Madras Agric. J., 100 (4-6): 612-618, June 2013
https://doi.org/10.29321/MAJ.10.001368

Enhancing Shelf Life of Coriander Leaves by Modified Atmospheric Packaging

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Coriander leaves used as culinary herbs have poor shelf life due to poor handling and packaging. A study was carried out for enhancing the shelf life of fresh coriander leaves by using modified atmosphere packaging. Based on oxygen (O_2) and carbon dioxide (CO_2) permeability, low density polyethylene bag with 152 micron thickness was selected and used for this study. The coriander leaves were subjected to pre-cooling at 10°C for 10 min. and packed in the bags with a product to free volume ratio of 1:7. The selected bags were flushed with 5% O_2, 5% CO_2 and 90% N_2 and stored at ambient and refrigerated conditions. The physical, biochemical and microbial quality of green coriander leaves revealed that no significant changes in weight, colour value, chlorophyll content and beta carotene content of coriander leaves up to 20th day of storage under refrigerated condition whereas at room temperature it stays only for four days.

Key words: Coriander leaves, microbial load, modified atmosphere packaging and shelf life.

The culinary herbs occupy an important place among the leafy vegetables as these provide adequate amounts of vitamins and minerals. These green leafy vegetables are typically low in fat, high in dietary fiber, and rich in folic acid, vitamin C, potassium and magnesium and richest source of calcium. Among the culinary herbs, coriander leaves are used for flavoring and garnishing different cuisines. India is the major producer of coriander leaves in the world. The fresh coriander leaves are highly perishable produce with a very short shelf life under the ambient conditions. However they suffer a lot in terms of post harvest losses because of poor handling practices, higher water activity and high rate of respiration. Hence the present study was carried out to increase the shelf life of coriander leaves.

Modified Atmosphere Packaging of Coriander leaves

Modified atmosphere packaging (MAP) is most commonly used for highly perishable commodities and effectively retards deterioration of fruits and vegetables. MAP utilizes polymeric films with selective permeability for O_2, CO_2 and water vapour to create a modified atmosphere around the packaged product due to respiration of the product and the selective permeability of the packaging material (Guevara *et al.,* 2003). Modified atmosphere reduces respiration rate, ethylene production and sensitivity and texture losses, improves chlorophyll and other pigment retention, delays ripening and senescence and reduces the rate of microbial growth and spoilage (Aguilera and Olivera., 2009).

MAP can prolong the shelf life of mushrooms *Pleurotus nebrodensis* to 90 days, inhibit the respiration and weight loss, and retard soluble sugars, titratable acidity and decrease in anthocyanin of strawberries (Zhang *et al.,*2003). The MAP using 0.03mm Poly ethylene (PE) film could inhibit weight loss and decrease the total soluble solids (TSS), firmness of fruits and keep an acceptable appearance of table tomatoes compared with control fruit.

Simon and Gonzalez (2011) studied the sensory and microbiological quality of fresh peeled white asparagus packaged in two different types of P-Plus films (commercial packaging films) and stored at two different temperatures (5 ºC and 10 ºC) for up to 14 days. It has been stated that Fresh appearance was maintained better at 5 ºC than at 10 ºC, being microbial spoilage the main limiting factor. The atmosphere generated with film A (around 7 % CO_2 and 15 % O_2) inhibited spoilage and maintained the acidity of asparagus better than the atmosphere generated by film B (around 2 % CO_2 and 20 % O_2). The shelf life of asparagus packaged in film A and stored at 5 ºC was 14 days.

The availability of techniques regarding the post harvest handling, processing and packaging criteria to enhance the quality with an extended shelf life of the coriander leaves are not optimized. Hence the present study on enhancing the shelf life of coriander leaves by modified atmospheric packaging was undertaken.

