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EFFECTS OF PACKAGING MATERIALS AND STORAGE TEMPERATURE ON FRUIT QUALITY AND SHELF LIFE OF MANDARIN

M. A. H. Talukder[1], M. M. Rahman[2], M. M. Hossain[2], M. A. K. Mian[3] and Q. A. Khaliq[4]

Abstract

The experiment was carried out to investigate the effects of packaging material and storage temperature on fruit quality and shelf life of mandarin. Fruits of Khasi type mandarin were packed in non-perforated and perforated polyethylene bag (0.5% and 1%) and compared to those without polyethylene baggy. Then fruits were stored in cool chamber having 5, 10, 15^0 C temperature and ambient condition. There were sixteen treatment combinations. Fruit decay, weight loss, total soluble solids (TSS) and total sugars increased while juice content, titratable acid and ascorbic acid content decreased with the increase in storage temperature and storage duration. Fruit decay was found minimum (16.67 %) up to 75 DAS at 5^0 C in 0.5% perforated polybag during storage. Minimum loss of fruit weight was recorded at 5^0 C (12.18 and 13.96%) at 75 DAS when fruits were stored in 0.5 and 1% perforated polybag, respectively. Total soluble solids were higher (10.8 %) in 1 % perforated polybag with storage at 10^0 C at 75 DAS. The TSS, total sugar and titratable acid content were found almost static from 75 to 90 DAS. Considering fruit decay, weight loss and quality, mandarin could be stored up to 75 days at 5^0 C and up to 60 days at 10^0 C both in 0.5 and 1 % perforated polybags.

Keywords: Mandarin, packaging materials, quality, shelf life, storage, temperature.

Introduction

Mandarin **(***Cirtrus reticulata* Blanco) is considered as one of the most important and popular citrus fruit in the world as well as in Bangladesh. It is cultivated widely in the tropical and subtropical regions. The consumption of fruits in Bangladesh per head per day is only 78 g (Anon., 2009) against the minimum requirement of 115 g per head per day (Islam, 2011). The current production of mandarin orange is 3448 metric ton (Anon., 2013). Although the current fruit production is considerably below the domestic requirement, sometimes the supply of fruit exceeds the local market demand particularly in the peak harvesting period. Moreover, fruits are perishable and the post harvest loss of fruits in Bangladesh ranges between 25-50% while it is only 5-25% in developed countries (Bhuyan *et al.,* 2008). A study conducted by Assam Agricultural University, Jorhat revealed that the post harvest loss of Khasi mandarin is about 13.95% (Deka *et al.,* 2004).

Mandarin cannot be stored for longer period at room temperature (Chundawat *et al.,* 1978) and are spoiled by decaying organisms.

[1]Pomology Division, Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur-1701, [2]Department of Horticulture, [3]Department of Genetics and Plant Breeding and, [4]Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.

To check the losses, fruits are stored in a convenient repository or warehouse to provide steady supply in future. In some cases, the storage improves the quality of the fruits. The storage of fruits meant to control the respiration rate, transpiration, pest infestation and to maintain the fruits quality in proper condition and to be used by the consumers in future (Chattopadhyay, 1994).

Fruits are packed for more efficient handling and marketing. Good package promotes sales and improves shelf life by reducing mechanical damage and water loss. Package protects the produce from physical, physiological and pathological deterioration during handling. In Bangladesh, the citrus fruits are generally packed in bamboo baskets, unventilated wooden boxes and even gunny bags. The principal aim of storage is to control deteriorative changes in the produce while prolonging its marketability thus helping in orderly marketing (Gangwar *et al.,* 2007). This also ensures better returns to the growers. These results have emphasized to adopt improved packaging techniques and cold storage facilities at the retail level. Hence, this study was conducted to find out suitable packaging material and storage temperature to increase the shelf life and reduce the loss of nutritional quality of mandarin.

