

Effects of Blanching, Drying, and Storage Techniques on the Retention of Beta-Carotene, Ascorbic Acid, and Chlorophyll in Selected Green Leafy Vegetables

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ABSTRACT

Background: Leafy vegetables are rich in micronutrients and phytochemicals essential for good health. However, they are seasonal and highly perishable, necessitating the development of effective preservation methods.

Objective: The study investigated the effects of blanching, drying, packaging, and storage treatments on the retention of β -carotene, ascorbic acid, and total chlorophyll in *Corchorus olitorus*, *Celosia argentea*, and *Cucurbita pepo* leaves.

Methods: The vegetables were blanched at $95 \pm 2^\circ\text{C}$ using (i) water, (ii) water followed by potassium metabisulphite (KMS) dip, and (iii) salt solution. Dried using (a) sun drying, (b) solar drying, (c) shade drying, and (d) low-temperature drying ($30 \pm 2^\circ\text{C}$, 48 hours); packaged in either polyethylene bags (PEB) or kraft paper bags and stored for three months at ambient temperature.

Results: Blanching with potassium metabisulphite was identified as the most suitable method, achieving retention of 81.0%, 87.2%, and 47.8% β -carotene; 33.0%, 28.5%, and 16.4% ascorbic acid; and 88.0%, 76.8%, and 93.6% total chlorophyll in *C. olitorus*, *C. argentea*, and *C. pepo* leaves, respectively. Drying at low temperature was selected, with retention of 43.05%, 58.47%, and 84.54% β -carotene; 35.84%, 31.86%, and 33.42% ascorbic acid; and 58.97%, 85.32%, and 50.0% total chlorophyll. PEB packaging yielded better results than kraft paper. After three months of PEB storage, retention levels were β -carotene (18%, 24%, and 26%), ascorbic acid (29%, 30%, and 42%), and total chlorophyll (19%, 15%, and 21%).

Conclusion: The results indicated that blanching with potassium metabisulphite, low temperature drying, and PEB packaging had a significant effect on the quality attributes measured.

Keywords: Ascorbic acid, Green leafy vegetables, β -Carotene, Chlorophyll, Processing methods

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INTRODUCTION

The leaves of *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* are widely

consumed in sub-Saharan Africa (1). These leaves are key components of various dishes, being inexpensive, easy to cook, and a rich source of

dietary fiber, calcium, zinc, iron, magnesium, and provitamin A carotenoids (2). However, their consumption is limited to a few days after harvest due to their high moisture content, which leads to a short storage life (3).

Blanching is a primary step in vegetable processing. It inactivates enzymes, modifies product texture, and retains color, thereby stabilizing the quality of leafy vegetables before usage (4). Additionally, blanching can reduce non-enzymatic browning reactions and destroy contaminating microorganisms (5). However, blanching can also lead to a decrease in nutritional quality, as heat-labile nutrients like ascorbic acid are easily degraded during the process (6).

Most edible leafy green vegetables are seasonal, and drying methods are effective for preserving them. The effects of drying methods are critical for consideration due to their significant implications for nutrient retention, residual phytochemicals, and overall stability of phytonutrients (7). Dehydration is a simple and economical preservation method for these leafy vegetables (8). Dehydration processing makes green leafy vegetables lightweight, easy to prepare, and convenient to transport and store (9). Dehydrated vegetables can be easily rehydrated to a fresh-like form and used throughout the year (10).

Dehydrated food products are hygroscopic, meaning they tend to absorb moisture from the surrounding atmosphere. This moisture movement can compromise quality, but can be controlled by using appropriate packaging materials (11). Singh and Sagar (12) studied the quality characteristics of dehydrated curry and drumstick leaves, emphasizing the role of packaging materials and storage temperature.

In rural areas, vegetables are often stored at ambient temperature, particularly when the market demand for fresh produce is low after harvest (13). To address this, vegetables are dried and stored for off-season consumption. Increased acceptance of dried vegetables in rural communities could alleviate micronutrient malnutrition, reduce the impact of seasonality, and improve food security during the dry season (14).

