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OPTIMIZATION OF DIFFERENT PACKAGING METHODS FOR EXTENDING SHELF-LIFE OF APPLE (*MALUS DOMESTIKA* BORKH.) DURING STORAGE

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ABSTRACT

Postharvest infrastructure is inadequate in India and losses are high. Cold storage facilities are scarce and beyond the reach of most of the growers. This study was undertaken to find a low cost solution for short term storage of apple in Uttarakhand state. Storage studies of apples harvested at optimum maturity were undertaken at ambient and zero energy cool chamber (ZECC) conditions for 120 days. ZECC is a low cost, cold storage structure for short term storage of fruits and vegetables. The effect of ISW (Individual Shrink Wrapping), TW (Tray Wrapping with 0.025 % and 0.05 % micro-perforations) was evaluated for control of postharvest losses/rotting and quality of fruits during storage. Results reveals that fruits kept in Tray Wrapping with 0.05 % perforations in ZECC conditions show minimum loss in weight i.e. (1.44%) and TSS (13.38 °Brix). Thus storage of apples in ZECC conditions (temperature 3.19 to 20.08°C) for a period of about 120 days after treating with Tray Wrapping with 0.050 % micro-perforation was highly beneficial, with minimum rotting (4%), changes in physico-chemical quality in terms of acidity (0.13 %) and sugars (11.13%). So this technology holds promise for the resource poor farmers in India.

INTRODUCTION

Apple (*Malus domestica* Borkh.) occupies a place of pride amongst temperate fruit crops of India and fetches very good price in the market. It matures by mid-August or early September in mid-hill conditions of India, which often results in the glut of fruits in the market (Chadha and Awasthi 2005; Wijewardane and Guleria, 2009). After harvesting, fruits are transported to plains for storage and marketing. It causes high post harvest losses. Further, rough handling and transportation usually shorten its storage life. Many techniques are used to extend its storage life, but refrigeration and controlled atmosphere (CA) storage are mostly used in different parts of the world including India. However, these facilities are very costly and out of reach of the marginal farmers. Moreover, most of these facilities are available in plains and producers had to bring their produce to these areas for storage. Number of chemicals have also been tried to extend the shelf life of apples, which as such may be injurious to health due to their residual effect. To overcome these problems, packaging via; individual shrink-wrapping, tray wrapping having 0.025 % and 0.05 % micro-perforations, has been used to reduce post harvest losses and to extend the shelf-life along with refrigerated storage in ZECC (Sharma and Singh, 2010; Sharma *et al.*, 2010; Issar *et al.*, 2011). It provides a barrier for the spread of microbial infection from infected lot to the healthy lot. Sharma and Pal (2009) reported the usefulness of shrink-wrapping of apples after cold storage to extend the self-life of apples during retail marketing. However, work on individual and tray wrapping of citrus fruits with heat shrinkable films have been done at NRC for citrus at Nagpur, particularly for extending the shelf-life of Nagpur mandarin and Mosambi sweet orange (Ladaniya, 2003). Batagurki *et al.* (1995) have strongly recommended that refrigeration and controlled atmosphere (CA) facilities are not only relatively expensive, but are not readily available and hence, it becomes imperative to go for plastic film packaging of apples for extending their shelf life in developing countries like India. However, no work has been conducted on apple in India on this aspect. Hence, we conducted these studies with the objective to optimize different packaging methods for extending shelf-life of apple fruits by using heat shrinkable film as packaging material for individual shrink wrapping and tray wrapping *i.e.* 0.025 % and 0.050 % micro-perforations coupled with storage under ZECC (a low cost on-field refrigerated storage of fruits *i.e.* Zero Energy Cool Chamber).

