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Effect of storage conditions on physico-chemical properties of cowpea leaves

[1*]MIANO A W, [1]ABONG G O, [1]NJUE L G, [2]MWANG'OMBE A W

[1]Department of Food Science, Nutrition and Technology, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya.
[2]Department of Plant Science and Crop Protection, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya.

*Corresponding author: annmiano49@gmail.com

Abstract

Cowpea leaves are highly perishable thus to improve their utilization, there's need for proper postharvest management. This study sought to determine the physicochemical changes of cowpea leaves during storage. The cowpea leaves were sorted and packaged using three main packaging materials; sacks, modified atmosphere packaging (cling film) and perforated trays which imitated storage in open crates. Samples were stored at different storage temperatures 30±2°C, 25±2°C and 10±2°C. The samples under storage were observed for physiochemical changes every two days for a period of eight days. Physico-chemical parameters were significantly ($p<0.05$) affected by the period and temperature of storage and packaging material. Storage in high and ambient temperatures, extended storage, and tray and sack showed higher deterioration in physicochemical properties as compared to low temperatures and modified atmosphere packaging. There was a significant difference in visual appearance, aroma and the overall acceptability of cowpea leaves stored under different conditions ($p< 0.05$). Storage conditions had an influence on the sensory quality, nutritional quality and the shelf life of cowpea leaves. Modified atmosphere packaging at 10°C was seen to preserve sensory with an overall acceptability mean score of 5.22 and nutritional attributes best as compared to modified atmosphere packaging, sack and tray packaging at ambient and extreme temperature storage where moisture (36.21±26.28a and 33.28±26.20a respectively), ascorbic acid (198.7±276.75a and 169.1±254.31a respectively), beta carotene (46.77±58.66a and 48.59±65.04a respectively) and color degradation (ΔE 11.89±5.99a and ΔE 11.29±5.27a respectively) was higher. A combination of low temperature and modified atmosphere packaging for storage would be recommended to extend the shelf life and in turn combat post-harvest losses and increase the utilization of the vegetable. Storage temperatures, packaging materials and duration of vegetable storage are vital when it comes to extending the commercial life of fresh cowpea leaves.

Keywords: *cowpea leaves; packaging material; physico-chemical properties; storage; temperature*

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Introduction

Cowpea is a dual-purpose crop that is consumed in all stages of crop growth, consumed as a vegetable and legume (Chikwendu *et al.,* 2014). Cowpea leaves are important in human diets due to their high nutritional value (Natabirwa *et al.,* 2017). Aside from preventing the occurrence of diseases such as beri beri and rickets, the presence of nutrients in vegetables do more. Vitamins and their precursors such as beta-

carotene, ascorbic acid and polyphenols are powerful antioxidants know to prevent diseases, muscular degradation and molecular damage (Chikwendu *et al.,* 2014). AIVs are highly perishable and losses are incurred mainly after harvest due to their nature (Gogo *et al.*, 2018).

Vegetables such as cowpea leaves undergo physical and chemical changes immediately after harvest which affects the quality in terms of the nutritional value, edibility and consumer acceptance (Kirigia *et al.*, 2017; Owade *et al.*, 2019). The changes are mainly due to the high water content of between 70-90% and the escalated respiration rate (Balan *et al.*, 2016; Varzakas, 2016). It is impossible to stop the physiological changes that occur but the use of appropriate post-harvest handling technologies can help control the changes (Varzakas, 2016). A predominant treatment for increasing the shelf life of vegetables is temperature control; a study by Owade *et al.*, (2019) has shown it remains a factor that determines the post-harvest quality of green leafy vegetables. The commercial life of vegetables is shortened with the increase in storage temperature since it affects the metabolism rate while high humidity and low temperatures preserved the shelf life and retention of phytochemicals (Owade *et al.*, 2019; Varzakas, 2016). On the contrary extremely low temperatures have been shown to cause chilling injuries to ALVs (Gogo *et al.*, 2016), the optimal temperature is between 10 and 13◦C, temperatures below 8-9◦C induced CI (Valenzuela *et al.*, 2017).

Vegetables and fruits are vulnerable to mechanical injury and dehydration, affecting the respiration rate appropriate post harvesting handling is necessary to avoid mechanical damage thus maintaining the quality (Valenzuela *et al.*, 2017). The use of appropriate packaging material protects food from unpleasant changes. Packaging material properties are determined by its permeability for gases and agents of degradation permeating from the external surrounding (Gogo *et al.*, 2016).

Materials and methods

Study Design

Cowpea leaves were harvested at 8 weeks then subjected to storage and physicochemical changes analysis at the Department of Food Science, Nutrition and Technology Laboratories.

Experimental Design

The cowpea leaves were sorted and packaged using three main packaging materials, Sacks, MAP (cling film) and perforated trays which imitated storage in open crates. The samples were then stored at different storage temperatures extreme temperatures (30±2°C), ambient temperatures (25±2°C) and cold storage (10±2°C). The samples under storage were then observed for physiochemical components, color, moisture, beta carotene and ascorbic acid every two days for a period of eight days.

A full factorial experimental design was implemented with three main packaging materials, Sacks, perforated trays and MAP (cling film) varied at three different temperatures 30±2°C, 25±2°C and 10±2°C for a period of eight days. All treatments were replicated twice.