Materials and Methods

Fruits of Khasi cultivar were harvested from the farmer's mandarin orchard at Juri, Moulvibazar. Fresh mature fruits were transported with an open van to BSMRAU, Salna, Gazipur. The experiment was conducted at the Laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur and Post-harvest section of Horticulture Research Centre, BARI, Gazipur during November 2009 to February 2010. There were 16 treatment combinations (1. P_1T_1= Non-perforated + 5^0 C, 2. P_1T_2= Non-perforated + 10^0 C, 3. P_1T_3= Non-perforated + 15^0 C, 4. P_1T_4= Non-perforated + Ambient condition, 5. P_2T_1= 0.5 % perforated + 5^0 C, 6. P_2T_2= 0.5 % perforated + 10^0 C, 7. P_2T_3= 0.5 % perforated + 15^0 C, 8. P_2T_4= 0.5 % perforated + Ambient condition, 9. P_3T_1= 1 % perforated + 5^0 C, 10. P_3T_2= 1 % perforated + 10^0 C, 11. P_3T_3= 1 % perforated + 15^0 C, 12. P_3T_4= 1 % perforated + Ambient condition, 13. P_4T_1= Without polybag + 5^0 C, 14. P_4T_2= Without polybag + 10^0 C, 15. P_4T_3= Without polybag + 15^0 C and 16. P_4T_4= Without polybag + Ambient condition). Fruits were packed in bamboo baskets using straw as lining material. The fruits were washed in running tap water and were dried through cooling fan. Six fruits were packed in 8 cm × 6 cm size polyethylene bags according to the treatment. Eighteen fruits were considered as one replication. Packs were stored at room temperature (20 ± 5^0 C) with related humidity around 50 ± 5% in November 10, 2009. This study continued up to February 10, 2010. The experiment was laid out in Completely Randomized Design (factorial) with three replications.

Data recorded

Data on physical parameters like fruit decay (%), weight loss (%), juice content (%) and total soluble solids and chemical parameters like total sugars, titratable acid and ascorbic acid were recorded at 15 days interval up to 90 days following by Ranganna (1986).

Statistical analysis

Data were analyzed statistically using MSTAT-C program. Before analysis data were transformed according to Gomez and Gomez (1984). Mean separation was done by Duncan Multiple Range Test (DMRT).

Results and Discussion

Fruit decay: Highest fruit decay was found in mandarin without polybag and the lowest was in 0.5% perforated polybag (Table 1). The decay was significantly higher in 1% polybag as compared to 0.5% perforated polybag and in non-perforated polybag as compared to 1% perforated polybag. In non-perforated polybag, decay was lower compared to without polybag that might be due to fruit sealing with polybag helps in checking both respiration and ethylene production. Similar results were reported by Jain and Chauhan (1995) and Choudhary and Kumbhare (1979). The loss of fruit due to decay was increasing with an increase in storage temperature irrespective of packaging materials (Table 1). In non-perforated polybag, all the fruits decayed within 75 days both at 5^0 C and 10^0 C. Most of the fruits rotted at 15^0 C within 60 days and it was 30 days in ambient condition. No fruit decay was observed up to 45 days after storage (DAS) at 5^0 C along with 0.5% perforated polybag. Minimum decay was recorded 4.17 and 16.67% at 60 DAS and 75

Table 1. Effect of packaging material and storage condition on percent fruit decay of mandarin fruit.

Treatment combination	Fruit decay (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	6.25 f	14.58 e	22.92 f	45.83 b	100.00 a	100.00 a
P_1T_2	6.25 f	16.67 e	33.33 e	47.92 b	100.00 a	100.00 a
P_1T_3	12.50 d	45.83 c	62.5 b	100.00 a	100.00 a	100.00 a
P_1T_4	41.67 ab	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a
P_2T_1	0.00 g	0.00 f	0.00 h	4.17 e	16.67 e	41.67 d
P_2T_2	0.00 g	0.00 f	6.25 g	10.42 d	22.92 d	52.08 bc
P_2T_3	8.33 ef	16.67 e	41.67 d	100.00 a	100.00 a	100.00 a
P_2T_4	22.92 c	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a
P_3T_1	0.00 g	0.00 f	4.17 g	10.42 d	27.08 c	50.00 c
P_3T_2	0.00 g	0.00 f	6.25 g	16.67 c	33.33 b	54.17 b
P_3T_3	10.42 de	22.92 d	54.17 c	100.00 a	100.00 a	100.00 a
P_3T_4	35.42 b	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a
P_4T_1	6.25 f	14.58 e	33.33 e	45.83 b	100.00 a	100.00 a
P_4T_2	14.58 d	18.75 de	35.42 de	100.00 a	100.00 a	100.00 a
P_4T_3	27.08 c	57.34 b	100.00 a	100.00 a	100.00 a	100.00 a
P_4T_4	45.83 a	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a
CV (%)	11.92	4.86	5.51	4.18	1.66	1.63
Level of significance	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance.

