

## Effect of modified atmospheric packing on the quality and shelf-life of apple (*Malus domestica*)

R R SHARMA<sup>1</sup>, D SINGH<sup>2</sup>, RAJBIR SINGH<sup>3</sup>, D B SINGH<sup>4</sup> and V K SAHARAN<sup>5</sup>

Central Institute of Post Harvest Engineering and Technology, Abohar, Punjab 152 116

Received: 22 June 2009; Accepted: 25 December 2009

### ABSTRACT

A study was conducted during 2005–06 to elucidate the effect of thickness and level of perforations of low-density polyethylene film bags on the quality and shelf-life of apples at room temperature. Fully mature 'Royal Delicious' apples (*Malus domestica* Borkh) were packed in low-density polyethylene film bags with different thicknesses (100, 150 and 200  $\mu$ ) having variable perforations (0, 0.5, 1.0, 1.5, 2.0%), or not packed at all (control), and stored at ambient conditions (22–28°C and 52–68% relative humidity). The observations on physiological loss in weight, and quality parameters, like fruit firmness (N), total soluble solids (%), titratable acidity (%), total sugars (%), ascorbic acid content (mg/100 g pulp) and sensory evaluation were recorded before packaging and at 10 days interval up to 40 days after packaging. Results of the study revealed that physiological loss in weight (%), increased with the increase in storage period, and level of perforation (0.0 to 2.0%) and correspondingly, fruit firmness (N) and extractable juice (%) decreased. The thickness of the low-density polyethylene bags did not influence the physiological loss in weight and decay loss significantly but perforations did so. Similarly, fruit firmness and juice recovery were influenced both by the thickness and perforations of the low-density polyethylene films. All quality parameters, like TSS, total sugars, and ascorbic acid content were influenced by the thickness and perforation of the films invariably but the acidity remain unaffected. However, best quality apples were obtained with 150  $\mu$  low-density polyethylene film bags at 1.0% perforation.

**Key words:** Apple, Fruit quality, Low-density polyethylene film, Modified atmosphere packing

Apple (*Malus domestica* Borkh.) is the most important temperate fruit of India. It is mainly cultivated in Jammu and Kashmir, Himachal Pradesh, Uttarakhand and to some extent in north-eastern states. Mostly Delicious varieties are grown which mature during August-September and to meet the demand of the consumers for a larger time of the year, we need to extend the shelf-life for a longer period (Chadha and Awasthi 2005). For this, different storage techniques like cold storage, controlled atmosphere storage and hyobaric storage etc. are used with which it can be stored for 5–6 months (Sharma *et al.* 2009). However, these facilities are very costly and sometimes become out of the reach of the marginal farmers, thus for short-term storage, we need some cheaper facilities.

To overcome these problems, modified atmosphere packaging of the produce could be one of the most viable alternatives for short-term storage, especially when cold storage facilities are not available. For this, different types of polyethylene films have been used and recommended by the scientists for several fruits (Ladaniya 2003). Such studies in apple have not been conducted in India, although, Batagurki *et al.* (1995) have strongly recommended. Hence, it becomes imperative to go for plastic film packaging of apples for extending their shelf-life and quality in developing countries like India.

### MATERIALS AND METHODS

These studies were conducted at Central Institute of Post Harvest Engineering and Technology, Abohar during 2005 and 2006. Fully mature apples of 'Royal Delicious' cultivar were harvested from a private orchard at Kullu (Himachal Pradesh) and transported to Abohar (Punjab). After sorting and grading, 1 kg apples were either packed in low-density polyethylene film bags of 100, 150 and 200  $\mu$  thickness, having variable perforation (0, 0.5, 1.0, 1.5, 2.0%), or not packed at all (control), and stored at ambient conditions (22–

<sup>1</sup>Senior Scientist (email: rrs\_fht@rediffmail.com), Division of Post Harvest Technology, IARI, New Delhi 110 012, <sup>2</sup>Senior Scientist (email: dinesh\_ciphet@yahoo.co.in), Division of Plant Pathology, IARI, New Delhi 110 012.