In Nigeria, traditional methods such as blanching, sun-drying, and storage are commonly used to prepare and extend the shelf life of leafy vegetables. However, there is limited information

on how these traditional methods affect the nutrient retention of these vegetables. This research was therefore aimed at evaluating the influence of methods of blanching, dehydration, and packaging on the retention of β -carotene, ascorbic acid, and chlorophyll contents of *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* leaves and their stability during storage

MATERIALS AND METHODS

Collection of green leafy vegetables

Three traditional green leafy vegetables commonly consumed by both rural and urban communities in south-eastern Nigeria were identified and used for the research work. The green leafy vegetables, which included *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo*, were purchased from Ogbate market in Enugu State. They were quickly transported to the laboratory.

Processing of green leafy vegetables

The edible and inedible portions of each leafy vegetable were separated. The inedible portions were discarded. The edible portions were washed with tap water, divided into four equal parts, and then subjected to various processing treatments as blanching, drying, packaging, and storage. Each of the samples (500 g) was ground with the aid of an electric blender, placed in an air-tight container, and kept frozen at -20°C until analysis. The untreated leaves (fresh) served as the control.

Blanching of green leafy vegetables

Green leafy vegetables were blanched for 10 minutes at $93 \pm 2^{\circ}\text{C}$, until residual peroxidase activity was no longer detectable (15). Three blanching treatments were applied: washed leaves were immersed in distilled water (vegetable to water ratio, 1:4 w/v) and immediately cooled in 10°C water; washed leaves were blanched in a 10% NaCl solution (1:4 w/v) and similarly cooled; and washed leaves were first blanched in distilled water, then dipped for one minute in a 5 g/L potassium metabisulphite solution before rapid cooling in 10°C water.

Using a peroxidase test solution (1% guaiacol and 2% hydrogen peroxide, 1:1), the blanching duration was standardized by measuring the peroxidase activity. The optimal blanching technique was chosen for drying after the retention of β -Carotene, Chlorophyll, and Ascorbic acid under various blanching circumstances was examined.

Drying of green leafy vegetables

Leaf samples, previously blanched with potassium metabisulphite, were evenly spread on trays at a load of 2 kg/m² and dried by one of four methods until moisture content reached 8%. For sun drying, trays were exposed to direct sunlight on a rooftop for 48 hours at an average temperature of approximately 35 ± 2 °C. Solar drying was carried out in a conventional solar dryer (low-cost Active Solar Dryer, ASD) maintained at 50 °C for 24 hours. Shade drying involved placing the trays on a laboratory bench and allowing natural air currents to desiccate the leaves over 48 hours, and the temperature was about 30 ± 2 °C. Finally, low-temperature drying was performed in a hot-air oven (Electrolux E130GF35JS Struers, Stockholm, Sweden) set to maintain 30 ± 2 °C with the leaves remaining in the oven for 30 hours.

Retention of β-Carotene, Chlorophyll, and Ascorbic Acid was analyzed under different drying conditions, and the best drying method was selected for further packaging and storing.

Packaging/Storing of the green leafy vegetables

Dried samples were packaged in either black coloured high density polyethylene (HDPE 300 gauge) bags or kraft paper bags and stored in enclosed dry places for three months at ambient temperature (30 ± 2 °C). Each package contained 50 g of the dried vegetables. One polyethylene and one kraft paper bag were opened each month, and the vegetables were analyzed for β-Carotene, Chlorophyll, and Ascorbic acid retention.

Estimation of residual peroxidase activity

Blanching time was standardized by checking the peroxidase activity with the help of the peroxidase test solution. A vial containing small pieces of blanched samples was filled with 1 mL of hydrogen peroxide (0.05 mL/30 mL water) and 1 mL of guaiacol (1 mL/100 mL ethyl alcohol). Absence of discoloration of the sample after 3 minutes confirmed no peroxidase activity (16).

Moisture content determination

Moisture content was by weighing 5 g of the sample and drying it in an air oven at 75°C for two hours and then at 105°C to constant weight (17). The moisture content of fresh vegetables was ascertained. Moisture content was determined by calculating the sample's weight loss.

