Indian Journal of Agricultural Sciences **86** (6): 738–42, June 2016/Article
https://doi.org/10.56093/ijas.v86i6.58845

Effect of packaging and storage environments on quality and shelf-life of bell pepper (*Capsicum annuum*)

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Received: 3 November 2015; Accepted: 21 January 2016

ABSTRACT

Bell pepper (*Capsicum annuum* L.) fruits of cultivar Indra were harvested at bright green colour stage and packed in different packaging films, viz. heat shrinkable film (15μ), cling film (15μ) and low density polyethylene film (LDPE 25μ). After packaging, the fruits were stored under two different conditions, i.e. super-market conditions (18-20°C; 90-95% RH) and ordinary market conditions (28-30°C; 60-65% RH). The shrink and cling film significantly checked the loss in weight, firmness and decay incidence and maintained various qualities attributes like ascorbic acid, chlorophyll content and overall sensory quality of the fruits during shelf-life better than unwrapped control fruits. The in-pack bell pepper in shrink and cling film created a suitable headspace environment with desired level of O_2 and CO_2 concentrations, which resulted in a better retention of freshness of the vegetable for its marketability. On the other hand, LDPE film accumulated very high level of CO_2, which led to formation of fermenting odour and decay of fruits. The data revealed that shrink and cling film proved quite effective in prolonging the shelf-life of bell pepper fruits for 10 and 7 days under super market conditions and ordinary market conditions, respectively, as against 5 and 2 days only in case of unpacked control fruits.

Key words: Bell pepper, Packaging films, Quality, Storage conditions

Bell pepper (*Capsicum annuum* L.) is an important commercial vegetable crop grown in India. It is a nutritious vegetable and is known to contain biologically active compounds such as antioxidants, vitamins and other phytochemicals (Marin *et al*. 2004). Bell pepper is a perishable crop and is liable to spoilage like all fruits and vegetables due to inadequate packaging techniques and improper storage conditions. The major post-harvest problem with this crop are excessive softening due to water loss that lead to shriveling, wilting and pathogenic disorders which severely reduce the quality and acceptability of the product (Rao *et al.* 2011). Generally, the growers and traders keep perishables under ambient conditions, where the quality of produce deteriorates rapidly.

The concept of super market is fast gearing up in Indian markets and selected Indian and exotic vegetable and fruits are being displayed in the super retail out-lets for attracting upper-end consumers. Packaging is an inevitable component for assuring the safe handling and delivery of fresh produce from producer to the consumer (Opara and Mditshwa 2013). One of the techniques is widely used in packaging of fruits and vegetables is modified atmosphere packaging (MAP). Packing of vegetables in polymeric films creates modified atmospheric conditions around the produce inside the package allowing lower degree of control of gases and can interplay with physiological processes of commodity resulting in reduced rate of respiration, transpiration and other metabolic processes of fresh produce (Chitravathi *et al*. 2015, Soltani *et al*., 2016). Thus, the aim of this study was to investigate the effects of different packaging films on post-harvest performance of bell pepper under super-market conditions (SMC) and ordinary market conditions (OMC).

MATERIALS AND METHODS

The fruits of bell pepper cv. Indra grown under naturally ventilated poly-house were harvested at commercial maturity. Three types of packaging films commercially available in the market, viz. heat shrinkable film (15 μ), cling film (15 μ) and low density polyethylene film (LDPE, 25 μ) were used for packaging of bell pepper fruits in paper molded trays (22 cm × 13 cm). The fruit were packed in trays (6 fruits in each tray) and tightly sealed with different packaging films. However, the shrink film wrapped packs were passed through a shrink wrapping machine (Model BS-450, Samrath Engineers, India) at 165ºC

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for 10 seconds. Thereafter, the packed fruits as well as control (non-packed) fruits were stored at 18-20°C and 90-95% RH under super market conditions (SMC) and 28-30°C and 60-65% RH under ordinary market conditions (OMC).