<sup>3,4</sup>Senior Scientist (email: rajbir\_singh1103@rediffmail.com, deshbsingh@yahoo.co.in), <sup>5</sup>Technical Officer (email: vinodsaharan.2008@rediffmail.com).

28°C and 52–68% relative humidity). Un-packed apples (control) were kept in plastic baskets. Each treatment combination consisted of 5 packs having 5 replications. Initial records of fruit weight (g), fruit firmness (N), juice recovery (%), total soluble solids (%), titratable acidity (%), total sugars (%) and ascorbic acid content (mg/100 g pulp) etc., were recorded before packaging. After packing, observations on physiological loss in weight (%), fruit firmness (N), juice recovery (%), and quality parameters were recorded at 10 days interval. For recording all these parameters, 5 fruits were randomly selected from a single lot, which was replicated 5 times.

Fruit firmness was recorded by measuring firmness force with the help of texture analyzer and expressed as N (Newton) (1N=kg/cm<sup>2</sup>×9.807). Total soluble solids (%) were recorded with hand refractometer and titratable acidity by titrating known amount of fruit juice with 0.1N NaOH solution using phenolphthalein indicator. Total sugars (%) and ascorbic acid (mg/100 g pulp) were also determined by following standard procedures. Sensory evaluation of stored apples was conducted by a panel of 5 trained experts, and represented on hedonic scale (0–9).

The experiment was laid-out in factorial complete randomized design and the 2 years data obtained from different parameters were pooled. The analysis of data was done according to standard procedures.

RESULTS AND DISCUSSION

*Effects on physiological loss in weight*

The data indicated that there was an increase in physiological loss in weight with the increase in perforations (0.0 to 2.0%) and storage period (Table 1). However, this increase was quite higher in low-density polyethylene film bags having more perforations (2.0%) than those no perforations or those, which were not packed at all (control). Apples in non-perforated low-density polyethylene film bags exhibited very high per cent physiological loss in weight at every period of observation, and after 40 days storage, un-packed fruits had the highest physiological loss in weight (18.2%). Irrespective of perforation, 100 µ low-density polyethylene film bags had lowest physiological loss in weight (7.3%) and unpacked fruits had the highest (11.4%). Irrespective of packing, un-perforated bags (0.0% perforation) had lowest physiological loss in weight (6.1%),

Table 1 Effect of low-density polyethylene film bag thickness and its perforations on the physiological loss in weight, fruit firmness and juice recovery in apple at room temperature