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Materials and Methods

Sample preparation

Local varieties of coriander leaves available in the market were selected for the study. The process flowchart for the Modified Atmospheric Packaging is given in the Fig.1. The leaves were procured, cleaned, washed and surface dried. The leaves were weighed and bundled into 50, 75 and 100g. The surface area of the leaves were found using a leaf area meter. The volume of each bundle was determined by water displacement method (Mohsenin, 1980). The weight-surface area relationship was established using regression equation. Product to free volume ratio for each bundle was calculated from the weight and volume of the product.

Pre treatments

The leaf bundles of known weight were given pre treatments like pre-chilling and pre-cooling to reduce the field heat.

Prechilling

The samples of known weight (50, 75 and 100 g) were dipped in a beaker containing chill water. The chilling temperature and duration was optimized by conducting respiration studies. The temperature was optimized as 5ºC and the duration was 10 minutes for best results.

Pre-cooling

The samples were kept under refrigeration (7-8ºC) for 10 minutes. Prolonged exposure leads to chilling injury and short duration exposure does not have significant effect of processing. So 7-8ºC and 10 minutes duration was found to be the opt temperature.

Respiration Studies

Respiration results loss of moisture from the fresh produce which causes the shrinkage and physiological loss in weight. The extent of respiration can be measured by determining the amount of substrate loss, oxygen consumed, carbon dioxide liberated, heat produced and energy evolved (Pantastico *et al.,* 1975). Respiration studies were conducted in closed containers and also in the permeable system (LDPE bag) with or without gas flushing.The desired gas composition was optimized based on the respiration rate as given in Table.5 and Table. 6 The optimized gas composition was 3 per cent O_2, 5 per cent CO_2 and 92 per cent N_2.

Experimental set up for respiration measurement

The containers made of Polyethylene terephthalate (PET) with 1.750 liters capacity and transparent nature were selected for the respiration study as a closed system. A single hole of 1cm diameter was made on the top of the lid and a silicon septum was fitted into the hole using brass fittings to draw gas for analysis.

Respiration measurement

The pre treated leafy bundles were kept inside the containers for the measurement of respiration rate. Gas samples were drawn from the container through silicon rubber septum using syringe and gas concentration was found out using MAP analyzer (Make: PBI Dansensor Model: Checkmate II). With the recorded gas composition the respiration rate of oxygen and carbon dioxide were calculated for the experimental values using Michaelis-menten equation given by Cameron *et al.,* (1989).

$$Ro_2 = \frac{y_{ti}o_2 - y_{tf}o_2 \times V}{100 \times M \times (t_f - t_i)} \quad — (1)$$

$$Rco_2 = \frac{y^{tf}co_2 - y^{ti}co_2 \times V}{100 \times M \times (t_f - t_i)} \quad — (2)$$

where,

Ro_2 and Rco_2 - respiration rate, in terms of O_2 and CO_2 evolved respectively, m^3/kg/h

V - free volume inside the container

yo_2^{ti} and yo_2^{tf} - volumetric concentration of O_2 at initial and final time respectively, %

yco_2^{ti} and yco_2^{tf} - volumetric concentration of CO_2 at initial and final time respectively,%

M - mass of the stored product, kg

t_i and t_f - initial and final time respectively, h

The respiration rate for the permeable system using polymeric film (LDPE) was calculated as per Lakakul, Beaudry and Hernandez (1999).

$$Ro_2 = \frac{Po_2 \times A}{100 \times L \times M} \times (y^eo_2 - yo_2) \quad — (3)$$

$$Rco_2 = \frac{Pco_2 \times A}{100 \times L \times M} \times (yco_2 - y^eco_2) \quad — (4)$$

where,

A - package surface area, m_2

L - package thickness, m

M - mass of stored product, kg

Po_2 and Pco_2 - film permeability coefficient for O_2 and CO_2 respectively, m^2 s^{-1}

y^eo_2 and yo_2 - volumetric concentrations of O_2 outside and inside the package, respectively, %

y^eco_2 and yco_2 - volumetric concentrations of CO_2 outside and inside the package, respectively, %

Storage study

The MAP of coriander leaves of best combination of gas composition (based on the respiration rate given in Table.5 and Table.6) packaging material (based on the permeability rate given in Fig.2. pre-treatment and product volume ratio were selected for storage studies. During the storage period, physiological, physical, bio-chemical and microbiological studies (total plate count method) were carried out to compare the results with the fresh leaves.

