International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(4): 894-898

Received: 07-05-2020
Accepted: 09-06-2020

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Effect of modified atmosphere packaging on shelf life extension of French bean (*Phaseolus vulgaris* (L.)

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DOI: https://doi.org/10.22271/chemi.2020.v8.i4f.9716

Abstract
In this study, three types of films (Polyethylene (PE), polypropylene (PP), PD-961) were used with and without perforation for modified atmosphere packaging to extend the shelf life as well as maintain the physiological and biochemical property of French bean pods at ambient storage condition (25.7- 31.1 °C and 21-51% RH). The physiological parameters evaluated in this experiment were gas composition inside the bag, physiological loss in weight, surface color and firmness of pods. PD-961 (both perforated and non-perforated) had low PLW (< 1.5%) with compare to control (20.41%). PD-961 maintained the equilibrium between CO_2 and O_2 inside the package. *l** value was minimum in the beans packed in non-perforated PE (48.42) . *-a** values of beans were significantly lower in non-perforated PD-961 beans (-11.5) similarly b value was minimum in non-perforated PD-961 beans (25.16) means PD-961 plays a role to maximum retention of green color. PD-961 films had best effect on the firmness of pods throughout the storage. Due to physiological quality PD-961 films were more acceptable and it also retains the biochemical quality *viz.* protein content, total antioxidant capacity, total phenols and total chlorophyll content of beans.

Keywords: French beans, PD-961 film, ambient storage condition, modified atmosphere packaging

Introduction
French bean is one of the most important legume vegetable of the world. Beans are grown on every continent except Antarctica. Indian is the fourth largest producer of green bean in the world after China, Indonesia and Turkey. In India, it is cultivated in an area of 1.38 lakh hectares with annual production of 13.7 lakh metric tonnes (Anonymous, 2017[a]) [1] and also have a scope for export from Indian market (Anonymous, 2017[b]) [2]. As production and cultivation of French bean is up to the mark but it is not available throughout the year because of poor postharvest characteristics such as very short shelf-life, fast shriveling/softening results in rapid loss of this nutritional quality (Yagiz *et al*. 2010) [3]. To make available the produce whole year there is requirement of enhance the shelf life of French bean. Management of crop after harvesting through modified atmosphere packaging is the one of the important method to extend the shelf life of French bean.

Materials and Methods
The study was carried out at the experimental Field of the Division of vegetable science, and Division of Postharvest Technology at ICAR-Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru, during 2016-18. The experimental site was geographically located at 13° 58' N Latitude, 78°E Longitude and at an elevation of 890 m above mean sea level. The maximum/minimum temperatures and RH during the cropping season were 24.1- 33.5 °C and 32-68%. Pods were harvested at optimum length, tenderness and without string development from the vegetable farm of IIHR. The harvesting was done manually in the morning hours (8 to 9 am) and transported to the laboratory of Division of postharvest technology and agricultural engineering. After receiving pods in the laboratory, they were sorted out to remove immature, misshaped, bruised, diseased and insect infested pods. Then pods were graded based on their uniform size, shape and development of seeds to maintain homogeneity in the experiment. Passive MAP has chosen to conduct this experiment. Three different types of films (Polyethylene (PE), polypropylene (PP), PD-961) were taken with and without

perforation. For perforation 14 pin holes have done (7 each side of the packet). The dimensions of the flexible packages were kept (19×17 cm). All packs were glued with septa to facilitate frequent monitoring of in-pack gas composition. Cleaned and sorted 500g fresh French beans has packed in each bags and stored at ambient condition. The details of the experiment treatment are shown below.

The details of the experiment treatment are shown below.

Treatment number	Treatment details
Treatment 1	PE Non-perforated
Treatment 2	PE perforated
Treatment 3	PP Non-perforated
Treatment 4	PP perforated
Treatment 5	PD-961 perforated
Treatment 6	PD-961 Non-perforated
Treatment 7	Non-packed

The experimental data on physiological loss in weight (PLW), colour, firmness, gas composition sensory quality and decay were recorded at 1 and 2 days interval of storage at ambient and cold storage conditions, respectively. The PLW of the fruits was calculated as cumulative percent loss in weight based on the initial fruit weight and loss in weight recorded at the time of periodical sampling. The firmness of the fruit was measured with the help of Instron-Universal testing machine (Model 4201, USA) having probe speed of 5 mm and expressed in kg/cm^2.