Beta-carotene determination

The method of the Association of Vitamin Chemists (18), as earlier described (19) was used to analyze beta carotene content. Acetone (20 mL parts) was used to extract a 1 g of the processed leaf sample until the residue was colourless. After transferring the extracts to a separating funnel, 50 mL of water and 10 mL of petroleum were added. The same process was used to extract the water-acetone layer after it was drawn into a different separating funnel. A volume of 50 milliliters was created by passing the petroleum extract obtained from each extraction through anhydrous sodium sulfate. A 10 cm long column of supercell and magnesium oxide (3:10) was filled with this extract (5 mL), and a 1 cm long column of anhydrous sodium sulfate was placed on top. Eluent (3 mL acetone: 97 mL petroleum ether) was used to wash the column until the β-carotene was removed and the filtrate turned colorless. Eluent was used to dilute the contents to 100 mL. The spectrophotometer (Shimadzu model UV-1601 PC, Kyoto, Japan) was used to measure the colour intensity at a wavelength of 450 nm. β-carotene concentration was determined using a standard curve.

Ascorbic acid determination

The 2, 6-dichloroindophenol (DCPIP) method (17) was used to determine vitamin C concentration. A volumetric flask (50 mL) was filled with additional solvent after five grams of the processed leaf sample had been macerated with a solution of 3% (w/v) meta-phosphoric acid and 8% (v/v) glacial acetic acid. After giving the mixture a good shake, 5 mL was pipetted into conical flasks. A gross pink colour that was steady for a minute was achieved by titrating the solution against standard DCPIP. Equation 1 was used to calculate the ascorbic acid content.

$$\text{Ascorbic acid (mg/100 mL)} = \frac{\text{Net titre} \times \text{Conc of DCPIP} \times \text{Total volume} \times 100}{\text{Volume pipetted} \times \text{Sample weight}} \quad (1)$$

Total chlorophyll determination

A previous method (20) was used to calculate the total chlorophyll content. Chlorophyll was extracted from 100 mg of leaf fraction in a vial with 7 mL of dimethyl sulfoxide after three hours of incubation at 65 °C. After filtering, dimethyl sulfoxide was added to make up to 10 mL of the extract. A spectrophotometer (Spectronic 20) was used to detect the color intensity at 645 and 663 nm wavelengths, and Arnon's formula (21) was used to determine the amount of chlorophyll as shown in Equation 2

$$C = 20.2A_{645} + 8.02A_{663} \quad (2)$$

Where C is the total chlorophyll contents in mg/g of acetone extract

A_{645} and A_{663} are absorption of the extract at 645 and 663 nm wavelengths.

Statistical analysis

Data generated from all analyses were subjected to statistical analysis using SPSS version 17.0 through one-way analysis of variance (ANOVA). Significant differences between the calculated means were tested at $p < 0.05$ using Fisher's least significant difference (LSD) test.

RESULTS

Effects of blanching and drying conditions on β -carotene retention

Tables 1–3 show the retention of β -carotene, ascorbic acid, and total chlorophyll during processing. The β -carotene concentrations in fresh leaves of *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* were 63.76, 46.66, and 82.60 mg/100 g (dry weight basis), respectively, representing 100% retention. Blanching the leaves in hot water at $93 \pm 2^\circ\text{C}$, followed by a potassium metabisulphite (KMS) dip (5 g/L in water) for 65 seconds, resulted in decreased β -carotene concentrations of 51.63, 40.70, and 39.46 mg/100 g, representing

81.0%, 87.2%, and 47.8% retention of the initial levels of β -carotene (Table 1). Similarly, 33.0%, 28.5%, and 16.4% of ascorbic acid (Table 2) and 88.0%, 76.84%, and 93.6% of total chlorophyll (Table 3) were retained, respectively, after blanching.