Low-density polyethylene film bag thickness (µ)	Perforation (%)	Days after storage																
		Physiological loss in weight (%)					Fruit firmness (N)					Juice recovery (%)						
		Day 10	Day 20	Day 30	Day 40	Mean	Day 10	Day 20	Day 30	Day 40	Mean	Day 10	Day 20	Day 30	Day 40	Mean		
100	0	1.9	5.6	6.8	11.3	6.4	67.5	63.0	53.0	44.5	57.0	67.2	64.7	55.8	51.6	59.8		
	0.5	2.3	5.7	7.6	10.7	6.6	67.2	62.5	53.4	44.1	56.8	67.0	64.5	55.0	51.4	59.7		
	1.0	2.6	5.7	8.7	10.8	7.0	67.0	61.2	53.4	44.0	56.4	66.6	64.0	55.0	51.4	59.3		
	1.5	5.7	6.9	9.3	11.8	8.4	67.0	60.4	53.0	43.5	56.0	66.5	64.0	55.0	51.2	59.2		
	2.0	5.8	7.0	9.5	11.9	8.6	65.5	58.5	51.5	42.0	54.4	63.5	62.5	54.2	50.2	57.6		
150	0	1.8	5.2	6.9	10.5	6.1	68.5	62.0	54.2	45.5	57.6	69.5	66.7	56.5	53.5	61.6		
	0.5	2.2	5.8	7.2	10.6	6.5	67.3	60.5	53.2	43.5	56.1	69.2	66.0	56.5	53.0	61.2		
	1.0	2.5	5.9	7.8	10.7	6.7	66.4	59.8	51.8	43.4	55.4	68.5	65.4	56.0	53.0	60.7		
	1.5	4.5	7.2	9.2	12.8	8.4	65.4	59.0	51.2	43.0	54.7	67.4	65.0	55.0	52.1	59.9		
	2.0	4.8	7.7	10.2	12.5	8.8	64.2	60.1	51.0	41.0	54.1	65.4	64.2	55.4	51.0	59.0		
200	0	1.9	4.5	6.8	10.3	5.9	69.5	62.4	53.2	43.5	57.2	69.1	66.4	61.2	52.8	62.4		
	0.5	2.2	4.6	7.2	11.2	6.3	67.3	60.5	53.2	43.5	56.1	69.0	66.2	61.0	52.0	62.1		
	1.0	2.4	6.2	9.8	12.0	7.6	65.9	59.8	51.6	43.4	55.2	69.2	65.4	60.2	51.7	59.1		
	1.5	4.5	7.6	10.0	11.9	8.5	65.8	59.3	51.4	43.1	54.9	68.7	65.0	59.8	51.2	61.2		
	2.0	6.2	8.5	10.2	12.6	9.4	64.4	60.5	51.6	41.2	54.5	67.4	63.5	58.9	50.4	60.0		
Un-packed (control)		6.7	9.2	11.3	18.2		62.5	50.5	36.2	26.2		62.1	58.3	55.4	47.5			
Mean		3.2	6.5	8.7	11.2		66.6	60.9	52.4	45.2		67.6	64.9	57.0	51.8			
Means for thickness	100 µ=7.4, 150 µ = 7.3, 200 µ = 7.5, control = 11.4						100 µ =56.1, 150 µ = 55.6, 200 µ = 55.6, control =35.1						100 µ =59.1, 150 µ = 60.1, 200 µ = 61.0, control = 55.8					
Means for perforation	0 = 6.1, 0.5 = 6.5, 1.0 = 7.1, 1.5 = 8.4, 2.0 = 8.9						0 = 57.3, 0.5 = 56.3, 1.0 = 55.7, 1.5 = 55.2, 2.0 = 54.3						0 = 61.3, 0.5 = 61.0, 1.0 = 59.7, 1.5 = 60.1, 2.0 = 58.0					
CD (P = 0.05)	Thickness (T) = 0.8, perforation (P) = 0.5, T×P = 1.3, storage period (S) =0.8, T×P×S= 4.5						Thickness (T) = 0.8, perforation (P) = 1.5, T×P = 3.3, storage period (S) =3.2, T×P×S= 5.3						Thickness (T) = 1.0, perforation (P) = 0.1.2, T×P = 1.8, storage period (S) = 1.2, T×P×S= 4.6					

Table 2 Effect of low-density polyethylene film bag thickness and its perforation on fruit quality of apples under ambient conditions