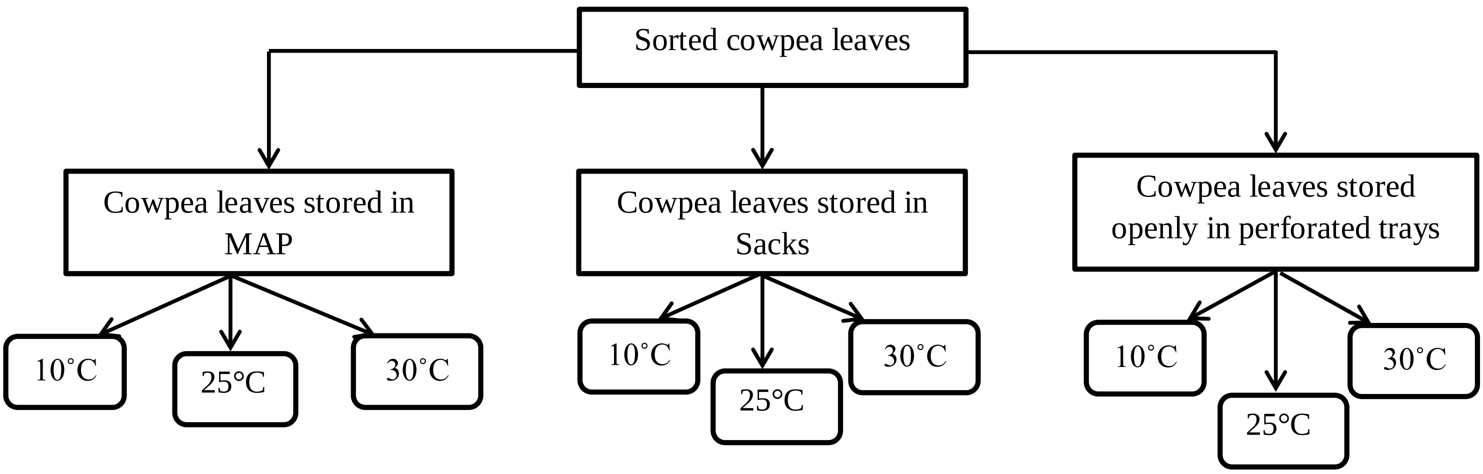


Figure 1. Experimental Arrangement

Sample Preparation

The cowpea variety (*Kunde Mboga*) was used in the study. Cowpeas were randomly planted

at the University of Nairobi field station. The cowpea leaves upon maturity at 8 weeks were harvested, packaged in sacks and quickly transported to the Pilot plant in the University of Nairobi via road under ambient conditions.

Study Site

The study site was at the Field station located at the College of Agriculture and Veterinary Sciences, the University of Nairobi, Nairobi County. The field is located West of Nairobi County along the latitudes 1˚ 15´ S, the longitudes 36˚ 44´E and an altitude of 1820 m above sea level (Kirakou, 2017). The area has an annual rainfall of 1060 mm which has a bimodal distribution with long rains between March and May and short rains between October and December (Onyango *et al.,* 2013). The temperature ranges from 13.7 and 24^{o}C. The soils of the area are deep well- drained, dark reddish brown to dark brown (Kirakou, 2017).

Materials and Methodology

Physical Changes of Cowpea Leaves during Storage

Moisture Content

Determination of moisture content was done using AOAC (2005) method number 930.15. Oven used was memmert 40500-IP 20 (Germany) to dry the samples. Weight of initial and final sample after drying was weighed using KERN PCB 3500-2 (Germany) weighing balance.

Determination of Cowpea Leaves Colour

Cowpea leaves colour change was determined by a handheld colorimeter (Colorimeter PCE-CSM 4- PCE Instruments UK Ltd, United Kingdom). The following parameters of color were recorded, L*, a *, b *. L * gave brightness and changes between 100 (white) to 0 (black). Parameter a * gave either color green (-a *) or red (+ a *) while b * gave either yellow (+ b *) or blue (-b *) (Wawire, 2013). The values were then used to calculate change in color ΔE.

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Chemical Changes of Cowpea Leaves during Storage

Vitamin C Determination

The vitamin C (Ascorbic Acid) content was determined using the titrimetric method of determination of vitamin C content of juices using TCA (AOAC, 1990). Vitamin C was extracted from 2 grams of the cowpea sample using trichloroacetic acid, 4% potassium iodide (5mls) was added to the mixture and titrated against N-bromossucinamide using starch as the indicator. The amount of vitamin C in samples was then determined by a standard formula.

$$\textbf{Vitamin C/100g dm} = \frac{\text{V.C 176mg}}{178} * \frac{100}{\text{Sample weight}}$$

Where;

V= Volume of N-bromossuccinimide

C= Concentration of N-bromossuccinimide

176= Molecular weight of N-bromossuccinimide

178= Molecular weight of Trichloroacetic acid

Beta-carotene Determination

Beta-carotene was determined as beta carotene the method used was number 44 of International Federation of fruit juice producers adopted in 1972. Cowpea color from samples was extracted using a 100 ml of acetone in a mortal using a pestle. The extracted sample (25 ml) was dried in a water bath. Petroleum ether was added to the dry sample to dissolve beta carotene and then eluted through a silica gel column. The sample was then collected in a 25 ml volumetric flask and absorbance read using a double beam spectrophotometer at 450 nanometer wavelength. The amount of beta carotene in samples was then determined by a standard formula.

$$\textbf{Beta Carotene/ 100g dm} = \left(\frac{100}{25} * 25\right)\frac{0.4}{0.12} * \frac{100}{\text{Sample weight}} * \textbf{Absorbance}$$

Where;

$\frac{0.4}{0.12}$ =constant

Sensory Analysis

Fresh cowpea leaves and cowpea leaves stored for two days under different storage conditions were evaluated for sensory attributes by an untrained panel of 18 panellists that were familiar with cowpea leaves. The Cowpea leaves samples were scored for visual appearance (color), aroma, texture and overall acceptability. The panellists were then allowed to make a score of the sensory attributes of the samples on a seven-point hedonic rating scale with 1 = dislike very much and 7= like very much.

Statistical Analysis

Statistical package for Social Sciences Software (IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA) was used to analyze sensory evaluation data. Agricolae package of the R package for statistical computing was used for analysis of variance (R core team, 2019). Means and standard deviations of physicochemical parameters were determined. Also, it was used to determine the correlation, in order to get the correlation co-efficient of parameters.

Results

Model Fitting

The akaike information criterion (AIC) -weights of all physicochemical parameters showed that main effect (factor) analysis was AIC best ranked model to explain variability in the physico- chemical attributes; thereby no need to run an interaction analysis (Table 1).