For colour determination of each sample, the reflectance spectra were measured at 2 different points on the pod surface and then the mean reflectance spectrum was obtained. These measurements were taken with Hunter Lab colourimeter (Model: Color Reader, CR-10, Konica Minolta, Japan) in terms of (L, a, b) values (Hunter 1975) [14]. Gas composition (% oxygen and % carbon dioxide) inside the MA packs was monitored, at regular intervals throughout the storage period using an autogas analyzer (Model: PBI-Densensor, UK). Total phenols were estimated according to the procedure given by Singleton and Rossi (1965) [10]. Total antioxidants were estimated using FRAP (Ferric Reducing Antioxidant Potential) method as described by Benzie and Strain (1996) [13]. Proteins contents were estimated by Modified Lowry's method. The amount of total chlorophyll in terms of mg g^{-1} fresh weight basis was estimated according to Hiscox and Isrealstam (1979). The experiment design was completely randomized design and each treatment was replicated thrice. The significance among treatment mean values was determined by least significant difference (LSD) at $p<0.05$ level.

Results and Discussion

Gas composition inside the package plays an important role to enhance the storage life of produce (Fig. 1 (a) and (b)). PE and PP non-perforated films maintained high CO_2 and low O_2 inside the pack compared to their counterparts with perforation. This might be due to the headspace conditions/gas composition achieved in the package depending on the interactions between the respiratory activity of the packaged produce and gas transfer through the polymeric matrix and micro-perforations (Lucera *et al.* 2011) [9]. The exception is non-perforated PD-961 film which maintained significantly low CO_2 and high O_2. The highest CO_2 was maintained in non-perforated PP film (40-47%) and lowest in perforated PD-961 (6-8%). Similarly, the highest O_2 was maintained in perforated PD-961 (13-15%) and lowest in non-perforated PE (near to zero %). This might be due to the compatibility and suitability of package film with the packed commodity and storage conditions (Mahajan *et al.* 2016) [4].

Physiological loss in weight (PLW) Changes in the weight loss of MA packed beans during ambient (25.7- 31.1 °C and 21-51% RH) storage conditions are shown in Fig. 2. The weight loss was significantly less in all modified atmosphere packaging pods as compared to unwrapped pods during ambient storage conditions (Dhall *et al.* 2012) [8]. Similar report in cucumber was reported by Elkashif *et al.* 1983 [15]; Homin and Woo 1999. The higher weight loss (20.41%)) in the control fruits after 5 days of storage at ambient conditions which makes the pods unmarketable whereas MA packed beans which showed less than 2% weight loss except in the beans packed with non-perforated PP film. This might be due to the differences in film permeability and barrier properties (Ubhi *et al.* 2014) [11]. Among MA films, beans packed in PE and PD-961 films (both perforated and non-perforated) had low PLW (< 1.5%) than those packed in PP film. The PLW of beans packed in non-perforated PP film was significantly high (4.85%) when compared to those packed in other packaging treatments (< 2%) reflecting the differences in the barrier property and gas permeability properties (Dhall *et al*., 2012; Ubhi *et al*., 2014) [8, 11].

The surface color in terms of Hunter *L**, *a** and *b** values of beans are presented in Table 1. At ambient storage conditions *l** value was minimum in the beans packed in non-perforated PE (44.58) after 2 days and maximum in non-packed beans (52.38) after 6 days. The results show that there is a significant influence of packaging material on the brightness (lightness or darkness) of the produce. -*a** values of beans were significantly higher in Perforated films (PE and PP) and non-packed beans compared to the beans packed in non-perforated (PE and PP) films. The -*a** of beans packed in PD-961 film was the same in both perforated and non-perforated films. -*a** value was the maximum in the non-packed beans (12.04) after 2 days and minimum in non-perforated PE (9.98) after 6 days similarly *b** values of beans were significantly higher in Perforated PP film (27.81) and minimum in the beans packed in non-perforated PD-961 film (25.16). At ambient storage conditions -*b** value was maximum in PP perforated (28.39) after 6 days and minimum PE non-perforated (23.0) after 2 days.

