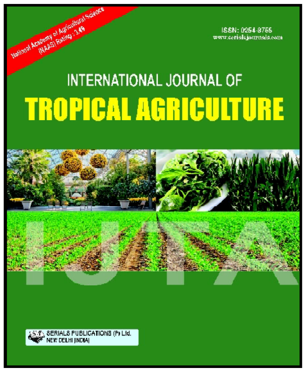

INTERNATIONAL JOURNAL OF TROPICAL AGRICULTURE

ISSN : 0254-8755

available at http: www.serialsjournals.com

© Serials Publications Pvt. Ltd.

Volume 36 • Number 1 • 2018

Effect of different packaging films on shelf life and quality of *Khasi* mandarin (*Citrus reticulata* Blanco) under ambient and cold storage condition

Namita Bhuyan[1], S. K. Kaul[2], P. C. Barua[3] and P. Kalita[4]

1&2 Department of Agriculture, Cooperation & Farmers Welfare, MoA, Krishi Bhawan–110001, New Delhi
[3] Department of Horticulture, Assam Agricultural University, Jorhat 785013, Assam, India
[4] Department of Crop Physiology, Assam Agricultural University, Jorhat 785013, Assam, India
E-mail: namitabhuyan107@gmail.com

Abstract: Effect of different packaging films and storage conditions on physico-chemical characteristics of *Khasi* mandarin (*Citrus reticulata* Blanco) fruits during storage was studied in the Quality Control and PHT Laboratory, Department of Horticulture, Assam Agricultural University, Jorhat during 2015. Physiologically mature fruit at colour beak stage were harvested and treated with hypo chloride solution (200ppm) for 2 minutes. Fruits were washed and moisture was removed in shade. Fruits were then individually packed in different perforated packaging films viz., low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC) and polyolefin films. Packed fruits were then stored at ambient (22-27°C and 70-75% RH) and cold storage conditions (6°C and 68-72% RH). The various physico-chemical and sensory attributes of fruits were recorded at weekly intervals during the entire storage period. Irrespective of treatments, a continuous decrease in acidity and ascorbic acid contents of fruits was noticed with the increasing of storage period, whereas TSS, sugar contents and the value of CCI (Citrus colour index) increased with progress of storage period. The fruits packed in perforated HDPE films retained the highest sensory and nutritional quality with slow and steadier change in ascorbic acid content, TSS, total sugar, titrable acidity and weight loss as compared to unpacked fruits. Fruit packed in perforated HDPE films under cold storage registered lower CCI value (1.76) as compared to other packaging material and storage conditions. Highest value was recorded in without packed fruits (3.31) under cold storage condition. Based on this study, results indicate that use of perforated HDPE films can prolong the shelf life by maintaining quality attributes and external appearance of *Khasi* mandarin fruits for 58 days and 35 days at cold storage and ambient condition respectively.

Keywords: *Khasi* mandarin, Packaging films, Storage conditions, quality

INTRODUCTION

Citrus fruit is the world's most popular fruit, due to its distinct flavour, taste, and aroma as well as multiple health promoting bioactive compounds (Al-Juhaimi and Ghafoor, [2]). Mandarin is the most important group in fresh citrus market because premiums are paid on these fruits due to attractive appearances, pleasant taste, convenience due to less seed and easy peeling characteristics (Ladaniya, [21]). *Khasi* mandarin is one of the important mandarin variety grown in all the zones of Assam. *Khasi* mandarin is charcterized with prolific bearing, excellent fruit quality and high juice content. The total cultivated area under *Khasi* mandarin is around 17.55 thousand hectare with production of 236.01 thousand tons. Average productivity of *Khasi* mandarin in Assam is about 13.44 MT per hectare, which accounts for about 5 per cent of total mandarin production in India (Ministry of Agriculture, [26]). The optimum period of *Khasi* mandarin maturity is from mid-October to mid-December. At the time of harvest, there is often a glut like situation in the local market causing huge losses to the farmers as they are compelled to dispose off their produce at low price. The two major problems limit the long term storage capability of citrus fruits, the first is pathological and physiological breakdown leading to decay and rind disorders; the second is weight loss (Purvis, [31] and Barua, [7]). Besides senescence, physiological and pathological disorders, surface evaporation is mainly responsible for the post-harvest deterioration of fresh citrus fruits. Excessive weight loss due to respiration/ transpiration can adversely affect the quality of fruits because it results in shrivelling and loss of gloss (Ben-Yehoshua [8]).

Modified atmosphere packaging (MAP) technology offers the possibility to extend the shelf life of fresh produce by retarding produce respiration rate, transpiration rate and delaying enzymatic degradation of complex substrates, thus avoiding the use of other chemical or thermal process such as freezing, dehydration and sterilization (Kader, [15] and Fonseca, [13]). Modified atmosphere packaging (MAP) technology is accepted now as the technology of the future. Although MAP has been reported to prolong the post-harvest quality of many fruits and vegetables, but the detailed effects of MAP on physiological and biochemical alterations during storage have not been entirely defined or explained for many fruits and vegetables available in Northeast India. It would, therefore be a great advantage to the growers and the retailers if the fruits could be held back in a good marketable condition over an extended periods of time. Under such conditions the prices can also be regulated to the advantage of both the growers and buyers. Therefore, a suitable means for storage of *Khasi* mandarin is very much needed for exploring wider market i.e. for exporting them to the outside markets. Hence, present study was carried out to evaluate the effect of packaging materials and storage condition on quality of *Khasi* mandarin fruits.