Independent variables

Green leaves	-	Coriander
Storage temperature	-	Ambient (27-33°C, 50 – 70 per cent RH) Refrigerator (7±1°C, 90- 95 per cent RH)
Packaging material	-	LDPE (152µ)
Pre treatment	-	Pre-chilling (5±1ºC, for 10 mins)Pre-cooling (8±1°C for 10 mins)
Gas composition	-	Oxygen (3%)Carbon dioxide (5 %) Nitrogen (92%)

Dependent variables

X **Physiological and physical properties**

W Physiological loss in weight

W Colour value

X **Biochemical properties and microbial load**

W Beta carotene

W Chlorophyll content

W Microbial load

Methods of estimation of dependent variables

Dependent variables	Method adopted
Physiological and physical properties	
Physiological loss in weight	PLW (%) = $\frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$
Colour value	Anonymous, Colour flex meter (Hunter lab)
Biochemical properties and microbial load	
Beta carotene	Ranganna (1979)
Chlorophyll content	Ranganna (1979)
Microbial load	Standard plate count method (Allen,1953)

Statistical Analysis

Statistical analysis was carried out to study the effect of different parameters (Pre treatments, storage conditions and product to free volume ratio) on all the dependent variables. Analysis of variance (ANOVA) was conducted with Factorial Completely Randomized block Design (FCRD) using the statistical software AGRES.

Results and Discussion

The experimental results of respiration rate of coriander leaves, change in oxygen concentration in the pre treatments and storage temperatures are discussed. The quality aspects of the green leaves such as physicochemical, microbiological and shelf life on the final quality of the modified atmosphere packaged green leaves are also discussed based on the results obtained from the experiments.

Physicochemical and Microbial Analysis for Fresh Coriander Leaves

The physicochemical and microbial analyses were carried out for the fresh coriander leaves as per the procedures given earlier.

Physicochemical characteristics of fresh coriander leaves

Physicochemical analysis such as moisture content, colour value, chlorophyll content and â-carotene for the fresh coriander leaves were analyzed and presented in Table.1.

Table 1. Physicochemical qualities of fresh coriander leaves

Physicochemical parameters		Coriander leaves
Moisture content (%, wb)		91.3
Colour value	L	40.75
	a	-9.34
	b	24.20
Chlorophyll content (mg/g)		1.23
β-carotene (mg /g)		42.86

Microbial analysis of fresh coriander leaves

The results of microbial analysis of fresh coriander leaves are given in Table.2. From the above results it was clear that the fungal population was lower than the bacterial population. This may be due to different agricultural and harvesting practices of coriander leaves.

Table. 2. Microbial analysis of fresh coriander leaves

Green leaves	Replication	Bacterial population x 10^5 cfu/mg	Fungi population x 10^3cfu/mg
Coriander leaves	I	12	4
	II	22	3
	III	18	3

Permeability of the Packaging Materials

The permeability of Low Density Poly Ethylene (LDPE) and Poly Propylene (PP) packaging materials of different thickness was assessed and selected for the study based on their permeability rate. It was inferred from the Fig 2. that the maximum permeability to oxygen was observed for LDPE – 3 (2392 ml/m^2/day**)** and the minimum was for LDPE – 1 (1067 ml/m^2/day).

LDPE-1 was selected as the packaging material, since it has less permeability to oxygen (1067 ml/ m^2/day) which was desirable for the study. More permeability to oxygen results in more availability of oxygen in the head space which increases respiration rate and results in decay of the product.