Legend:

P_1 = Non-perforated polybag
P_2 = 0.5 % perforated polybag
P_3 = 1 % perforated polybag
P_4 = Without polybag

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

DAS, respectively. At 90 DAS, it was increased up to 41.67%. Whereas, minimum fruit decay was recorded at 45 DAS (6.25%) and 60 DAS (10.42%) at 10^0 C in same packaging material. Fruit decay was the minimum at 45 DAS (4.17%) in 1% perforated polybag at 5^0 C. At 75 and 90 DAS it was increased to 27.08 and 50.00%, respectively. A good number of fruit decay was recorded at 45 DAS (6.25%) and 60 DAS (16.67%) at 10^0 C in same packaging material. Liu *et al.* (1998) reported 'Ponkan' mandarin fruits stored at 20^0 C had higher amount of decay. They also reported that the optimum temperature for long term storage of mandarin was 12.5-15.0^0 C.

All the fruits decayed in both type of packet at 60 DAS at 15^0C storage. In without polybag, cent percent fruit was decayed within 75 days at 5^0 C stored and it was within 60 days at 10^0 C. In ambient condition, 41.67% fruit rotted at 15 DAS in without polybag and all the fruits rotted within 30 DAS. In ambient condition, all the fruits rotted in between 15 to 30 days in without polybag. Deka *et al.* (2006) suggested mandarin fruits without any treatment could be kept for 19 days in ambient conditions.

Weight loss

The highest loss of fruit weight was observed in ambient condition at 15 days after storage and the lowest in non-perforated polybag (Table 2). This loss was significantly higher in 0.5% perforated polybag as compared to non-perforated polybag and it was also higher in 1% perforated polybag compared to 0.5% perforated polybag.

Loss of fruit weight increased with the rise in storage temperature at 15 DAS. This trend continued until the fruit decayed. Minimum loss of fruit weight was observed at 5^0 C (12.18 and 13.96%) at 75 DAS when stored in 0.5 and 1% perforated polybag, respectively. Cohen *et al.* (1994) suggested that the fruits lose their weight after harvesting, such weight loss being mostly due to water loss. They also suggested weight loss depends mostly on storage temperature.

Juice content

The highest juice content was observed in the fruit of without polybag wrapping and the lowest in non-perforated polybag at 15 DAS (Table 3). The juice content decreased with an increase in storage temperature. This trend continued until the fruits were rotten. After 90 days of storage, maximum juice content (38.60%) was observed in 0.5% perforated polybag when stored at 5^0C which was followed by 1% perforated polybag at the same storage temperature (38.42%). The juice content decreased with an increase in storage period in all the treatment combinations. Jain and Chauhan (1995) observed that the juice content decreased with the increasing of storage period and it was directly correlated with the loss of fruit weight due to evaporation.

Total soluble solids

The highest total soluble solid (TSS) was observed in the fruit of without wrapping and the lowest in non-perforated polybag at 15 DAS (Table 4). The TSS increased with an increase in storage temperature. This trend continued until the fruits were rotten.

The highest TSS was observed in without wrapping and it was lowest in non-perforated polybag. The TSS increased with an increase in storage temperature and storage duration.

Table 2. Effect of packaging material and storage condition on weight loss of mandarin fruit.

Treatment combination	Weight loss (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	1.36 m	2.58 i	5.10 g	6.25 g	-	-
P_1T_2	1.51 m	3.05 h	5.26 g	6.66 f	-	-
P_1T_3	1.87 l	3.72 g	5.77 f	-	-	-
P_1T_4	4.10 gh	-	-	-	-	-
P_2T_1	2.98 j	4.27 f	6.14 f	9.46 e	12.18 d	17.23 d
P_2T_2	2.33 k	5.76 e	8.42 d	12.57 c	15.87 b	18.32 b
P_2T_3	4.57 ef	8.50 b	12.57 a	-	-	-
P_2T_4	7.18 c	-	-	-	-	-
P_3T_1	3.36 i	5.60 e	7.80 e	11.69 d	13.96 c	17.50 c
P_3T_2	4.29 fg	6.85 d	9.39 c	14.47 a	17.85 a	21.67 a
P_3T_3	6.68 d	9.12 a	12.75 a	-	-	-
P_3T_4	8.00 b	-	-	-	-	-
P_4T_1	3.85 h	7.77 c	9.24 c	13.30 b	-	-
P_4T_2	4.75 e	8.45 b	10.85 b	-	-	-
P_4T_3	7.60 b	9.35 a	-	-	-	-
P_4T_4	11.25 a	-	-	-	-	-
CV (%)	2.04	2.95	2.08	2.55	2.27	2.53
Level of significance	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1 % level of significance, **Significant at 1 % level of significance.