MATERIALS AND METHODS

The *Khasi* mandarin fruits were harvested at physiologically mature, i.e. colour break stage from the orchard of Tinsukia district of Assam. Only healthy fruits were treated with 100 ppm sodium hypo chloride solution for 2 minutes. After washing and drying surface moisture in shade the fruits were subject to loose packed individually packing in five different packaging films *viz.*, low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC) and polyolefin films. The packaging film bags of 12 cm x 18 cm in size and perforated with 12 numbers of pin holes. Thereafter, film-packed fruits were stored under ambient (22-27°C and 70-75% RH) and cold storage (6-7°C and 68-72% RH) conditions. Physico-chemical parameters were recorded at weekly interval for 60 days. At the end of storage quarantine treatment, about 250 fruits from best treatment were held at retail marked condition for 7 days to asses fruit ripeness as well as ensuring its quality and overall acceptability at market condition (Serry, [37]).

The physiological loss in weight (PLW) after each interval of storage was calculated by subtracting final weight from the initial weight of the fruits and expressed in per cent. The fruit firmness was measured with the help of Stable Micro System TA – XT plus texture analyzer (Texture Technologies Corp. UK) using P/5 mm cylindrical aluminium probe and expressed in terms of kg/f (Singh and Reddy,[38]). The colour change of orange fruit was measured using Hunter Lab Colour Quest XE Colorimeter (Hunter Associated Laboratory, Reston, Virginia). Total soluble solid was determined by a digital hand refractometer and expressed as °Brix. The total sugars and titratable acidity were estimated as per standard procedures (AOAC,[4]). Ascorbic acid content was determined using 2, 6-dichlorophenol indophenols dye method. The overall organoleptic rating of the fruits was done by a panel of five judges on the basis of external appearance of fruits, texture, taste, and flavour, making use of a 9-point Hedonic scale (Amerine [3]). The data was analyzed statistically in completely randomized design.

RESULTS AND DISCUSSION

Physiology weight loss

It is evident from the data presented in Table 1 that there was a sharp increase in PLW of fruits stored at room temperature, whereas the increase in PLW was found to be slow in fruits stored in cold storage under all the treatments. Packaging film exhibited greater influence in minimizing the physiological loss in weight. The maximum mean physiological loss in weight was observed in control under ambient condition (10.97%) and also recorded in cold storage condition (7.53%). The minimum mean PLW was recorded in HDPE film packed fruits in cold storage condition (1.55%) and similar result was also recorded in ambient condition (0.78%). The interaction effect of packaging (P), storage period (D) and condition (S). *viz.,* S x P, P x D, S x D, S x V x P were found to be significant.

The minimum weight losses in film packed fruits is due to the fact that the film served as a mechanical barrier to the movement of water vapour and this helps to maintain saturated micro-atmosphere around the fruit and reduce produce weight loss (Suparlan and Itoh, [41]and [32]). Besides, the low temperature in cold storage and the CO_2 tension around and within the fruits may also slow down the enzymatic activities, respiration and ethylene production leading to extension of storage life of fruits (Roy, [34]). This result was in conformity with the findings of Ben-Yehoshu, [9], Naz, [28] in sweet orange, Ramin and Khoshbakhat, [31] and Kaur and Singh [15] lemon, and in acid lime.

Firmness

Firmness of *Khasi* mandarin showed a decreasing trend with increase in storage period but at the end of the storage period the control (unpacked) fruits under ambient and cold storage condition produce a hard texture (Table 2); however, the polymeric film packed fruits showed a beneûcial effect on ûrmness retention. In ambient storage, maximum mean firmness (1.69 kg/f) was recorded in fruits packed with HDPE films as compared to other treatments and minimum was recorded in control (1.44 kg/f). In cold storage conditions, significant effect of treatments were recorded and maximum mean firmness retained in fruits packed with HDPE films (1.87 kg/f) after 58 days of storage. The minimum fruit firmness was recorded in control under ambient condition (0.90 kg/f) and also recorded in cold storage condition (1.11kg/f). The interaction effect of packaging (P), storage period (D) and condition (S). *viz.,* S x P, P x D, S x D, S x V x P were found to be significant.

Table 1

Physiological loss in weight (%) of the fruits as influenced by different treatments

Treatment	*Ambient condition (S1)*					*Cold storage (S2)*								
	Days after storage					*Days after storage*								
	7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P_1	0.87	1.30	2.70	3.80	2.17	0.16	0.55	0.90	1.25	1.56	2.10	2.40	2.63	1.44
P_2	0.62	1.20	1.90	2.47	1.55	0.06	0.18	0.25	0.43	0.70	1.21	1.44	1.96	0.78
P_3	0.92	1.85	2.81	3.86	2.36	0.14	0.44	0.86	1.00	1.33	1.78	2.20	2.48	1.28
P_4	0.98	1.78	2.76	4.13	2.41	0.38	0.80	1.17	1.44	1.98	2.42	2.68	2.94	1.73
P_5	0.94	2.10	2.87	3.98	2.47	0.28	0.64	1.10	1.43	1.68	2.00	2.43	2.80	1.55
P_0	6.48	15.45	-	-	10.97	4.12	6.21	7.12	9.33	10.87	-	-	-	7.53
Mean	1.80	3.95	2.61	3.65		0.86	1.47	1.90	2.48	3.02	1.90	2.23	2.56	
	P	D	S	P X D	S X P	S x D		D x S x P						
SEd(±)	0.017	0.021	0.012	0.051	0.029	0.036		0.088						
$CD_{(P=0.05)}$	0.033	0.040	0.023	0.099	0.057	0.070		0.172						