Firmness decreased significantly with increasing storage duration at ambient storage conditions which might be due to the activity of hydrolytic enzymes, cell wall lysing enzymes and senescence process with the progress in storage days (Singh *et al.* 2014) [12]. In the ambient storage conditions, the firmness value was maximum in perforated PD-961 (13.84 kg/cm^2) after 2 days and minimum in non-packed beans (9.4 kg/cm^2) after 6 days (Table 2).

Total protein content at ambient condition shown in Table 2. It was significantly higher (2.266%) in non-packed beans and minimum in the beans packed in perforated PP film (1.477%). At ambient storage conditions, the protein content was maximum in the unpacked beans (2.681%) after 6 days and minimum in perforated PP film (1.384%) after 4 days. Increase of protein content in control is may be due to reduction of moisture contents of pods.

Total antioxidant capacity of beans increased with an increase in storage duration at ambient storage conditions which might be due to the growth characteristics of the pods (Prasad *et al.* 2014) [5]. At room temperature also irrespective of the packaging film the antioxidant capacity of beans increased significantly during 6 days of storage (Table 2). Irrespective

of the storage duration, it was significantly high in non-packed beans followed by perforated PE, PP and PD-961 films compared to their non-perforated counterparts. At ambient conditions among all the treatment combinations total antioxidant capacity value was minimum in the beans packed in PE non-perforated (8.630 mg ascorbic acid equivalence/100g) after 2 days and maximum in non-packed beans (13.930 mg ascorbic acid equivalence/100g) after 6 days. Our results are in line with the findings of Selcuk and Erkan (2015) [16] who reported that packaging affects the total antioxidant capacity of Medlar fruits.

Total phenols of beans after storage at ambient conditions increased slightly irrespective of the packaging method. Irrespective of the storage duration, it was significantly high in non-packed beans (24.96 mg /100g) and minimum in the beans packed in PE non-perforated film (16.99 mg /100g) (table 3). At RT among all the treatment combinations total phenol content was minimum in the beans packed in PE non-perforated (14.81 mg /100g) after 2 days and maximum in non-packed beans (29.25 mg /100g) after 6 days.

The data on the effect of MA packaging on the total chlorophyll content of the French bean pods are presented in table 3. There was a gradual decrease in total chlorophyll content of pods with an increase in storage duration at ambient storage conditions which might be due to its degradation with the progression of storage (Shi *et al.*, 2019). It was significantly high in the beans packed in PP non-perforated film (0.0576 mg /100g) and minimum in the non-packed beans (0.0447 mg /100g). At RT among all the treatment combinations total chlorophyll content was minimum in the non-packed beans (0.0310 mg /100g) after 6 days and maximum in PP non-perforated film (0.0583 mg /100g) after 2 days. Our results collaborate findings of Shi *et al.* (2019) [7].

Table 1: Influence modified atmosphere packaging on the surface colour of French beans stored at ambient conditions (25.7- 31.1 °C and 21-51% RH).

Packeging/ Duration	Hunter Surface colour values														
	L*					a*					b*				
	0 Days	2 Days	4 Days	6 Days	Mean T	0 Days	2 Days	4 Days	6 Days	Mean T	0 Days	2 Days	4 Days	6 Days	Mean T
PE Perforated	47.80	47.92	48.56	49.48	48.65	-12.1	-11.32	-11.26	-10.98	-11.19	25.4	26.44	26.18	26.83	26.48
PE Non- perforated	47.80	44.58	49.84	50.84	48.42	-12.1	-10.86	-10.12	-9.98	-10.32	25.4	23	26.2	26.85	25.35
PP Perforated	47.80	47.1	46.62	48.08	47.27	-12.1	-11.38	-11.54	-11.3	-11.41	25.4	27.3	27.74	28.39	27.81
PP Non- perforated	47.80	47.72	48.38	49.38	48.49	-12.1	-11.46	-11.1	-10.94	-11.17	25.4	25.6	26.5	27.15	26.42
PD Perforated	47.80	47.32	49.86	51.4	49.53	-12.1	-11.6	-11	-10.64	-11.08	25.4	24.36	27.24	27.89	26.5
PD Non- perforated	47.80	45.99	49.2	50.6	48.6	-12.1	-11.82	-11.54	-11.14	-11.5	25.4	25.24	24.8	25.45	25.16
Control (Non-packed)	47.80	52.9	53.2	52.38	52.83	-12.1	-12.04	-11.36	-10.8	-11.4	25.4	25.58	26.72	26.16	26.15
Mean D	47.80	47.65	49.38	50.31		-12.1	-11.5	-11.13	-10.83		25.4	25.36	26.48	26.96	
	F test	SE	CD			F test	SE	CD			F test	SE	CD		
D	**	1.347	3.55			**	0.258	0.679			**	0.61	1.609		
T	*	0.882	2.324			**	0.169	0.444			**	0.4	1.053		
DxT	NS	3.012	7.938			NS	0.576	1.518			NS	1.365	3.598		