Effects of different drying conditions

The effects of different drying conditions on the retention of β -carotene, ascorbic acid, and total chlorophyll in blanched leaf samples were studied. The results indicated that low temperature drying ($30 \pm 2^\circ\text{C}$) provided the highest retentions and was, therefore, selected for further packaging and storage studies. The β -carotene concentrations in blanched leaf samples of *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* (51.63, 40.70, and 39.46 mg/100 g, respectively) represented 100% retention before drying treatments. After low-temperature drying at ($30 \pm 2^\circ\text{C}$), significant ($p < 0.05$) reductions in β -carotene concentrations (22.23, 23.80, and 33.36 mg/100 g) were observed, which corresponded to 43.05%, 58.47%, and 84.54% retention of the initial levels (Table 1). Similarly, 35.84%, 31.86%, and 33.42% retention of ascorbic acid (Table 2), and 58.97%, 85.32%, and 50.0% retention of total chlorophyll (Table 3) were observed, respectively.

Table 1: Retention of β -carotene (mg/100g Dry weight basis) during blanching and drying

Leaf Type	<i>Corchorus olitorius</i>	<i>Celosia argentea</i>	<i>Cucurbita pepo</i>
Processing conditions			
Blanching			
Fresh vegetables (Control)	63.76 ^a ±1.02	46.66 ^a ±0.78	82.60 ^a ±0.81
Plain water	48.36 ^d ±0.55	35.50 ^c ±1.04	36.56 ^c ±1.03
Plain water and KMS dip	51.63 ^b ±2.85	40.70 ^b ±1.57	39.46 ^b ±1.46
Salty water	50.46 ^c ±1.92	34.33 ^c ±1.27	34.03 ^d ±1.46
Drying			
KMS blanched leaves (Control)	51.63 ^b ±2.85	40.70 ^b ±1.57	39.46 ^b ±1.46
Sun	11.50 ^h ±0.68	14.23 ^f ±1.078	20.30 ^f ±0.97
Solar dryer	18.93 ^f ±1.26	17.70 ^e ±0.63	23.30 ^e ±0.92
Shade	15.43 ^g ±0.91	17.03 ^e ±0.91	20.16 ^f ±0.92
Low temperature ($30 \pm 2^\circ\text{C}$)	22.23 ^e ±0.95	23.80 ^d ±0.78	33.36 ^d ±0.49

All values are mean \pm standard error of the mean (n=3). Means with different letters within a column are significantly different ($p < 0.05$). KMS: Potassium metabisulphite

Effect of packaging and storage duration on retention of β -carotene

The dried leaves demonstrate that 100% retention corresponds to 22.4, 23.7, and 34.3 mg of β -carotene in 100g (dry weight basis) of dried *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* leaves at low temperatures

($30 \pm 2^\circ\text{C}$) (Figure 1). Following three months of storage, the *Cucurbita pepo* sample in the polyethylene bag had retentions of 8.9 mg/100g, representing 26%, whereas the *Celosia argentea* sample in the Kraft-paper bag had retentions of 3.3 mg/100g, representing 15%.

Table 2: Retention of ascorbic acid (mg/100g, Dry weight basis) during blanching and drying

Leaf Type	<i>Corchorus olitorius</i>	<i>Celosia argentea</i>	<i>Cucurbita pepo</i>
Processing conditions			
Blanching			
Fresh vegetables (Control)	875.03 ^a ±2.11	389.16 ^a ±1.41	466.16 ^a ±3.38
Plain water	355.60 ^c ±4.30	106.53 ^{bc} ±1.07	74.16 ^b ±1.47
Plain water and KMS dip	379.03 ^b ±1.97	110.96 ^b ±0.99	76.30 ^b ±0.81
Salty water	225.20 ^d ±1.83	102.43 ^c ±3.67	65.73 ^c ±2.82
Drying			
KMS blanched leaves (Control)	379.03 ^b ±1.97	110.96 ^b ±0.99	76.30 ^b ±0.81
Sun	61.00 ^h ±1.81	25.20 ^g ±2.17	13.46 ^f ±1.21
Solar dryer	90.10 ^f ±1.55	32.73 ^f ±1.41	23.83 ^e ±1.48
Shade	81.83 ^g ±2.15	33.80 ^e ±1.45	22.80 ^e ±1.36
Low temperature (30±2°C)	103.60 ^e ±3.25	35.36 ^d ±1.58	25.50 ^d ±1.18