The Packaging material (LDPE 152µ) was chosen based on the permeability rate of the material

Process Flow Chart / Experimental Procedure for Coriander Leaves

Coriander leaves

↓

Trimming (removal of root, unwanted materials)

↓

Washing (to remove soil particles)

↓

Shade drying (to remove surface moisture)

↓

Weighing & bundling (50, 75 and 100 g)

↓

Pre-treatment

↓ Pre-chilling (5ºC, 10 min in cold water) | ↓ Pre-cooling (10ºC, 10 min in refrigeration)

Packing in LDPE bags

↓

Gas flushing and sealing

↓

Respiration measurement

↓

Storage study

↓ Refrigerated condition | ↓ Ambient condition

Fig.1. Flow chart for modified atmosphere packaging of coriander leaves

to oxygen. Among them LDPE 152μ was selected which has less permeability to oxygen.

Weight - Surface Area Relationship of Coriander Leaves

Surface area of the leaves play a major role in respiration. Hence the determination of weight and surface area is important in the respiration study.

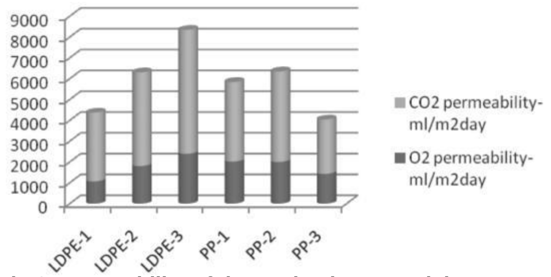

Fig.2. Permeability of the packaging materials

The relationship between weight and surface area for coriander leaves are presented in the following equation

Coriander $A_s=241.45W-38.06$ ($R^2=0.9899$) -- (5)

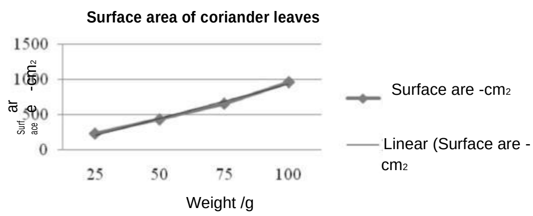

Fig.3. Relationship between weight and surface area of coriander leaves

It has been inferred from the Fig.3 that the weight of the material increases the surface area and results in increased respiration rate.

Determination of respiration rate under closed system

The respiration study using closed system without gas flushing for coriander revealed that under ambient condition the respiration rate was more than the refrigerated condition. Table 3 states that the minimum RRO_2 was 0.1901 m_3/kgh under

Table 3. Effect of Product volume ratio, pre treatments and duration on respiration rate of coriander under ambient and refrigerated condition for closed system

Product volume ratio	Treatment	Duration	Ambient condition		Refrigerated condition	
			RRo_2 m_3/kgh	$RRco_2$ m_3/kgh	RRo_2 m_3/kgh	$RRco_2$ m_3/kgh
1:11	Control	3	0.2228	0.1412	0.0163	0.0489
		6	0.2282	0.1630	0.0978	0.0163
		9	0.2065	0.1593	0	0.0163
		12	0.2051	0.1670	0.0652	0.0163
	Pre chilled	3	0.2064	0.1358	0.0163	0.0326
		6	0.2146	0.1630	0.0652	0.0163
		9	0.2028	0.1593	0.0163	0.0326
		12	0.2010	0.1598	0.0489	0.0326
	Pre cooled	3	0.2119	0.1304	0.0163	0.0163
		6	0.2091	0.1223	0.0978	0.0326
		9	0.1974	0.1430	0.0326	0.0163
		12	0.1901	0.1494	0.0815	0.0163
1:10	control	3	0.2592	0.1584	0.0216	0.0216
		6	0.2448	0.1638	0.0216	0.0324
		9	0.2196	0.1488	0.0432	0.0108
		12	0.2045	0.1566	0.0432	0.0216
	Pre chilled	3	0.2520	0.1728	0.0216	0.0324
		6	0.2430	0.1818	0.0216	0.0216
		9	0.2196	0.1656	0.0324	0.0324
		12	0.2016	0.1512	0.0324	0.0108
	Pre cooled	3	0.2592	0.1800	0.0216	0.0324
		6	0.2466	0.1800	0.0108	0.0216
		9	0.2244	0.1680	0.0324	0.0216
		12	0.2025	0.1476	0.0432	0.0216
1:7	control	3	0.2137	0.1262	0.0154	0.0231
		6	0.2382	0.1545	0.0231	0.0077
		9	0.2189	0.1459	0.0077	0.0077
		12	0.2034	0.1409	0.0154	0.0154
	Pre chilled	3	0.2240	0.1365	0.0231	0.0154
		6	0.2524	0.1622	0.0540	0.0231
		9	0.2386	0.1536	0.0154	0.0154
		12	0.2169	0.1590	0.0154	0.0154
	Pre cooled	3	0.2137	0.1364	0.0231	0.0154
		6	0.2317	0.1635	0.0540	0.0386
		9	0.2133	0.1596	0	0
		12	0.1944	0.1506	0	0.0154

ambient condition and it was zero in refrigeration condition. This due to fact that there was no changes in the concentration of O_2 during respiration (no metabolic activity has taken place at that time). The pre cooling treatment with the product to free volume ratio of 1:7 was found to be effective in reducing the respiration rate under both the conditions.

Determination of respiration rate under permeable system

For the permeable system without gas flushing the lowest respiration rate was got for the samples having a free volume ratio of 1:7 and pre cooled coriander leaves after 12 hours. The minimum respiration rate for coriander leaves in the refrigerated condition was about 0.0326 m_3/kgh. (Table.4)

Table 4. Effect of Product volume ratio, pre treatments and duration on respiration rate of coriander under ambient and refrigerated condition for permeable system

Product volume ratio	Treatment	Duration	Ambient condition		Refrigerated condition	
			RRo_2 m_3/kgh	$RRco_2$ m_3/kgh	RRo_2 m_3/kgh	$RRco_2$ m_3/kgh
1:11	Control	3	0.12811	0.32196	0.08108	0.22268
		6	0.08676	0.21417	0.06081	0.19644
		9	0.07568	0.22315	0.05892	0.16878
		12	0.07541	0.19928	0.05595	0.16736
	Pre chilled	3	0.16217	0.49216	0.10703	0.32905
		6	0.14027	0.40919	0.08108	0.25317
		9	0.11081	0.31298	0.07081	0.23261
		12	0.09771	0.27019	0.06284	0.21346
	Pre cooled	3	0.20271	0.54180	0.10217	0.24395
		6	0.15000	0.41274	0.08027	0.24254
		9	0.14757	0.36735	0.06487	0.19951
		12	0.13865	0.32870	0.05716	0.17800
1:10	control	3	0.09720	0.24803	0.05184	0.16283
		6	0.07938	0.23761	0.04428	0.11928
		9	0.06624	0.20101	0.04212	0.10792
		12	0.06075	0.18271	0.03861	0.11762
	Pre chilled	3	0.14148	0.43736	0.07884	0.22909
		6	0.12420	0.37251	0.05832	0.16661
		9	0.10008	0.28936	0.04860	0.13790
		12	0.08532	0.24661	0.04266	0.12946
	Pre cooled	3	0.15984	0.40896	0.08748	0.26696
		6	0.13338	0.34411	0.07614	0.21868
		9	0.11736	0.29883	0.05616	0.16472
		12	0.09747	0.26791	0.04698	0.14129
1:7	control	3	0.10125	0.25347	0.05022	0.12922
		6	0.08829	0.25631	0.04091	0.09301
		9	0.07020	0.20756	0.03753	0.08804
		12	0.05670	0.17431	0.03260	0.08467
	Pre chilled	3	0.11583	0.35997	0.06804	0.19667
		6	0.10449	0.30956	0.05306	0.15159
		9	0.08532	0.24542	0.04374	0.12236
		12	0.06824	0.19649	0.03726	0.10597
	Pre cooled	3	0.13284	0.38127	0.07209	0.19312
		6	0.10692	0.29359	0.05306	0.15336
		9	0.09207	0.25371	0.03888	0.12591
		12	0.07938	0.21691	0.03341	0.11041

Optimization of Gas Composition

The respiration rate decreased with the decrease in temperature due to less reaction rate at lower temperatures (Zhang *et al.,* 2003). The gas composition was optimized based on the respiration rate under ambient and refrigerated conditions. The lowest respiration rate of O_2 obtained in the refrigerated system for coriander leaves was 0.1080 m_3/ kgh for the gas composition containing 5 per cent O_2, 5 per cent CO_2 and 90 per cent N_2 as mentioned in the Table 5 and Table 6.

Table 5. Effect of gas composition on respiration rate of coriander under ambient condition using permeable system.

Gas composition	Duration-h	Gas composition- %			RO_2	RCO_2
		O_2	CO_2	N_2		
O_2- 3%,	3	0.93	8.2	90.87	0.3219	0.5801
CO2-5%	6	0.006	11.8	88.194	0.1684	0.4178
and N_2-92%	9	0.001	15	84.999	0.1123	0.3543
O_2- 4%,	3	0.93	8.2	90.87	0.3219	0.5801
CO_2-5%	6	0.006	11.8	88.194	0.1684	0.4178
and N_2-91%	9	0.001	15	84.999	0.1123	0.3543
O_2- 5%,	3	2.1	8.5	89.4	0.3029	0.6014
CO_2-5%	6	0.4	13.8	85.8	0.1652	0.4888
and N_2-90%	9	0.001	16.8	83.199	0.1123	0.3969

The PLW was less, the colour value, chlorophyll and beta carotene contents were retained much in the case of 5 per cent O_2, 5 per cent CO_2 and 90 per cent N_2 gas composition. So this composition was chosen for storage study along with pre cooling treatment and 1:7 as product to free volume ratio for coriander leaves. The storage study was conducted under ambient condition and in refrigerated condition.

Table 6. Effect of gas composition on respiration rate of coriander under refrigerated condition using permeable system.

Gas composition	Duration-h	Gas composition- %			RO_2	RCO_2
		O_2	CO_2	N_2		
O_2- 3%,	3	2.1	6.9	91	0.3029	0.4878
CO_2-5%	6	0.8	8	91.2	0.1620	0.2829
N_2-92%	9	0.1	9.1	90.8	0.1118	0.2147
O_2- 4%,	3	2.1	6.9	91	0.3029	0.4878
CO_2-5%	6	0.8	8	91.2	0.1620	0.2829
N_2-91%	9	0.1	9.1	90.8	0.1118	0.2147
O_2- 5%,	3	3.7	6.8	89.5	0.2770	0.4807
CO_2-5%	6	2.1	8.3	89.6	0.1515	0.2936
N_2-90%	9	0.8	9.3	89.9	0.1080	0.2194

Storage studies

Storage study for coriander leaves were conducted based on the optimized parameters. The optimized product volume ratio of 1:7, LDPE film of thickness 152 m and the gas composition of 5 per cent O_2, 5 per cent CO_2 and 90 per cent N_2 were chosen as best composition for storing coriander leaves under MAP. The storage study was conducted for a period of 20 days, during the period the various physical, physiological, biochemical and microbiological analysis were done at an interval of 4 days and the results are discussed as follows.

Effect of gas composition on the physiological loss in weight of coriander leaves

The physiological loss in weight indicated that there was loss of moisture from the coriander leaves. During storage period the loss in weight was more (4.1 per cent) in the case of leaves stored under ambient condition.

Fig.4. shows that the loss in weight was less under refrigerated condition than the ambient condition. The PLW was more at 30ºC this may be due to less humidity of the atmospheric air compared to that in refrigerated condition.

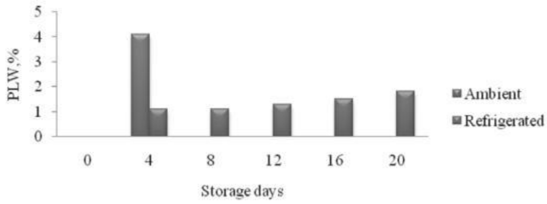

Fig.4. Physiological loss in weight of coriander leaves during storage

The PLW may be mainly due to the water loss as the product of respiration (Wills *et al.,* 1989) and also due to transpiration water loss during the storage period. There was a maximum of 1.8 per cent weight loss observed on 20th day of storage.

Effect of gas composition on the colour value of coriander leaves

The colour of the leaves were rated as L, a and b values. The L coordinate measures the luminance of the colour and ranges from black at 0 to white at 100. In other words, *l* value represented the lightness of the colour. The coordinate 'a' measures red when positive and green when negative. The coordinate 'b' measures yellow when positive and blue when negative.

It is observed from the Table.7 that the colour value L has decreased under ambient storage. Similarly 'a' value and 'b' value also decreased. The change in 'a' value was important because at ambient condition the value gets decreased, resulting in degreening of the coriander leaves. Under refrigerated condition the lightness has increased to 42.42 and there was no much deviation in 'a' value and 'b' value. This shows that the greenness was maintained during the storage period for up to 20 days at 14ºC.

Table 7. Effect of storage period on colour value for coriander leaves

Storage days	Colour value					
	Ambient condition			Refrigerated condition		
	L	a	b	L	a	b
0	40.75	-9.34	24.4	40.75	-9.34	24.4
4	30.99	-3.14	14.18	41.23	-9.01	22.67
8	-	-	-	42.54	-8.46	22.87
12	-	-	-	35.42	-9.22	23.42
16	-	-	-	38.33	-8.76	22.99
20	-	-	-	42.42	-9.03	23.95

Effect of gas composition during the storage period of coriander leaves

The O_2 concentration inside the LDPE bag was recorded at 4 days interval during the storage period at ambient and refrigerated condition is presented in Fig.5. The initial gas level was kept at 5 per cent O_2, 5 per cent CO_2 and rest as N_2. It has been seen that the O_2 concentration of the ambient stored coriander leaves has started declining and reached 0.002 per cent at the fourth day of storage and decayed. The refrigerated stored leaves remain fresh and the O_2 concentration till 8th day was declining and later there was a increase in the concentration, this might be due to permeability of the packaging material to the gases (mainly due to vapour pressure difference between storage and outside atmosphere). The value again decreased to 0.1 per cent during the 20th day because the available oxygen would have been used for respiration.

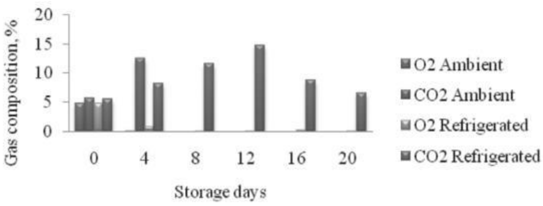

Fig.5. Change in gas composition during storage of coriander leaves

The concentration of CO_2 achieved during the storage period inside the packaging film presented in the Fig.5. It was inferred from the graph that the concentration steadily increased from the initial period of storage to till 12th day (14.7 per cent) and after that it starts declining to 0.05 per cent under the refrigerated condition. The decrease in CO_2 was accompanied by increased in O_2 value. This is due difference in gas concentration in and out of storage bags.

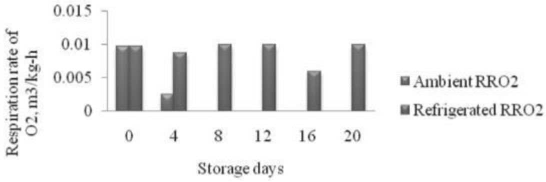

Fig.6. Respiration rate of O_2 during storage of coriander leaves

Effect of gas composition on the respiration Rate of O_2

The respiration rate of the coriander leaves stored under ambient condition (30ºC) has started ceasing, during the 4th day because the material has started to decay. When the oxygen concentration was less than 1 per cent anaerobic condition would have been reached. Under this condition the leaves may produce off flavour and off odour.