Table 2
Firmness (kg/f) of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P1	2.12	1.94	1.56	1.24	0.93	1.56	2.12	2.04	1.97	1.81	1.54	1.4	1.28	1.15	1.71
P2	2.12	2.03	1.74	1.44	1.10	1.69	2.12	2.09	2.01	1.90	1.79	1.71	1.59	1.49	1.87
P3	2.12	1.95	1.67	1.39	0.88	1.60	2.11	2.04	1.95	1.79	1.64	1.42	1.26	1.05	1.71
P4	2.12	2.01	1.69	1.35	0.70	1.57	1.98	1.79	1.57	1.45	1.32	1.12	1.05	0.89	1.48
P5	2.12	1.94	1.64	1.33	0.86	1.58	2.1	2.01	1.85	1.72	1.44	1.25	1.11	1.01	1.62
P0	2.12	0.9	1.29	-	-	1.44	1.97	1.77	1.41	1.11	1.38	-	-	-	1.63
Mean	2.12	1.80	1.60	1.35	0.89		2.07	1.96	1.79	1.63	1.52	1.38	1.26	1.12	
	P	D	S	S X P	P XD	S x D	D x S x P								
SEd(±)	0.007	0.008	0.005	0.011	0.020	0.014	0.035								
CD(P=0.05)	0.013	0.016	0.009	0.022	0.040	0.028	0.068								

The progressive decrease in the fruit firmness with advancement of storage may be due to the continuous transpiration and degradation of pectic substances in the middle lamella of the cell wall that leads to the loss of cell wall integrity thus causing loss of firmness leading to shriveling and softening (Solomos and Laties, [40]). Maximum textual quality was retained in polymeric film packed fruits under cold storage which might be due to films ability to create modified atmosphere conditions around the fresh fruits. Further, low temperature and high humidity maintained inside these films, help in reducing the transpiration loss and respiration activity, delay ripening process and thus retained turgidity of the cells (Zagory and Kader,[47])). Increase in firmness values at the end of the storage period may be attributed to surface drying of the fruits due to water loss by respiration and transpiration (Martin-Belloso and Soliva-Fortuny, [39]). This finding is in the same line with Khazael [18] in bitter orange.

Titratable acidity

A gradual decline in titratable acidity contents was observed with an increase in storage period (Table 3). Fruits packed with HDPE films (P_2) retained the highest mean TA (0.66%) under ambient conditions and Cold storage condition (0.70%). The control treatment had the lowest mean titratable acidity under both the storage condition (ambient and Cold storage conditions i.e, 0.59 and 0.65% respectively). Interactions among Packaging x storage and storage period x packaging were found significant, but non-significant among storage period x storage condition and storage period x storage condition x packaging.

The faster rate of decline in acidity at room temperature might be due to faster metabolic reactions leading to earlier senescence at higher temperature. The organic acids involved in the respiratory process are not oxidized at a faster rate at lower temperature, and therefore their levels remained high in cold storage condition as compared to ambient condition. Furthermore, fruits packed in HDPE film bags retained higher acidity content of fruits as compared to control, the reason might be the development of modified atmosphere (higher Co_2 and lower O_2) around fruits in polymeric film bags that slowed down various metabolic processes resulting in lower utilization of acids and decreased activity of invertage enzyme resulting in slow conversion of acids into sugars. This finding is in conformity with the findings of Kaur and Singh [16] in lemon and Chattopadhyay, [10], in orange and Tariq [43] in Clementine mandarin.

Total sugar

Total sugar content in the fruits increased with increase in storage period upto a certain period of storage and thereafter slow and steady decline was observed (Table 4). The control fruits registered maximum average total sugar (7.23%) and minimum was recorded in fruits packed with HDPE films under ambient condition (7.05%). Similar trend was noticed under cold storage condition, where control fruits recorded higher total sugar content (6.98%) and lowest was recorded in HDPE film packed fruits (6.91%). A gradual increase in mean total sugar content upto 21 days under ambient and 49 days under cold storage was noticed during storage and thereafter declined slowly and steadily, whereas control fruits recorded highest total sugars after 7 days in ambient condition (7.77%) and 28 days in cold storage condition(7.18%) of storage as compared to film packed fruits and thereafter declined at a faster rate resulting in development of odd flavour . Interactions among Packaging x storage, storage period x packaging, period x storage condition and storage period x storage condition x packaging were found to be significant.

Total sugar content of the fruits showed an increasing trend throughout the storage period but decreased at the time of shelf life termination of

Table 3

Titratable acidity (%) of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P1	0.76	0.69	0.64	0.62	0.54	0.65	0.74	0.73	0.7	0.68	0.66	0.64	0.63	0.6	0.68
P2	0.76	0.71	0.64	0.61	0.59	0.66	0.75	0.73	0.71	0.69	0.67	0.66	0.65	0.64	0.70
P3	0.76	0.69	0.60	0.59	0.56	0.65	0.73	0.71	0.69	0.67	0.65	0.63	0.61	0.58	0.67
P4	0.76	0.68	0.60	0.54	0.50	0.62	0.73	0.69	0.65	0.62	0.6	0.58	0.57	0.56	0.64
P5	0.76	0.68	0.62	0.60	0.53	0.64	0.74	0.72	0.68	0.64	0.65	0.62	0.63	0.6	0.67
P0	0.76	0.52	0.48	-	-	0.59	0.72	0.67	0.64	0.57	0.51	-	-	-	0.65
Mean	0.76	0.66	0.61	0.59	0.54		0.74	0.71	0.68	0.65	0.62	0.63	0.62	0.60	
	P	D	S	S X P	P XD	S x D	D x S x P								
SEd(±)	0.288	0.004	0.002	0.005	0.009	0.006	0.015								
CD(P=0.05)	0.006	0.007	0.004	0.010	0.017	NS	NS								