All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different (p < 0.05). KMS: Potassium metabisulphite

Table 3: Retention of chlorophyll (mg/g, Dry weight basis) during blanching and drying

Leaf Type	<i>Corchorus olitorius</i>	<i>Celosia argentea</i>	<i>Cucurbita pepo</i>
Processing conditions			
Blanching			
Fresh vegetables (Control)	9.50 ^a ±0.47	11.53 ^a ±0.98	14.53 ^a ±1.09
Plain water	7.60 ^c ±0.52	6.73 ^d ±0.74	12.63 ^c ±0.94
Plain water and KMS dip	8.36 ^b ±1.04	8.86 ^b ±0.82	13.60 ^b ±1.12
Salty water	7.50 ^c ±1.11	7.83 ^c ±0.73	10.56 ^d ±0.85
Drying			
KMS blanched leaves (Control)	8.36 ^b ±1.04	8.86 ^b ±0.82	13.60 ^b ±1.12
Sun	3.80 ^e ±0.72	5.83 ^e ±0.71	5.63 ^f ±0.61
Solar dryer	4.56 ^d ±0.57	7.50 ^c ±0.45	6.33 ^e ±0.69
Shade	3.70 ^e ±0.63	6.53 ^d ±0.67	5.63 ^f ±0.46
Low temperature (30±2°C)	4.93 ^d ±0.69	7.56 ^c ±0.75	6.80 ^e ±0.92

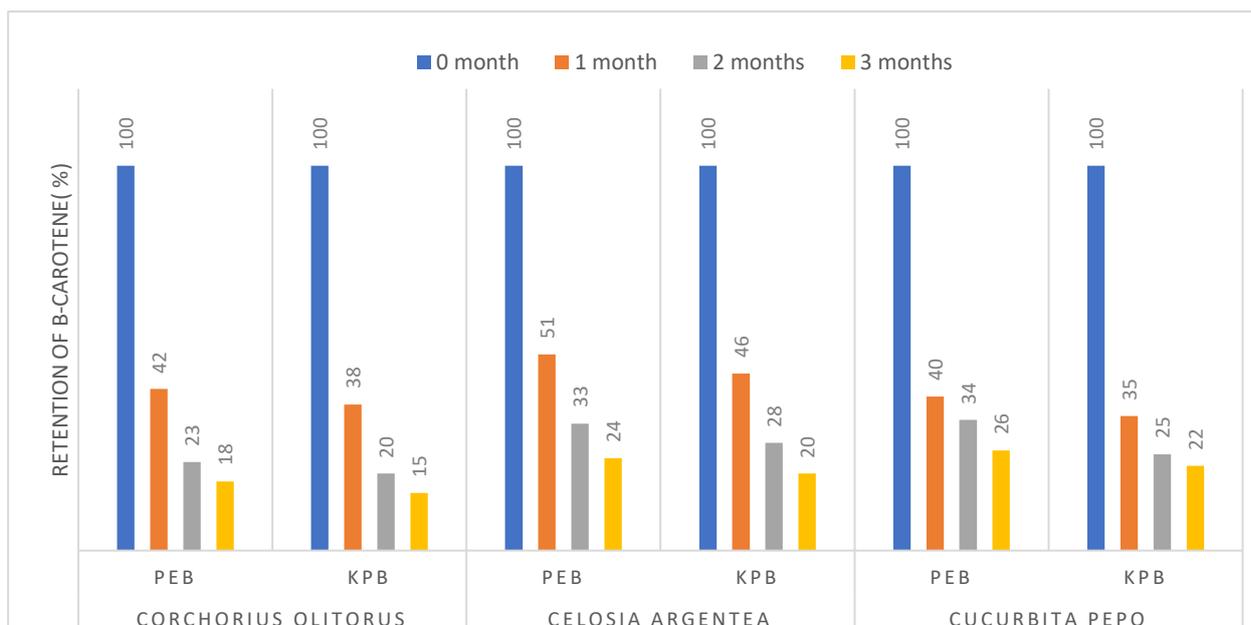
All values are mean ± standard error of the mean (n=3). Means with different letters within a column are significantly different (p < 0.05). KMS: Potassium metabisulphite.