Table 1

Model Selection Based on Akaike information Criterion

Physicochemical Parameter	Delta_AICc		AICc weight	
	Factor	Interaction	Factor	Interaction
Moisture	0.00	233.7	1	0
Beta Carotene	0.00	11.85	1	0
Ascorbic acid	0.00	136.3	1	0
L*	0.00	7.02	1	0
a*	0.00	67.38	1	0
b*	0.00	5.69	0.95	0.05

Moisture Content of Stored Cowpea Leaves

The days of storage had a significant ($p<0.05$) impact on the moisture content with the eighth day recording the lowest moisture content. Increase in days of storage led to a decrease in moisture of the cowpea leaves (Figure 2).

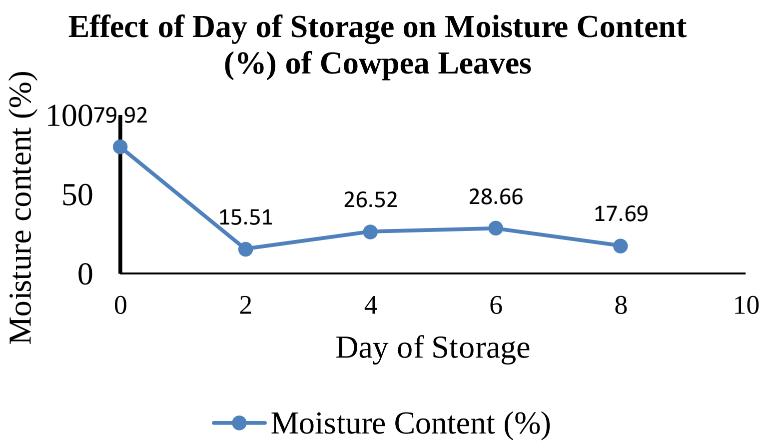


Figure 2. Effect of Day of Storage on Moisture Content (%) of Cowpea Leaves

The type of packaging material also had a significant ($p<0.05$) effect on the moisture content of the leaves. Leaves stored in sacks recorded the highest moisture loss while those stored in MAP having the lowest loss in moisture (Figure 3).

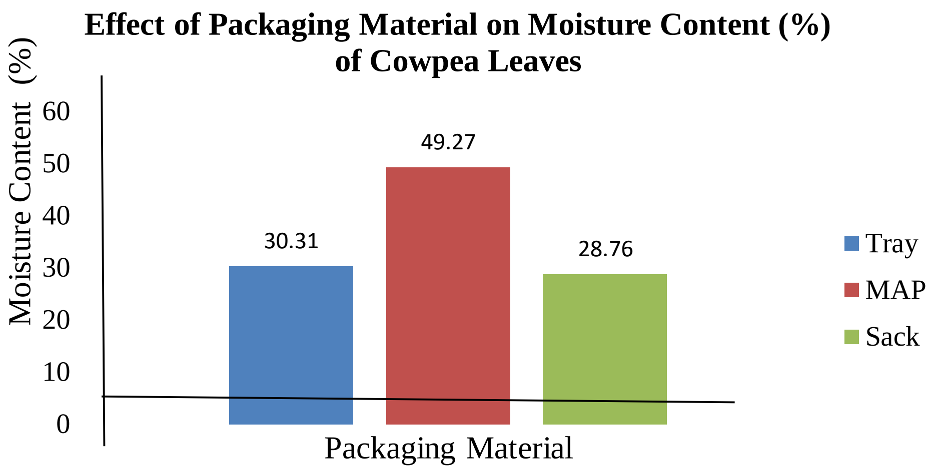


Figure 3. Effect of Packaging Material on Moisture Content (%) of Cowpea Leaves

Temperature of storage significantly ($p<0.05$) affected the moisture loss of the leaves, however, there was no significant ($p>0.05$) difference in moisture loss among the three temperature (Figure 4).

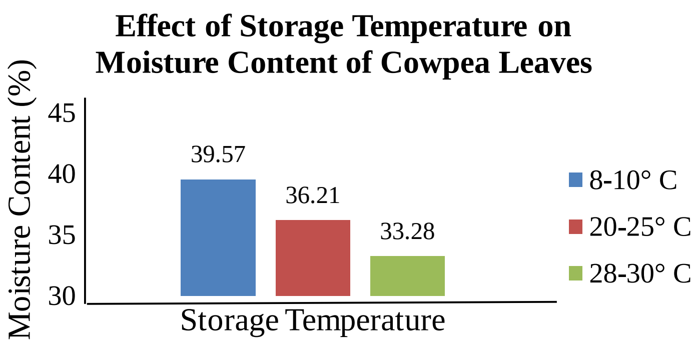


Figure 4. Effect of Storage Temperature on Moisture Content (%) of Cowpea Leaves

Stability of Color of Stored Cowpea Leaves

Color change of cowpea leaves was highest on the second day of storage $\Delta E=15.12$, the difference decreased as the days of storage increased. Color change during storage was recorded in terms of changes in the l*(lightness), a* (green to red) and b*(blue to yellow). Color change was significantly ($p<0.05$) influenced by the days of storage greenness increased the first four days then a decrease was seen after the fourth day of storage with the eighth day being the least green (a*=-2.14) (Figure 5).

