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QUALITY AND BIOCHEMICAL CHANGES IN FILM PACKAGED KINNOW MANDARIN DURING AMBIENT STORAGE

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ABSTRACT: The effect of four heat shrinkable films viz., D955 (12 micron), D955 (15 micron), Opti-Max and Xenith, with or without treatment of Sodium carbonate (3%) or Thiophanate methyl (0.1%) was evaluated for individual wrapping of Kinnow (Citrus *nobilis* Lour x *Citrus deliciosa* Ten.) fruits to maintain their shelf life under ambient conditions (temperature: 12° to 18°C & RH: 55 to 70%). The lowest physiological loss in weight was in the fruits treated withThiophanate methyl (0.1%)+Xenith film, and the highest shriveling was observed in unwrapped fruits after 60 days of storage. The weight loss increased with the advancement of storage period. Colour development was not adversely affected any heat-shrinkable film and colour retention was better in fruits sealed in D955 (12 micron) and HDPE (10 micron) after 30 days of storage. Highest titratable acidity was retained in fruits treated with Opti-Max followed by Thiophanate methyl (0.1%) + Opti-Max film. TSS : acid ratio decreased as the storage period advanced. The maximum ascorbic acid content was recorded in the fruits treated with Thiophanate methyl (0.1%) +Xenith film. During storage, the major change in internal quality observed was a reduction in acidity and ascorbic acid, and increase in total soluble solids and total sugars of fruits. Changes in acidity, sugars, TSS and ascorbic acid of the shrink-wrapped fruits were lower than that of non-wrapped fruits during 60 days of storage under ambient conditions.

Keywords : *Kinnow, D955, Xenith, Opti-max, shelf life, physiological weight loss, vitamin-C.*

The major cause of loss of quality in 'Kinnow' mandarin, as in other citrus fruits is moisture loss (Ben-Yehoshua, 1). A possible way to prolong shelf life could be to maintain a high level of humidity in the environment during transportation and retailing. Film wrapping seems to be the cheapest and most suitable way to reduce transpiration and maintain fruit freshness. Wrapping offers the advantage of creating a humid environment regardless of temperature and vapour pressure differences in the various environments encountered along the distribution chain. Besides, the environmental conditions along the distribution chain are generally unpredictable and difficult to control. However, if the film characteristics do not meet the requirements of the commodity, anaerobic respiration may be stimulated, resulting in an increased rate of breakdown of organic acids and sugars (Hardenburg et al., 13 ; Kader, 15).

The vapour transmission rate of the film is also important because, if the in-package atmosphere is saturated, the risk of decay is enhanced. In addition, if condensation forms inside the package, it will greatly impair gas diffusion and make it difficult to see the product. Similarly, postharvest decays frequently cause extensive losses in citrus fruits before or after it reaches the consumer. A significant proportion of this loss can be prevented by applying effective fungicides to the fruit soon after harvest. The objective of this study was to evaluate the possibility of lengthening the post-harvest life of 'Kinnow' mandarin under ambient conditions by testing four heat shrinkable films along with the use of a fungicide and sodium carbonate.

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MATERIALS AND METHODS

Fully ripe Kinnow fruits, uniform in size and free from blemishes and bruises were collected from the citrus groove at Punjab Agricultural University, Ludhiana. After picking, the fruits were immediately brought to the laboratory and were prepared for storage within 4-6 hours of harvest. The fruits, which received injury of any type during harvesting or handling were rejected. All the fruits were washed thoroughly with tap water and divided into four lots. The first lot was air dried and fruits were individually seal-packaged in four different heat shrinkable films i.e. D955 (15 micron), D955 (12 micron), Opti-Max and Xenith. All heat shrinkable films were of Cryovac make. The second and third lot were dipped in aqueous solution of 0.1 per cent Thiophanate methyl and 0.3 per cent Sodium carbonate for two minutes, respectively. The fruits were air dried at room temperature and individually seal-packaged in four shrink films using Weldotron, USA shrink packaging machine. The fourth lot was sealed with electric sealer in 10 micron HDPE bags of size 10x15 cm. Washed fruits but without any treatment were kept as control.