F test @ 1% : **
F test @ 5% : *
CD @ 1%

Table 2: Influence modified atmosphere packaging on the firmness, protein and total antioxidant capacity of French bean stored at ambient conditions (25.7- 31.1 °C and 21-51% RH).

Packaging/Duration	Firmness (kg/cm^2)					Protein (%)					Total antioxidant capacity (mg ascorbic acid equivalence /100g)				
	0 Days	2 Days	4 Days	6 Days	Mean T	0 Days	2 Days	4 Days	6 Days	Mean T	0 Days	2 Days	4 Days	6 Days	Mean T
PE Perforated	15.030	13.560	13.180	12.226	13.499	1.669	1.938	2.213	2.303	2.030	8.227	9.420	10.950	13.087	10.421
PE Non- perforated	15.030	13.104	12.568	Spoiled	13.567	1.669	1.723	1.782	Spoiled	1.725	8.227	8.630	10.160	Spoiled	9.006
PP Perforated	15.030	12.234	11.682	11.402	12.587	1.669	1.247	1.384	2.167	1.477	8.227	9.157	10.687	12.820	10.223
PP Non- perforated	15.030	11.644	11.232	Spoiled	12.635	1.669	1.851	2.038	Spoiled	1.853	8.227	8.897	10.420	Spoiled	9.181
PD Perforated	15.030	13.842	13.662	12.756	13.823	1.669	1.849	2.034	2.124	1.917	8.227	9.660	11.187	13.323	10.599
PD Non- perforated	15.030	13.252	12.864	Spoiled	13.715	1.669	1.928	2.193	Spoiled	1.930	8.227	9.940	11.470	Spoiled	9.879
Control (Non-packed)	15.030	12.656	12.144	9.400	12.308	1.669	2.127	2.591	2.681	2.266	8.227	10.263	11.793	13.930	10.094
Mean D	15.030	12.899	12.476	11.446		1.669	1.809	2.034	2.319		8.227	9.424	10.952	13.290	
	F test	SE	CD			F test	SE	CD			F test	SE	CD		
D	**	0.177	0.465			**	0.029	0.078			**	0.214	0.570		
T	**	0.134	0.351			**	0.022	0.059			**	0.162	0.431		
DxT	**	0.355	0.930			**	0.059	0.157			**	0.428	1.141		

F test @ 1% : **
F test @ 5% : *
CD @ 1%

Table 3: Influence modified atmosphere packaging on total phenols and total chlorophyll capacity of French bean stored at ambient conditions (25.7- 31.1 °C and 21-51% RH).

Packaging/Duration	Total phenols (mg/100g)					Total chlorophyll content (mg/100g)				
	0 Days	2 Days	4 Days	6 Days	Mean T	0 Days	2 Days	4 Days	6 Days	Mean T
PE Perforated	20.329	20.493	21.643	23.073	21.384	0.0647	0.0500	0.0427	0.0353	0.0482
PE Non- perforated	20.329	14.812	15.855	Spoiled	16.998	0.0647	0.0413	0.0330	Spoiled	0.0463
PP Perforated	20.329	20.725	21.768	23.217	21.510	0.0647	0.0560	0.0473	0.0417	0.0524
PP Non- perforated	20.329	18.203	19.246	Spoiled	19.259	0.0647	0.0583	0.0497	Spoiled	0.0576
PD Perforated	20.329	21.739	22.783	24.232	22.271	0.0647	0.0537	0.0453	0.0390	0.0507
PD Non- perforated	20.329	21.797	22.841	Spoiled	21.656	0.0647	0.0513	0.0427	Spoiled	0.0529
Control (Non-packed)	20.329	26.754	27.797	29.246	24.960	0.0647	0.0460	0.0373	0.0310	0.0447
Mean D	20.329	20.646	21.705	23.507		0.0647	0.0510	0.0426	0.0368	
	F test	SE	CD			F test	SE	CD		
D	**	0.3732	0.9951			**	0.0015	0.0040		
T	**	0.2821	0.7522			**	0.0011	0.0030		
DxT	**	0.7463	1.9901			**	0.0030	0.0080		