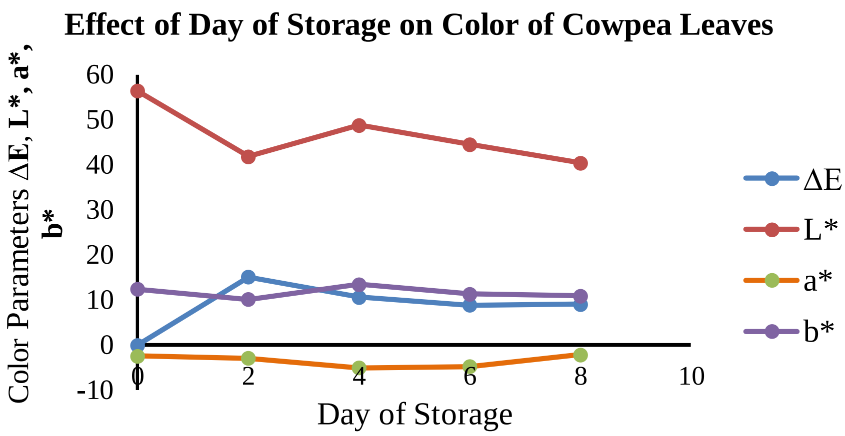
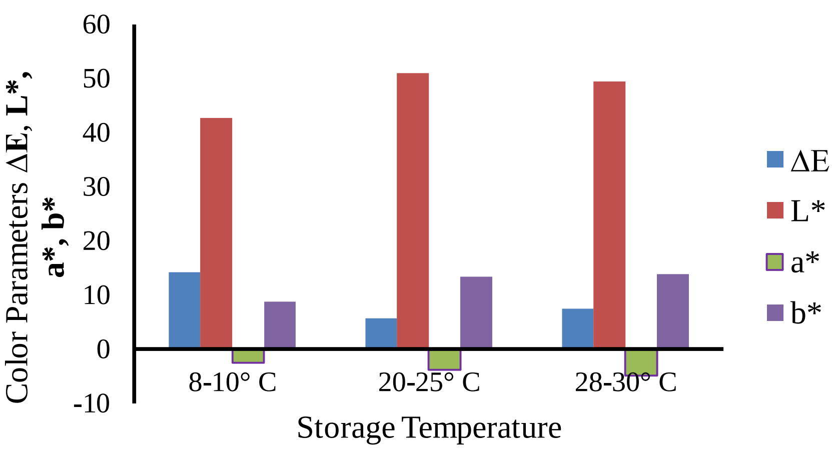


Figure 5. Effect of Day of Storage on Color of Cowpea Leaves

Temperature of storage significantly ($p<0.05$) affected the color of cowpea leaves. At 30°C, the b* was the highest (+13.89±5.04) as compared to 20°C (+13.41±3.85) and 10°C (+8.76±4.32b), a higher positive value of b* indicated more yellowness in the cowpea leaves thus deterioration of green color of cowpea leaves (Figure 7).

Figure 7.

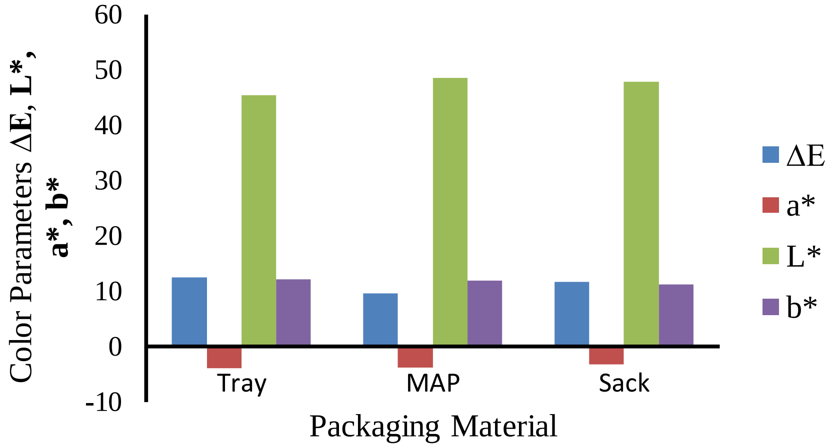
Effect of Storage Temperature on Color of Cowpea Leaves



Color difference was highest in samples stored under ambient and high temperatures ΔE =11.89, 11.29 respectively while the least difference was evident in samples stored under low temperatures ΔE=10.8. Cowpea leaves on the first day of storage were lighter in color (L*=56.37) as compared to those stored for eight days having duller color (L*=40.39). The dullest color was evident in samples stored openly in trays. Cowpea leaves that were stored in MAP type of packaging were greener as compared to samples stored in sacks and perforated trays, while yellowness was more in samples that were stored in perforated trays. Cowpea leaves samples that were stored under ambient and high temperatures conditions had the highest L* values (50.98 and 49.99, respectively) as compared to samples stored under low temperature. Samples stored using MAP were more color stable with the least color difference (ΔE=9.58) as compared to samples stored in trays ΔE=12.47 and sacks ΔE=11.76 (Figure 6).

Figure 6.

Effect Packaging Material on Color of Cowpea Leaves

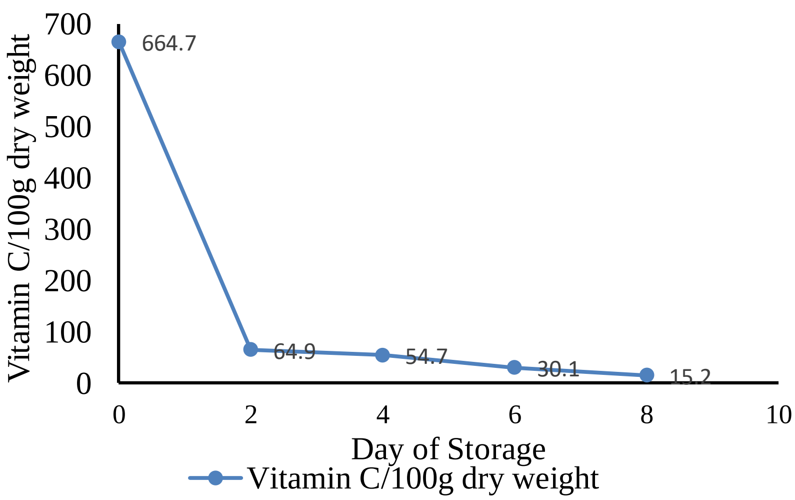


Vitamin C (Ascorbic Acid) Content of Stored Cowpea Leaves

Vitamin C content of the cowpea leaves significantly ($p<0.05$) decreased with increasing period of storage with day zero having the highest and day eight lowest amount (Figure 8).