Table 4
Total sugar (%) of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	14	21	SLT	Mean	7	14	21	28	35	42	49	SLT	Mean
P1	6.75	6.88	7.04	7.50	7.26	7.09	6.78	6.82	6.93	7.03	7.16	7.21	7.23	7.16	7.01
P2	6.75	6.82	6.98	7.36	7.32	7.05	6.76	6.80	6.85	6.88	6.98	7.04	7.06	7.04	6.91
P3	6.75	6.89	7.01	7.5	7.25	7.08	6.77	6.83	6.91	7.01	7.11	7.18	7.20	7.17	6.99
P4	6.75	6.9	7.06	7.59	7.31	7.12	6.79	6.91	7.03	7.15	7.23	7.28	7.31	7.24	7.08
P5	6.75	6.87	7	7.52	7.25	7.08	6.78	6.86	6.99	7.11	7.23	7.27	7.29	7.27	7.06
P0	6.75	7.77	7.16	-	-	7.23	6.81	6.93	7.05	7.18	7.15	-	-	-	6.98
Mean	6.75	7.02	7.04	7.49	7.28		6.78	6.86	6.96	7.06	7.14	7.20	7.22	7.18	
	P	D	S	S X P	P XD	S x D	D x S x P								
SEd(±)	0.009	0.011	0.006	0.015	0.026	0.018	0.011								
CD(P=0.05)	0.017	0.021	0.012	0.029	0.051	0.036	0.021								

the fruits. The probable reason for this increase might be due to the hydrolysis of polysaccharides by hydrolytic enzymes resulting in formation and accumulation of sugar (Abdur [1]). The decline in the sugar content at the later stages of storage may be attributed to the fact that after the completion of hydrolysis of polysaccharides, no further increase in sugars occurred and subsequently a decline in these parameters is predictable as they along with other organic acids are primary substrate for respiration (Wills, [45]). The rate of increase or decrease in sugar content in perforated HDPE films under cold storage was comparatively slower than those stored in ambient condition. This might be due to reduced loss of moisture and metabolic activity under low temperature and modified atmosphere (higher CO_2 and low O_2) inside the package. The higher sugar content was recorded in unpacked fruits under ambient condition. This might be attributed to rapid loss of moisture and fast hydrolysis of polysaccharides to soluble forms of sugars under higher temperature and low humidity condition. This finding was in conformity with the findings of Bal, [6] in Ber and Keditsu, [17] in *Khasi* mandarin.

Total Soluble Solids (TSS)

The percent total soluble solid increased with the advancement of storage period rather slowly in the beginning but at a faster pace as the storage period advanced (Table 5). At the end of 58 days in cold storage, significant minimum mean TSS was recorded by fruits stored in perforated HDPE bags (8.34 ^{o}B) and maximum was recorded in PVC packed fruits (8.66 ^{o}B) followed by control fruits (8.64 ^{o}B). In ambient condition it was observed that minimum was recorded in HDPE film packed fruits (8.71 ^{o}B) and maximum was recorded in control fruits (9.09 ^{o}B). Interactions among Packaging x storage, storage period x packaging and storage period x storage were found significant, but non-significant among storage period x storage condition x packaging.

The increase in TSS content might be due to dehydration and hydrolysis of polysaccharides. Similar observations were also reported by Jawandha,[14] in Kinnow mandarin, Deka,[11] in *Khasi* mandarin. The gradual increment of TSS in fruits packed with HDPE films may be due to the effect of packaging film, acting as a physical barrier for transpiration losses and creating a modified atmosphere (higher concentration of CO_2 and depletion of O_2), which reduces the metabolic activity of the fruits. The highest TSS was recorded in control fruits under ambient condition which might be due to relatively high temperature and low relative humidity which caused faster rate of respiration and transpiration losses. This result is in general agreement with the findings Asrey, [5] in Kinnow mandarin, Kaur and Singh, [16] in lemon and Tariq, [43] in Clementine mandarin.

Ascorbic acid

The ascorbic acid content of the fruit showed linear decline during storage irrespective of different treatments (Table 6). However, the HDPE film packed fruits maintained the highest ascorbic acid content as compared to control fruits under both the storage conditions (ambient condition 33.97mg/100gm and cold storage 34.79mg/100gm which was at par with LDPE). Control fruits recorded the lowest mean ascorbic acid content in ambient (32.16mg/100gm) and also in cold storage condition (33.78mg/100gm).

