates and phytates. The Na/K ratio in the body is of great concern for prevention of high blood pressure. Na/K ratio of less than one is recommended (FND, 2002). In this study only *C. olitorius* had a Na/K ratio higher than one. Hence, consumption of these ALVs would probably alleviate hypertension and related ailments. Potassium is an essential mineral for controlling the salt balance in human tissues. *C. ochroleuca*, *C. gynandra* and *S. scabrum* were the best source of this element. Children, women of reproductive age and pregnant women need food with high iron content since they are most vulnerable to micronutrient deficiency and anemia. Iron is an essential trace element for haemoglobin formation, normal functioning of the central nervous system and in the oxidation of carbohydrates, protein and fats. In this study, *C. olitorius* and *C. ochroleuca* had significantly higher iron content as compared to *C. gynandra* and *S. scabrum*. Hence the high value of iron in these vegetables makes them a potential source of iron for the vulnerable groups. Other mineral elements detected in reasonable amounts were zinc, sodium and manganese. Iron, Zinc and Manganese are antioxidant micronutrients and their presence could therefore boost the immune system (Talwar *et al.*, 1989).

3.3. Fatty acid composition

The fatty acid profile of ALV leaves is shown in Table 3. Results indicated that, unsaturated fatty acids recorded higher amounts than the saturated fatty acids (SFA). This was attributed to the presence of linoleic acid ($C_{18:2\Delta9;12}$), α-linolenic ($C_{18:3\Delta9;12;15}$) and oleic ($C_{18:1\Delta9}$) acid. *Corchorus olitorius* exhibited significantly higher values of unsaturated fatty acids, linoleic acid ($C_{18:2\Delta9;12}$), α-linolenic ($C_{18:3\Delta9;12;15}$) and oleic ($C_{18:1;9}$) acids (300.6±15.12, 186.6±17.82 and 75.1±7.83 mg/100g DWB, respectively) ($P < 0.05$). The predominant SFA was palmitic acid ($C_{16:0}$) with 157.3±13.16 mg/100g and 169.8±9.31 mg/100g DWB in *C. ochroleuca* and *C. olitorius*, respectively. However, *C. olitorius* and *C. ochroleuca* was composed of high amounts of total fatty acids, whereas *C. gynandra* and *S. scabrum* had significantly lower ($P < 0.05$) amounts of the fatty acids.

3.4. Vitamin C composition

The amount of ascorbic acid in plants varies greatly, depending on such factors as the variety, weather, and maturity. As well, the most significant determinant of vitamin C content in foods is how the food is stored and prepared. Therefore, vitamin C content in fresh vegetables was significantly higher than that of dried samples ($P < 0.05$) (Table 4). However, solar drying led to significantly high loss in vitamin C content compared to shade drying or cooking.

Table 2. Mineral composition of the Vegetables

Vegetable	Treatment	Mineral concentration (mg/100g DWB)						
		Zn	Mn	Ca	Mg	Fe	K	Na
C. olitorius	Solar	3.9^{a}±0.01	23.5^{b}±2.08	34.0^{c}±3.51	53.9^{a}±3.89	20.0^{a}±0.34	3.9^{e}±0.14	11.2^{c}±0.36
	Shade	4.1^{a}±0.06	16.7^{c}±1.31	38.9^{c}±0.82	56.5^{a}±0.75	22.2^{a}±0.15	1.3^{e}±0.06	12.5^{c}±1.42
	Cooked	*BDL	11.1^{c}±1.04	26.2^{d}±2.48	23.4^{c}±1.61	11.2^{b}±0.20	1.0^{e}±0.11	4.8^{d}±0.21
	Fresh	5.0^{a}±0.17	23.5^{b}±2.01	40.3^{c}±2.13	67.2^{a}±2.03	19.9^{a}±1.03	3.8^{e}±0.19	13.2^{c}±0.97
C. ochroleuca	Solar	0.03^{d}±0.02	22.6^{b}±7.60	45.5^{c}±2.11	27.0^{c}±2.10	7.5^{c}±1.15	106.0^{b}±3.24	23.7^{b}±1.75
	Shade	0.05^{d}±0.01	24.1^{b}±1.15	74.8^{b}±6.98	26.6^{c}±3.77	13.6^{b}±0.52	121.7^{a}±2.60	21.4^{b}±1.78
	Cooked	*BDL	6.3^{d}±0.21	17.0^{d}±1.13	15.3^{d}±1.81	2.6^{d}±0.17	59.4^{d}±3.17	14.7^{c}±1.50
	Fresh	0.08^{d}±0.01	27.3^{b}±1.85	70.5^{b}±4.18	41.7^{b}±1.89	10.8^{b}±1.25	120.6^{a}±3.13	24.4^{b}±1.23
C. gynandra	Solar	*BDL	36.1^{a}±12.71	81.9^{a}±7.15	20.8^{d}±0.48	5.4^{c}±1.51	100.6^{b}±5.20	45.0^{a}±7.20
	Shade	*BDL	27.1^{b}±0.03	92.8^{a}±4.98	24.8^{c}±5.00	4.6^{cd}±0.10	105.7^{b}±1.29	42.8^{a}±3.56
	Cooked	0.08^{c}±0.02	8.3^{d}±0.12	72.2^{b}±3.04	13.3^{d}±3.79	0.4^{e}±0.12	56.0^{d}±3.19	21.9^{b}±1.92
	Fresh	0.1^{c}±0.03	35.6^{a}±1.20	94.1^{a}±5.37	32.7^{c}±1.98	4.1^{d}±0.73	104.9^{b}±8.73	46.3^{a}±2.26
S. scabrum	Solar	0.7^{c}±0.02	3.6^{d}±1.63	89.9^{a}±8.30	44.2^{b}±4.20	4.1^{d}±1.01	86.9^{c}±2.62	4.1^{d}±1.80
	Shade	1.0^{b}±0.02	6.8^{d}±1.92	86.2^{a}±4.11	46.8^{b}±2.95	4.4^{d}±0.97	82.0^{c}±1.12	3.6^{d}±0.71
	Cooked	0.07^{d}±0.02	1.7^{e}±0.15	22.0^{d}±2.82	19.3^{c}±2.43	1.5^{e}±0.16	50.9^{d}±0.11	2.6^{d}±0.15
	Fresh	1.2^{b}±0.03	7.4^{d}±1.43	90.2^{a}±2.30	50.2^{b}±2.87	3.9^{cd}±1.71	87.3^{c}±2.37	4.4^{d}±1.72