Fruits were packed in corrugated fiber board (CFB) boxes before their storage in non-controlled room conditions, with the temperature ranging from 12° to 18°C and relative humidity (RH) ranging from 55 to 70%.

Twenty fruits from each treatment were numbered with a felt-tip pen and weighed at the start of experiment and weight of these fruits was recorded at different storage intervals to assess physiological loss in weight. The colour of selected fruits from each treatment was noted with the help of colour chart (Wilson, 20). Juice and peel percentage were recorded as per standard procedure. Chemical analysis of the juice was carried out as previously reported byD'Aquino and Palma (8), and included acidity expressed as grams of citric acid in 100 ml of juice, total soluble solids (TSS) expressed as degrees Brix and ascorbic acid (mg ascorbic acid/100 g of juice).

RESULTS AND DISCUSSION

The minimum mean loss in weight (2.91%) was observed in fruits treated with Xenith + Thiophanate methyl (0.1%) followed by Xenith + Sodium carbonate (3%) in an ascending order (Table 1). The maximum mean weight loss to the tune of 18.28 per cent occurred in control i.e. the fruits without any treatment. The fungicidal application coupled with Xenith sealing was most effective in reducing weight loss in Kinnow. It might be due to blocking of aperture on lenticels, thereby, reducing the rate of transpiration and respiration (Dhatt *et al.,* 10; Mahajan *et al.,* 17). Similarly, days of ambient storage had a significant influence on post-harvest weight loss. Minimum mean weight loss (1.84 per cent) was noticed after 30 days of storage and it increased with duration of ambient storage. Reduced loss of weight in untreated fruits as compared to sealed fruits can be attributed to the creation of semi-permeable barrier around the fruit by different films and the water saturated atmosphere inside the bag. A similar reduction in the physiological loss of weight in individually seal packed grapefruit, Shamuoti oranges and lemons with HDPE film was observed by Ben-Yehoshua *et al.* (2, 3 and 4), who attributed it to high humidity and no air circulation inside the seal package.

Since most of the water is lost from peel tissue, moisture loss primarily affects the appearance of the fruit. The consequences of peel moisture loss are shrinkage, softening, shriveling and deformation of the fruit. Desiccation of peel is one of the most important

Table 1 : Effect of different treatments on physiological weight loss and peel contentduring ambient storage of Kinnow fruits.

Treatments	Physiological weight loss (%)				Peel (%)			
	30 days	45 days	60 days	Mean	30 days	45 days	60 days	Mean
D955 (15 micron)	1.33	2.50	5.80	**3.21**	25.50	25.00	24.80	**25.10**
D955 (15 micron) + Thiophanate methyl (0.1%)	1.32	3.01	5.80	**3.38**	25.28	24.15	23.88	**24.44**
D955 (15 micron)+ Sodium Carbonate (3%)	1.51	3.50	5.70	**3.57**	24.63	24.12	23.07	**23.94**
D955 (12 micron)	1.47	3.70	6.70	**3.96**	24.27	23.85	23.35	**23.82**
D955 (12 micron)+ Thiophanate methyl (0.1%)	1.60	3.40	5.80	**3.60**	26.05	24.97	24.41	**25.14**
D955 (12 micron) + Sodium Carbonate (3%)	1.32	3.60	6.75	**3.89**	25.48	24.55	23.92	**24.65**
Opti-Max	1.31	3.75	5.93	**3.66**	25.48	24.54	23.91	**24.64**
Opti-Max +Thiophanate methyl (0.1%)	1.65	2.77	5.33	**3.25**	24.26	23.39	23.25	**23.63**
Opti-Max + Sodium Carbonate (3%)	1.58	2.50	6.88	**3.65**	24.26	23.38	23.27	**23.64**
Xenith	1.92	2.63	6.43	**3.66**	24.62	24.15	23.59	**24.12**
Xenith + Thiophanate methyl (0.1%)	1.44	2.30	5.00	**2.91**	26.64	24.80	24.59	**25.34**
Xenith + Sodium Carbonate (3%)	1.26	2.68	5.17	**3.04**	25.50	24.47	24.20	**24.72**
HDPE (10 micron)	1.16	3.90	5.92	**3.66**	24.50	23.94	23.68	**24.04**
Control (No treatment)	6.94	17.52	30.38	**18.28**	20.10	16.90	15.66	**17.55**
Mean	1.84	4.13	7.68		24.75	23.73	23.26	
C.D. (P = 0.05)	Treatment = 0.93; Storage interval = 0.43; Treatment × Storage interval = 1.16				Treatment = 2.19; Storage interval = 1.01; Treatment × Storage interval = 3.79			
Initial value	NA				28.07			