Effect of packaging and storage duration on retention of ascorbic acid

Additionally, 100% retention indicates that there are 103.6, 35.3, and 25.5 mg of ascorbic acid in 100g (dry weight basis) of dried *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* leaves at a low temperature (30±2°C) (Figure 2). After three months of storage, the retention varied between 10.8 mg/100g (42%) in the *Cucurbita pepo* sample wrapped in a polyethylene bag and 4.3 mg/100g (12%) in the *Celosia argentea* sample put in a Kraft-paper bag.

Effect of packaging and storage duration on retention of total chlorophyll

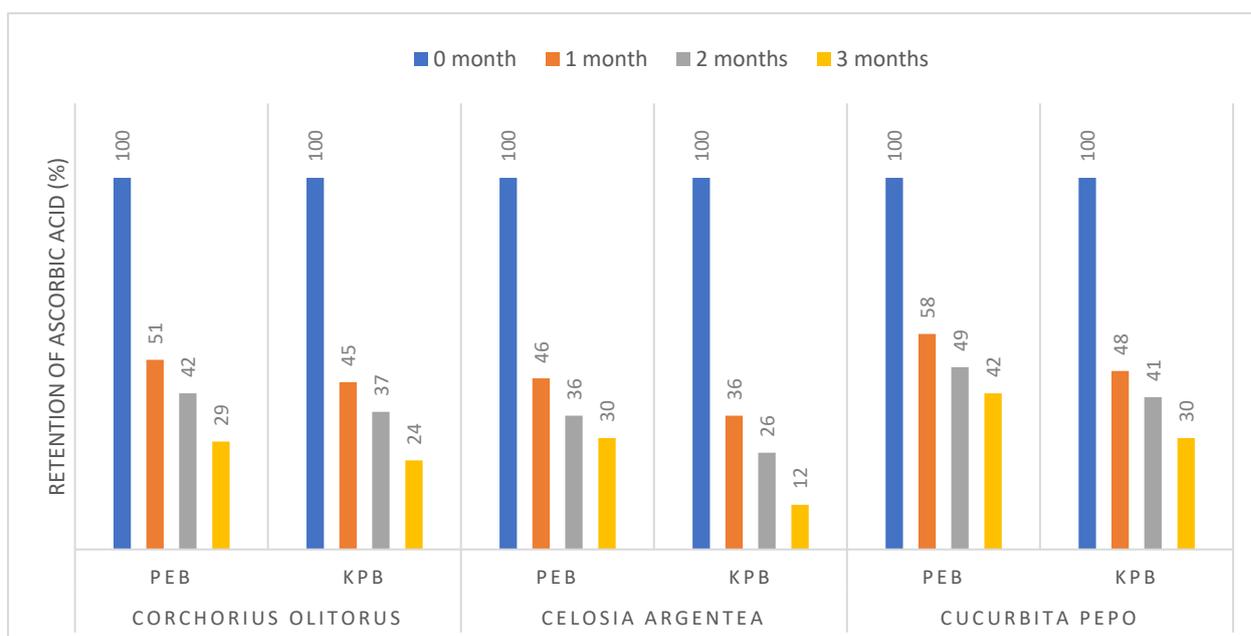
Drying standardization procedures showed that the low temperature (30±2°C) drying method was adjudged best for further processing. One hundred percent retention represents 4.8, 6.8, and 7.7 mg total chlorophyll present in 100g (dry weight basis) of temperature (30±2°C) dried *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* leaves (Figure 3). At the end of the three months of storage, the retention ranged between 1 mg/100 g (13 %) in *Celosia argentea* packaged in kraft paper bags and 4.5 mg/100 g (21%) in *Cucurbita pepo* packaged in polyethylene bags.



