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Rupakshi
Department of Horticulture, MHU, Karnal, Haryana, India

RK Goyal
Department of Horticulture, MHU, Karnal, Haryana, India

Corresponding Author:
Rupakshi
Department of Horticulture, MHU, Karnal, Haryana, India

Effect of packaging on TSS, acidity and sugar content of Kinnow fruits stored at room temperature

Rupakshi and RK Goyal

Abstract
This study was carried out in the PG Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during the years 2019 and 2020. Kinnow fruits harvested from the orchard were individually wrapped in Low Density Polyethylene 25 micron, Polypropylene 25 micron, Cling film and Shrink wrap film. Among all the packaging materials used, shrink wrap film maintained the quality parameters like TSS and sugars. There was no significant effect of packaging films on reducing sugars.

Keywords: Kinnow, wrapped, TSS, sugars

Introduction
Kinnow is in high demand in Indian markets because of its quality traits (Dhatt and Mahajan, 2011) [1]. Mandarin orange is most common among the citrus fruits grown in India (Rupakshi and Goyal, 2021) [2]. Fruits are highly perishable since they contain very high amount of water and exhibit relatively high metabolic activity (Goyal, 2017) [3]. Post-harvest losses of fresh fruits in India are quite high, thus, reduction of these losses becomes quite necessary. The role of packaging is very important in post-harvest operations of horticultural crops but its role is still underestimated in the country. To avoid shriveling and to increase fruit shelf life, proper packaging is very important as it protects fruit from physical (firmness), physiological (Weight) and pathological (decay) deterioration. Out of various packaging materials, plastic films are commonly used in fruit packaging (Patel *et al.*, 2009) [4]. Use of polymeric films is very pronounced in packaging of fruits with a purpose to extend their storage life. Packing of fruits in polymeric films creates modified atmospheric conditions around the produce inside the package allowing lower degree of control of gases and can interplay with physiological processes of commodity resulting in reduced rate of respiration, transpiration and other metabolic processes of fruits (Lange, 2000) [5].

Material Methodology
The present investigations were carried out in the PG Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during the year 2019 and 2020. The fresh fruits of Kinnow mandarin having uniform size were harvested with the help of secateurs at mature stage keeping small intact pedicel with each fruit from the Horticulture Farm, CCS Haryana Agricultural University, Hisar. Fruits were cleaned with muslin cloth and used for experiment. Kinnow fruits were individually wrapped in Low Density Polyethylene 25 micron, Polypropylene 25 micron, Cling film and Shrink wrap film and then kept in Corrugated Fibre Boxes (CFB) for storage using packaging material. Digital refractometer was used for determination of total soluble solids by putting a drop of juice on the prism and the values were expressed in percentage. Titratable acidity was determined in terms of citric acid as per the method suggested by AOAC (1990) [6]. Method given by Hulme and Narain (1931) [7] was used for estimation of sugars.

Results and Discussion
Total soluble solids (%): The analysis of variance of the total soluble solids of stored Kinnow fruits packed in different packaging materials presented in Table 1 followed significant

variation in TSS with respect to packaging films and storage period, however, interaction between the packaging films and storage duration was non-significant.

Table 1: Effect of different packaging films on TSS (%) of Kinnow fruits stored at room temperature.

Treatments	Storage period (Days)											
	2019						2020					
	0	**7**	**14**	**21**	**28**	**Mean**	**0**	**7**	**14**	**21**	**28**	**Mean**
LDPE 25 micron	9.60	9.87	10.17	10.37	10.77	10.15	9.70	9.93	10.23	10.40	10.87	10.23
PP 25 micron	9.60	9.80	10.23	10.43	10.77	10.17	9.70	9.87	10.20	10.47	10.80	10.21
Cling film	9.60	9.83	10.13	10.43	10.67	10.13	9.70	9.90	10.17	10.43	10.83	10.21
Shrink wrap film	9.60	9.83	10.10	10.40	10.60	10.11	9.70	9.80	10.07	10.30	10.73	10.12
Control (Unwrapped)	9.60	10.00	10.27	10.60	10.83	10.26	9.70	10.07	10.23	10.47	10.97	10.29
Mean	9.60	9.87	10.18	10.45	10.73		9.70	9.91	10.18	10.41	10.84	
C.D. at 5%	T= 0.06, D= 0.06, T X D= NS						T= 0.05, D= 0.05, T X D= NS					

Minimum TSS (10.11 and 10.12% during 2019 and 2020, respectively) was recorded in Kinnow fruits wrapped in shrink wrap film, which was at par with LDPE 25 micron and cling film during 2019 and it was recorded maximum (10.26 and 10.29%) in unwrapped control fruits. Packaging films maintain humid micro-climate inside them and result in slow hydrolysis of starch, pectic acid, proteins and fats and thus low TSS (Goncalves *et al*., 2000; Park, 2002; Carrillo-lopez *et al*., 2003 and Pongener *et al*., 2011) [8-11]. The TSS of Kinnow fruits went on increasing with the increase of storage period. Minimum TSS (9.60 and 9.70%) was recorded on zero day of storage and maximum (10.73 and 10.84%) on 28th day of storage during 2019 and 2020, respectively. The increase in TSS of fruits during storage could be due to breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch and other polysaccharides into sugars (Rana *et al*., 2015; Pongener *et al*., 2011 and Randhawa *et al*., 2009) [11-13]. