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Effect of Surface Coatings on the Shelf Life and Quality of Kinnow Fruits During Storage

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Abstract

The Kinnow mandarin (*Citrus nobilis* x *Citrus deliciosa*) fruits of uniform size, disease and bruise free were picked randomly from all the four directions of the plants with the help of secateur. The fruits were sorted and washed with chlorine solution (100 ppm). Thereafter, the fruits were coated with 'Nipro Fresh SS 40T and SS 50' formulations. The fruits were air dried and packed in corrugated fibre board boxes (10 Kg capacity). The coated and control (uncoated) fruits were stored under cold storage conditions (5-7°C and 80-85% RH) and under ambient conditions (11-19°C and 80-85% RH). The various physico-chemical attributes of fruits were recorded in 30, 45 and 60 days in cold stored fruits and at 5, 10 and 15 days in fruits stored at ambient conditions. The results of the study indicated that Kinnow fruits coated with 'Nipro Fresh SS 40T or SS 50' showed significant delay in the change of weight loss, firmness, TSS, titratable acidity and vitamin-C content of Kinnow fruits. The present study envisaged that Kinnow fruit wax coated with these formulations can be successfully stored for 45 days under cold storage conditions (5-7^{o}C and 90-95% RH) and for 10 days under ambient conditions (11-19^{o}C and 65-70% RH) with highly acceptable sensory quality. The uncoated fruits, on the other hand, maintained postharvest shelf life of 30 days in cold storage and 5 days at ambient conditions.

INTRODUCTION

Kinnow mandarin (*Citrus nobilis* x *Citrus deliciosa*) is a predominantly citrus fruit of Punjab and ranks first with respect to area and production. It occupies an area of 41 thousand ha with an annual production of 8 Lac tones (Annon, 2012). The area under Kinnow is increasing at a faster rate due to its wider adaptability and very high economic returns to growers. It has an attractive colour, high juice content and pleasant taste. Due to these quality traits, Kinnow is in high demand not only in Indian markets, stretching from Delhi to Kolkata, Hyderabad, Bangalore and Chennai but also in Sri Lanka, Thailand and some middle east countries like Bahrain, Kuwait and Saudi Arabia (Dhatt and Mahajan, 2011). The commercial harvesting of Kinnow fruit in Punjab falls between December to February and these months often witness with arrival of truck loads of Kinnow fruits at major wholesale markets of India. Marketing of clean and attractive fruit that is free of decay and surface blemishes, is one of the main concerns of citrus fruit traders. Waxing of fruits, in the packinghouse operations, is an integral part of the handling system for Kinnow and other citrus fruits. In a commercial packing line, washing of fruits in clean water is the primary step done to yield clean and attractive fruits. However, during the washing operation, the natural wax coating of Kinnow is removed from the fruits. This renders undesirable side effects to the fruits which limit its marketable life. Therefore, the application of food grade waxes to Kinnow fruits become imperative to enhance the consumer acceptability and shelf life.

Research on edible coatings and films has been intense in recent years. Attempts to

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diminish crop losses and maintain the quality of fresh fruit for a longer period is a priority for all the producers (Ribeiro et al., 2007). Application of coating is a simple and effective technique, which can help in reducing the post harvest losses and enhancing the shelf life of fruits by reducing the rate of respiration, transpiration and other metabolic processes of fruits (Zagory and Kader 1988). Edible coatings provide a barrier against external elements and therefore increase shelf life by reducing gas exchange, loss of water, flavours, aroma and soluble migration towards the cuticle (Guilbert et al., 1996)

The use of food grade wax coatings on fresh fruits and vegetables have been approved by the Food Safety and Standard Authority of India under regulation 7.3.1 (FSSA, 2006) and with the enforcement of this act, various types of wax formulations are now-a-days being supplied by leading companies in the markets. Therefore, the application of these formulations needs to be tested and investigated in depth during post harvest operations of various commodities. Hence the present study was planned to study the effect of different wax coatings on shelf life and quality of Kinnow fruits under cold and ambient storage conditions.