MATERIALS AND METHODS

Freshly harvested and optimum matured uniform sized, free from diseases and mechanical injury apple fruits of cv. Red Delicious were collected for the study. Fruits after thorough sorting and grading, were washed and hydro-cooled at 0-2ºC for about 2 hrs and followed by drying under shade. The dried fruits were then used for conducting further experiments. The experiment was carried out in two different storage conditions viz., Ambient Temperature Storage (9.80 to 28.93ºC) and ZECC Storage (3.19 to 20.08ºC). One lot of fruits were packed in polythene bags of dimensions 35cm (l) x 27cm (b) and 18μ thickness, nearly 6 kg fruits under each treatment were kept for determination of physico-chemical parameters and another lot of about 1 kg fruits was kept for recording PLW. The three packaging treatments T_2, T_3 and T_4 *i.e.* Individual shrink wrapping (ISW), Tray wrapping (TW) (medium sized apple tray, whole tray was shrinked wrapped) with 16 micro perforations as 0.025 % perforation and 32 micro perforations as 0.050 % perforation along with control (unpacked fruits). Both lots of fruits were stored under two storage conditions and evaluated periodically (initial, 30, 60, 90 and 120 days) for various physical and chemical quality attributes. Standard methods were used for recording observations on various physical and chemical (Ranganna, 1997; Sharma and Nautiyal 2009). Total soluble solids were recorded at room temperature using Erma hand Refractrometer and were corrected using Standard Reference Tables and expressed in terms of ºBrix at 20ºC. Acidity was determined by titrimetric method. Total and reducing sugars were estimated using Lane and Eynon's (1923) volumetric method. Pressure/ fruit firmness was determined with the help of Effigy penetrometer (Model FT 327) and expressed in Kg/cm^2. Number of fruits showing sign of decay or rotting was counted separately in each treatment at each storage interval. The cumulative number of rotten fruits was calculated at the end of storage period and expressed as per cent. Physiological loss in weight (PLW) was worked out as cumulative loss in weight of fruits under various treatments based on the initial fruit weight (before storage).

RESULTS AND DISCUSSION

PLW

Physiological Loss in Weight of apple fruit increased with the increase in storage period in both the conditions. Higher weight loss of untreated fruits (T_1) 9.56 % may be due to the unsealing of lenticels' that are responsible for higher rate of transpiration and respiration, which are subjected to the physiological activities as compared to lowest in fruits subjected to tray wrapping with 0.050 % micro-perforations *i.e.* (T_4) is 1.44 %. Under ambient conditions fruits showed highest (23.74 %) PLW than those, packed in tray wrapping with 0.025 % and 0.050 % micro-perforations kept in ZECC which might be attributed to higher relative humidity maintained continuously in the ZECC, consequently reducing the rate of moisture exchange between fruits and environment during storage upto 120 days, suffered minimum loss in weight *i.e.* (0.48 %). Therefore packaging treatment was found to be highly effective in reducing PLW losses of apples during storage. These results are in conformity with the findings of Gohlani and Bisen (2012).

Rotting

Minimum per cent (nil to 4 %) of rotting was recorded Individual Shrink Wrapping, Tray Wrapping (0.050 % micro-perforations) treatments along with storage in ZECC for whole of the 120 days of storage and maximum rotting was observed in control *i.e.* 18% (Fig. 1). This might be due to the creation of modified atmosphere around the apples and film act as barrier to external damaging factors. Micro-perforations provide better gas and water vapour transmission thereby the growth of micro-organisms at low temperature (ZECC) reduces incidences of decay.

Firmness

A gradual decrease in flesh firmness was observed from 5.72 to 3.11 Kg/cm^2 during 120 days of storage. Higher firmness was recorded in control apples, might due to greater loss of water from fruits resulting into higher force for puncturing the fruits. Similarly, decrease in firmness force in apples wrapped in Heat shrinkable films during storage must be due to the fact that there is development of mealyness in the fruit with the advancement in storage period. Overall effect of packaging treatments on fruit flesh firmness after 120 days of storage under both ambient and ZECC condition was statistically not significant.

Total Soluble Solids

Table 1: Effect of packaging methods on physiological loss in weight (%) of apples during storage under different storage conditions

Storage conditions (S)	Treatment (T)	Storage intervals (I) (days)						Mean (T)
		initial	30	60	90	120	Mean (I)	
Ambient (9.80 to 28.93°C)	Control	0.00	5.00	10.3	47.7	55.70	23.74	13.79
	ISW	0.00	0.82	1.61	9.91	10.42	4.55	2.74
	TW 0.025%	0.00	3.90	6.00	8.78	9.86	5.70	3.11
	TW 0.050%	0.00	1.54	3.90	7.67	8.12	4.25	2.36
	Mean	0.00	2.82	5.45	18.51	21.02	9.56	
ZECC(3.19 to 20.08 °C)	Control	0.00	0.00	4.30	6.70	8.20	3.84	
	ISW	0.00	0.00	0.61	0.77	3.22	0.92	
	TW 0.025%	0.00	0.00	0.26	0.85	1.46	0.51	
	TW 0.050%	0.00	0.00	0.21	0.73	1.45	0.48	
	Mean	0.00	0.00	1.35	2.26	3.58	1.44	
Grand mean (I)		0.00	1.41	3.40	10.39	12.30		
	$CD_{0.05}$					$CD_{0.05}$		
Treatment (T)	0.14				T x S	0.54		
Storage conditions (S)	0.27				T x I	0.85		
Storage intervals (I)	0.42				S x I	0.60		
					T x S x I	1.21		