The decrease in ascorbic acid during storage may be due to the oxidation of L-ascorbic acid into dehydroascorbic acid (Mapson,[24]). The retention of ascorbic acid content in Uni-packing with HDPE can be attributed to moisture retention and higher CO2 concentration in the packages (Vines and Obserbacher,[44]) which may have decreased the rate of respiration and subsequently slowing down the overall senescence in citrus fruits (Peteracek,[29]). Similar trend has been obtained by Yumbya,[42] in

Table 5

TSS (°B) of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P1	8	8.20	8.58	9.38	9.70	8.77	8.03	8.23	8.41	8.63	8.84	9.08	9.30	9.38	8.66
P2	8	8.21	8.48	9.08	9.76	8.71	8.02	8.06	8.13	8.22	8.33	8.53	8.83	8.93	8.34
P3	8	8.20	8.50	9.32	9.78	8.76	8.02	8.10	8.28	8.46	8.71	9.01	9.33	9.45	8.60
P4	8	8.23	8.57	9.37	9.88	8.81	8.04	8.14	8.34	8.56	8.86	9.13	9.43	9.45	8.66
P5	8	8.11	8.35	9.34	9.86	8.73	8.03	8.11	8.31	8.45	8.66	8.97	9.30	9.36	8.58
P0	8	9.26	10.00	-	-	9.09	8.30	8.58	8.90	9.22	8.83	-	-	-	8.61
Mean	8	8.37	8.75	9.30	9.80		8.07	8.20	8.40	8.59	8.71	8.94	9.24	9.31	
	P	D	S	S X P	P X D	S x D	D x S x P								
SEd(±)	0.005	0.006	0.003	0.008	0.014	0.010	0.025								
CD(P=0.05)	0.010	0.011	0.007	0.016	0.029	0.020	NS								

Table 6
Ascorbic acid (mg/100gm) of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P1	36.13	34.66	33.66	33.07	31.94	33.89	35.26	35.15	34.83	34.57	34.32	34.10	33.92	33.68	34.66
P2	36.13	34.72	33.83	32.93	32.24	33.97	35.35	35.14	34.94	34.73	34.50	34.24	34.08	33.98	34.79
P3	36.13	34.42	33.44	32.44	31.73	33.63	35.18	34.92	34.72	34.52	34.32	34.00	33.90	33.01	34.52
P4	36.13	34.46	33.26	32.26	31.57	33.54	35.18	34.65	34.51	34.39	34.17	33.93	33.82	33.63	34.49
P5	36.13	34.26	33.24	32.17	31.67	33.49	35.24	34.89	34.64	34.20	34.02	34.13	33.74	33.60	34.51
P0	36.13	32.16	28.18	-	-	32.16	34.68	33.82	33.18	32.68	32.18	-	-	-	33.78
Mean	36.13	34.11	32.60	32.57	31.83		35.15	34.76	34.47	34.18	33.92	34.08	33.89	33.58	
	P	D	S	S X P	P XD	S x D	D x S x P								
SEd(±)	0.133	0.163	0.094	0.231	0.401	0.283	0.694								
CD(P=0.05)	0.262	0.320	0.184	0.453	0.786	0.555	NS								

passion fruits, Serry, [37] in Washington navel orange, Kumar and Kumar, [20] in aonla, Kohli and Bhambota, [19] in acid lime and Ramin and Khoshbakhat [33] in acid lime.

CCI value (Citrus colour index)

The present study revealed that the colour value CCI of the fruits, showed an increasing trend with the progress in the storage period. Maximum mean CCI was recorded in control fruits under both the storage condition (2.91 and 3.31 under ambient condition and cold storage respectively) and minimum mean CCI was recorded in fruits packed with HDPE films under cold storage condition (1.76) and similar trend was observed in ambient condition (2.29). This might be attributed to the rate of decline in chlorophyll content. Accumulation of carotenoid content was at very slower rate during storage. Further, slow and steadier change in peel colour might be due to low temperature and oxygen stress condition which results in retardation of degradation process of chlorophyll by chorophyllase enzyme (Matsumoto, [25]). The temperature under cold storage condition increases biosynthesis and accumulation of individual carotenoids (b-carotene, b-cryptoxanthin, a-cryptoxanthin, lutein, zeaxanthin, antheraxanthin, 9-cis-violaxanthin) than the fruits kept at ambient condition. These individual carotenoid compounds impart characteristic colour of mandarin fruits (Tao, [42]). This result is in general agreement with the findings of Singh and Reddy, [38] in Nagpur mandarin, Plaza, [30] in Valencia mandarin and Tao[44] in navel orange

Sensory quality

The investigation indicated that, overall organoleptic score based on colour, flavour, texture and taste of the fruits increased initially and thereafter, it decreased with advancement of storage period (Table 8).

The maximum average sensory score was observed by fruits packed in HDPE film (7.36 in ambient and 7.61 in cold storage) under both the storage conditions followed by LDPE film packed fruits (7.20 in ambient and 7.48 in cold storage condition).The control fruits registered the minimum sensory score (6.60 and 7.10 under ambient and cold storage condition respectively). Increasing value at initial storage period might be due to increase in sweetness and change of fruits colour from greenish yellow to orange in colour. The decrease in organoleptic score might be due to loss of moisture and spoilage resulting in shrinkage of fruits. Highest overall organoleptic score was recorded in perforated HDPE film packed fruits under cold storage condition (7.61), because polymeric film prevented the build up of ethylene under high CO_2, while cold storage treatment retarded enzymatic activity, respiration and activity of pathogens. These changes resulted in slower down the ripening and senescence, enhancing shelf life and maintaining fruit quality during storage. These results are with conformity of the findings of Lal [23] and Lal and Dhaka [22] in pomegranate.

Shelf life

Data on shelf life assessment of *Khasi* mandarin is furnished in Table 9. Fruits packaged with P_2 showed the highest mean shelf life (44 days) followed by P_5 (39.50 days) and the lowest mean value was recorded in P_0 (24.50 days). In case of storage condition, fruits at cold storage showed the highest value (50.33days), while fruits kept under ambient condition recorded the lowest value (24.67days). Interaction effect of packaging material and storage conditions had significant influence on storage life.