causes of loss of commercial value of citrus fruits. In present study reduction in moisture loss, as evident from peel percentage was observed in all the film wrapping treatments as compared to unwrapped fruits (Table 1). The maximum mean peel percentage (25.34) was observed in fruits treated with Xenith + Thiophanate methyl 0.1 per cent which was significantly higher than control (17.55). Lower peel percentage in unwrapped fruits clearly indicated desiccation of peel, thereby rendering the fruits unmarketable. Storage interval had significant influence on peel percentage of Kinnow fruits under ambient conditions, the maximum mean peel percentage (24.75) was noticed after 30 days of storage, and peel percentages decreased with the advancement in storage interval.

The maximum mean juice percentage (48.35) was observed in Xenith + Thiophanate methyl (0.1%) followed by D955 (15 micron) + Sodium carbonate (3%). However, the minimum mean juice percentage (38.06) was found in control, which was significantly lower than all other treatments (Table 2). Among the storage intervals, the maximum mean juice percentage (49.58) was found after 30 days of storage interval, which was significantly higher than 45 and 60 days of storage intervals. In this experiment all the treatments resulted in higher juice percentage as compared to control. The significantly higher juice recovery was observed with the use of different films as compared to non-sealed fruits. This might be attributed to reduction in transpiration and respiration losses in sealed fruit. The significant decrease in juice percentage with prolongation of storage was probably due to continuous dehydration of peel and juice (Das and Dash, 9). However, Eaks and Masias (12) and Cohen *et al.* (6) reported that the increase in juice content occurs in lime and lemon during storage at ambient temperature but not in other citrus fruits, the initial increase might be due to the fact that initial loss of moisture takes place from the peel only.

The total soluble solids (TSS) content of fruits increased with the increase in storage interval (Table 2). The minimum mean total soluble solids (11.12 °Brix) were recorded in the treatment Opti-max + Sodium carbonate 3 per cent followed by HDPE (10 micron). Whereas, the maximum mean total soluble solids (13.57 °Brix) were recorded in the fruits kept without any treatment. Among the storage intervals, the minimum mean total soluble solids (11.19°Brix) was found after 30 days of storage, which was significantly lower than 60 days of ambient storage. The total soluble solids increase with an increase in the storage

Table 2 : Effect of different treatments on juice content and TSS during ambient storage of Kinnow fruits.