Table 2: Effect of packaging methods on fruit firmness (kg/cm²) of apples during storage under different storage conditions

Storage conditions (S)	Treatment (T)	Storage intervals (I)						Mean (T)
		initial	30	60	90	120	Mean (I)	
Ambient (9.80 to 28.93°C)	Control	5.720	5.033	5.800	4.333	2.233	4.624	4.641
	ISW	5.720	5.833	4.367	4.567	3.867	4.871	4.571
	TW 0.025%	5.720	6.133	4.200	4.233	1.967	4.451	4.767
	TW 0.050%	5.720	5.333	3.633	4.567	3.133	4.477	4.867
	Mean	5.720	5.583	4.500	4.425	2.800	4.606	
ZECC(3.19 to 20.08°C)	Control	5.720	5.433	3.933	3.967	4.233	4.657	
	ISW	5.720	5.433	4.333	3.333	1.933	4.271	
	TW 0.025%	5.720	6.267	6.233	3.800	3.400	5.084	
	TW 0.050%	5.720	6.167	5.233	5.033	4.133	5.257	
	Mean	5.720	5.825	5.083	4.033	3.425	4.817	
Grand mean (I)		5.720	5.704	4.792	4.229	3.112		
	$CD_{0.05}$					$CD_{0.05}$		
Treatment (T)	NS				T x S	0.75		
Storage conditions (S)	NS				T x I	NS		
Storage intervals (I)	0.59				S x I	0.35		
					T x S x I	NS		

Table 3: Effect of packaging methods on fruit TSS (°Brix) of apples during storage under different storage conditions

Storage conditions (S)	Treatment (T)	Storage intervals (I) days						Mean (T)
		initial	30	60	90	120	Mean (I)	
Ambient (9.80 to 28.93°C)	Control	12.30	13.20	13.93	14.67	15.00	13.82	13.54
	ISW	12.30	12.93	13.87	14.40	15.33	13.77	13.48
	TW 0.025%	12.30	12.60	14.00	15.20	15.87	13.99	13.73
	TW 0.050%	12.30	13.07	13.77	15.27	15.93	14.07	13.84
	Mean	12.30	12.95	13.89	14.88	15.53	13.91	
ZECC(3.19 to 20.08°C)	Control	12.30	12.73	13.07	13.80	14.40	13.26	
	ISW	12.30	12.60	12.93	13.60	14.53	13.19	
	TW 0.025%	12.30	12.33	13.27	14.20	15.27	13.47	
	TW 0.050%	12.30	12.73	13.27	14.00	15.73	13.61	
	Mean	12.30	12.60	13.13	13.90	14.98	13.38	
Grand mean (I)	12.30	12.77	13.51	14.39	15.26			
	$CD_{0.05}$					$CD_{0.05}$		
Treatment (T)	0.15				T x S	NS		
Storage conditions (S)	0.10				T x I	0.34		
Storage intervals (I)	0.17				S x I	0.24		
					T x S x I	NS		

Table 4: Effect of packaging methods on acidity of apples during storage under different storage conditions

Storage Conditions (S)	Treatment (T)	Storage Intervals (I) days						Mean (T)
		Initial	30	60	90	120	Mean (I)	
Ambient (9.80 to 28.93°C)	Control	0.45	0.33	0.23	0.20	0.12	0.26	0.27
	ISW	0.45	0.36	0.26	0.20	0.10	0.28	0.27
	TW 0.025%	0.45	0.34	0.24	0.22	0.14	0.28	0.28
	TW 0.050%	0.45	0.41	0.31	0.23	0.13	0.30	0.30
	Mean	0.45	0.36	0.26	0.21	0.12	0.28	
ZECC(3.19 to 20.08 °C)	Control	0.45	0.40	0.21	0.18	0.14	0.28	
	ISW	0.45	0.28	0.25	0.22	0.12	0.26	
	TW 0.025%	0.45	0.36	0.27	0.24	0.14	0.29	
	TW 0.050%	0.45	0.27	0.34	0.26	0.16	0.30	
	Mean	0.45	0.33	0.27	0.22	0.14	0.28	
Grand mean (I)	0.45	0.34	0.26	0.22	0.13			
	$CD_{0.05}$						$CD_{0.05}$	
Treatment (T)						T x S		
Storage conditions (S)						T x I		
Storage intervals (I)						S x I		
						T x S x I	0.030	