Values are given as means of two replicates ± standard deviation. Means with different small letters within a column are significantly different ($P < 0.05$). *BDL= Below detectable level. DWB= Dry weight basis.

Table 3: Composition of fatty acids in the ALVs

Fatty acid	Fatty acid content of ALVs (mg/100g DWB)			
	C. olitorius	*C. ochroleuca*	*C. gynandra*	*S. scabrum*
Caprylic(8:0)	23.6^{a}±5.81	10.01^{b}±1.23	5.8^{c}±0.24	9.2^{b}±0.07
Capric(10:0)	2.6^{b}±0.14	8.2^{a}±0.83	1.8^{b}±0.09	10.1^{a}±1.76
Lauric(12:0)	5.3^{a}±0.27	3.5^{b}±1.46	2.4^{b}±0.32	0.8^{c}±0.46
Myristic(14:0)	119.4^{a}±3.65	90.4^{b}±8.01	84.4^{b}±0.40	105.4^{a}±17.68
Palmitic(16:0)	169.8^{a}±9.31	157.3^{a}±13.16	108.0^{b}±7.03	113.1^{b}±2.08
Stearic(18:0)	35.2^{a}±0.41	37.7^{a}±5.93	18.4^{c}±0.08	29.5^{b}±1.82
Linoleic(18:2)	300.6^{a}±15.12	272.4^{a}±24.34	180.3^{b}±3.16	173.2^{b}±8.97
Linolenic(18:3)	186.6^{a}±17.82	130.2^{b}±2.39	67.3^{c}±10.03	129.9^{b}±2.86
Oleic(18:1)	75.1^{a}±7.83	38.5^{b}±6.97	27.3^{b}±0.18	32.3^{b}±0.08

Values are given as means of two replicates ± SEM. Means with different small letters within a row are significantly different ($P < 0.05$). SEM= Standard error of the mean

There was also a significant difference ($P < 0.05$) in the vitamin C content between the different ALVs. Fresh *C. olitorius* exhibited the highest amount of vitamin C content (153.7±7.75 mg/100g DWB), while *S. scabrum* had the least (62.6±4.57 mg/100g DWB). On the other hand, the vitamin C content of *C. ochroleuca* and *C. gynandra* were not significantly different. The loss in vitamin C on drying and cooking was between 79 – 97%.

Vitamin C is a highly effective antioxidant and a very small daily intake of this vitamin for an adult is required to avoid deficiency disease scurvy. Even in small amounts it can protect indispensable molecules in the body, such as proteins, lipids (fats), carbohydrates, and nucleic acids (DNA and RNA) from damage by free radicals and reactive oxygen species that can be generated during normal metabolism as well as through exposure to toxins and pollutants (e.g. smoking). However, there has been, and continues to be, vigorous debate on what the optimum daily intake of vitamin C is. In an attempt to balance the competing claims, and ensure the general population's good health, the Federal Food and Drug Administration has adopted a recommended dietary allowance (RDA) of 60 mg/day for adults aged 15 or older, less (15-45 mg/day) for children, and more (80-120mg/day) for pregnant and lactating women (Brody, 1994). Increased consumption of vegetables has been associated with protection against various age-related diseases (Lindeberg *et al.*, 2003). The dietary constituents responsible for this association is not known, but well-characterized antioxidants, including vitamins C and E, or β-carotene, are often assumed to contribute to the observed protection. Vitamin C has also been documented that it slows the aging process, reduce the risk of certain types of cancer, improve lung function, and reduce complications associated with diabetes (Sebastian *et al.*, 2003).

