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Effect of modified atmosphere packaging on shelf life and quality of curry leaves and *Moringa* leaves

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Abstract

Fresh curry leaves (*Murraya koenigii* L.) and *Moringa* leaves (*Moringa oleifera* L.) are prone to rapid spoilage. This study assessed modified atmosphere packaging (MAP) using various gas compositions, packaging materials and storage temperatures to enhance the quality and stability of these leaves. The experiment utilized three gas mixtures (a. 2% O_2, 4% CO_2, 94% N_2; b.4% O_2, 6% CO_2, 90% N_2; c. 6% O_2, 8% CO_2, 86% N_2) and different packaging films (using low-density polyethylene (LDPE), polypropylene (PP) and aluminium laminate films) with leaves stored at ambient and refrigerated temperatures. The most effective treatment was LDPE packaging with a C_1 gas composition, extending shelf life up to 20 days under refrigeration with minimal weight loss (7.68% in curry leaves and 10.87% in *Moringa* leaves) and maintained nutrient quality (higher ascorbic acid retention-2.47 mg/100 g and 177.67 mg/100 g). The study indicates that using MAP with LDPE in a low O_2 and moderate CO_2 environment is effective for prolonging the freshness of curry and *Moringa* leaves.

Keywords: Modified atmosphere packaging, leafy vegetables, storage conditions, post-harvest preservation, shelf life

1. Introduction

Murraya koenigii commonly known as curry plant belongs to the family Rutaceae. The plant is a medicinal plant and native to India, Sri Lanka and other South Asian countries. Curry leaves or sweet neem leaves are used in a variety of Indian dishes. The plant is highly valued for its leaves which are used for flavouring and spicing of food. Leaves are rich in many bioactive compounds like polyphenols, alkaloids and flavonoids which showed multiple bioactive functions like antioxidant, anticancer, antimicrobial, antidiabetic and hepatoprotective. Higher concentration of the bioactive compounds seen in plants leaves showed higher antioxidant activities. Whereas, *Moringa* leaves also contains non-nutritive chemicals or phytochemicals involving self-defence mechanism. Those phytochemicals include catechol, tannins, steroids, triterpenoids, flavonoids, saponins, alkaloids and reducing sugars having medicinal properties.

In India, vegetable production contributes nearly 59% of total horticultural output, with a steady increase in per capita availability (Kumar *et al.*, 2017) [4]. Among leafy vegetables, *Moringa* (*Moringa oleifera* L.) and curry leaf (*Murraya koenigii* L.) are widely consumed owing to their exceptional nutritional, medicinal and culinary importance.

Despite their importance, both leaves are highly perishable and undergo rapid postharvest deterioration due to high respiration rate, moisture loss, enzymatic activity and microbial spoilage, leading to severe quality losses. Low-temperature storage below 10 °C is effective in slowing senescence and preserving quality; however, such facilities are often unavailable during transportation and marketing in developing countries. Storage conditions significantly influence chlorophyll retention, ascorbic acid content, phenolics and antioxidant activity in leafy vegetables (Singh and Sagar, 2010; Serea *et al.*, 2014) [8, 7].

Modified atmosphere packaging (MAP) is an effective postharvest technology that alters the gaseous composition surrounding the produce, thereby reducing respiration rate, delaying senescence and suppressing microbial growth. The study indicates that *Moringa* leaves stored in refrigerated conditions exhibited the least reduction in shelf life compared to those at ambient temperatures. Notably, aluminum foil-wrapped leaves maintained a shelf life of twelve days, significantly longer than the four days of the control group.

Among various packing materials, polyethylene covers of 400-gauge thickness without vent gave a shelf life of nine days, whereas HDPE with vent and LDPE without vent both had eight days. In contrast, LDPE with vent at ambient conditions had a substantially shorter shelf life of two days. These findings align with Panta and Kanal (2018) [6], who observed similar results for coriander leaves stored without perforations in cold environments.

2. Materials and Methods

2.1 Modified atmosphere packaging (MAP) treatments

Curry and *Moringa* leaves were packaged using modified atmosphere packaging under different gas compositions, packaging materials and storage temperatures. Three gas combinations consisting of oxygen (O_2), carbon dioxide (CO_2) and nitrogen (N_2) were employed:

- C_1: 2% O_2, 4% CO_2, 94% N_2
- C_2: 4% O_2, 6% CO_2, 90% N_2
- C_3: 6% O_2, 8% CO_2, 86% N_2

Three packaging films, namely low density polyethylene (LDPE), polypropylene (PP) and aluminium laminate (Al), were used. The packaged samples were stored under two temperature conditions: ambient temperature (38 ± 2 °C) and refrigerated storage (8 ± 1 °C).