Materials and Methods

The present investigation was carried out at Punjab Horticultural Postharvest Technology Centre, Punjab Agricultural university Ludhiana during the year 2012-13. Kinnow fruits of uniform size, disease and bruise free were picked randomly from all the four directions of the plants with the help of secateur during February. The fruits were sorted graded and washed with chlorine solution (100 ppm). Thereafter fruits were divided into the requisite lot for further handling. Two types of wax formulations viz 'Nipro Fresh SS 40T and SS 50' (Manufacturer and supplier: NIPRO Technologies Ltd, Panchkula, Haryana, India,) were tested on Kinnow fruits. Two lots of Kinnow fruits, each consisting of 325 fruits were selected for application of coatings. There were three treatments and three replications under each storage conditions and each replication was comprised of 12 fruits. The fruits were coated with the help of a piece of foam pad drenched with particular coating material and applied gently on the surface of fruits. Thereafter fruits were air dried. The coated and control (un-coated) fruits were stored under cold storage conditions (5-7°C and 80-85% RH) and at ambient conditions (11-19°C and 80-85% RH). The various physico-chemical parameters of fruits were recorded at different intervals viz 30, 45 and 60 days in case of cold stored fruits and at 5, 10 and 15 days under ambient conditions. The physiological loss in weight (PLW) of the fruit was calculated on initial weight basis and results were expressed in percent. The firmness of the fruit was measured with the help of Texture Analyzer (Model TA-HDi Make, Stable Microsystems, UK) using a compression platen (75 mm diameter). The total soluble solid (TSS) of the fruit was recorded with hand refractometer and correction at 20°C was applied. The titratable acidity and ascorbic acid contents were determined as per standard procedure (AOAC, 2005). Three fruits from each replication were drawn at each storage interval for determining the biochemical traits of the fruit. For PLW, 12 fruits in each treatment and replication were kept separately for recording the weight loss during a stipulated period of storage. The overall organoleptic quality of the fruit was determined by a panel of 10 judges using 9-point Hedonic scale (Amerine et al., 1965). The fruit juice was extracted with the help of screw type extractor and was strained through mesh (32 mm) and weighed. The percentage of juice was calculated on fresh weight basis. The experiment consists of three treatments and three storage intervals and each treatment was replicated thrice.

The experiment was arranged in a completely randomized design. SAS 9.3 was used for analysis of variance and p-values were worked out from the data. The parameters which differed significantly at $p<0.05$ level were further subjected to mean comparison using LSD at the 5 % level of significance.

Results and Discussion

Physiological loss in weight (PLW)

In general, the weight loss of Kinnow fruits increased with the increase in storage period under both the storage conditions (Table 1). Under cold storage conditions, the fruits coated with SS-40T recorded the lowest average weight loss (5.27%) closely followed by SS-50 (5.55%). The uncoated fruits recorded the highest average weight loss (7.37%). In case of Kinnow fruits the acceptable level of weight loss is up to 5.5% above which the fruits show the symptoms of shriveling and likely to fetch a lower price in the market (Mahajan et al., 2002). Keeping this value in view, the fruits coated with SS-40T remained firm and fresh up to 45 days of storage with 5.12% weight loss, closely followed by SS-50, which recorded the weight loss of 5.50%. The untreated Kinnow fruits registered 5.04% weight loss after 30 days of storage and afterwards it increased to 7.38% after 45 days of storage and finally 9.71% weight loss recorded after 60 days of storage. The control (uncoated) Kinnow fruits were found to be non-saleable after 45 days of storage due to excessive moisture loss and shriveling. Under ambient conditions, the Kinnow fruits coated with SS-40T registered the lowest average weight loss (5.18%) followed by SS-50 (5.69%), while the uncoated fruits recorded the highest weight loss (8.44%). SS-40T and SS-50 recorded 5.20% and 5.50% weight loss, respectively after 10 days of storage, while untreated fruits recorded a 9.28 % weight loss. Hence, the wax coated Kinnow fruits maintained the marketable quality upto 10 days as against control fruits which were found to be saleable only up to 5 days. Fruit weight loss is mainly associated with respiration and moisture evaporation through the peel. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and surrounding atmosphere and also the storage temperature (Ghasemnezhad, 2010). Wax coatings act as a semi permeable barrier, thereby restricting water transfer and thus delaying dehydration (Ribeiro et al., 2007). Moldao-Martinse (2003) demonstrated that edible coatings regulate the moisture loss of fruits and vegetables by creating a modified atmosphere due to barrier properties to gases and moisture. Application of different edible coatings have been reported to play an important role in lowering the weight loss of melon (Congo et al., 2007), sweet lime (Bishnoi et al., 2009) and apple (El-Anany et al., 2009).