Figure 8

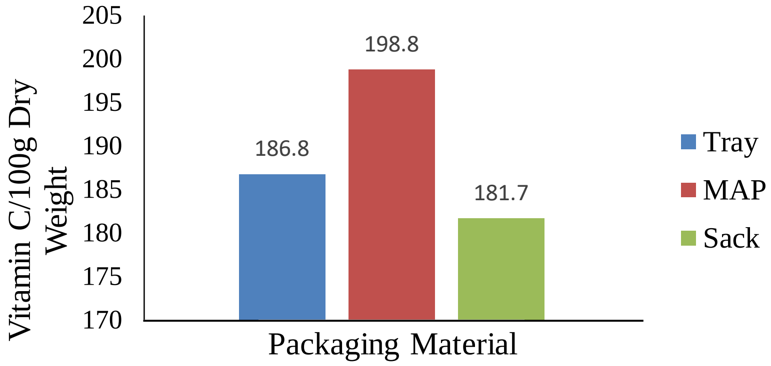
Effect of Day of Storage on Vitamin Content of Cowpea Leaves



Packaging material; significantly ($p<0.05$) influenced the retention of vitamin C in the leaves with modified atmosphere packaging retaining the highest and sacks recording the highest loss in vitamin C (Figure 9).

Figure 9

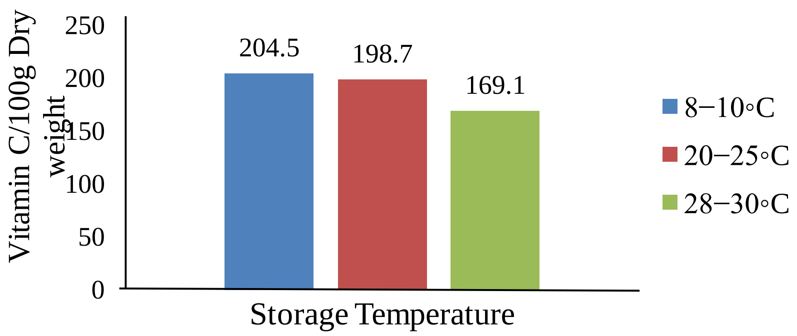
Effect of Packaging Material on Vitamin Content of Cowpea Leaves



Temperature of storage significantly ($p<0.05$) caused reduction in vitamin C content. Higher losses were evident in samples stored under high temperatures. Loss in vitamin C was not significantly ($p>0.05$) different among the three storage temperatures (Figure 10).

Figure 10

Effect of Storage Temperature on Vitamin Content of Cowpea Leaves

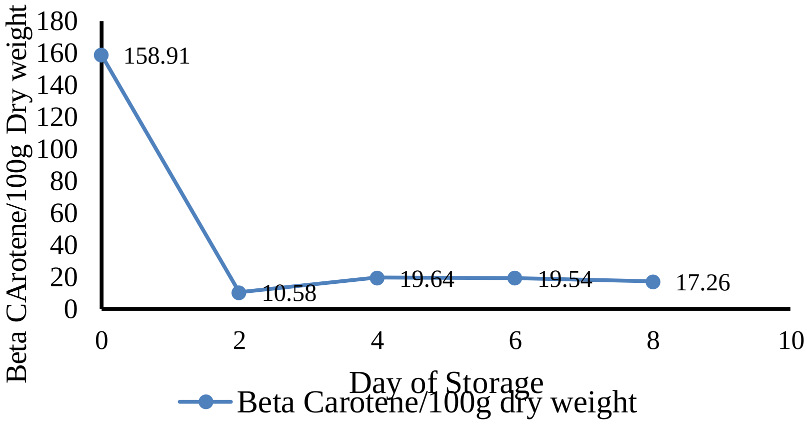


Beta-carotene Content of Stored Cowpea Leaves

Beta-carotene content of the cowpea leaves decreased significantly ($p<0.05$) with increasing days of storage. Day zero recorded the highest beta carotene content in the leaves (Figure 11).

Figure 11

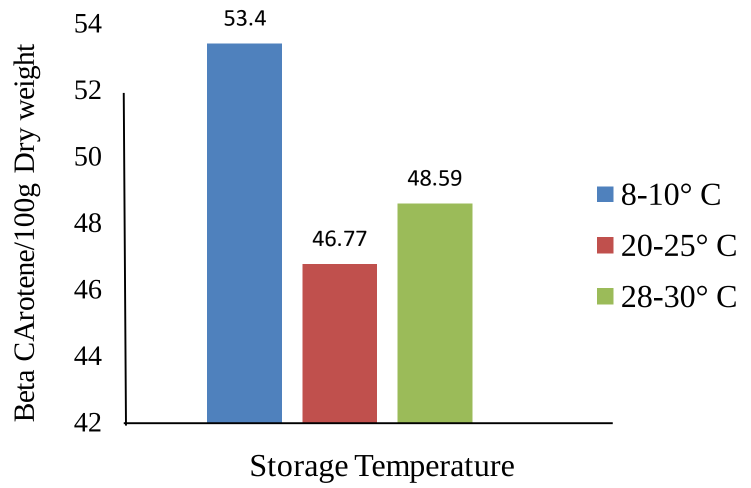
Effect of Day of Storage on Beta Carotene Content of Cowpea leaves



Beta carotene retention in the leaves was significantly ($p<0.05$) influenced by the type of packaging material used. Leaves stored in MAP had the highest beta carotene retained (Figure 12).

Figure 12

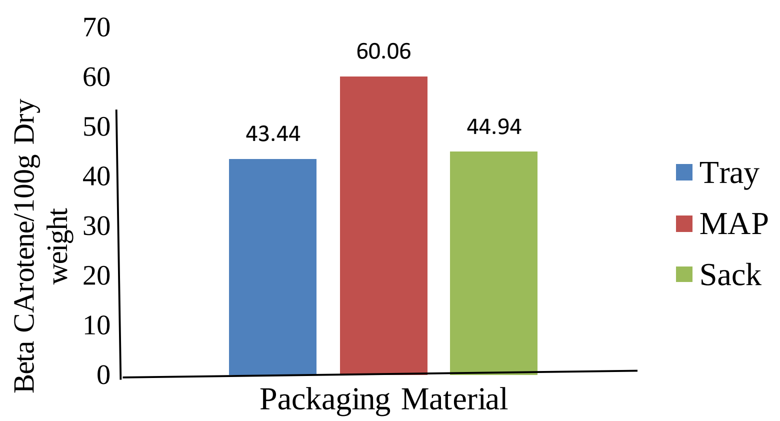
Effect of Storage Temperature on Beta Carotene Content of Cowpea leaves



Temperature of storage significantly ($p<0.05$) influenced beta carotene content in the leaves with those stored at 8-10°C recording the highest amount and those at 28-30°C having the least (Figure 13).