2.2 Experimental design

The experiment was laid out in a completely randomized design (CRD) with a factorial arrangement. A total of 18 treatment combinations (3 gas compositions × 3 packaging materials × 2 storage temperatures) were employed for curry leaves, and the same set of treatments was applied to *Moringa* leaves. Each treatment was replicated three times. Gas composition, packaging material and storage temperature were considered as independent variables, while physico-chemical and microbial attributes were taken as dependent variables.

2.3 MAP system and packaging operation

The MAP system consisted of gas cylinders (O_2, CO_2 and N_2), a gas mixer (Dansensor MAP Mix 9001 ME), a stainless steel buffer tank and a vacuum–gas flushing packaging machine. Individual gas cylinders were fitted with pressure regulators and connected to the gas mixer through high-pressure flexible tubing. Gas mixing was carried out by adjusting the CO_2 concentration and gas mix ratio as per the manufacturer's guidelines. The mixed gas was temporarily stored in a buffer tank and subsequently flushed into the packaging pouches after vacuum creation. Packaging involved evacuation of air, injection of the desired gas mixture and heat sealing of the pouch.

2.4 Headspace gas analysis

The headspace concentrations of O_2, CO_2 and N_2 in the packaged samples were measured using an $O_2/CO_2/N_2$ gas analyzer (PBI Dansensor). Gas analysis was performed by inserting a hypodermic needle through a rubber septum attached to the package surface prior to opening the pouch.

2.5 Physico-chemical analysis

2.5.1 Weight loss

Weight loss was determined using an electronic balance (Essae, FB 200±0.01 g accuracy). The initial sample weight (10±0.5 g) was recorded before storage, and the final weight was recorded at the end of storage. Weight loss (%) was calculated.

2.5.2 Moisture content

Moisture content was determined by the oven-drying method following AOAC. 1990 [1] method. Approximately 5 g of sample was dried at 105 °C for 3 h, and moisture content was expressed on both wet and dry basis.

2.5.3 Ascorbic acid content

Ascorbic acid content was estimated by the 2, 6-dichlorophenol indophenol titrimetric method (AOAC 2005) [2]. Samples were extracted in 4% oxalic acid and titrated against standardized dye solution. Results were expressed as mg ascorbic acid per 100 g fresh weight.

2.6 Microbial analysis

Microbial quality was assessed by determining total viable count (TVC). After serial diluting the samples up to 10^{5}, No. of colonies were counted on Plate Count Agar (PCA) using the pour plate method. Plates were incubated at 37 °C for 48 h, and microbial load was expressed as colony-forming units per gram (CFU/g), (Mohammadi *et al*. 2019) [5].

2.7 Statistical analysis

The experimental data were analyzed statistically using analysis of variance (ANOVA) under a completely randomized design (CRD) with factorial arrangements. The effects of gas composition (A), packaging material (B), storage temperature (C) and their interactions were evaluated using OPSTAT software. Differences among treatment means were considered statistically significant at $p<0.05$.

3. Results and Discussion

3.1 Effect of MAP on Physico-Chemical Properties of Leaves

The Curry leaves and *Moringa* leaves were packed under two different conditions viz. refrigeration temperature and ambient temperature in three different packaging materials Low density Polyethylene (LDPE), Aluminium (Al) and Polypropylene (PP) in three different compositions of 2%, 4%, 94% (C1); 4%, 6%, 90% (C2) and 6%, 8%, 86% (C3) of O_2, CO_2 and N_2 respectively. The storage temperatures were measured using a digital thermometer (Plate 1).

Plate 1: Curry leaves and *Moringa* leaves stored at ambient and refrigerated temperature

3.2 Effect of MAP on weight loss in curry leaves and *Moringa* leaves (at ambient and refrigerated temperature)

For ambient temperature *Moringa* leaves packaged in LDPE + C1 experienced the lowest weight loss of 10.39% over 15 days, followed by LDPE + C2 (13.94%) and LDPE + C3 (17.37%). LDPE also resulted in the longest shelf life overall at 15 days, compared to 6 days for both Al and PP under ambient temperature. For Curry leaves, weight loss on the 3rd day showed no significant differences among compositions or packaging (p>0.05), but from the 6th day until the end of storage, significant differences (p<0.05) were observed based on the composition and packaging materials used. For refrigerated temperature, curry and *Moringa* leaves packed in Low-Density Polyethylene (LDPE) exhibited the lowest weight loss during storage, with both showing a shelf life of 20 days. Specifically, curry leaves stored with LDPE + C1 recorded a weight loss of 7.68%, and *Moringa* leaves with LDPE + C1 had a weight loss of 10.87%. Comparatively, samples in Aluminum (Al) and Polypropylene (PP) displayed shorter shelf lives of 15 days and 20 days, respectively, when stored at refrigerated temperatures. Overall, LDPE demonstrated less physiological weight loss in *Moringa* leaves compared to Polypropylene.