Low-density polyethylene film bag thickness (µ)	Days after storage																									
	Perforation (%)				Total sugars (%)				Acidity (%)				Ascorbic acid (mg/100 g pulp)													
	Day 10	Day 20	Day 30	Day 40	Day 10	Day 20	Day 30	Day 40	Day 10	Day 20	Day 30	Day 40	Day 10	Day 20	Day 30	Day 40										
100	0	9.6	10.2	10.4	10.4	10.4	10.4	10.2	7.6	8.9	9.2	9.3	8.8	1.14	1.13	1.12	1.12	1.12	1.12	1.12	1.12	2.65	2.50	2.43	2.24	2.46
	0.5	9.8	10.3	10.4	10.4	10.4	10.4	10.2	7.8	9.3	9.4	9.4	9.0	1.15	1.14	1.12	1.12	1.13	1.13	1.13	1.13	2.72	2.60	2.50	2.32	2.54
	1.0	10.0	11.3	11.5	11.6	11.6	11.1	11.1	8.2	9.6	9.8	10.1	9.4	1.22	1.20	1.19	1.19	1.20	1.20	1.20	1.20	2.78	2.70	2.62	2.42	2.63
	1.5	10.2	11.2	11.5	11.5	11.5	11.1	11.1	8.2	9.6	9.9	10.2	9.5	1.22	1.20	1.19	1.19	1.20	1.20	1.20	1.20	2.78	2.66	2.58	2.40	2.62
	2.0	10.0	11.0	11.4	11.4	11.4	11.0	11.0	8.3	9.6	9.8	10.3	9.5	1.20	1.18	1.15	1.15	1.17	1.17	1.17	1.17	2.78	2.50	2.30	2.12	2.43
150	0	9.7	11.2	11.7	11.8	11.8	11.1	11.1	7.9	8.9	9.5	9.6	9.5	1.16	1.14	1.14	1.13	1.14	1.14	1.14	1.14	2.65	2.50	2.43	2.24	2.46
	0.5	9.8	11.5	11.8	12.0	12.0	11.3	11.3	8.2	9.6	10.8	11.2	10.0	1.18	1.15	1.14	1.14	1.15	1.15	1.15	1.15	2.70	2.58	2.48	2.36	2.53
	1.0	10.4	13.5	13.7	13.5	13.5	12.8	12.8	8.3	9.9	10.5	10.6	9.8	1.24	1.20	1.18	1.16	1.19	1.19	1.19	1.19	2.79	2.74	2.68	2.52	2.68
	1.5	10.2	13.3	13.5	13.6	13.6	12.7	12.7	8.2	9.3	9.4	9.6	9.1	1.22	1.20	1.18	1.15	1.18	1.18	1.18	1.18	2.78	2.68	2.63	2.49	2.65
	2.0	10.2	13.2	13.4	13.5	13.5	12.6	12.6	8.2	8.6	8.9	9.3	8.8	1.19	1.15	1.14	1.14	1.15	1.15	1.15	1.15	2.76	2.55	2.34	2.18	2.46
200	0	9.4	9.8	10.2	10.5	10.5	10.0	10.0	7.8	8.8	9.0	9.0	8.7	1.15	1.13	1.13	1.12	1.13	1.13	1.13	1.13	2.60	2.44	2.40	2.20	2.41
	0.5	9.8	10.3	10.5	10.5	10.5	10.3	10.3	7.9	10.3	10.5	10.5	9.8	1.16	1.14	1.13	1.13	1.14	1.14	1.14	1.14	2.70	2.52	2.42	2.30	2.51
	1.0	10.0	10.8	10.7	10.6	10.6	10.5	10.5	8.3	9.9	10.5	10.6	9.8	1.22	1.20	1.19	1.18	1.19	1.19	1.19	1.19	2.75	2.74	2.66	2.50	2.66
	1.5	10.2	10.7	10.9	11.0	11.0	10.5	10.5	8.2	8.9	9.4	9.5	9.0	1.22	1.20	1.20	1.18	1.20	1.20	1.20	1.20	2.70	2.60	2.55	2.42	2.57
	2.0	10.0	10.5	10.8	11.0	11.0	10.3	10.3	8.0	8.5	8.8	8.9	8.6	1.18	1.15	1.14	1.14	1.15	1.15	1.15	1.15	2.72	2.50	2.30	2.10	2.41
Control		11.5	12.4	12.4	12.0	12.0			9.1	10.0	10.1	10.1		1.11	1.10	1.09	1.09					2.65	2.45	2.30	2.11	
Mean		10.0	11.3	11.5	11.6	11.6			8.1	9.3	9.0	9.2		1.19	1.16	1.15	1.15									
Means for thickness	100 µ = 10.7, 150 µ = 12.1, 200 µ = 10.3																									
Means for perforation	0 = 10.4, 0.5 = 10.6, 1.0 = 11.5, 1.5 = 11.5, 2.0 = 11.3, control = 12.1																									
CD (P=0.05)	Thickness (T) = 0.6, perforation (P) = 0.6, TxP = 1.1, storage period (S) = 0.6, xPxS = 1.0																									
	Thickness (T) = 0.1, perforation (P) = 0.2, TxP = 0.5, storage period (S) = 0.6, TxPxS = 1.2																									
	Thickness (T) = NS, perforation (P) = 0.08, TxP = 0/11, storage period (S) = 0.13, TxPxS = 0.4																									
	Thickness (T) = 1.2, perforation (P) = 0.6, TxP = 1.6, storage period (S) = 0.8, TxPxS = 3.2																									
	100 µ = 9.2, 150 µ = 9.4, 200 µ = 9.2																									
	0 = 9.0, 0.5 = 9.6, 1.0 = 9.7, 1.5 = 9.2, 2.0 = 9.0, control = 9.8																									
	100 µ = 1.16, 150 µ = 1.16, 200 µ = 1.16																									
	0 = 1.13, 0.5 = 1.14, 1.0 = 1.19, 1.5 = 1.19, 2.0 = 1.16, control = 1.10																									
	100 µ = 2.54, 150 µ = 2.56, 200 µ = 2.51, control = 2.38																									
	0 = 2.44, 0.5 = 2.53, 1.0 = 2.60, 1.5 = 2.61, 2.0 = 2.43, control = 2.38																									