Figure 13

Effect of Packaging Material on Beta Carotene Content of Cowpea leaves



Correlation between Physico-chemical Parameters of Stored Cowpea Leaves

There was a strong linear relationship between moisture content and beta carotene (R=0.91) in stored cowpea leaves, an increase in moisture content showed an increase in beta carotene. Correspondingly vitamin C increased with increase in moisture content (Table 2).

Table 2

Correlation Co-efficient of Physico-chemical Parameters

	% Moisture	L*	a*	b*	Vit C/dwb	Beta carotene/dwb
% Moisture	N/A	0.48	0.04	0.16	0.85	0.91
L*	0.48	N/A	-0.09	0.44	0.60	0.57
a*	0.04	-0.09	N/A	-0.65	0.26	0.23
b*	0.16	0.44	-0.65	N/A	0.07	0.04
Vit C/dwb	0.85	0.60	0.26	0.07	N/A	0.96
Beta carotene/dwb	0.91	0.57	0.23	0.04	0.96	N/A

A strong linear relationship between vitamin c and beta carotene was also evident (0.96).

Sensory Analysis of Stored Cowpea Leaves

Fresh cowpea leaves had the highest mean score, Table 3.

Table 3

Mean Descriptives of Sensory Attributes of Cowpea Leaves

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Visual Appearance (Color)	**100**	18	5.67	1.283	.302	5.03	6.30	3	7
	101	18	5.22	1.060	.250	4.69	5.75	3	7
	102	18	4.56	1.199	.283	3.96	5.15	3	7
	103	18	5.11	.900	.212	4.66	5.56	3	7
	104	18	3.61	.778	.183	3.22	4.00	3	6
	105	18	4.44	1.423	.336	3.74	5.15	2	7
	106	18	5.44	.784	.185	5.05	5.83	4	7
	107	18	2.44	.984	.232	1.96	2.93	1	4
	108	18	2.06	.873	.206	1.62	2.49	1	4
	109	18	3.06	.725	.171	2.69	3.42	2	5
	Total	180	4.16	1.586	.118	3.93	4.39	1	7
Aroma	**100**	18	5.39	.979	.231	4.90	5.88	3	7
	101	18	5.22	.878	.207	4.79	5.66	4	7
	102	18	3.89	1.451	.342	3.17	4.61	1	6
	103	18	4.72	1.074	.253	4.19	5.26	3	6
	104	18	4.22	.878	.207	3.79	4.66	3	6
	105	18	4.28	.826	.195	3.87	4.69	2	5
	106	18	4.89	1.231	.290	4.28	5.50	2	7
	107	18	3.11	1.231	.290	2.50	3.72	1	5
	108	18	2.33	1.328	.313	1.67	2.99	1	5
	109	18	3.11	.900	.212	2.66	3.56	1	5
	Total	180	4.12	1.435	.107	3.91	4.33	1	7
Texture	**100**	18	5.61	1.092	.257	5.07	6.15	3	7
	101	18	4.67	.840	.198	4.25	5.08	3	6

	102	18	4.28	1.320	.311	3.62	4.93	2	6
	103	18	5.00	.907	.214	4.55	5.45	3	7
	104	18	3.94	1.162	.274	3.37	4.52	2	6
	105	18	4.11	1.568	.369	3.33	4.89	1	7
	106	18	4.89	1.079	.254	4.35	5.43	2	6
	107	18	3.50	1.425	.336	2.79	4.21	1	5
	108	18	2.61	1.195	.282	2.02	3.21	1	5
	109	18	3.33	1.188	.280	2.74	3.92	1	5
	Total	180	4.19	1.442	.107	3.98	4.41	1	7
Overall Acceptability	**100**	18	5.67	.970	.229	5.18	6.15	4	7
	101	18	5.11	.758	.179	4.73	5.49	4	7
	102	18	4.50	1.339	.316	3.83	5.17	1	6
	103	18	5.22	1.114	.263	4.67	5.78	2	7
	104	18	4.00	.970	.229	3.52	4.48	2	5
	105	18	4.33	1.029	.243	3.82	4.85	2	6
	106	18	5.22	1.263	.298	4.59	5.85	1	7
	107	18	2.78	1.263	.298	2.15	3.41	1	5
	108	18	2.39	1.461	.344	1.66	3.12	1	5
	109	18	3.06	.998	.235	2.56	3.55	1	4
	Total	180	4.23	1.553	.116	4.00	4.46	1	7

There were significant differences in all sensory attributes of at least between two or more of the ten samples, Table 4.

Table 4

Analysis of Variance on Sensory Attributes of Cowpea Leaves

One Way Analysis of Variance						
		Sum of Squares	Df	Mean Square	F	Sig.
Visual Appearance (Color)	Between Groups	271.494	9	30.166	28.676	.000
	Within Groups	178.833	170	1.052		
	Total	450.328	179			
Aroma	Between Groups	163.717	9	18.191	15.097	.000
	Within Groups	204.833	170	1.205		
	Total	368.550	179			
Texture	Between Groups	129.028	9	14.336	10.023	.000
	Within Groups	243.167	170	1.430		
	Total	372.194	179			
Overall Acceptability	Between Groups	212.828	9	23.648	18.371	.000
	Within Groups	218.833	170	1.287		
	Total	431.661	179			

P-value is significant at <0.05

There was a statistical significance difference of sample variances in visual appearance, aroma and the overall acceptability p-values of less than 0.05 (p-value=0.022, 0.021, 0.031 respectively), Table 5.