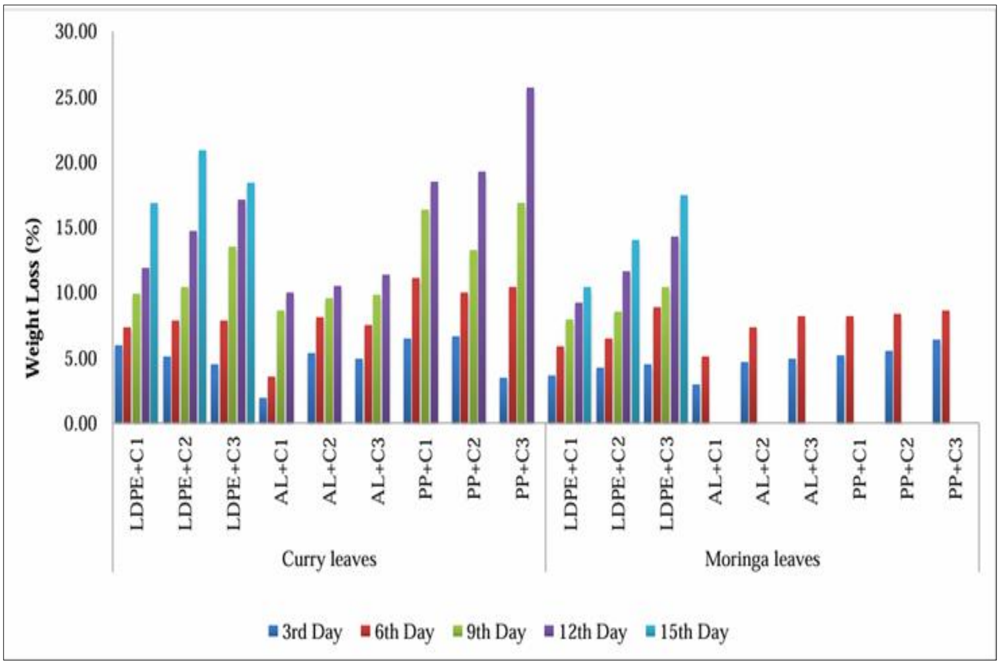

Fig 1: Effect of MAP on weight loss in curry leaves and *Moringa* leaves at ambient temperature

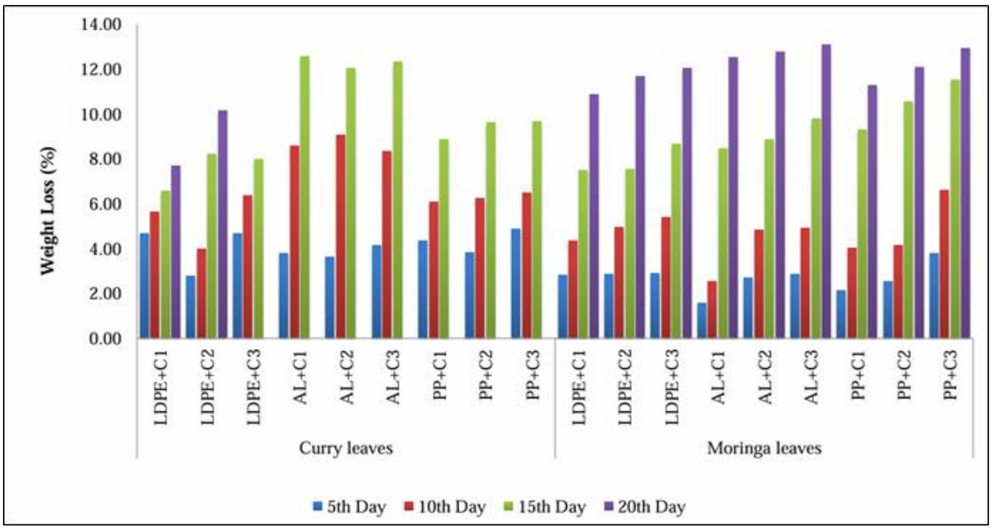

Fig 2: Effect of MAP on weight loss in curry leaves and *Moringa* leaves at Refrigerated temperature

3.3 Effect of MAP on moisture content in curry leaves and *Moringa* leaves (at ambient and refrigerated temperature)

Moringa leaves packed in LDPE + C1 exhibited the highest moisture content at ambient temperature (71.02%) with a shelf life of 15 days, followed by LDPE + C2 (68.22%) and LDPE + C3 (65.50%). The moisture content values of Curry leaves were not significantly different on the 3rd day but differed significantly from the 6th day onwards (p<0.05). Refrigerated conditions increased the moisture content and shelf life for *Moringa* leaves, with LDPE + C1 again recording the highest at 70.62% and a shelf life of 20 days. LDPE packaging consistently outperformed Al and PP in moisture retention across both temperature conditions.