Firmness

The firmness of fruits followed a declining trend commensurate with the advancement in storage period (Table 2).The highest mean fruit firmness (1118 g force) was recorded in SS 40T coated fruits, followed by SS 50 coating (1102 g force), while the lowest mean fruit firmness (933 g force) was noticed in case of control fruits under cold storage conditions, whereas under ambient conditions, the SS 40T and SS 50 coated fruits and control (uncoated) fruits registered average firmness of 1077, 1058 and 886 g force respectively. In general the control (uncoated) fruits experienced a faster loss of firmness under both the storage conditions compared to coated fruits. Fruit firmness is one of the most crucial factors in determining the post-harvest quality of fruits (Shear, 1975). Softening of fruits is caused either by the breakdown of insoluble protopectins into soluble pectin or by hydrolysis of starch (Mattoo et al., 1975). The loss of pectic substances in the middle lamella of the cell wall is perhaps the key steps in the ripening

process that lead to the loss of cell wall integrity thus cause loss of firmness and softening (Solomos and Laties, 1973). The coating of fruits with SS 40T and SS 50 resulted in higher fruit firmness, during storage, which might be due to reduction in moisture loss and respiratory activity and thus maintained the turgidity of the cells. Application of wax coatings have been reported to maintain the firmness of fruits during storage and marketing (Ribeiro et al., 2007, Adetunji et al., 2012).

Table 1 Effect of coatings on PLW (%) and firmness (g force) of Kinnow fruits under cold storage and at ambient conditions

Treatment	Cold Storage, days			Mean	Room Temperature, days			Mean
	30	45	60		5	10	15	
PLW (%)								
Nipro Fresh SS 40T	3.08	5.12	7.60	5.27	3.21	5.20	7.14	5.18
Nipro Fresh SS 50	3.45	5.50	7.70	5.55	3.68	5.50	7.90	5.69
Control	5.04	7.38	9.71	7.38	4.28	9.28	11.75	8.44
Mean	3.86	6.00	8.34		3.72	6.66	8.93	
LSD at 5% Treatment = 0.15, Storage = 0.13,T x S = NS					Treatment = 0.08, Storage = 0.09, T x S = 0.16			
Firmness (g force)								
Nipro Fresh SS 40T	1270	1165	920	1118	1230	1116	885	1077
Nipro Fresh SS 50	1255	1144	908	1102	1211	1100	862	1058
Control	1140	936	724	933	1120	870	667	886
Mean	1222	1082	851		1187	1029	805	
LSD at 5% Treatment = 6.8, Storage = 9.3 ,T x S =1.35					Treatment = 11.08, Storage =14.2, T x S = 23.5			

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Table 2 Effect of coatings on organoleptic quality and juice yield of Kinnow fruits under cold storage and ambient temperature conditions