Treatments	Juice (%)				TSS (%)			
	30 days	**45 days**	**60 days**	**Mean**	**30 days**	**45 days**	**60 days**	**Mean**
D955 (15 micron)	51.51	46.36	44.00	**47.29**	11.13	11.23	11.77	**11.38**
D955 (15 micron) + Thiophanate methyl (0.1%)	49.00	48.00	44.15	**47.05**	11.27	11.60	11.73	**11.53**
D955 (15 micron)+ Sodium Carbonate (3%)	50.48	48.00	46.00	**48.16**	11.23	11.33	11.63	**11.40**
D955 (12 micron)	51.20	45.00	41.76	**45.98**	11.17	11.23	11.43	**11.28**
D955 (12 micron)+ Thiophanate methyl (0.1%)	46.72	45.50	41.58	**44.60**	11.00	11.40	11.93	**11.44**
D955 (12 micron) + Sodium Carbonate (3%)	49.33	45.90	43.55	**46.26**	11.03	11.33	11.47	**11.28**
Opti-Max	51.29	47.00	45.00	**47.76**	11.00	11.17	12.00	**11.39**
Opti-Max +Thiophanate methyl (0.1%)	51.57	48.00	42.14	**47.24**	10.97	11.00	12.23	**11.40**
Opti-Max + Sodium Carbonate (3%)	50.66	46.00	41.85	**46.17**	10.47	11.07	11.83	**11.12**
Xenith	50.10	46.95	41.29	**46.11**	11.03	11.33	12.17	**11.51**
Xenith + Thiophanate methyl (0.1%)	51.27	50.39	43.40	**48.35**	10.97	11.40	11.50	**11.29**
Xenith + Sodium Carbonate (3%)	49.30	47.58	44.65	**47.17**	11.50	11.63	11.70	**11.61**
HDPE (10 micron)	49.92	47.81	43.17	**46.97**	11.13	11.27	11.40	**11.27**
Control (No treatment)	41.78	38.24	34.16	**38.06**	12.80	13.66	14.26	**13.57**
Mean	49.58	44.48	42.62		11.19	11.48	11.93	
CD (P = 0.05)	Treatment = 3.56; Storage interval = 1.66; Treatment × Storage interval = 6.16				Treatment = 1.23; Storage interval = 0.57; Treatment × Storage interval = 2.12			
Initial Value	55.02				9.8			

interval. It may be due to increased hydrolysis of polysaccharides and concentration of juice due to dehydration. Although, total soluble solids increased with increase in storage period but the quality of fruit deteriorated because of disturbed TSS : acid ratio and development of off-flavour. Similar, results were also reported by Chance and Harding (5) in Pope's summer orange and Singhrot *et al.* (19), Dhatt *et al.* (10) and Jawandha *et al.* (14) in Kinnow fruits. Similar trend was recorded for total sugars (Table 3). All the treatment resulted in lower total sugars percentage than control, but total sugars increased with increase in storage period. The increase in total sugars percentage was probably due to respiratory break down of polysaccharides (Dutt *et al.,* 11).

The maximum mean acid percentage (0.72) was noticed in the fruits treated with only Opti-Max, followed by fruits treated with Opti-Max + Thiophanate methyl (0.1%). Among storage intervals the maximum mean acidity (0.73) was recorded after 30 days, which was significantly higher than 45 and 60 days of storage interval (Table 3). The acidity decreased with prolongation of storage period. The decrease in acidity might be due to the utilization of organic acids in respiratory process. Gradual decreases in acidity in citrus have been reported by Ben-Yehoshua (1).

Gradual decrease in acidity was observed with prolongation of storage interval, as a result TSS :acid ratio also changed (Table 4).The minimum mean TSS :acid ratio (15.88) was found in the fruit wrapped with Opti-Max followed by Opti-Max + Thiophanate methyl (0.1%) and it was significantly lower than control. Among the storage intervals, the minimum mean TSS :acid ratio (15.71) was recorded after 30 days of storage, and it was significantly lower than recorded after 60 days of storage. It is evident that TSS :acid ratio increased with increase in storage period. This might be due to the increase in total soluble solids and decrease in acidity during storage period.

The mean ascorbic acid ranged from 15.62 to 18.17 mg/100 ml juice (Table 4). The maximum mean ascorbic acid (18.17 mg/100 ml) was found in Kinnow fruits treated with Xenith + Thiophanate methyl (0.1), whereas, the least mean ascorbic acid (15.62 mg/100 ml) was recorded in control.Among the storage intervals, the maximum mean ascorbic acid (19.35

Table 3 : Effect of different treatments on total sugars and acidity during ambient storage of Kinnow fruits.