Statistical analysis indicated significant differences in moisture content for both *Moringa* and Curry leaves based on composition and packaging materials under refrigeration (*p*<0.05). Overall, LDPE packaging was noted to effectively obstruct moisture infusion.

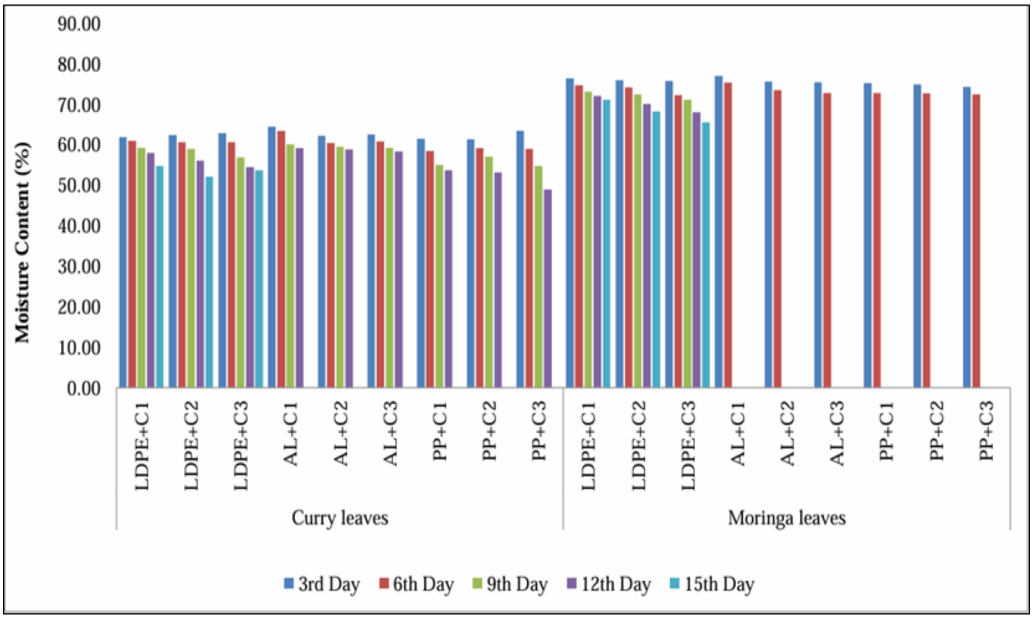

Fig 3: Effect of MAP on moisture content in curry leaves and *Moringa* leaves at ambient temperature

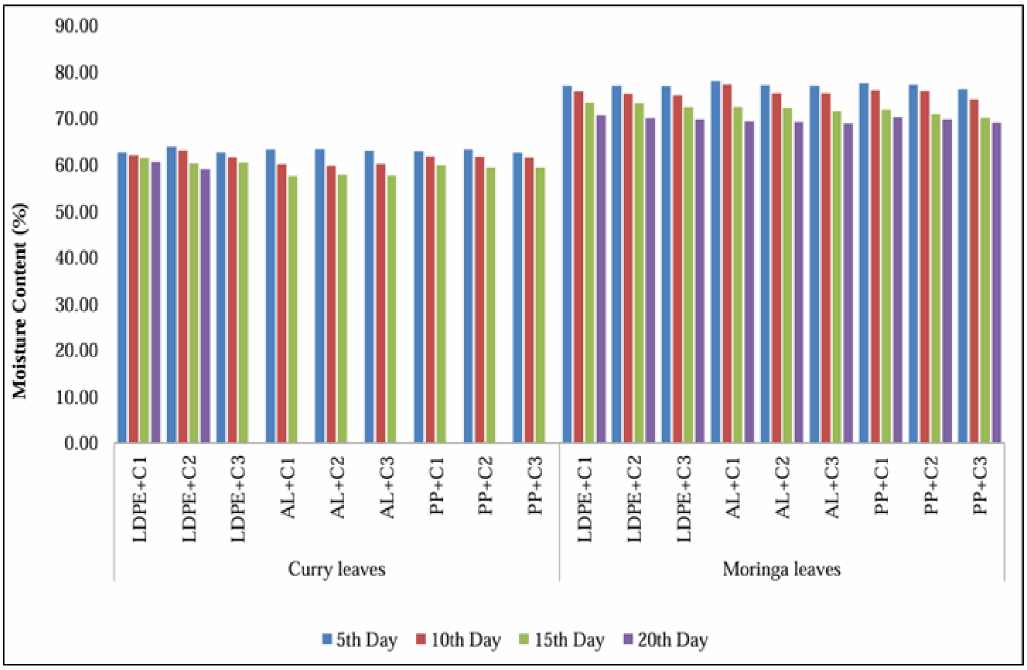

Fig 4: Effect of MAP on moisture content in curry leaves and *Moringa* leaves at refrigerated temperature