Legend:

P_1 = Non-perforated polybag
P_2 = 0.5 % perforated polybag
P_3 = 1 % perforated polybag
P_4 = Without polybag
- all fruits decay

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

Table 3. Effect of packaging material and storage condition on juice content of mandarin fruit.

Treatment combination	Juice content (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	50.46	49.82 a	49.33 a	48.77 a	-	-
P_1T_2	50.26	49.57 a	49.16 a	48.51 a	-	-
P_1T_3	49.87	48.51 ab	47.72 b	-	-	-
P_1T_4	49.77	-	-	-	-	-
P_2T_1	49.44	48.16 a-c	47.35 bc	45.31 b	42.21 a	38.60 a
P_2T_2	49.12	47.87 a-c	47.10 bc	44.72 bc	41.28 b	37.46 b
P_2T_3	48.85	46.61 b-d	44.06 e	-	-	-
P_2T_4	47.20	-	-	-	-	-
P_3T_1	49.10	47.94 a-c	47.13 bc	45.08 b	40.17 a	38.42 a
P_3T_2	48.60	46.56 b-d	46.81 b-d	43.76 c	39.85 b	37.21 b
P_3T_3	48.32	46.11 b-d	45.50 de	-	-	-
P_3T_4	47.56	-	-	-	-	-
P_4T_1	48.35	46.65 b-d	46.00 cd	44.25 bc	-	-
P_4T_2	47.74	45.83 cd	45.36 de	-	-	-
P_4T_3	47.25	45.30 d	-	-	-	-
P_4T_4	46.47	-	-	-	-	-
CV (%)	6.22	2.19	1.63	1.96	3.56	2.93
Level of ignificance	NS	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, NS = Not Significant, Initial juice content was 50.63% Legend:

P_1 = Non-perforated polybag
P_2 = 0.5% perforated polybag
P_3 = 1% perforated polybag
P_4 = Without polybag
- all fruits decay

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

Table 4. Effect of packaging material and storage condition on total soluble solids (TSS) of mandarin fruit.

Treatment combination	TSS (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	8.9	9.1 e	9.4 d	9.8 d	-	-
P_1T_2	8.9	9.2 de	9.7 cd	10.0 cd	-	-
P_1T_3	9.1	9.4 b-e	9.9 bc	0.0 e	-	-
P_1T_4	9.2	-	-	-	-	-
P_2T_1	9.0	9.3 c-e	9.6 cd	10.2 bc	10.3 b	10.2 b
P_2T_2	9.1	9.5 b-e	9.9 bc	10.5 ab	10.6 ab	10.6 a
P_2T_3	9.3	9.8 a-d	10.2 ab	-	-	-
P_2T_4	9.4	-	-	-	-	-
P_3T_1	9.0	9.4 b-e	9.9 bc	10.4 ab	10.6 ab	10.6 a
P_3T_2	9.2	9.7 a-e	10.1 ab	10.7 a	10.8 a	10.9 a
P_3T_3	9.3	10.0 ab	10.4 a	-	-	-
P_3T_4	9.5	-	-	-	-	-
P_4T_1	9.3	9.6 b-e	10.2 ab	10.6 a	-	-
P_4T_2	9.3	9.9 a-c	10.4 a	-	-	-
P_4T_3	9.5	10.3 a	-	-	-	-
P_4T_4	9.7	-	-	-	-	-
CV (%)	2.96	2.21	1.13	1.84	1.15	1.41
Level of significance	NS	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, NS = Not Significant, Initial TSS content was 8.8%.

Legend:

P_1 = Non-perforated polybag
P_2 = 0.5% perforated polybag
P_3 = 1% perforated polybag
P_4 = Without polybag
- all fruits decay

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

TSS content was observed higher (10.8%) at 75 DAS in 1% perforated polybag storage at 10^0 C followed by same polybag storage at 5^0 C as well as 0.5% perforated polybag storage at 10^0 C (10.6%). Hence, TSS was increased with an increase in storage period in all the treatment combinations. The TSS increased during storage which was probably due to hydrolysis of polysaccharides from non-soluble fraction to soluble fraction. The results are in agreement with the findings of Singh (1988). Yang-Yong Joon and Yang (2001) observed soluble solids content of mandarin fruits in cold storage increased until two months of storage and then decreased sharply.