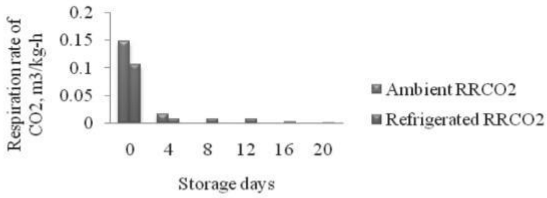

Fig.7. Change in respiration rate of CO_2 during storage of coriander leaves

From the Fig.6. it has been observed that under the refrigerated condition the metabolic activity and the oxygen consumption were found to be low. The respiration rate remains same up to 12th day and during 16th day the rate decreased suddenly this may be due to lower metabolic activity during the storage period.

Effect of gas composition on the respiration rate of CO_2 of coriander leaves

There was a constant decrease in the respiration rate of CO_2 both during the ambient storage condition and refrigerated storage. This state is clear from the Fig.7.

Effect of gas composition on the Chlorophyll and β - carotene content of coriander leaves

The Fig.8. stated that the chlorophyll content of the coriander leaves under modified atmospheric storage

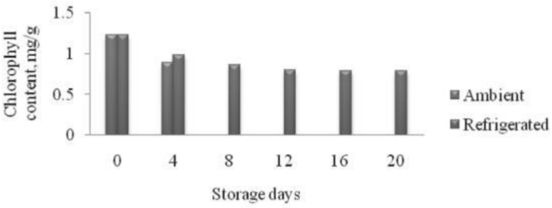

Fig.8. Chlorophyll content during storage of coriander leaves

reduced gradually during the storage period. It was seen that the initial chlorophyll content was same for both ambient and refrigerated condition and during the storage period the value decreases up to 8th day and after that there was no change in the value.

β - carotene is an essential source of vitamin A in coriander leaves. The β- carotene content during storage period decreased from the initial value. From the Fig.9. it was observed that the β - carotene content at the end of the storage *i.e*. on 20th day was found to be 35.88 mg/g but the initial value was 42.86 mg/g.

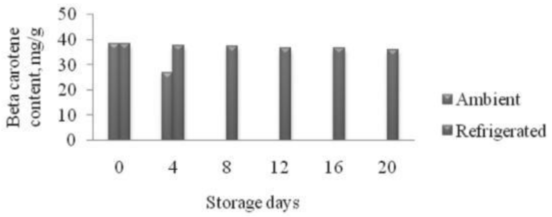

Fig.9. β - carotene content during storage of coriander leaves

Effect of gas composition on the microbial population of coriander leaves

Maintaining the quality of the food product during storage was mainly due to inhibition of growth of spoilage micro organisms and in most cases the condition chosen were that those reduce the microbial growth. The low level of oxygen may inhibit the surface growth of pathogenic anaerobic bacteria

Table 8. Microbial load on the 20th day of storage in coriander leaves

Sample	Bacterial population x 10^6 cfu/mg	Fungi population x 10^4 cfu/mg
1	14	3.0
3.	16	3.0
2	14	3.0

particularly *Clostridium botulinum* but it would not prevent anaerobic condition present on the body of the product (Hotchkiss, 1988).

Generally low O_2 and high CO_2 with low temperature condition was selected for safe food products in MAP. So the microbial growth during the storage period was within the permissible level (Table.8).

Conclusion

Storage of coriander leaves at refrigerated condition with modified atmosphere packaging with 5 per cent O_2, 5 per cent CO_2 and 90 per cent N_2 was effective in extending the shelf life upto 20 days. The quality parameters like weight loss, colour value, chlorophyll and beta carotene content of coriander leaves were not altered significantly up to 20 days. The microbial population of the stored samples was within the permissible level after 20 days.

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Received: September 27, 2012; Accepted: February 18, 2013