4 Quality characteristics of curry leaves and *Moringa* leaves

4.1 Effect of MAP on ascorbic acid in curry leaves and *Moringa* leaves (at ambient and refrigerated temperature)

The Curry leaves packed in LDPE had longer shelf life (15 days) followed by Al and PP (12 days). Spoilage was observed in *Moringa* leaves on 6th day in both Al and PP, whereas the LDPE had longer shelf life (20 days). Ascorbic acid content of stored produce generally decreases more rapidly at higher storage temperature since it was thermo labile. The reason for the decrease of ascorbic acid under ambient conditions due to the oxidation of ascorbic acid to de-hydro ascorbic acid by the enzyme, ascorbic-nase (Ambrose *et al*. 2017) [3].

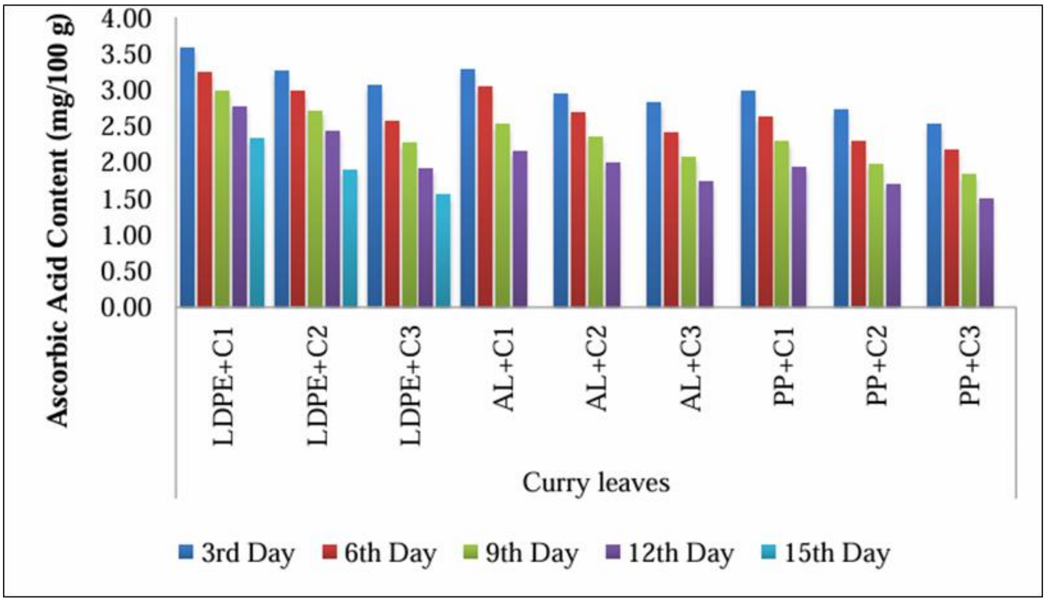

Fig 5: Effect of MAP on ascorbic acid in curry leaves at ambient temperature

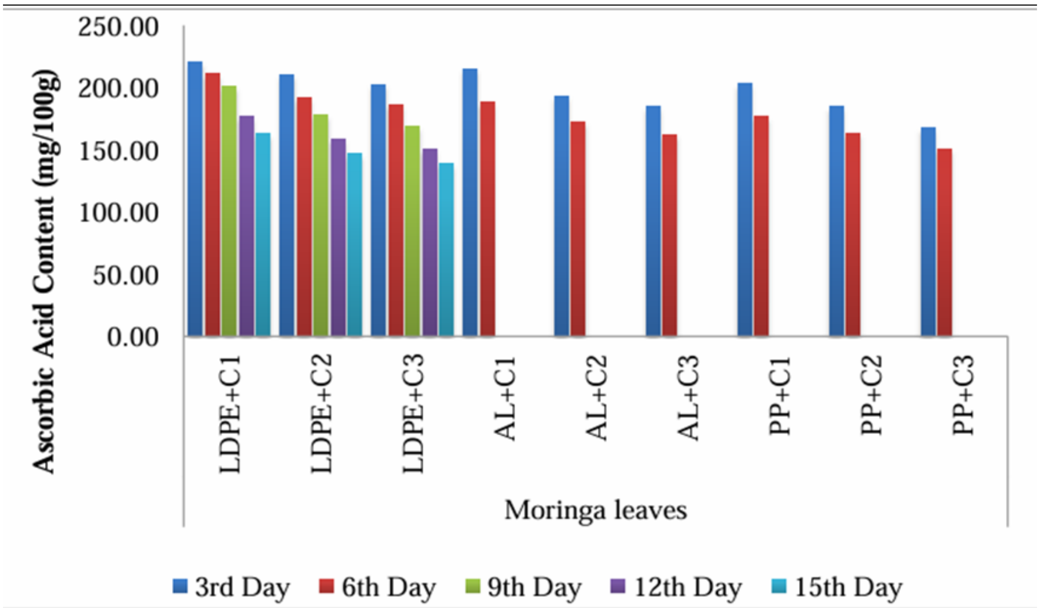

Fig 6: Effect of MAP on ascorbic acid in *Moringa* leaves at ambient temperature

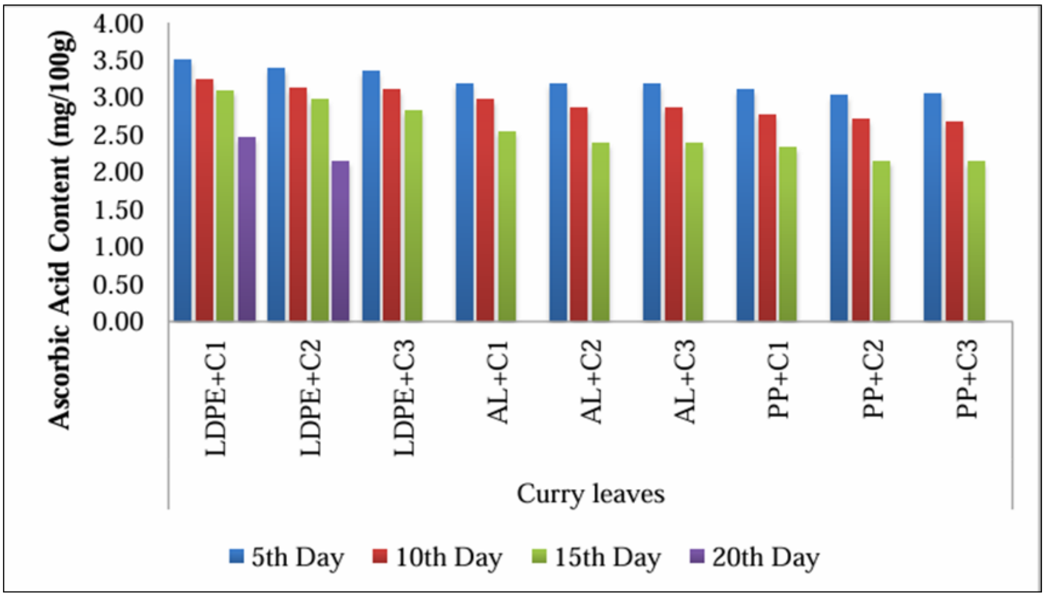

Fig 7: Effect of MAP on ascorbic acid in curry leaves at refrigeration temperature

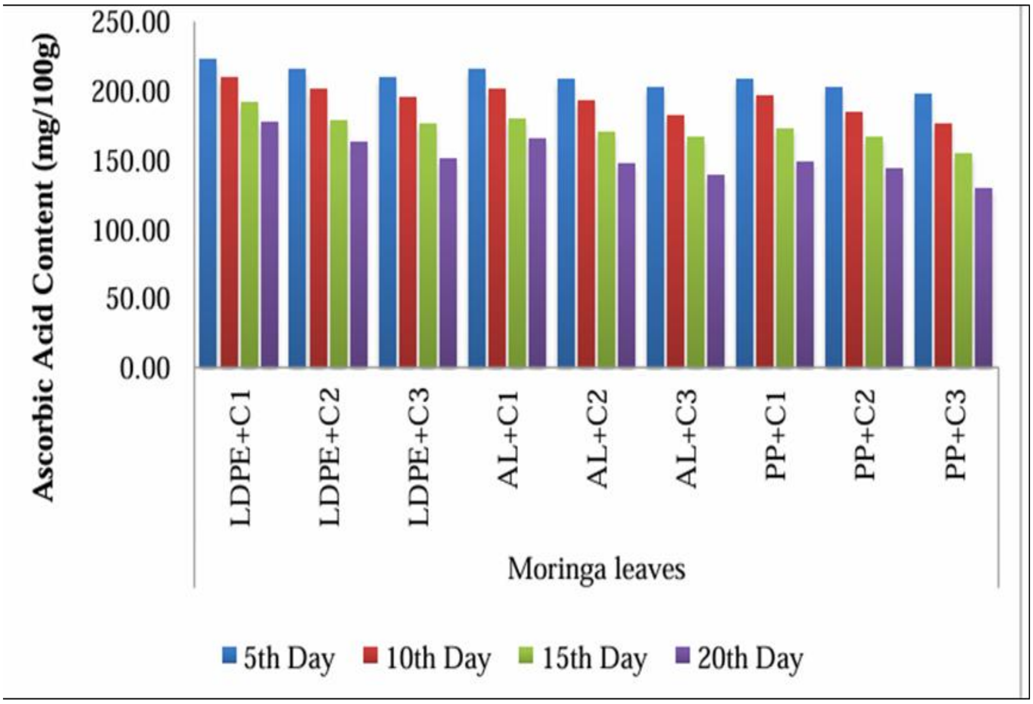

Fig 8: Effect of MAP on ascorbic acid in *Moringa* leaves at refrigeration temperature