Total sugars

The highest total sugar was observed in fruit of without polybag and the lowest was in non-perforated polybag at 15 DAS (Table 5). The total sugars also increased with the increases in storage temperature and storage duration. This increase of sugar may be due to the conversion of organic acids through gluconeogenesis (Echeverria and Valich, 1989). At 75 days of storage, total sugar content was observed 7.06 and 7.12% at 5^0 and 10^0 C in 0.5% perforated polybag and 1% perforated polybag, respectively. At 90 days after storage sugar content was almost static. This might be due to increase in senescence process and breakdown of sugar in respiration process and gluconeogenesis process was almost stopped. Similar trend was observed in 1% perforated polybag with same storage temperature. The results are in agreement with the findings of Singh (1988).

Table 5. Effect of packaging material and storage condition on total sugar of mandarin fruit.

Treatment combination	Total sugars (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	6.43 e	6.47 d	6.59 b	6.80 a	-	-
P_1T_2	6.48 de	6.56 cd	6.62 b	6.96 a	-	-
P_1T_3	6.52 de	6.63 b-d	6.83 b	-	-	-
P_1T_4	6.65 c-e	-	-	-	-	-
P_2T_1	6.46 e	6.68b-d	6.78 b	6.91 a	7.06 a	7.07 a
P_2T_2	6.52 de	6.79 bc	6.90 b	6.98 a	7.12 a	7.15 a
P_2T_3	6.70 c-e	7.22 a	7.47 a	-	-	-
P_2T_4	6.89 a-c	-	-	-	-	-
P_3T_1	6.52 de	6.72 b-d	6.85 b	6.94 a	7.10 a	7.12 a
P_3T_2	6.66 c-e	6.84 bc	6.92 b	7.05 a	7.15 a	7.16 a
P_3T_3	6.80 b-d	7.28 a	7.50 a	-	-	-
P_3T_4	7.05 ab	-	-	-	-	-
P_4T_1	6.59 c-e	6.76 b-d	6.91 b	7.04 a	-	-
P_4T_2	6.71 c-e	6.92 b	7.08 ab	-	-	-
P_4T_3	6.87 a-c	7.31 a	-	-	-	-
P_4T_4	7.12 a	-	-	-	-	-
CV (%)	1.34	1.49	2.63	1.59	1.26	1.61
Level of Significance	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, Initial total sugars content was 6.38% Legend:

P_1 = Non-perforated polybag
P_2 = 0.5% perforated polybag
P_3 = 1% perforated polybag
P_4 = Without polybag
- all fruits decay

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

Titratable acid

The titratable acid content of mandarin fruits was significantly affected by packaging material. A continuous decrease in titratable acid content with increase in storage period of fruit was observed in different packaging materials (Table 6). This decrease may be due to its degradation in the fruits during storage. After 75 days of storage, titratable acid content was observed lower (0.792 and 0.786%) at 5^0C and 10^0 C in 0.5% perforated polybag compared to 1% perforated polybag along with same storage temperature. Titratable acid decreased to 0.762% from its initial content (0.990%) at 75 DAS stored at 10^0 C along with 1% perforated polybag. Echeverria and Ismail (1990) found a decrease in titratable acid in 'Hamlin orange and 'Robinson' tangerines during 9 weeks of storage at 15^0 C. This decrease of titratable acid may be due to the conversion of organic acids to sugars through gluconeogenesis (Echeverria and Valich, 1989). Saucedo *et al.* (1997) reported wrapping had no effect on titratable acidity.

Ascorbic acids

The ascorbic acid content of mandarin fruits was significantly affected by packaging material. Continuous and drastic decrease in ascorbic acid content with the increase in storage period from its initial content (36.43 mg/100 ml juice) was observed in different packaging materials (Table 7). This decrease was might be due to its degradation in the fruits. The lowest ascorbic acid content (15.21 mg/100ml juice) was observed in 1% perforated polybag along with storage at 10^0 C compared to 0.5% perforated polybag in same storage temperature at 90 DAS. Nagy

Table 6. Effect of packaging material and storage condition on titratable acid content of mandarin fruit.