followed by 1 or 1.5% perforation, however differences were observed to be non-significant. The highest per cent physiological loss in weight was recorded in 2% perforated low-density polyethylene film bags (8.9%) (Table 1). Irrespective of low-density polyethylene film thickness or perforation, physiological loss in weight was the lowest at 10 days of storage (3.2%) and highest after 40 days of storage (11.9%). The treatment combinations, ie thickness  $\times$  perforation  $\times$  storage period was also observed to be significant. The increase in physiological loss in weight with the increase in storage period might be due to fact that with the increase in storage period or perforation, higher amount of water might have evaporated from the apples and hence, physiological loss in weight might have increased. Similarly, apples in control had higher physiological loss in weight than other treatments, because they were kept in open and had no barrier for moisture loss than other treatments. Bhusan *et al.* (2002) had also reported the similar effect of low-density polyethylene thickness and perforation on physiological loss in weight of kiwifruit. Asrey *et al.* (2004) reported that pre-treated strawberries have longer shelf-life if packed in plastic punnets. Increase in physiological loss in weight and decay might be due to the fact that there must have higher evaporation or moisture loss and/or development of pathogens causing decay. Singh *et al.* (2007) had reported similar effects of polyethylene packing on shelf-life of passion fruit.

#### *Effects on quality characteristics*

Fruit firmness showed declining trend with the increase in storage time and perforation (Table 1). Irrespective of perforations, fruits packed in 100  $\mu$  low-density polyethylene film bags had higher firmness (56.1 N) than unpacked (control) fruits (35.1N). Similarly, fruit firmness was highest in un-perforated bags (57.3 N) and lowest in apples packed in 2.0% perforated low-density polyethylene film bags (54.3 N). Further, fruit firmness was recorded to be the highest after 10 days of storage (66.6 N) and lowest after 40 days of storage (45.2 N). Decline in firmness with the increase in storage period may be attributed to the development of meakness in apples due to conversion of starch into soluble carbohydrates over storage period. Pandey *et al.* (2006) have also reported a decline in fruit firmness of apple with the increase in storage period. The treatment combination, ie thickness $\times$ perforation $\times$ storage period was also significant for fruit firmness for apples.

Fruits packed in perforated low-density polyethylene films had better total soluble solids, total sugars and ascorbic acid content than the unpacked ones (control), but titratable acidity remained unaffected. Apples packed in low-density polyethylene (150  $\mu$ ) had highest TSS (12.1%), total sugars (9.4%) and ascorbic acid content (2.56 mg/100 g pulp) than those packed in 100 or 200  $\mu$ . low-density polyethylene film bags. Among different perforations, best TSS (11.5%), total

sugars (9.7%) and ascorbic acid content (2.66 mg/100 g pulp) were observed in 1.0% perforated films. Further, TSS and total sugars content showed increasing trend with the increase in storage period up to 30th day of storage and after that a declining trend (Table 2). In contrast, ascorbic acid content declined with the increase in storage period from 10th to 40th day at ambient conditions. Increase in total soluble solids and total sugars contents with the increase in storage period and decrease in ascorbic acid content has been reported by Pandey *et al.* (2006) and Hussain *et al.* (2009) in apple, and such effects of different thickness and perforations on TSS, total sugar or ascorbic acid content have also been reported by Bhusan *et al.* (2002) in kiwifruit, Singh and Mandal (2006) and Singh and Sharma (2009) in peaches.