Treatment	Cold Storage, days			Mean	Room Temperature, days			Mean
	30	45	60		5	10	15	
Organoleptic quality								
Nipro Fresh SS 40T	8.0	7.5	6.8	7.4	8.0	7.2	6.5	7.2
Nipro Fresh SS 50	8.0	7.0	6.2	7.0	8.0	7.0	6.0	7.0
Control	7.6	6.0	5.5	6.4	7.0	5.8	5.2	6.0
Mean	7.9	6.8	6.2		7.6	6.6	5.9	
LSD at 5% Treatment = 0.4 , Storage = 0.05 ,T x S = 0.9					Treatment = 0.3, Storage = 0.5, T x S = 0.6			
Juice yield (%)								
Nipro Fresh SS 40T	49.61	48.37	46.56	48.18	43.00	41.42	40.57	41.66
Nipro Fresh SS 50	47.31	46.58	45.38	46.42	42.37	41.09	40.37	41.28
Control	45.46	44.00	40.00	43.15	40.02	36.12	34.25	36.80
Mean	47.46	46.32	49.38		41.80	39.54	38.40	
LSD at 5% Treatment = 1.02 , Storage = 1.30 ,Tx S = 2.26					Treatment = 1.66, Storage = 1.92, TxS = NS			

Organoleptic quality

The maximum mean organoleptic rating (7.4 and 7.2) was recorded in SS 40 T coated fruits followed by SS 50 coating (Table 3), while the lowest mean organoleptic score was recorded in the control fruits (6.4 and 6.0) under both the storage conditions, The fruits coated with SS 40T and SS 50 recorded better acceptability score (7.5 and 7) upto 45 days of storage under cold storage conditions and upto 10 days of storage (7.2 and 7) under room temperature conditions while the uncoated fruits maintained the acceptability rating upto 30 days under cold storage conditions (7.6) and 5 days at ambient conditions (7) respectively. Wax coatings have been reported to maintain the gloss, flavour and aroma of fruits (Olivas and Barbosa-Canovas, 2005). Since consumers buy fruits with their eyes, a commodity that exhibits a better visual quality will be perceived by a consumer superior over the others. Mahajan et al. (2005) and Bishnoi et al. (2008) noticed that wax coatings helped in maintaining highly acceptable organoleptic quality of pear and apple fruits without development of off-flavour. The added gloss to the fruit will also make the Kinnow fruits more appealing to consumers

Total soluble solids (TSS)

Under cold storage conditions, the fruits coated with SS 40T recorded the highest average TSS content (10.8%), followed by SS 50 (Table 4), whereas, the control fruits recorded the lowest average TSS content (9.47%). The similar trend was observed in case of room temperature conditions, where SS 50 coated fruits registered the highest average TSS content (10.6%) followed by SS 40T (10%), while the control fruits recorded the lowest average TSS content (9.67). A perusal of the data further revealed that, the TSS content of coated fruits increased with the increase in storage period, reached its peak value at 45 days of storage (11.8% and 11%) under cold storage conditions , whereas under room temperature conditions, the peak value of TSS content was noticed after 10 days of storage (10.4% and 11.4%) and declined thereafter. On the other hand, in case of uncoated fruits, the peak value of TSS content was noticed at 30 days (10%) and 5 days (10.2%) under cold storage and room temperature conditions, respectively. The increase in TSS during storage may possibly be due to the breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch into sugars (Wills et al., 1980). The delayed increase in TSS over a longer period of time in coated Kinnow fruits might be attributed that coatings delayed the metabolic and respiratory activity of fruit and hence might have retarded the fruit ripening and senescence processes. The results are in agreement with the findings of Sidhu et al. (2009) for wax coated pear fruits.

Acidity

The acidity of fruits declined continuously with the advancement in storage under both the storage conditions (Table 5). The fruits coated with SS 40T and SS 50 recorded slightly higher acidity as compared to control (untreated fruits). The average values of acidity in fruits coated with SS 40T and SS 50 and control (untreated fruits) was found to be 0.57%, 0.56% and 0.47% under cold storage conditions, and 0.57%, 0.55%, 0.49% under ambient conditions, respectively. The decrease in titratable acids during storage may be attributed to utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits (Echeverria and Valich, 1989). The coatings helped in better retention of acidity as compared to control, which might be due to the positive role of coatings in delaying the ripening process of fruits (El-Anany et al., 2009). Patriaca et al. (2005) indicated that coating with PVC pack were effective in retention

of titratable acidity of strawberry fruit during storage.