Treatments	Total sugars (%)				Acidity (%)			
	30 days	45 days	60 days	Mean	30 days	45 days	60 days	Mean
D955 (15 micron)	7.58	7.83	8.06	**7.82**	0.68	0.66	0.65	**0.66**
D955 (15 micron) + Thiophanate methyl (0.1%)	7.55	7.79	8.03	**7.79**	0.64	0.63	0.60	**0.62**
D955 (15 micron)+ Sodium Carbonate (3%)	7.57	7.79	8.05	**7.80**	0.70	0.68	0.55	**0.64**
D955 (12 micron)	7.56	7.92	8.11	**7.86**	0.68	0.66	0.64	**0.66**
D955 (12 micron)+ Thiophanate methyl (0.1%)	7.50	7.80	8.05	**7.78**	0.72	0.68	0.66	**0.69**
D955 (12 micron) + Sodium Carbonate (3%)	7.54	7.84	8.09	**7.82**	0.72	0.68	0.65	**0.68**
Opti-Max	7.68	7.90	8.13	**7.90**	0.77	0.73	0.66	**0.72**
Opti-Max + Thiophanate methyl (0.1%)	7.57	7.70	8.09	**7.79**	0.78	0.74	0.60	**0.71**
Opti-Max + Sodium Carbonate (3%)	7.47	7.65	8.00	**7.71**	0.68	0.64	0.57	**0.63**
Xenith	7.52	7.68	8.03	**7.74**	0.76	0.69	0.64	**0.70**
Xenith + Thiophanate methyl (0.1%)	6.84	7.03	7.19	**7.02**	0.77	0.71	0.59	**0.69**
Xenith + Sodium Carbonate (3%)	7.43	7.63	7.90	**7.65**	0.77	0.65	0.63	**0.69**
HDPE (10 micron)	8.06	8.92	8.98	**8.65**	0.77	0.68	0.57	**0.67**
Control (No treatment)	9.15	9.42	9.89	**9.49**	0.71	0.70	0.67	**0.69**
Mean	**7.64**	7.92	8.19		0.73	0.68	0.62	
CD (P = 0.05)	Treatment = 0.71; Storage interval = 0.33; Treatment × Storage interval = 1.2 M				Treatment = NS; Storage interval = 0.04; Treatment × Storage interval = NS			
Initial value	6.50				0.94			

mg/100 ml) was observed after 30 days of storage, which was significantly higher than that recorded 45 and 60 days of storage intervals. Ascorbic acid decrease with increase in storage period, this decrease in ascorbic acid content may be due to the oxidation of ascorbic acid with time. The maximum reduction in ascorbic acid was observed in the fruits kept under control; this might be due to higher rate of oxidation of ascorbic acid in unwrapped fruits. Similarly, Kohli and Bhombota (16) reported decrease in ascorbic acid in lime and Kinnow with the increase in storage period. The less reduction of ascorbic acid in treatments other than control might be due to lesser availability of oxygen for oxidation of ascorbic acid. Miller and Heilman (18) reported that the reduction in ascorbic acid is directly related with respiration rate because during respiration phenolic compounds get converted to quinines, but during normal course of metabolism quinines are converted back to phenols by ascorbic acid. As long as the adequate supply of ascorbic acid prevails, reversible reaction remains continuous, hence continuous reduction in ascorbic acid occurred during the storage period.

The colour of the fruits after 30 days of ambient storage (Table 5) was noted as light orange (024B) to medium orange (025B). The fruits which were wrapped with HDPE (10 micron) and control developed higher colour range, which was categorized as medium orange (025B). The fruits exhibited slight variation in colour after 45 days of ambient storage. The colour of fruits in the HDPE (10 micron) and D955 (12 micron) was deep orange colour 025A and dull orange colour (026A) was found only in control.After 60 days of ambient storage there was further improvement in colour in all the treatments, the fruits were noted as deep orange (025A) in most of treatments, except D955 (12 micron), HDPE (10 micron) and control, which were dull orange in colour (026A). At different storage intervals a minor variation in fruit colour was recorded in all the treatments. The colour variation trend exhibited in all the treatments at different storage intervals has the support of findings of Cohen *et al.* (7).