HDPE films under cold storage (58 days) exhibited slow rate of deterioration of quality as compare to other packaging materials. The highest acceptability of fruits packaged with HDPE under cold storage might be due to the high barrier properties of HDPE films against the migration of

Table 7

CCI Value of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P1	-1.86	0.92	2.31	5.88	6.12	2.68	-1.21	0.49	2.51	2.81	3.48	4.29	5.36	5.82	2.41
P2	-1.86	0.41	1.87	5.31	5.73	2.29	-1.93	-0.46	1.43	2.26	2.79	3.07	5.03	5.49	1.76
P3	-1.86	1.15	2.42	5.79	6.1	2.72	-0.77	0.83	3.64	4.04	4.19	4.41	5.86	5.98	2.92
P4	-1.86	1.15	2.81	6.02	6.3	2.88	-0.06	1.08	3.84	3.88	4.6	4.95	6.01	6.02	3.16
P5	-1.86	0.97	2.08	5.22	5.74	2.43	-1.00	0.76	3	3.35	4.15	4.69	6.32	5.99	2.82
P0	-1.86	4.32	6.28	-	-	2.91	1.32	4.04	4.71	5.92	5.71	-	-	-	3.31
Mean	-1.86	1.49	2.96	5.64	6.00		-0.61	1.12	3.19	3.71	4.15	4.28	5.72	5.86	
	P	D	S	S X P	P XD	S x D	D x S x P								
SEd(±)	0.012	0.015	0.009	0.022	0.037	0.014	0.065								
CD(P=0.05)	0.024	0.030	0.017	0.042	0.073	0.028	0.127								

Table 8
Overall organoleptic scores of the fruits as influenced by different treatments

Treatment	*D0*	*Ambient condition (S1)*					*Cold storage (S2)*								
		Days after storage					*Days after storage*								
		7	*14*	*21*	*SLT*	*Mean*	*7*	*14*	*21*	*28*	*35*	*42*	*49*	*SLT*	*Mean*
P1	7.14	7.31	7.45	7.71	6.41	7.20	7.12	7.55	7.71	7.75	7.79	7.91	7.57	6.83	7.48
P2	7.14	7.25	7.39	7.81	7.24	7.36	7.23	7.38	7.42	7.76	7.78	7.98	8.09	7.69	7.61
P3	7.14	7.36	7.43	7.65	6.29	7.18	7.23	7.5	7.59	7.72	7.86	7.92	7.62	6.58	7.46
P4	7.14	7.46	7.4	7.59	6.21	7.16	7.3	7.48	7.62	7.75	7.79	7.9	7.61	6.35	7.44
P5	7.14	7.29	7.38	7.64	6.36	7.16	7.15	7.41	7.58	7.6	7.65	7.84	7.56	6.73	7.41
P0	7.14	7.56	5.09	-	-	6.60	7.38	7.41	7.63	7.07	5.94	-	-	-	7.10
Mean	7.14	7.37	7.02	7.68	6.50	7.11	7.24	7.46	7.59	7.61	7.47	7.91	7.69	6.84	7.42
	P	D	S	S X P	P XD	S x D	D x S x P								
SEd(±)	0.007	0.008	0.005	0.011	0.020	0.014	0.034								
CD(P=0.05)	0.013	0.016	0.009	0.022	0.038	0.028	0.067								

moisture, oxygen and other gases (Sandhya,[36]) that results in low respiration and transpiration rate and also help in reduce sensitivity to ethylene synthesis (Saltveit[35]). Fruits (control) stored in ambient condition (14 days) recorded minimum shelf life. This might be due to high temperature coupled with faster microbial decay (Oluwafemi, [28]). This result is in general agreement with the findings of Dhatt and Randhawa, [12] in Kinnow mandarin.

Marketability

The effect of market period at (24°C±1) and 75 per cent RH for 7 days on fruits parameters, presented in Table 9, showed an increased in physiological weight loss and TSS in the fruits. There was a slight decrease in titrable acidity, ascorbic acid and sugar content. Firmness decreased with the increase in storage period. It was observed that the rate of change of physico-chemical constituents were faster in fruits under retail market condition as compared to cold storage condition. Considering all the sensory and quality attributes of the fruits after marketing period, all fruits were judged "like very moderately". The fruits had good taste, texture and overall acceptance at the end of market condition, allowing additional 7 days shelf life under market condition.

Table 9
Shelf life of the fruits as influenced by different treatments

Treatment	*Ambient condition (S1)*	*Cold storage (S2)*	*Mean*
P1	26.00	52.00	39.00
P2	30.00	58.00	44.00
P3	26.00	52.00	39.00
P4	25.00	53.00	39.00
P5	27.00	52.00	39.50
P0	14.00	35.00	24.50
Mean	24.67	50.33	
	P	S	P x S
SEd(±)	0.509	0.359	0.880
CD(P=0.05)	1.000	0.712	1.740

Table 10
Physico-chemical characteristics of the fruits after marketability

Sl. No.	*Physico-chemical characteristics*	*Best quarantine treatment (after 60 days of storage)*	*After seven days under retail market*
1.	PLW (%)	1.68	1.86
2.	Texture (kg/f)	1.60	1.42
3.	TSS (° B)	9.02	9.24
4.	Titrable acidity (%)	0.66	0.54
5.	TSS/acidity ratio	13.67	17.11
6.	Total sugar (%)	7.33	7.24
7.	Ascorbic acid (mg/100gm)	35.40	43.24
8.	Overall acceptability	7.81(nine hedonic scale)	80.00 % (Crisosto, 2005)

CONCLUSION

One of the major benefits of modified atmosphere packaging (MAP) is the prevention or retardation of fruit water loss, senescence and associated biochemical and physiological changes. Packaging of *Khasi* mandarin fruits in HDPE films seems to maintain the physico-chemical qualities and shelf life under cold storage condition and ambient conditions by 58 and 30 days respectively as compared to 35 and 14 days only in control (unpacked) fruits. This technology can be helpful in minimizing the postharvest losses and hence, extend marketing period of *Khasi* mandarin.