4.2 Microbial Analysis of Curry Leaves and *Moringa* Leaves

4.2.1 Effect of MAP on microbial load in curry leaves and *Moringa* leaves (at ambient and refrigerated temperature)

The microbial load of curry and *Moringa* leaves was assessed at ambient and refrigeration temperatures, measured in log cfu/g. At ambient temperature, curry leaves packed in LDPE + C1 recorded the lowest microbial count of 5.60 log cfu/g, while the highest was in LDPE + C3 (5.69 log cfu/g). *Moringa* leaves followed a similar trend with counts of 5.62 log cfu/g in LDPE + C1 and 5.70 log cfu/g in LDPE + C3 after 15 days. Both types remained consumable for 15 days in LDPE. Refrigerated storage extended the shelf life to 20 days for both leaf types, with curry leaves in LDPE + C1 showing the lowest count of 5.45 log cfu/g and *Moringa* leaves in LDPE + C1 at 5.48 log cfu/g. Microbial growth was notably higher at ambient temperature due to elevated atmospheric gas effects, while refrigeration reduced growth due to lower temperatures and humidity, resulting in longer shelf life for the leave.

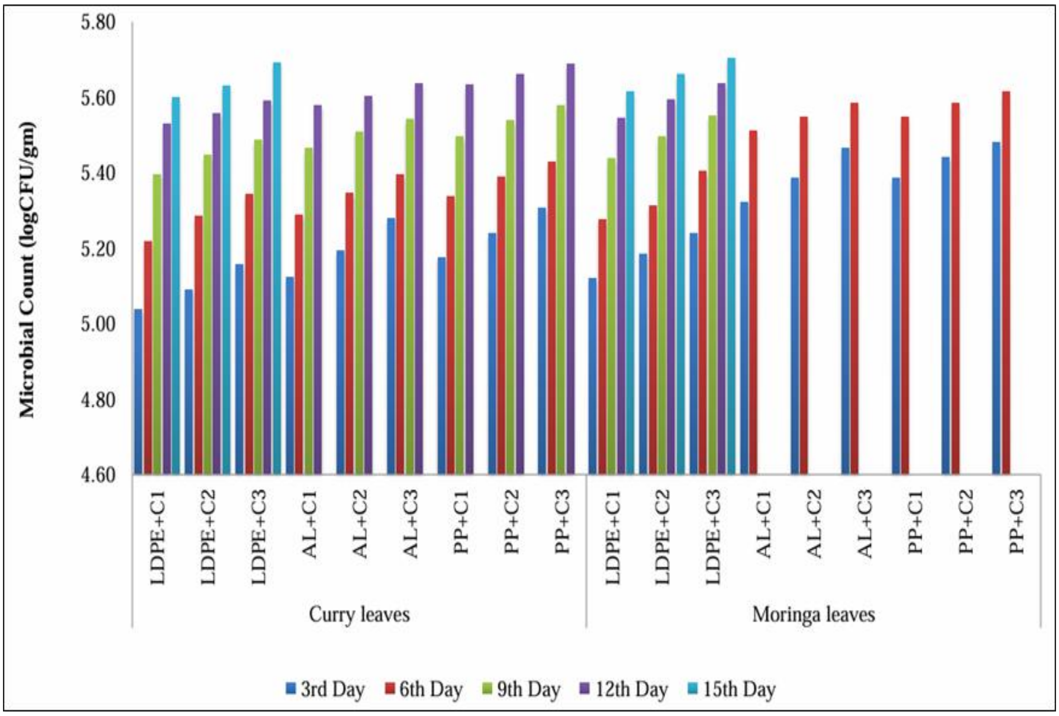

Fig 9: Effect of MAP on microbial load in curry leaves and *Moringa* leaves at ambient temperature