Table 4 : Effect of different treatments on TSS :acid ratio and ascorbic acid during ambient storage of Kinnow fruits.

Treatments	TSS : Acid ratio				Ascorbic acid (mg/100 ml juice)			
	30 days	45 days	60 days	Mean	30 days	45 days	60 days	Mean
D955 (15 micron)	16.48	17.0	18.25	**17.25**	19.45	17.15	14.65	**17.08**
D955 (15 micron) + Thiophanate methyl (0.1%)	17.61	18.41	19.56	**18.52**	18.72	16.68	15.50	**16.97**
D955 (15 micron)+ Sodium Carbonate (3%)	16.11	16.85	21.16	**18.04**	20.17	16.75	15.81	**17.58**
D955 (12 micron)	16.42	17.02	17.86	**17.10**	18.85	16.37	15.80	**17.01**
D955 (12 micron)+ Thiophanate methyl (0.1%)	15.33	16.80	18.08	**16.74**	18.28	16.23	14.71	**16.41**
D955 (12 micron) + Sodium Carbonate (3%)	16.46	16.86	17.63	**16.98**	19.31	17.42	15.55	**17.43**
Opti-Max	14.30	15.24	18.09	**15.88**	19.45	17.15	15.15	**17.25**
Opti-Max +Thiophanate methyl (0.1%)	14.06	14.86	20.50	**16.47**	18.80	15.80	14.93	**16.51**
Opti-Max + Sodium Carbonate (3%)	15.40	17.30	20.79	**17.83**	20.32	16.05	15.47	**17.28**
Xenith	14.10	16.35	19.04	**16.80**	18.28	15.23	14.88	**16.13**
Xenith + Thiophanate methyl (0.1%)	14.24	15.10	19.46	**16.57**	20.93	17.89	15.69	**18.17**
Xenith + Sodium Carbonate (3%)	14.98	17.95	18.57	**17.17**	19.41	17.53	15.78	**17.57**
HDPE (10 micron)	14.57	16.57	19.92	**17.02**	20.70	17.47	15.70	**17.96**
Control (No treatment)	18.03	19.51	21.28	**19.61**	18.27	14.83	13.77	**15.62**
Mean	15.71	16.87	19.48		19.35	16.61	15.24	
CD (P = 0.05)	Treatment = 1.22; Storage interval = 0.57; Treatment × Storage interval = 2.11				Treatment = NS; Storage interval = 0.64; Treatment × Storage interval = 2.37			
Initial value	10.43				24.25			

Table 5. Effect of different treatments on colour of Kinnow fruits during ambient storage.

Treatment	Colour of Kinnow fruits			
	30 days	45 days	60 days	Mean
D955 (15 micron)	024A	025B	026A	024A
D955 (15 micron) + Thiophanate methyl (0.1%)	024B	025B	025A	024B
D955 (15 micron)+ Sodium Carbonate (3%)	024A	025B	025A	024A
D955 (12 micron)	024A	025A	026A	024A
D955 (12 micron)+ Thiophanate methyl (0.1%)	024A	024A	025A	024A
D955 (12 micron) + Sodium Carbonate (3%)	024A	025B	025A	024A
Opti-Max	024A	024A	025A	024A
Opti-Max +Thiophanate methyl (0.1%)	024A	025B	025A	024A
Opti-Max + Sodium Carbonate (3%)	024A	025B	025A	024A
Xenith	024A	025B	025A	024A
Xenith + Thiophanate methyl (0.1%)	024A	025B	025A	024A
Xenith + Sodium Carbonate (3%)	24A	025B	025A	024A
HDPE (10 micron)	25B	025A	026A	025B
Control (No treatment)	025B	026A	026A	025B

Analysing all the aspects considered, the best results were obtained combining Xenith film with Thiophanate methyl (0.1%). This treatment reducedmoisture loss, preservedjuice and without much alteration in the chemical characteristics.

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