Table 3 Effect of coatings on TSS (%), acidity (%) and vitamin-c (mg%) content of Kinnow fruits under cold storage and ambient conditions

Treatment	Cold Storage, days			Mean	Room Temperature, days			Mean
	30	45	60		5	10	15	
				TSS (%)				
Nipro Fresh SS 40T	9.80	11.80	10.80	10.80	9.60	10.40	10.00	10.00
Nipro Fresh SS 50	10.00	11.00	10.20	10.40	9.80	11.40	10.60	10.60
Control	10.00	9.20	9.20	9.47	10.20	9.60	9.20	9.67
Mean	9.93	10.67	10.07		9.87	10.47	9.93	
LSD at 5% Treatment = 0.09 , Storage = 0.11 ,T x S = 0.18 Treatment = 0.05, Storage 0.07, TxS = 0.11								
				Acidity (%)				
Nipro Fresh SS 40T	0.64	0.57	0.49	0.57	0.63	0.57	0.51	0.57
Nipro Fresh SS 50	0.60	0.57	0.52	0.56	0.59	0.55	0.50	0.55
Control	0.51	0.48	0.42	0.47	0.54	0.50	0.44	0.49
Mean	0.58	0.54	0.48		0.59	0.54	0.48	
LSD at 5% Treatment = 0.04, Storage =0.05 ,T x S =NS Treatment = 0.03, Storage = 0.04, T x S = NS								
				Vitamin-C (mg%)				
Nipro Fresh SS 40T	16.70	19.69	16.80	17.73	17.90	19.14	18.54	18.53
Nipro Fresh SS 50	18.37	17.90	20.16	18.81	21.48	15.66	18.00	18.38
Control	20.04	15.90	16.80	17.58	17.90	17.40	18.00	17.77
Mean	18.37	17.83	17.92		19.09	17.40	18.18	
LSD at 5% Treatment = 0.10 , Storage = 0.13 ,T x S = 2.10 Treatment =0.18, Storage = 0.20, TxS = 0.37								

Vitamin- C

The vitamin-C content of fruits followed a declining trend commensurate with advancement of storage period (Table 6). However, the coated fruits registered slightly higher vitamin- C compared to control fruits. The fruits coated with SS-40T, SS-50 and control (untreated fruits) recorded 17.73, 18.81 and 17.58 mg% vitamin-C content under cold storage condition, while 18.53, 18.38, 17.77 under room temperature conditions respectively. The wax coatings have the potential benefit of better retention of the ascorbic acid. Mahajan et al. (2002) and Kerch (2011) have reported higher ascorbic acid content in Kinnow and cherry fruits coated with shellac and chitosan and chitooligosaccharides as compared to uncoated fruits.

Juice recovery

In general, the juice recovery from Kinnow fruits declined with the increase in storage period (Table 7). However, the Kinnow fruits coated with SS-40T and SS-50 showed gradual decrease in juice yield as compared to control. The average values of juice yield in SS-40T, SS-50 and control (uncoated) fruits were 48.18%, 46.42%, 43.15% under cold storage conditions and 41.66%, 41.28%, 36.80% under ambient conditions, respectively. The maintenance of higher juice percentage in coated fruits is obvious due to reduced loss of moisture and firmness (Table 1).

CONCLUSION

Kinnow fruits coated with 'Nipro Fresh SS 40T and SS 50' followed by storage under cold storage and at ambient conditions was found to be beneficial because these wax coatings helped to extend the shelf life without deterioration in quality of fruit. The coatings reduced the weight loss, retained the firmness and maintained the overall quality of Kinnow fruits up to 45 days in cold storage (5-7 °C, 90–95% RH) and for 10 days at ambient conditions (11-19°C, 80-85% RH).

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