F test @ 1%: **
F test @ 5%: *
CD @ 1%

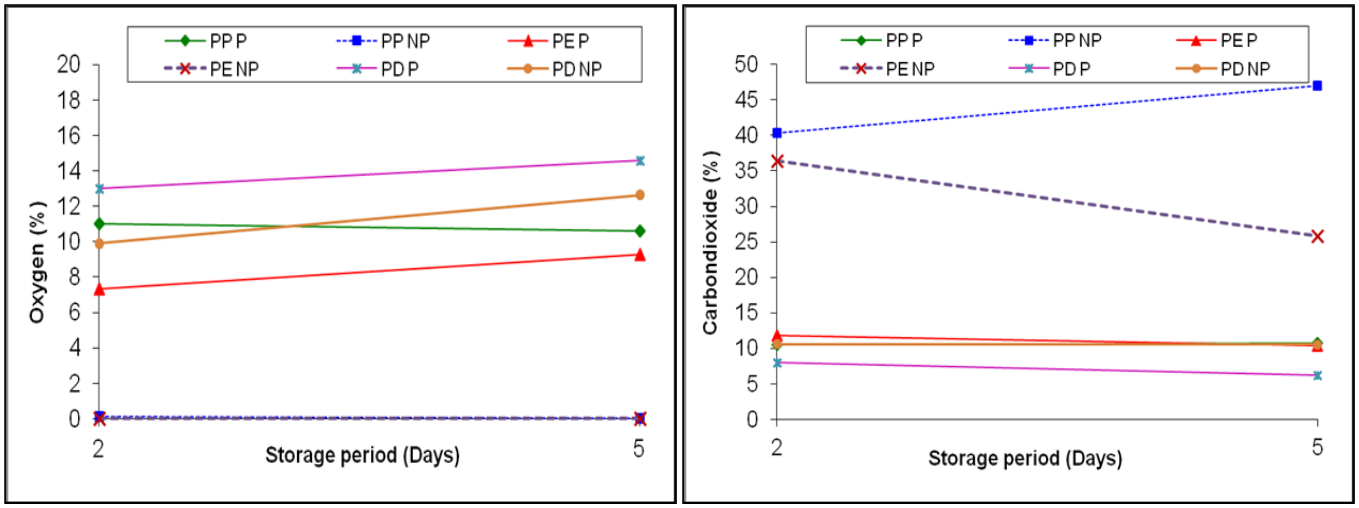

Fig 1: Effect of various MA packaging on internal gas composition of French bean stored at ambient condition

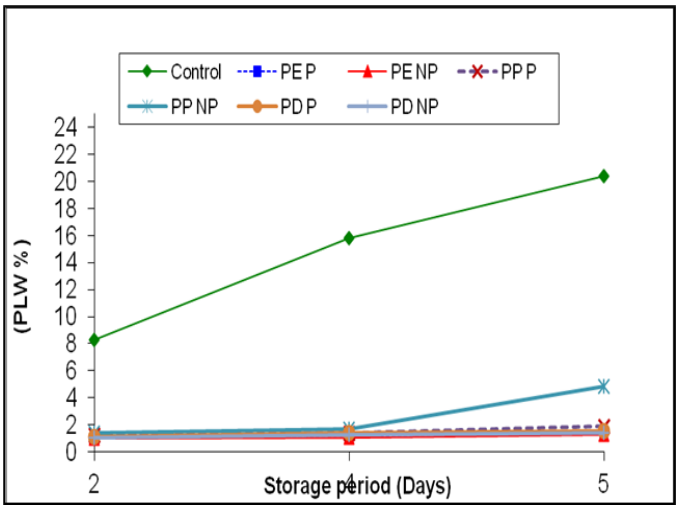

Fig 2: Effect of MAP on Physiological loss of weight of French bean stored at ambient condition

Conclusion

Packaging of French bean pods in film (MAP) was found to be beneficial because it helped to extend the shelf life without deterioration in physiological and biochemical quality of pods. Among the modified atmosphere packaging PD 961 films showed better result among all films specially PD 961films non-perforated reduced the weight loss, retained the firmness, color and biochemical quality of pods.

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