The physiological loss in weight (PLW) of stored fruit was calculated by subtracting final weight from the initial weight of the fruits and expressed in per cent. Firmness of fruit was measured with the help texture analyser (Model TA-HDi, Stable Micro System, England). The bell pepper fruit was kept on the platform of the instrument and compressed to a distance of 5 mm with 75 mm diameter compression probe (p/75). The results were expressed as g force of compression. The decay percentage of treated and untreated fruit was calculated as the number of decayed fruit divided by initial number of all fruit multiplied by hundred. The overall organoleptic rating of the fruit was done by a panel of 10 judges by using 9-point Hedonic scale (Amerine *et al.* 1965). The ascorbic acid and chlorophyll content were estimated as per standard procedure (AOAC 2005). The in-package gaseous composition (CO_2 and O_2 conc.) of sealed fruit package was monitored at periodic intervals with the help of portable Head Space Gas Analyzer (Model: GS 3/P, Make: Systech Instruments, UK). A sample of 0.5 ml was automatically withdrawn from the headspace atmosphere with a pin-needle connected to the injection system. Gases were analyzed with inbuilt sensors for CO_2 and O_2. The instrument was calibrated towards air.

The experiment consisted of 4 treatments and 3 storage intervals for SMC experiment and 4 treatments and 4 storage intervals for OMC experiment. Both experiments were laid out in completely randomized design with three replications for each treatment and each storage interval. Each replication was comprised of 6 fruit. In total there were 216 fruit in SMC experiment and 288 fruit in OMC experiment. The experiments were conducted for two seasons (2012-13 and 2013-14). The data were pooled for both the seasons and analyzed for variance by using the SAS (V 9.3, SAS Institute Inc., Cary, NC, USA) package.

RESULTS AND DISCUSSION

The per cent PLW, in general, increased with the advancement of storage period rather slowly in the beginning but at a faster pace as the storage period advanced (Table 1). It was noticed that shrink film packed fruits registered the lowest average PLW (3.4 %) and ranged between 2.2 to 4. 7 from 5 to 15 days of storage as compared to control where PLW was found to be the highest and ranged between 3.6 to 13.2% under SMC. Similarly under OMC, the lowest mean PLW (1.1%) was observed in fruits packed in shrink film and the highest (14.5%) was observed in control fruits. Water loss is a critical factor in shortening the storage life and increasing deterioration of many fruit during storage, which reduce both market value and consumer acceptability. The reduction in weight loss in film-packed fruits is attributed to restricted respiratory

Table 1 Effect of different packaging films on physiological loss in weight (PLW), firmness and decay of bell pepper under super and ordinary market conditions

Treatment	Super market conditions				Ordinary market conditions				
	5 days	10 days	15 days	Mean	2 days	4 days	7 days	10 days	Mean
PLW (%)									
Shrink film	2.2	3.4	4.7	3.4	0	0.9	1.5	2.1	1.1
Cling film	2.5	3.7	5.3	3.8	0	1.3	2.0	3.1	1.6
LDPE film	2.7	6.2	10.1	6.3	0	1.0	3.2	5.9	2.5
Control	3.6	8.0	13.2	8.3	3.6	8.2	19.3	27.0	14.5
Mean	2.8	5.3	8.3		0.9	2.9	6.5	9.5	
LSD (P=0.05)	Treatment:0.29; storage=0.26; T × S= 0.51				Treatment:0.24; storage=0.24 ; T × S = 0.48				
Firmness (g force)									
Shrink film	1364	1331	1303	1333	1346	1323	1264	1200	1283
Cling film	1343	1313	1272	1309	1334	1314	1252	1182	1271
LDPE film	1317	1275	1147	1246	1318	1288	1224	1161	1248
Control	1276	1142	1016	1145	1285	1151	1119	1061	1154
Mean	1325	1265	1185		1321	1269	1215	1151	
LSD (P=0.05)	Treatment:3.05; storage=2.65; T × S = 5.29				Treatment:3.93; storage=3.93; T × S = 7.85				
Decay (%)									
Shrink film	0.0	0.0	3.0	1.0	0	0	0	0	0.0
Cling film	0.0	0.0	4.0	1.3	0	0	0	0	0.0
LDPE film	2.0	9.0	16.5	9.2	0	5.5	10.5	16.5	8.1
Control	0.0	4.0	9.5	4.5	0	0	5.0	10.0	3.8
Mean	0.5	3.3	8.3		0	1.4	3.9	6.6	
LSD (P=0.05)	Treatment:0.19; storage=0.16; T × S = 0.32				Treatment:0.97; storage=0.97; T × S = 1.94				

Results represent pooled data of two seasons during 2012 and 2013. Each value represents means for six replicates (3 per season).

process of fruits inside the packaging films (Ben Yehoshua 1985). The positive role of shrink film in reducing the PLW of cucumber has been reported by Rao *et al*. (2000).