Table 5

Test of Homogeneity of Variance on Sensory Attributes of Cowpea Leaves

Test of Homogeneity of Variances					
		Levene Statistic	df1	df2	Sig.
Visual Appearance (Color)	Based on Mean	2.235	9	170	.022
	Based on Median	1.347	9	170	.216
	Based on Median and with adjusted df	1.347	9	137.437	.218
	Based on trimmed mean	2.254	9	170	.021
Aroma	Based on Mean	1.726	9	170	.086
	Based on Median	1.382	9	170	.200
	Based on Median and with adjusted df	1.382	9	153.848	.201
	Based on trimmed mean	1.622	9	170	.112
Texture	Based on Mean	2.005	9	170	.041
	Based on Median	1.241	9	170	.273
	Based on Median and with adjusted df	1.241	9	154.181	.274
	Based on trimmed mean	2.107	9	170	.031
Overall Acceptability	Based on Mean	1.470	9	170	.163
	Based on Median	1.043	9	170	.408
	Based on Median and with adjusted df	1.043	9	148.935	.409
	Based on trimmed mean	1.426	9	170	.181

P-value is significant at <0.05

Fresh cowpea leaves (100), cowpea leaves stored using MAP at 20°C, MAP at 10°C, Tray at 10°C and Sack at 10°C belonged to the same subset and therefore did not differ significantly in the overall acceptability from the fresh cowpea leaves samples, samples stored in Trays at 20°C, sacks at 20°C, sacks at 30°C, tray at 30 °C and MAP at 30°C differed significantly in the overall acceptability from the fresh cowpea leaves, Table 6.

Table 6

Homogeneous subsets of Cowpea Leaves Samples

Overall Acceptability						
Tukey HSD[a]						
Samples of stored cowpea leaves	N	Subset for alpha = 0.05 1	2	3	4	5
108	18	2.39				
107	18	2.78				
109	18	3.06	3.06			
104	18		4.00	4.00		
105	18			4.33	4.33	
102	18			4.50	4.50	4.50
101	18			5.11	5.11	5.11
103	18				5.22	5.22
106	18				5.22	5.22
100	18					5.67
Sig.		.757	.278	.103	.363	.070

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 18.000.

[1]100-Fresh cowpea leaves, 101-Sack 10°C, 102-Tray 10°C, 103-MAP 10°C, 104-Sack 20°C, 105-Tray 20°C, 106-MAP 20°C, 107-Sack 30°C, 108- Tray 30°C and 109-MAP 30°C

Discussion

Moisture Content of Stored Cowpea Leaves

Moisture content of fresh cowpea leaves was recorded to be at 79.92%. The moisture content was in line with moisture content reported by Wawire (2013) who reported a moisture content of 81.81 ± 0.80%. The rate of decrease in moisture of the vegetable was radical on the first two days of storage and constantly decreased as the days of storage increased. High moisture loss was seen in cowpea leaves that were openly stored in perforated trays, sacks were the second best option to preserve moisture in cowpea leaves with MAP being the best option. High temperatures were seen to have the highest impact on moisture increase in temperature led to a decrease in moisture content of cowpea leaves. Water loss in vegetables due to transpiration decreases freshness which is mainly characterized by shrivelling, wilting, succulence, loss of firmness and crispiness rendering the vegetable unsalable if lost is more than 3% (Ambuko *et al.,* 2017). The use of film to package fresh produce decreases the rate of water loss (Irtwange, 2006), increase CO2 which decreases the rate of respiration and ethylene production (Sudhakar Rao and Shivashankara, 2018). Semi- permeable film prevents water vapor diffusion creating a higher relative humidity in the package and in turn reducing the rate of transpiration (Sudhakar Rao and Shivashankara, 2018). The high moisture loss of cowpea leaves was attributed by transpiration, the rise in the moisture content on the second day of storage could have been caused by the vegetables absorbing moisture from the atmosphere and also due to water that has condensed in the packaging material due to transpiration (Bovi *et al.,* 2016).

Color of Stored Cowpea Leaves

The lighter color in samples stored under ambient and high temperature could have been contributed by the high values of yellowness which depicted chlorophyll degradation hence cowpea leaves deterioration. Studies of effect of temperature in color changes of green vegetables (broccoli and amaranth) reported an increase in brightness (L*) with increase in storage temperature (Mampholo *et al.,* 2015; Varzakas, 2016). Increase in brightness of broccoli at temperatures 5°C, 10°C and 20°C was 12%, 19% and 30% respectively, change in brightness was also linear to storage time (Varzakas, 2016). Greenness in the vegetable increased in the first four days of storage then a decrease in greenness as the days of storage increased. Yellowness of the vegetable increased with increase in storage days whereby the fourth day of storage recorded the highest reading then a decrease was seen, the decrease in yellowness was seen since the remaining samples were stored under low temperatures. A study by Kirigia *et al.,* (2017) observed yellowing, wilting and browning on the sixth day of storage this is in harmony with what was reported. High storage temperatures increased the yellowness of cowpea leaves with samples stored under temperatures between having the highest b* value 13.89. A study on amaranth showed yellowing of vegetable stored under ambient temperatures (25°C) in MAP occurred after four days of storage (Nyaura *et al.,* 2014). Yellowing in green vegetables was related to a decrease in chlorophyll content in a leaf sample. A study also indicated that no yellowing occurred in samples stored under low temperatures since leaf metabolism is slowed down at low temperatures (Kirigia *et al.,* 2017). A study done by Manolopoulou and Varzakas (2016) showed that the highest total color change was evident on the first day of vegetable storage which agreed to the findings. With color variation pronouncing itself more at storage in high temperatures and maintenance of variations in low temperatures as recorded in our findings. Furthermore, chlorophyll degradation of most fresh vegetables is delayed by storage at high relative humidity and low temperatures increasing their commercial life.