Storage time (months)

Figure 1: Percentage retention of β -carotene during storage at ambient temperature ($30 \pm 2^\circ\text{C}$)

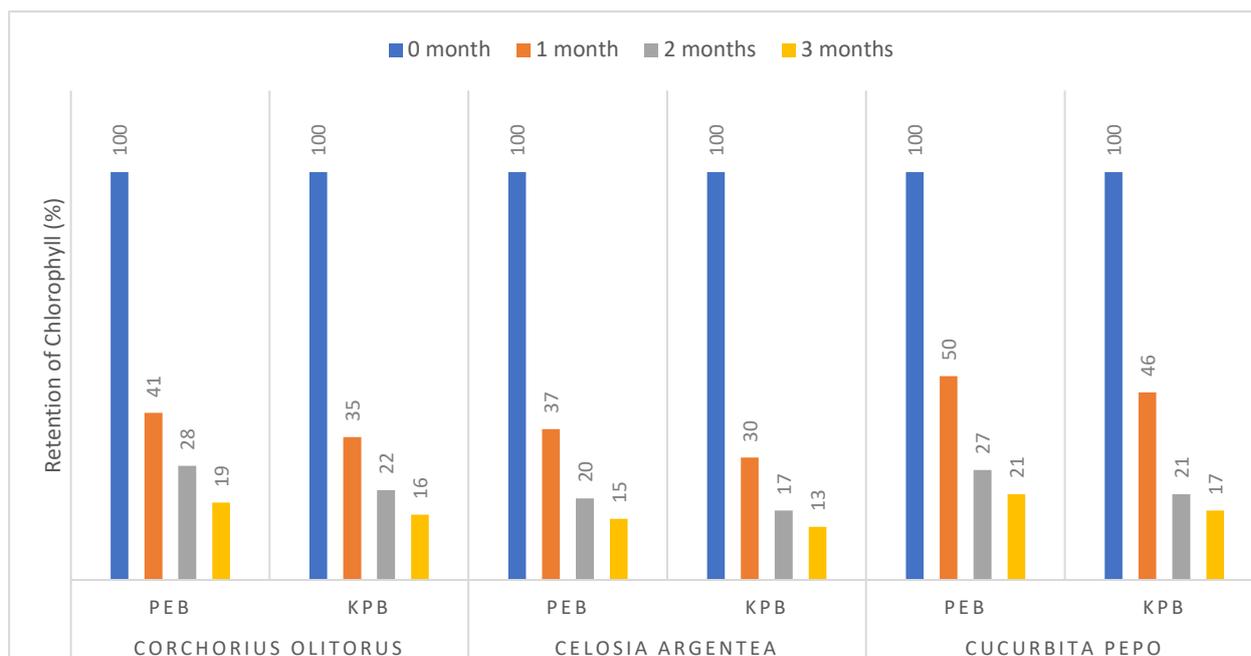
100% Retention represents β -carotene present in 100g (Dry weight basis) of Low temperature ($30 \pm 2^\circ\text{C}$) dried leaves.
 KPB: Kraft paper bag. PEB: Polyethylene bag.



Storage time (months)

Figure 2: Percentage retention of ascorbic acid during storage at ambient temperature ($30 \pm 2^\circ\text{C}$)

100% Retention represents Ascorbic acid present in 100g (Dry weight basis) of Low temperature ($30 \pm 2^\circ\text{C}$) dried leaves.
 KPB: Kraft paper bag. PEB: Polyethylene bag.



Storage time (months)

Figure 3: % Retention of total chlorophyll during storage at ambient temperature ($30 \pm 2^\circ\text{C}$)

100% Retention represents the Total chlorophyll present in 100g (Dry weight basis) of low temperature ($30 \pm 2^\circ\text{C}$) dried leaves.
 KPB: Kraft paper bag. PEB: Polyethylene bag.