The firmness, in general, followed a declining trend commensurate with advancement in storage period (Table 1). The fruits packed in shrink packaging film maintained the highest average firmness (1 333 g force) and control fruits registered the lowest mean firmness (1 145 g force) under SMC. The firmness of fruits in shrink film declined slower and steadily and ranged between 1 364 to 1 303 g force from 5 to 15 days of storage interval, whereas in case of control fruits, the decline in firmness was found to be abrupt and sharp and ranged between 1276 to 1016g force, thereby leading to excessive softening and shrivelling of fruits. Under OMC, the shrink film packed fruits recorded the highest average firmness (1 283 g force) and ranged between 1 346 to 1 200 g force from 2 to 10 days of storage, whereas, in control, the fruits experienced a faster loss of firmness during storage and ranged between 1 285 to 1 061 g force with the average fruit firmness of 1 154 g force. The texture, in particular, crispness of pepper is an important quality attribute to the consumer. Flaccidity development appears to be directly associated with water loss in pepper (Lownds *et al.*1994). The lower rate of softening in packed fruits might be due to the effect of the films in lowering the rate of respiration, delaying the ripening process and reduction in moisture loss (Majidi *et al*. 2014). The maintenance of higher firmness with heat shrinkable packaging film was noticed in broccoli (Yettela *et al*. 2010).

The decay of bell pepper fruit under both storage conditions was found to be lower in shrink and cling packaging films (Table 1). Under SMC, the average fruit decay was observed to be 1.0 and 1.3% in shrink and cling films, whereas in LDPE film the level of decay was quite high (9.2%). Similarly, under OMC the shrink and cling films recoded negligible fruit decay. On the other hand the level of decay was the highest in LDPE film (8.1%). In the present studies, the LDPE film packed fruits recorded the highest spoilage of fruits, even higher than unpacked control fruits under both the storage conditions. The occurrence of higher decay incidence in LDPE film might be due to accumulation of excessive water vapour inside the package, because of restricted movement of water through the film (Yekula *et al*. 2013). The lower decay incidence in modified atmosphere packaged leafy vegetables was confirmed by Zenoozian (2011).

The ascorbic acid of bell pepper fruits experienced a linear decline as the storage period advanced (Table 2). It was noticed that shrink film packed fruits showed higher ascorbic acid over the other treatments throughout the storage period and recorded mean ascorbic acid (20.8 mg %)

Table 2 Effect of different packaging films on ascorbic acid, chlorophyll and sensory quality of bell pepper under super and ordinary market conditions

Treatment	Super market conditions				Ordinary market conditions				
	5 days	10 days	15 days	Mean	2 days	4 days	7 days	10 days	Mean
Ascorbic acid (mg per 100g)									
Shrink film	23.3	20.7	18.4	20.8	25.0	22.7	18.8	14.5	20.3
Cling film	22.2	20.3	17.4	20.0	24.3	21.6	17.9	13.7	19.4
LDPE film	21.9	17.5	14.9	18.1	23.3	19.8	16.3	10.6	17.5
Control	20.8	16.2	13.5	16.8	21.8	18.0	13.8	9.3	15.7
Mean	22.2	18.7	16.1		23.6	20.5	16.7	12.0	
LSD (P=0.05)	Treatment:0.37; storage=0.32; T × S = 0.65				Treatment:0.94; storage=0.94; T × S = NS				
Chlorophyll (mg/100 g)									
Shrink film	0.075	0.066	0.059	0.067	0.073	0.067	0.049	0.031	0.055
Cling film	0.071	0.060	0.050	0.060	0.069	0.061	0.043	0.028	0.050
LDPE film	0.059	0.048	0.038	0.048	0.063	0.050	0.037	0.023	0.043
Control	0.048	0.033	0.019	0.033	0.057	0.043	0.029	0.019	0.037
Mean	0.063	0.052	0.042		0.066	0.055	0.040	0.025	
LSD (P=0.05)	Treatment:0.005; storage=0.004; T × S = NS				Treatment:0.003; storage=0.003; T × S = NS				
Sensory quality									
Shrink film	7.8	7.5	6.7	7.3	7.8	7.4	7.2	7.2	7.4
Cling film	7.6	7.2	6.2	7.0	7.7	7.3	7.0	6.4	7.1
LDPE film	7.3	6.4	5.7	6.5	7.5	7.0	6.3	6.0	6.7
Control	7.0	6.2	5.3	6.2	7.2	6.8	6.0	5.0	6.3
Mean	7.4	6.8	6.0		7.6	7.1	6.6	6.2	
LSD (P=0.05)	Treatment:0.44; storage=0.44; T × S = NS				Treatment:0.50; storage=0.49; T × S = NS				