Vitamin C (Ascorbic Acid) Content of Stored Cowpea Leaves

Ascorbic acid content of fresh cowpea leaves drastically decreased with increase in storage period, the longer the storage period the higher the losses of the vitamin. The ascorbic acid content reported was highest on the day of sample collection 664.7 mg/100 g of sample on dry weight basis. These were superior but more comparable to cowpea leaves samples done by Imungi et al. (1983) which were 410 mg/100g of total solids. Other studies showed much lower values 164.3 mg / 100g fresh cowpea leaf DWB (Ndawula et al, 2004), 170-220 mg/100 g fresh weight (Wawire, 2013), and 70-203 mg/100g dry matter (Owade *et al.,* 2019). Ascorbic acid content was seen to be more susceptible to degradation when a commodity is subjected to extreme post-harvest handling and storage conditions such as extreme temperatures, low relative humidity, chilling and physical damage (Wawire, 2013). Retention of ascorbic acid in cowpea leaves was more pronounced in samples that were stored using cling film (MAP). A comparative study on amaranth vegetable stored in MAP type of packaging showed that losses were higher at ambient (25°C) temperatures as compared to low temperatures (10°C) (Nyaura *et al.,* 2014). Losses of ascorbic acid in samples that were stored in sacks were seen to been slightly higher as compares to samples that were stored openly in perforated trays. A study by Mampholo *et al.,* (2015) showed the rate of deterioration of AA in unpacked Amaranth leaves as the storage days increased was higher compared to leaves packed in MAP type of packaging. Losses of AA are lower when the concentration of oxygen is low; storage of vegetables in MAP increases the concentration of CO^2 while decreasing that of O^2 (Raju *et al.,* 2011). Sample stored at highest temperatures (28-30° C) were to have the highest losses of ascorbic acid, while retention was more in low temperatures (8-10° C) as compared to ambient temperatures (20-25°C). A different study by Nyaura *et al.,* (2014) showed that high losses of ascorbic acid in vegetable amaranth occurred under high storage temperatures as compared to samples stored under low temperatures, these findings are in agreement with the results.

Beta-carotene Content of Stored Cowpea Leaves

The concentration of beta-carotene of cowpea leaves was seen to be slightly higher (158.91 mg/100g dwb) to a study done by in Tanzania which had a beta carotene value of 147.68±6.98 mg/100g (Nicanuru, 2016). A different study in Uganda by Ndawula *et al.,* (2004) reported beta carotene values of fresh cowpea leaves as 140.9 mg / 100g fresh dry matter. A study by Owade *et al.,* (2019) showed that beta carotene values that were lower 32.74-36.55 mg/100 DWB whereas another different study by Nawiri *et al.,* (2013) reported 80.6.0 mg/100g DWB. Beta carotene concentration in samples drastically decreased on the first two days of storage, there was increase in the fourth day then a decrease till the last day of storage. Higher retention of beta carotene was observed in samples that were stored in MAP type of packaging. Concentration of beta carotene was lowest in samples stored in perforated trays; retention of the vitamin was highest for samples stored in MAP type of packaging followed by samples stored in sacks. A comparative study on amaranth vegetable done by Nyaura *et al.,* (2014) reported that beta carotene retention was highest in vegetable samples that were stored under low temperatures in MAP which concurs to the findings. Cowpea leaves stored under ambient temperature was seen to have higher beta carotene as compared to other storage samples stored under high temperatures but lower than those stored under high temperatures. High temperature storage of vegetables for and extended storage time gradually decreased beta carotene in vegetables (Anjum *et al.,* 2008). Reports showed that beta carotene retention in MAP packaged amaranth vegetable was higher as compared to samples that were openly stored under ambient and low temperatures with increasing storage period (Mampholo *et al.,* 2015; Negi and Roy, 2004).

Correlation between Physic-chemical Parameters of Stored Cowpea Leaves

Increase in moisture content of stored cowpea leaves showed an increase in both the vitamin C and beta carotene content of the vegetable. Findings agreed to what was reported showing water loss in vegetables caused a significant reduction in both beta carotene and vitamin C content (Ezell and Wilcox, 1959; Ezell and Wilcox, 1962; Toivonen, 2011). A study by Balan et al (2016) reported a decrease in both vitamin C content and beta-carotene in stored fresh vegetables with losses occurring due to prolonged chilling temperature storage. The report also argued that total carotenoids were more stable during storage as compare to the vitamin C content. The loss of moisture in cowpea leaves made ascorbic acid and beta-carotene susceptible to oxidation. Oxidation of the two follows the first order kinetics. Beta-carotene in dehydrated systems tends to degrade faster mainly due to autocatalytic oxidation. The presences of water in fresh vegetables tend to slow down the rate of oxidation through dilution or hydration of heavy metal catalysts or through precipitation of heavy metal catalysts to hydroxides. In addition to, the hydrogen bond in water bond with hydroperoxides which motivates radical recombination counteracting peroxide decomposition and in turn interrupts the oxidation reaction chain (Lavelli and Zanoni, 2007).

Sensory Analysis of Stored Cowpea Leaves

The panelist preferred fresh cowpea leaves over other samples since it had the highest mean scores in all the sensory attributes and an overall acceptability mean score of 5.67 followed by sample that were stored in MAP at 10° and 20°C with both having the same overall acceptability mean score of 5.22. Moisture has been seen as an important aspect to maintain quality of fresh vegetables including cowpea leaves (Ambuko *et al.,* 2017). Cowpea leaves samples that were stored under high temperatures in perforated trays were the least preferred with the lowest means scores of all attributes and overall acceptability mean score of 2.39. Extended storage in high temperatures was seen to accelerate the physiological processes in cowpea leaves which led to high moisture loss, shrivelling, wilting and yellowing in green leafy vegetable. These reasons thus explain the preference of fresh cowpea leaves

Conclusion

The quality of stored cowpea leaves is significantly affected by the storage conditions. The high vitamin content of cowpea leaves was noted and could be used as a means to curb hidden hunger especially in arid and semi-arid lands. The storage temperature, packaging material and storage time were seen to have effect on the nutritional and sensory quality. The rate of deterioration of micronutrients was seen to be higher in cowpea leaves stored in high and ambient temperatures and open storage whereas retention was more in MAP and cold storage. Also, long storage periods negatively affected overall quality of cowpea leaves.

It is recommended that a combination of modified atmosphere packaging and MAP and low temperatures of between 8-10°C be used to preserve and extend the commercial value of cowpea leaves to reduce the post-harvest losses.

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