There was a general trend of increase in TSS with time upto 120 days under refrigerated condition whereas under room temperature TSS increased (from 12.30 °B to 15.93 ° B), which might be due to hydrolysis of starch and pectin substances

Table 5: Effect of packaging methods on reducing sugar (%) of apples during storage under different storage conditions

Storage Conditions (S)	Treatment (T)	Storage Intervals (I) initial	30	60	90	120	Mean (I)	Mean (T)
Ambient (9.80 to 28.93°C)	Control	8.90	10.70	11.98	13.57	15.24	12.08	12.23
	ISW	8.90	10.30	11.19	12.73	14.31	11.49	11.52
	TW 0.025%	8.90	9.5	11.90	12.55	15.00	11.57	11.51
	TW 0.050%	8.90	10.33	11.34	14.17	15.03	11.95	11.54
	Mean	8.90	10.21	11.60	13.26	14.90	11.77	
ZECC(3.19 to 20.08°C)	Control	8.90	10.60	12.21	14.88	15.28	12.37	
	ISW	8.90	10.37	10.68	13.34	14.51	11.56	
	TW 0.025%	8.90	9.33	10.50	13.77	14.74	11.45	
	TW 0.050%	8.90	9.30	10.48	12.55	14.43	11.13	
	Mean	8.90	9.90	10.97	13.63	14.74	11.63	
Grand mean (I)		8.90	10.05	11.28	13.45	14.82		
	$CD_{0.05}$					$CD_{0.05}$		
Treatment (T)	0.12				T x S	0.17		
Storage conditions (S)	0.86				T x I	0.27		
Storage intervals (I)	0.13				S x I	0.19		
					T x S x I	0.38		

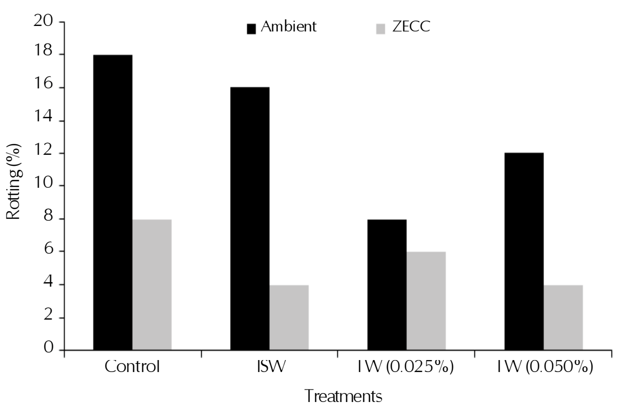

Figure 1: Effect of packaging treatments on rotting (%) of apple fruits after 120 days of storage

and slow metabolic transformation in soluble components resulting in slow buildup of sugars and TSS due to retarded ripening process. There was more conversion of polysaccharides into simple sugars resulting in higher TSS in fruits at room temperature than under refrigerated storage possibly due to higher temperature and respiration rate. These results are in conformity with the findings of Bhat *et al.* (2014).

Titratable acidity

With the advancement of storage, acidity shows a gradually declining pattern under all treatments (Table 4). due to the utilization of organic acids in respiration during storage. The fruits packed in Tray wrapping with 0.050 % micro-perforations had lowest acidity (0.13 %) than other packaging treatments after each storage interval. overall fruits stored in ZECC coupled with various packaging treatments showed minimum decrease in acid content than those kept in ambient condition might be due to the fact that the fruits kept in former condition experienced slower rate of respirational changes as compared to the latter one.

Sugars

Sugar follows an increasing trend, which might be attributed to loss in weight of fruits and partly to hydrolysis of cell wall polysaccharides. During storage period reducing sugars varied between 8.90 to 14.82 per cent. Fruits stored under cold storage showed lesser changes in reducing sugars as compared to ambient condition storage, might be due to the conversion of starch into sugars. Rapid deterioration in sugars at ambient temperature has also been reported. This was mainly because the pace of degenerative changes leading to senescence that occurs with advancement of fruit age during storage. The increase in sugars was in conformity with the findings of Reshi *et al.,* 2014.

Further, due to low temperature, the conversion of polysaccharides into sugar might have been reduced, thus, showing lower mean total sugar contents under ZECC as compared to those under ambient conditions. Higher loss in weight of control fruits might be a reason of increase in the concentration of sugars.

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