Results represent pooled data of two seasons during 2012 and 2013. Each value represents means for six replicates (3 per season).

followed by cling film packed fruits (20 mg %). The control fruits showed the lowest mean ascorbic acid (16.8 mg %) under SMC. The ascorbic acid content in shrink and cling film packed fruits, ranged between 23.3 to 18.4 and 22.2 to 17.4 mg %, respectively, from 5 to 15 days of storage as compared to control, where ascorbic acid was found to be the lowest and ranged between 20.8 to 13.5 mg %. Under OMC, the highest mean ascorbic acid content (20.3 mg %) was observed in shrink film packed fruits and it was closely followed by cling film packed fruits (19.4 mg %). On the other hand, the lowest mean ascorbic acid (15.7 mg %) was observed in unpacked control fruits. The decrease in ascorbic acid during storage may be due to the oxidation of L-ascorbic acid into dehydroascorbic acid (Mapson 1970). The influence of packaging films on maintaining higher ascorbic acid content in okra has also been reported by Babarinde and Fabunmi (2009).

The chlorophyll content of the bell pepper fruit declined during storage irrespective of different packaging films (Table 2). However, the shrink film packed fruits maintained the highest chlorophyll content (0.067, 0.055 mg/100g) followed by cling film (0.060, 0.037 mg/100g). The control fruits registered chlorophyll (0.033, 0.037 mg/100g) under both the storage conditions. The decrease in chlorophyll during storage is expected due to chlorophyll degradation as a result of chlorophyllase enzyme activity leading to senescence (Gong and Mattheis 2003). The maintenance of green colour in modified atmosphere packaged cucumber during storage was reported by Dhall *et al.* (2012).

A gradual decline in sensory score was noticed in shrink and cling film packed fruits as compared to control, where decline was sharp under both the storage conditions (Table 2). The maximum average sensory score was shown by fruits packed in shrink film (7.3 and 7.4) followed by cling film (7.0 and 7.1) under both the marketing conditions. The control fruits registered the minimum sensory score (6.2 and 6.3). Successful control of respiration of vegetable and fruit by modified atmosphere packaging (MAP) can result in maintaining high organoleptic quality of produce. Shrink film packed peach fruits successfully maintained freshness, crispness and aroma during storage (Mahajan *et al.* 2015).