Treatment combination	Titratable acid (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	0.968 a	0.941 a	0.905 a	0.870 a	-	-
P_1T_2	0.961 ab	0.933 ab	0.890 ab	0.831 b	-	-
P_1T_3	0.952 a-c	0.895 cd	0.852 cd	-	-	-
P_1T_4	0.946 a-c	-	-	-	-	-
P_2T_1	0.951 a-c	0.927 a-c	0.883 ab	0.830 b	0.792 a	0.788 a
P_2T_2	0.948 a-c	0.911 a-c	0.866 bc	0.815 bc	0.786 a	0.784 a
P_2T_3	0.945 a-c	0.870 d	0.830 de	-	-	-
P_2T_4	0.933 b-d	-	-	-	-	-
P_3T_1	0.959 ab	0.922 a-c	0.850 cd	0.816 bc	0.782 a	0.778 a
P_3T_2	0.956 a-c	0.897 cd	0.811 ef	0.800 c	0.762 b	0.761 b
P_3T_3	0.951 a-c	0.840 e	0.795 f	-	-	-
P_3T_4	0.948 a-c	-	-	-	-	-
P_4T_1	0.943 a-c	0.907 a-c	0.833 de	0.804 c	-	-
P_4T_2	0.937 b-d	0.902 b-d	0.824 e	-	-	-
P_4T_3	0.928 cd	0.895 cd	-	-	-	-
P_4T_4	0.914 d	-	-	-	-	-
CV (%)	0.70	1.31	1.14	1.00	1.79	1.07
Level of Significance	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, Initial titratable acid content was 0.990%. Legend:

P_1 = Non-perforated polybag
P_2 = 0.5% perforated polybag
P_3 = 1% perforated polybag
P_4 = Without polybag
- all fruits decay

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

Table 7. Effect of packaging material and storage condition on ascorbic acid content of mandarin fruit.

Treatment combination	**Ascorbic acid content (mg/100ml juice)**					
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
P_1T_1	34.17 a	31.87 a	28.47 a	22.17 cd	-	-
P_1T_2	33.87 ab	31.30 a	27.33 b	21.20 e	-	-
P_1T_3	33.25 a-c	29.48 b	25.95 d	0.00 f	-	-
P_1T_4	32.26 a-e	-	-	-	-	-
P_2T_1	32.85 a-c	28.40 c	26.77 bc	24.45 a	21.14 a	18.67 a
P_2T_2	32.64 a-d	27.35 de	25.62 de	23.70 b	20.40 b	17.15 b
P_2T_3	31.10 c-f	25.67 fg	24.33 f	-	-	-
P_2T_4	30.22 e-g	-	-	-	-	-
P_3T_1	32.00 a-e	28.20 cd	26.29 cd	23.16 b	19.53 c	16.46 c
P_3T_2	31.67 b-e	27.19 e	25.16 e	22.44 c	18.22 d	15.21 d
P_3T_3	30.44 d-g	25.28 g	23.80 f	-	-	-
P_3T_4	29.21 fg	-	-	-	-	-
P_4T_1	31.64 b-e	27.36 e	24.35 f	21.72 de	-	-
P_4T_2	31.45 c-f	26.50 ef	23.66 f	-	-	-
P_4T_3	29.22 fg	25.29 g	-	-	-	-
P_4T_4	28.58 g	-	-	-	-	-
CV (%)	3.91	2.42	2.49	3.97	5.70	5.07
Level of significance	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, Initial ascorbic acid content was 36.43 mg/100 ml juice Legend:

P_1 = Non-perforated polybag
P_2 = 0.5% perforated polybag
P_3 = 1% perforated polybag
P_4 = Without polybag
- all fruits decay

T_1 = Storage at 5^0 C
T_2 = Storage at 10^0 C
T_3 = Storage at 15^0 C
T_4 = Storage in Ambient condition

and Smoot (1977) reported that Vitamin-C decreased in packed juice product but no change in vitamin C in the fresh fruit during post harvest period.

Conclusion

This study indicated that fruit decay, weight loss, TSS and total sugars increased during storage, while juice content, titratable acid and ascorbic acid content decreased with the increase in storage temperature and storage duration. The lowest fruit decay was observed in 0.5% perforated polybag compared to 1% perforated and non-perforated polybag. The TSS, total sugar and titratable acid content were almost static during 75 to 90 days after storage. Based on fruit decay, weight loss and quality, mandarin could be stored up to 75 days at 5^0 C and up to 60 days at 10^0 C both in 0.5 and 1% perforated polybag.

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