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Selection of film for modified atmosphere packaging of chillies (*Capsicum annuum* L.) based on permeability

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ABSTRACT : The design of MAP requires thorough understanding of characteristics and effects of packaging material on fresh produce during storage.Film permeability declines with reduction in temperature of different films (LDPE, HDPE and PP). The rates of oxygen consumption and carbon dioxide evolution increases with rise in temperature (5, 10 and 15^{0}C). The O_2 and CO_2 permeability per unit thickness increased as temperature increased. All the films had lower permeabilities than required. So 10, 15 and 20 perforations were made in the film of highest permeability *i.e.* LDPE was selected for packaging of chillies under modified atmosphere packaging.

KEY WORDS : Packaging, Permeability, Modified atmosphere packaging, Chillies

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The vegetables play a vital role in our diet as they are major source for our nutrition requirement. Chilli is one of the most important commercial crops of India. It belong to the family Solanaceae, are herbaceous or semi-woody annuals or perennials. *C. annuum* and *C. frutescens* are commercially cultivated species. India is the largest producer of chillies in the world. Its production level covers around 1.1 million tons annually. India also has the maximum area dedicated to the production of this crop. The major regions where chilli is cultivated in India are AP, Karnataka, Maharashtra, UP, Punjab, TN, Rajasthan, Orissa, West Bengal and M.P. Andhra Pradesh stands first in the list of leading chilli-producing states in India.

Chillies are perishable in nature having limited shelf-life and high susceptibility to postharvest problems like shriveling, wilting and are also susceptible to fungal infections. Packaging of peppers in polymeric films has been reported to inhibit fruit respiration, delay ripening, decrease ethylene production, reduce chilling injury, retard softening, slow down compositional changes associated with ripening, maintain colour and extend shelf-life (Kader *et al.*, 1989).It also reduces the moisture loss and modifies the atmosphere inside the package. An atmosphere of reduced O_2, elevated CO_2, and a balance of N_2 helps in reduction of respiration rate, ethylene production, decay and the physiological changes. The design and generation of an optimum modified atmosphere is used to achieve equilibrium inside the package and it depends upon various factors such as film characteristics (gas and water vapor permeability), storage temperature, free volume inside the package, respiration rate of the produce and the type of film with respect to its thickness (O'Beirne, 1991). If the produce is sealed in a film which in not sufficiently permeable, detrimental anaerobic conditions may occur; conversely, if produce is sealed in a film with excessive permeability, the modified atmosphere will not be retained and moisture loss may occur both of which may affect produce quality (Lioutas, 1988). So permeability of the packaging material is one of the most important factors for selecting the package and maintaining the quality of the food product. The permability limit for maximum CO_2 and minimum O_2 concentration varies from crop to crop; therefore, a film should be selected according to the desired gas concentration for a specific product for a desired length of storage (Kaur, 2009). The objective of the present study was selection of the best suitable film for the extended shelf-life of chillies.

■ METHODOLOGY

The present study was carried out to design modified atmosphere packaging (MAP) for selection of appropriate polymeric films of desired physical and gas exchange characteristics suitable for extending the shelf-life of green chillies. Respiration rates of freshly harvested green chillies were measured with gas analyser and matched with permeabilities of different polymeric films of variable thickness commercially available. The best suitable polymeric film meeting the requirements was selected and evaluated for extending the shelf-life of freshly harvested green chillies under different storage conditions. The gas composition (*i.e.* O_2 and CO_2 concentrations) of environment inside the package was also analysed during the storage period as the optimum functionality of package depends on these gas concentrations inside the package.

Gas permeability of the films :

The oxygen permeability (Po_2) and carbon-dioxide permeability (Pco_2) of three films *i.e.* LDPE, HDPE and PP at 25°C (Valentas *et al.*, 1997) are listed in Table A.

The permeabilities at different temperatures *i.e.*5, 10 and 15⁰C were found using eq. (1).

$$P_2 = P_1 e^{\frac{E_P}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} \qquad (1)$$

or $P_2 = P_1 f$

where $$f = e^{\frac{E_P}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} \qquad (2)$$

Ep = Activation energy at temperature T_1, kcal/mo1

R = Gas constant, 0.001987 kcal/mol.K

If the values of permeability P_1 are given at temperature T_1, then value of the permeability P_2 at temperature T_2 can be calculated with known activation energy (Ep). 'f' values at 5, 10 and 15⁰C for LDPE, HDPE, PP material are calculated in Table B.

The calculated f values in Table B were used in eq. (2) to calculate permeabilities at temperatures 5, 10 and 15°C and are shown in Table C.

Oxygen (O_2):

Oxygen permeability of film was measured using the eq. (3) given below

Table A : Permeability of LDPE, HDPE and PP in terms of O_2 and CO_2 at 25°C

	LDPE	HDPE	PP
Po_2	82.126	16.51-74.083	26.331
Pco_2	444.076	97.366	88.9

Units : (10^{-6} ml-m/m^2 hr-kPa)

Table B : f values corresponding to oxygen (O_2) and carbon dioxide (CO_2) permeability for LDPE, HDPE, PP at 5, 10 and 15°C

Temperature (T_2,°C)		Activation energy Ep (kcal/mol)			f $\left[= \exp\frac{Ep}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$		
		LDPE	HDPE	PP	LDPE	HDPE	PP
5	O_2	10.287	8.373	11.483	0.286	0.361	0.248
	CO_2	9.33	7.177	9.091	0.321	0.418	0.331
10	O_2	10.287	8.373	11.483	0.398	0.473	0.358
	CO_2	9.33	7.177	9.091	0.433	0.526	0.443
15	O_2	10.287	8.373	11.483	0.547	0.612	0.510
	CO_2	9.33	7.177	9.091	0.578	0.656	0.587

R = 0.001987 kcal/mol.K

Table C : Permeability of LDPE, HDPE, PP in terms of O_2 and CO_2 at 5, 10 and 15°C

Temperature (°C)	LDPE		HDPE		PP	
	Po_2	Pco_2	Po_2	Pco_2	Po_2	Pco_2
5	23.5	142.9	6-26.8	40.7	6.5	29.4
10	32.7	192.6	7.8-35	51.2	9.4	39.3
15	44.9	256.9	10-45.3	63.9	13.4	52.1

Units : (10^{-6} ml-m/m^2 hr-kPa)

$$PO_2 \text{ Z } \frac{RRO_2 \text{ x t x W}}{\text{A x}(O_2 \text{ atm} - O_2 \text{ pkg})} \qquad (3)$$

Carbon-dioxide (CO_2):

Carbon-dioxide permeability of the film was found out using the equ. (4)

$$PCO_2 \text{ Z } \frac{RRCO_2 \text{ x t x W}}{\text{A x}(CO_2 \text{ pkg} - CO_2 \text{ atm})} \qquad (4)$$

The length and the breadth of the package were measured and the area of the package available for gas exchange was estimated as twice the area (0.0529 m^2) of one surface of package. Weight of the produce taken is 100, 150 and 200g. Void volume of package was determined by water displacement method (Singh, 2011). Different void volume could be obtained varying the quantity of the produce that was filled in the package. The desired level of O_2 and CO_2 are 3% and 5%, respectively.

■ RESULTS AND DISCUSSION

The value of film permeability decreases as temperature decreases in different films. Tables 1 and 2 give values of oxygen permeability per unit

Table 1 : Required oxygen permeability per unit thickness (PO_2/t) at 5, 10 and 15°C of fresh green chillies

Temperature (°C)	O_2 level (%)	$\left(\frac{PO_2}{t}\right)$ (10^{-6}ml/m^2-h-kPa)		
		100g	150g	200g
5	3	473.40	710.1	946.8
10	3	711.69	1067.535	1423.38
15	3	838.53	1257.795	1677.06

Table 2 : Required carbon-dioxide permeability per unit thickness (PCO_2/t) at 5, 10 and 15°C of fresh green chillies

Temperature (°C)	CO_2 level (%)	$\left(\frac{PCO_2}{t}\right)$ (10^{-6}ml/m^2-h-kPa)		
		100g	150g	200g
5	5	888.07	1332.105	1776.14
10	5	1524.47	1525.97	3048.94
15	5	1842.67	2764.005	3685.34

Table 3 : Oxygen permeability per unit thickness (PO_2/t) of different films at 5, 10 and 15°C

Temperature (°C)	Thickness (gauge)	LDPE	HDPE	PP
5	100	23.5	6-26.8	6.5
	150	15.6	4-17.8	4.3
	200	11.75	3-13.4	3.2
10	100	32.7	7.8-35	9.4
	150	21.8	5.2-23.3	6.3
	200	16.3	3.9-17.5	4.7
15	100	44.9	10-45.3	13.4
	150	29.9	6.6-30.2	8.9
	200	22.4	5-22.6	6.7

Po_2/t , Units: 10^{-6}ml/m^2-h-kPa

Table 4 : Carbon-dioxide permeability per unit thickness (PCO_2/t) of different films at 5, 10 and 15°C

Temperature (°C)	Thickness (gauge)	LDPE	HDPE	PP
5	100	142.9	40.7	29.4
	150	95.2	27.1	19.6
	200	71.4	20.3	14.7
10	100	192.6	51.2	39.3
	150	128.4	34.1	26.2
	200	96.3	25.6	19.6
15	100	256.9	63.9	52.1
	150	171.2	42.6	34.7
	200	128.4	31.9	26.0

Po_2/t, Units: 10^{-6} ml/m^2-h-kPa

thickness $\left(\frac{PO_2}{t}\right)$ and carbon dioxide permeability per unit thickness $\left(\frac{PCO_2}{t}\right)$, respectively, as calculated from O_2 and CO_2 levels which, are desired inside the package for increasing the shelf-life and maintaining the quality of packed freshly harvested green chillies. The rates of oxygen consumption at temperatures 5, 10 and 15ºC were at 44.735, 67.253 and 77.761 ml $kg^{-1}h^{-1}$ and the rates of CO_2 evolution at same temperatures were 23.043, 39.556 and 47.812 ml $kg^{-1}h^{-1}$, respectively.

Tables 1 and 2 shows that the oxygen and carbon-dioxide permeability increased with rise in temperature. The permeability of films shown in Table C were converted to the units, permeability per unit thickness and the values are listed in Tables 3 and 4.

Conclusion :

For extending the shelf-life of chillies, perforations were done to meet the film permeability with the crop. By comparing the values of required permeabilities with those of commercially available films, it was found that all the films had lower permeabilities than the required. Therefore, for extending the shelf-life of freshly harvested green chilli perforations were done. So, 10, 15 and 20 perforations were made in the packaging film of highest permeability. The thickness of the film used was 100, 150 and 200 gauges.

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