BIBLIOGRAPHY

Abdur, R.; Sajid, M.; Saeeda and Najia (2011). Effects of wet heat treatment (wht) durations on the quality of sweet orange stored at room temperature.*Sarhad J. Agric.* **27**(2): 190-196.

Al-Juhaimi, F.Y. and Ghafoor, K. (2013). Bioactive compounds, antioxidant and physico-chemical properties of juice from lemon, mandarin and orange fruits cultivated in Saudi Arabia. *Pakistan J. Bot.* **45**(4): 1193-1196.

Amerine, M.A.; Pangborn, R.M. and Rossler, E.B. (1965). Principles of sensory evaluation of food. Academic Press, New York, pp. 366-374.

AOAC (1984). Official Methods of Analysis, 14thedn. Association of Official Analytical Chemists, Washington, DC.

Asrey, R.; Sasikala, C. and Singh, D. (2012). Combinational impact of Debaryomyceshanseniibioagont and 1-Methyecyclopropen (1-MCP) on shelf life and quality attributes of Kinnow mandarin. Hort.Flora. Res. Spectr.1(2): 103-109.

Bal, J.S.; Singh, P. and Singh, R. (1978). Preliminary observation on the storage behaviour of ber at room and refrigeration temperature. J. Res. PAU Ludhiana15(4): 396-399.

Barua, P.C. (1991). Studies on postharvest management and processing of Khasi mandarin (Citrus reticulata Blanco.) fruits. Ph.D.Thesis submitted to Haryana Agril. University, Hissar.

Ben-Yehoshua, S.; Kobiler, I. and Shapiro, B. (1979). Some physiological effects of delaying deterioration of citrus fruits by individual seal packaging in high density polyethylene film. J. American Soc. Hortic. Sci.104: 868-872.

Ben-Yehoshua, S.; Kobiler, L. and Shapiro, B. (1981). Effects of cooling versus seal packaging with high-density polyethylene on keeping qualities of various citrus cultivars. J. American Soc. Hort. Sci.106: 536-540.

Chattopadhyay, N.; Hore, J.K. and Sen, S.K. (1992). Extension of storage life of sweet orange (C. sinensisOsbeck) cv. Jaffa. Indian J. Plant Physiol. 35.

Deka, B.C.; Choudhury, S. and Bhattacharyya, A. (2012). Pre-harvest treatments for shelf-life extension of Khasi mandarin under different storage conditions. Indian J. Hort. 69(2): 2012: 252-257.

Dhatt, A.S. and Randhawa, J.S. (1994). Extending the postharvest life of unrefrigerated Kinnow fruit by individual seal packaging. *Punjab Hort. J.***34**: 27-29.

Fonseca, S.C.; Oliveira, F.A.R. and Brecht, J.K. (2002). Modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages: a review. J. Food Engg. 52: 99-119.

Jawanda, J.S.; Singh, R. and Vij, V.K. (1978). Studies on extending post harvest life of Kinnow mandarin. Punjab Hort. J.18(3&4): 149-153.

Kader, A.A.; Zagory, D. and Kerbel, E.L. (1989). Modified atmosphere packaging of fruits and vegetables. Rev. Food Sci. Nutr.28(1): 1-30.

Kaur, S. and Singh, S. (2012). Effect of various post-harvest treatments on shelf life of lemon (Citrus limon) cv. Baramasi during ambient storage. Prog. Agric.12(2): 277-283.

Keditsu, R.; Sema, A. and Maiti, C.S. (2003). Effect of modified packaging and low temperature on post harvest life of 'Khasi' mandarin. J. Food Sci. Tech.40: 646-651.

Khazael, N.; Jouki, M. and Ali, J. (2011). Effects of modified atmosphere packaging on physico-chemical characteristics and sensory evaluation of bitter orange (Citrus aurantium). Indian J. Agril. Sci. 81(11): 1014-1018.

Kohli, R.R. and Bhambota, J.R. (1966). Storage of lime (Citrus aurantifoliaSwingle). Indian J. Hort. 23:140-146.

Kumar, N.S and Kumar, J. (2004). Effect of HDPE, LDPP and PVC packaging on the ascorbicacid content and decay loss during storage of aonla fruits cv. Chakaiya. Haryana J. Hort. Sci.33(3-4): 213-15.

Ladaniya, M.S. (2008a). Commercial fresh citrus cultivars and producing countries. In: Citrus Fruit: Biology, Technology and Evaluation. Acadamic Press Elsevier, USA, p. 18.

Lal, G. and Dhaka, R.S. (2003). Evaluation of storage behaviour of date palm (P. dactylifera) cultivars in Rajasthan. *The Indian J. Agric. Sci.* 73(10): 553-555.