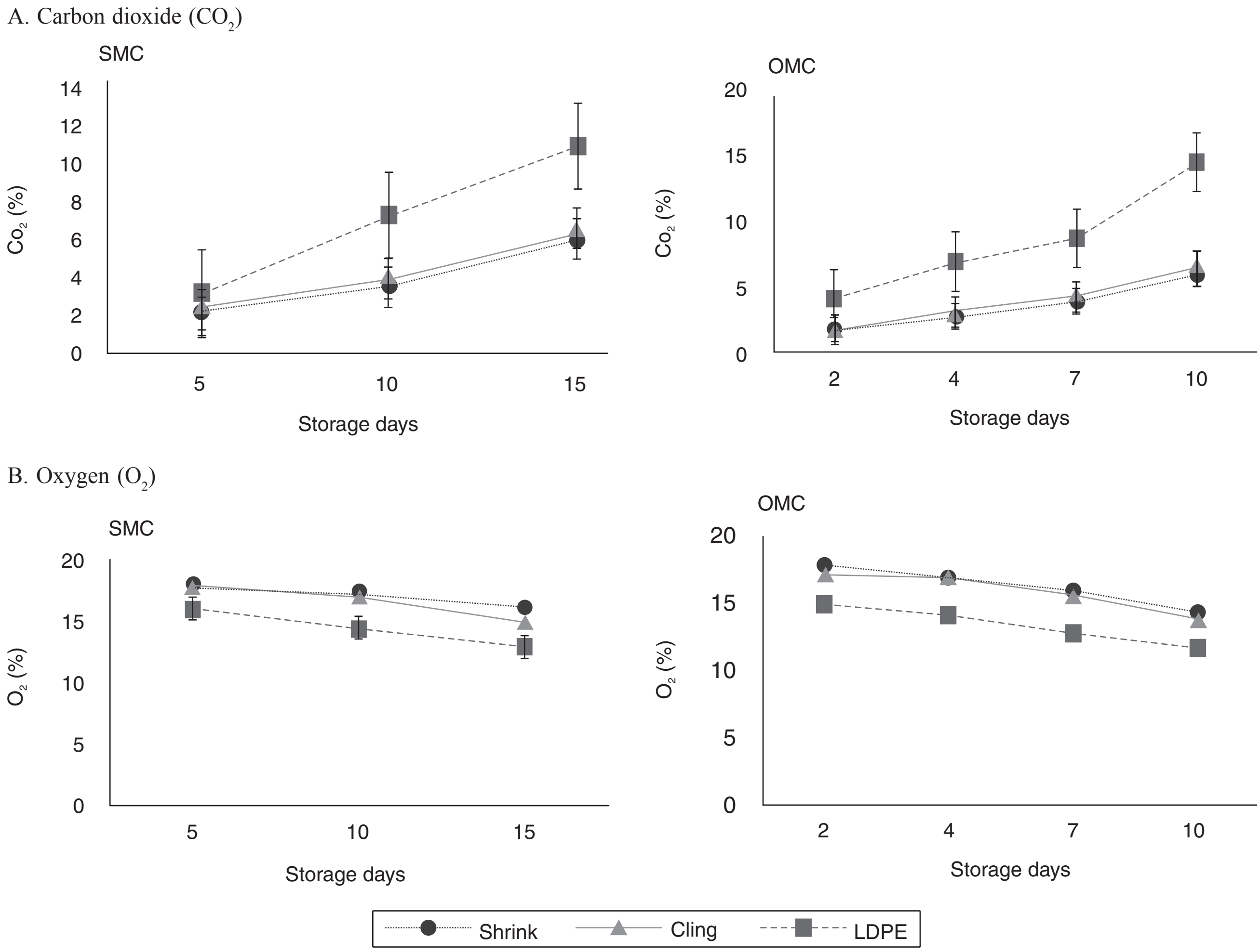

Fig 1 Effect of different packaging films on CO_2 level (A) and O_2 level (B) of bell pepper under super market condition (SMC) and ordinary market conditions (OMC). Results represent pooled data of two seasons during 2012 and 2013. Vertical bars represent ± S.E of means for six replicates (3 per season)

During storage a decrease in O_2 and an increase in CO_2 levels occurred for passive modified atmospheric packaging (MAP) in all the three films under SMC as well as under OMC (Fig 1). However, gaseous composition in-side the package was significantly different depending on the type of film used. The heat shrinkable packaging film registered a gradual increase in CO_2 and decrease in O_2 concentration within the package, whereas LDPE film recorded a sharp increase in CO_2 and decrease in O_2 concentration inside the package. Reduced respiration rate in shrink packed zucchini due to impressive gas barrier properties of heat shrinkable film was reported by Megias *et al*. (2015). Modification of the atmosphere around the fresh produce in the package made of flexible plastic films has been confirmed (Zagory and Kader 1998).

Packaging of bell pepper fruits in paper molded trays followed by wrapping with heat shrinkable film or cling film seems to hold promise in improving the shelf-life and maintaining the quality under super market and ordinary market conditions by 10 and 7 days, respectively, as against 5 and 2 days only in case of unpacked control. This technology can be helpful in minimizing the post-harvest losses of bell pepper during retail marketing.

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