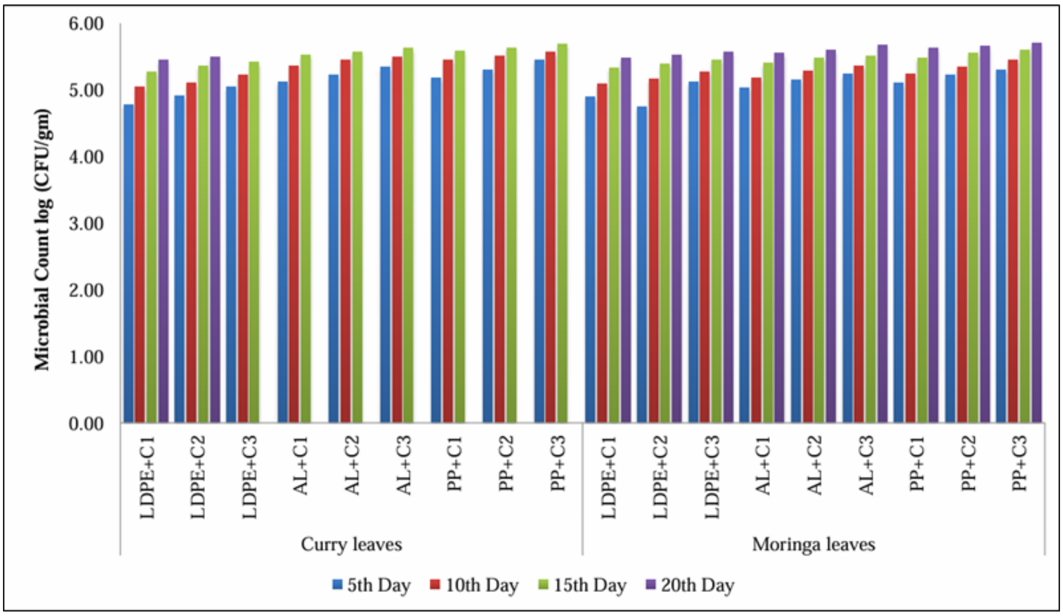

Fig 10: Effect of MAP on microbial load in curry leaves and *Moringa* at refrigerated temperature

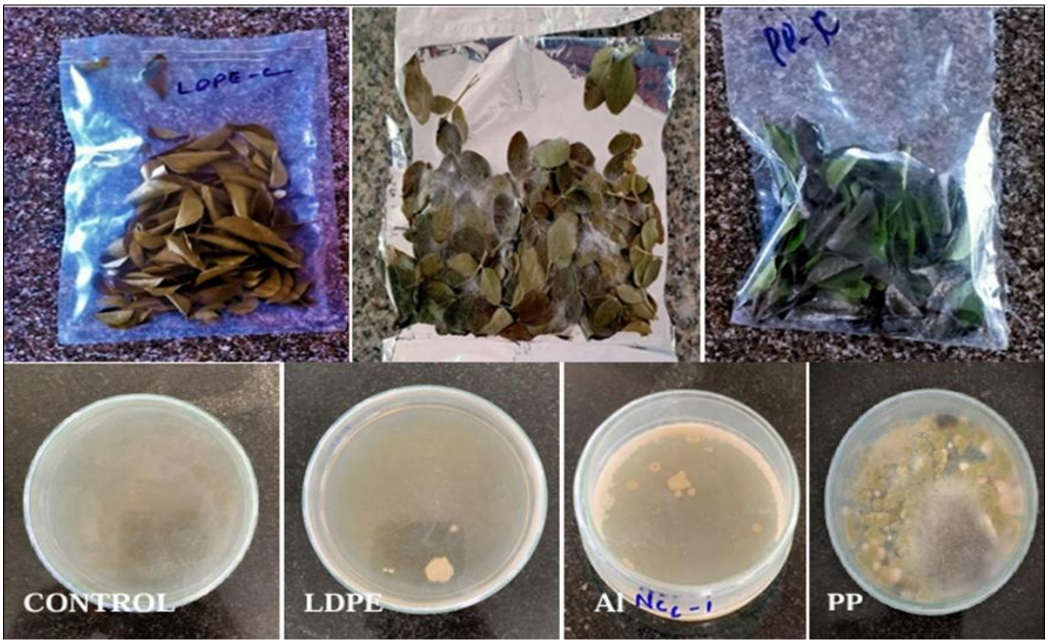

Plate 2: Microbial growth in stored leaves

Conclusion

The study concluded that LDPE packaging material was found to be best for increasing shelf life of curry leaves and *Moringa* leaves at ambient and refrigerated temperature compared to Al and PP. Storage at refrigerated temperature maintained the quality of *Moringa* and curry leaves compared to storage at ambient temperature. The MAP gas composition of C1 (2%, 4%, 94%) was found to be the best for increasing shelf life compared to C2 (4%, 6%, 90%) and C3 (6%, 8%, 86%) at both ambient and refrigerated temperatures. MAP using LDPE with low O_2 and moderate CO_2 under refrigeration is a promising technique for extending the postharvest life of fresh curry and *Moringa* leaves.

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