Table 4. Vitamin C content of the Vegetables

Sample	Vitamin C content mg/100g DWB			
	Fresh	**Shade dried**	**Solar dried**	**Cooked**
C. olitorius	153.7^{aA}±7.75	16.7^{bA}±0.37	12.4^{cA}±0.23	26.3^{bA}±0.95
C. ochroleuca	92.8^{aB}±8.13	9.9^{bB}±0.91	4.0^{cB}±0.20	11.9^{bC}±1.13
C. gynandra	104.3^{aB}±6.68	14.7^{bA}±0.32	5.7^{cB}±0.40	16.2^{bB}±0.42
S. scabrum	62.6^{aC}±4.57	8.0^{bB}±0.17	2.4^{cC}±0.06	10.0^{bC}±1.73
LSD	0.63	0.15	0.12	0.21
CV%	12.2	24.2	20.4	31.2

Values are given as means of three replicates ± SEM. Means with different small letters within a row and capital letters within a column are significantly different ($P < 0.05$). SEM= Standard error of the mean. LSD= Least significant difference. CV= Coefficient of variation.

3.5. Beta-Carotene

Fresh ALVs had significantly higher β-carotene contents compared to the dried and cooked ALVs ($p<0.05$). *Cleome gynandra* had the highest content of β-carotene (8.7±0.16 mg/100g DWB), while *C. olitorius* had 7.7±0.32 mg/100 g DWB and *C. ochroleuca*, 6.2±0.19 mg/100g DWB. *Solanum scabrum* exhibited the lowest β-carotene content among the vegetables (4.6±0.25 mg/100g DWB) (Figure 1). There was significant destruction of both beta-carotene and ascorbic acid during drying though there were no much significant differences ($p>0.05$) for the solar and shade dried vegetables. It is generally recognized that dehydration of leafy vegetables results in losses of nutritional components, the extent of loss depending on the type of vegetable (Gareth *et al.*, 1998). Apparently, the destruction of carotene was relatively lower when initial drying temperature was low for example when stored in shade therefore, the higher the temperature of storage, the higher was the loss in beta-carotene.

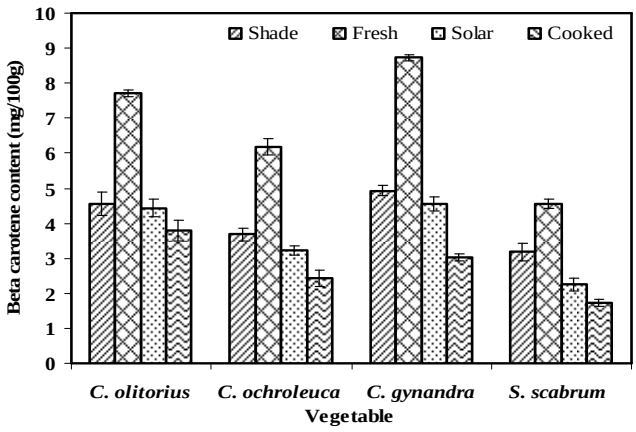

Fig. 1: Beta-carotene content of ALV leaves. Values are given as means of three replicates ± standard error. Shade, fresh, solar and cooked in the key above includes the different treatments. Recommended Dietary Allowance (RDA) = 12 mg/100g. (Abukutsa-Onyango, 2003)

4. CONCLUSION

The selected commonly consumed ALVs in Kenya contain substantial amount of micro nutrients which might be helpful in the prevention of some metabolic diseases. They contribute substantially to minerals especially calcium, phosphorus and iron, important proteins, vitamins, fiber, essential amino acids and certain hormone precursors which are usually in short supply in daily diets. Vitamins and minerals are involved in many roles such as assisting in releasing energy, helping balance hormones, strengthening certain body tissues and structures and are involved in facilitating the body's chemical reactions. In addition, their inclusion in the required amounts is vital in promoting the health of the immune system. Since these ALVs contain a lot of nutritive compounds, the intake of the mixture of these vegetables is recommended. This will enable derivation of full dose of the nutrients since no single plant is rich in all the plant chemicals. Though the leaves in particular contain relatively high levels of some minerals, the processing methods prior to consumption which may include drying and cooking may reduce their final consumed amount. Ultimately, drying of vegetables can result in loss of some nutrients; therefore, they should be stored in a cool, dark, dry place and used within a short time for best retention of nutrients.

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