Fruits packed in un-perforated bags contained slightly higher juice content (61.3%) than those packed in perforated bags. Apples packed in low-density polyethylene bags with 2.0% perforation had the least extractable juice (58.0%) over other perforations or those, which were not packed at all (control) (55.8%). Similarly, at low perforations, apples were comparatively juicier than at higher perforations and the juice content declined with the increase in storage time from 10 days (62.5%) to 40 days (47.5%) (Table 1). Among different thicknesses of low-density polyethylene films, there was no significant difference as far as juice recovery is concerned. Lower juice contents in higher perforations may be due to higher moisture loss and *vice versa*. Similarly, due to increase in storage period from 10th to 40th day, moisture loss progressively increased, which might be responsible for lower juice recovery (Pandey *et al.* 2006, Hussain *et al.* 2009) These results are in accordance with the findings of Bhusan *et al.* (2002), who reported that kiwifruits packed in low-density polyethylene films with different thicknesses and perforations affected juice content significantly.

#### *Sensory evaluation of apple*

Organoleptic evaluation of apple revealed that fruits in control had better score after 10 days of storage (8.2) than apples packed in different low-density polyethylene film bags with variable perforations. However, non-significant differences occurred among different low-density polyethylene films (Data not shown). In all, fruits in 100 or 150  $\mu$  low-density polyethylene with 1.0% perforation had highest sensory score (7.8) after 30 days of storage declined with subsequent storage.

It can be concluded from these studies that apple could be kept safely under ambient conditions for about 30 days in low-density polyethylene films of 100 or 150  $\mu$  thickness with 1.0% perforation. Unpacked fruits can only be kept for 20 days at room temperature. Hence, shelf-life can be delayed by 10 days with this packing technique.

#### REFERENCES

Asrey R, Jain R K and Singh R. 2004. Effect of pre-harvest chemical

- treatments on shelf-life of Chandler strawberry (*Fragaria × ananassa*). *Indian Journal of Agricultural Sciences* **74**(9): 485–7.
- Batagurki S B, Raghavan G S V, Smith J P and Orsat V. 1995. Plastic film packaging of apples and mangoes. *Phala Samskarana* **5**: 172–7.
- Bhusan S, Tripathi S N and Thakur N K. 2002. Effect of modified atmosphere packaging on the quality of kiwifruit stored at room temperature. *Journal of Food Science and Technology* **39** (3): 279–83.
- Chadha K L and Awasthi R P. 2005. *The Apple*. Malhotra Publishing House, New Delhi.
- Hussain P R, Dar, M A, Meena R S, Mir, M A, Safi, F and Wani A M. 2009. Changes in quality of apple (*Malus domestica*) cultivars due gamma irradiation and storage conditions. *Journal of Food Science and Technology* **45** (1): 44–9.
- Ladaniya M S. 2003. Shelf-life of seal-packed Mosambi sweet orange fruits in heat shrinkable and stretchable films. *Haryana Journal of Horticultural Science* **32**: 50–3.
- Pandey G, Verma M K and Tripathi A N. 2006. Studies on storage behaviour of apple cultivars. *Indian Journal of Horticulture* **63**(4): 368–71.
- Singh A, Yadav D S, Patel R K and Bhuyan M. 2007. Effect on shelf life and quality of passion fruit with polyethylene packaging under specific temperature. *Journal of Food Science and Technology* **44** (2): 201–4.
- Singh D and Mandal G. 2006. Post harvest quality and spoilage of peach fruits stored in perforated bags. *Indian Journal of Horticulture* **63** (4): 55–61.
- Singh D and Sharma R R. 2009. Post-harvest behaviour of peaches (*Prunus persica*) pre-treated with antagonist *D. hansenii* and calcium chloride. *Indian Journal of Agricultural Sciences* **79** (8): 674–8.
- Sharma R R, Singh D and Singh R. 2009. Studies on transport losses and quality parameters in apple packed in different containers. *Indian Journal of Horticulture* **66**(2): 245–8.