DISCUSSION

The results indicated that blanching for 65 seconds at $93 \pm 2^\circ\text{C}$ in water, followed by a potassium metabisulphite (KMS) dip, provided adequate peroxidase inactivation. Leaching losses and the retention of β -carotene, ascorbic acid, and total chlorophyll were better with the sulfur treatment. This method was judged the best and selected for further drying of the vegetables. Significant ($p < 0.05$) reductions in leaf constituents were observed across treatments, though the reductions were significantly lower compared to fresh leaves. Blanching of spinach and amaranth for 1 minute at 95°C was reported to result in a negative peroxidase test (22). Blanching inactivated peroxidase with more than 90% activity loss after 3 minutes of blanching *C. esculenta* leaves at different temperatures (23). Literature contains similar observations of nutrient losses during heat treatments. Investigation has shown that greater concentrations of total carotenoids were found in fresh leaves than in blanched ones (24). Observation after 1 minute of blanching at 71, 82, and 93°C , also revealed that about 55%, 49%, and 29% of ascorbate, respectively, were retained in the leaves of *C. esculenta* (23). Similarly, significant ($p < 0.05$) losses in ascorbic acid (42–51%) and total chlorophyll (52.27–59.16%) when five locally

consumed leafy vegetables were blanched for 5 minutes at 100°C were reported (25).

Significant differences ($p < 0.05$) were observed in the constituent contents across all drying methods. A comparison of drying methods applied to different crops showed that maximum losses of β -carotene, ascorbic acid, and total chlorophyll occurred during sun drying and shade drying, while low-temperature drying ($30 \pm 2^\circ\text{C}$) resulted in maximum retention of the constituents. The less harsh conditions during low-temperature drying make it a promising option. The longer drying time observed during shade drying likely contributed to higher losses. Free radical oxidation degrades carotenes, and the extent of degradation depends on drying temperature and oxygen exposure, which were higher during sun drying.

Constituent reductions in the dried vegetable samples were primarily due to heat exposure. These findings align with the report that vitamin losses in green leafy vegetables depend on the processing method, drying temperatures, and drying procedures (26). Higher losses of ascorbic acid and total carotene during open sun drying compared to enclosed drying for cassava, cowpea, and African spinach leaves have been reported (27). The decrease in ascorbic acid during dehydration is likely due to oxidation (28).

Furthermore, it has been observed that 40–43.92% and 48.9–67.5% β -carotene, respectively, were lost during solar and hot air drying of carrots (30). There is also a report that chlorophyll is degraded by heat, with retention affected by temperature and duration (31).

During storage, percentage retention of β -carotene, ascorbic acid, and total chlorophyll was highest in the first month but decreased as the storage period progressed. The high losses during the first month may be attributed to oxidation by the residual oxygen in the package, which was higher initially than in subsequent months. As storage progressed, the residual oxygen in the package decreased, reducing the oxidation rate of constituents. Similar trends in nutrient losses during fruit and vegetable storage have been reported by other researchers.

β -carotene losses in stored dehydrated vegetables are primarily due to volatilization and degradation (32, 33). Losses of ascorbic acid during storage have been similarly reported (34, 35). Ascorbic acid content decreases more rapidly at higher storage temperatures (36), emphasizing that conservative processing and low storage temperatures are critical for ascorbic acid retention. There are also reports on reductions in vitamin C content of cherry tomato, plum tomato, and mango powders stored in polyethylene bags and metallized polyester pouches under ambient conditions (25–32°C) (37, 38).

Furthermore, chlorophyll is easily degraded by factors such as light and oxygen during storage (39). The decrease in chlorophyll content might be due to its oxidation and conversion to pheophytin (40). Samples packed in PEB retained higher chlorophyll content than those in KP, likely due to reduced oxidation. Oxidative degradation increases with storage duration and temperature, as well as with packaging that is permeable to oxygen and light (41).

CONCLUSION

Potassium metabisulphite employed to blanch *Corchorus olitorius*, *Celosia argentea*, and *Cucurbita pepo* leaves, decreased losses of β -carotene, vitamin C, and chlorophyll. When compared to sun and shade drying, low-temperature drying at $30 \pm 2^\circ\text{C}$ produced higher retention of β -carotene, vitamin C, and chlorophyll. The results indicated that storage period and packaging materials significantly affected the measured quality attributes. Dehydrated leaves packaged in PEB (300-gauge HDPE) for one month under ambient conditions

showed appreciable retention of the measured constituents.

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