Lal, G.; Fageria, M.S.; Gupta, N.K.; Dhaka, R.S. and Khandelwal, S.K. (2002). Shelf-life and quality of ber (Z. mauritiana) fruits after post-harvest water dipping treatments and storage. *J. Hort. Biotechnol.* 77(5): 576-579.

Mapson, L.W. (1970). Vitamins in fruits. In :Biochemistry and fruits and their products. Hulme, A.C. (ed). Academic Press, London and New York, Vol. 1.

Matsumoto, H.; Ikoma, Y.; Kato, M.; Nakajima, N. and Hasegawa, Y. (2009). Effect of postharvest temperature and ethylene on carotenoid accumulation in the flavedo and juice sacs of Satsuma mandarin (Citrus unshiu Marc.) fruit. *J. Agric. Food Chem.* 57: 4724-4732.

Ministry of Agriculture (2017). State wise area and production for Individual horticulture crops. In: Horticultural Statistics at a glance 2017. Chanu press Pvt. Ltd. New Delhi, p. 182.

Naz, F.; Mohammad, S.; Nazli, M.; Khan, F.K. and Shah, T.H. (1997). Effect of storage, temperature and packaging materials on the extension of storage life of cv. Blood Red orange. *Sarhad J. Agricul.* 13(3): 299-320.

Oluwafemi, J.C.; Mahajan, P.V.; Al-Said, F.A.J. and Opara, U.L. (2013). Modified atmosphere packaging technology of fresh and fresh-cut produce and the microbial consequences—A Review. *Food Bioproc. Technol.* **6**: 303-329.

Petracek, P.D.; Dou, H. and Pao, S. (1998). The influence of applied waxes on postharvest physiological behaviour and pitting of grapefruit. Postharv. Biol. Technol. 14: 99-106.

Plaza, L.; Crespo, I.; de Pascual-Teresa, S.; de Ancos, B.; Sánchez-Moreno, C.; Muñoz, M. and Cano, M.P. (2011). Impact of minimal processing on orange bioactive compounds during refrigerated storage. Food Chem.124:646-651.

Purvis, A.C. (1983). Moisture loss and juice quality from waxed and individually seal-packaged citrus fruits. Proc. Fla. State Hort. Soc. 96: 327-329.

Rai, D.R.; Tyagi, S.K.; Jha, S.N. and Mohan, S. (2008). Qualitative changes in the broccoli under modified atmosphere packaging in perforated polymeric film. *J. Food Sci. Technol. Mysore* 45(3): 247-250.

Ramin, A.A. and Khoshbakhat, D. (2008). Effect of microperforated polyethylene bags and temperatures on the storage quality of acid lime *fruit. J. Agric. Environ. Sci.* 3(4): 590-594.

Roy, S.K. (2001). Storage of tropicl and sub-tropcal fruits. *Indian J. Hort.* 158: 164-169.

Saltveit, M.E. (2003). Is it possible to find an optimal controlled atmosphere? *Postharv. Biol. Technol.* **27**: 3-13.

Sandhya (2010). Modified atmosphere packaging of fresh produce: current status and future needs. *Food Sci. Technol.* **43**: 381-392.

Serry, N.K.H. (2010). Some modified atmosphere packaging treatments reduce chilling injury and maintain postharvest quality of Washington Navel Orange. *J. Hort. Sci. Ornamen. Plant.* 2(3): 108-113.

Singh, K.K. and Reddy, B.S. (2006). Post harvest physio-mechanical properties of orange peel and fruit. J. Food Engg. 73(2): 112-120.

Soliva-Fortuny, R.C.; Elez-Martínez, P. and Martín-Belloso, O. (2004). Microbiological and biochemical stability of fresh-cut apples preserved by modified atmosphere packaging. Innov. Food Sci. Emerg. Technol. 5: 215-224.

Solomos, T. and Laties, G.G. (1973). Cellular organization and fruit ripening. *Nature* 245: 390-391.

Suparlan, K. and Itoh, K. (2003). Combined effects of hot water treatment (HWT) and modified atmosphere packaging (MAP) on quality of tomatoes. Pack. Technol. Sci. 16: 171-178.

Tao, N.; Wang, C.; Xu, J. and Cheng, Y. (2012). Carotenoid accumulation in postharvest "Cara Cara" navel orange (Citrus sinensisOsbeck) fruits stored at different temperatures was transcriptionally regulated in a tissue-dependent manner. Plant Cell Rep. 31: 1667-1676.

Tariq, M.K.; Thompson, A.K.; Asi, A.A.; Virk, A. and Javid, M.F. (2004). Curing and seal packaging effect on peel and pulp weight loss in scuffing damaged and undamaged citrus fruits. J. Agric. Res. 42(1): 67-72.

Vines, H.M. and Oberbacher, M.F. (1961). Changes in carbon dioxide concentrations within fruit and containers during storage. Proc. Flarida State Hort. Soc.74: 243-246.

Wills, R.B.H.; Bembridga, P.A. and Scott, K.J. (1980). Use of flesh firmness and other objective test to determine consumer acceptability of 'Delicious' apples. Australian J. Expt. Agric. Anim. Husb. 20: 252-69.

Yumbya, P.; Ambuko, J.; Shibairo, S. and Owino, W.O. (2014). Effect of modified atmosphere packaging on the shelf life and postharvest quality of purple passion fruit (Passiflora edulis Sims). J. Postharv. Technol.02(01): 025-036.

Zagory, D. and Kader, A.A. (1988). Modified Atmosphere Packaging of fresh produce. Food Technol.42 (Sept.): 70-77.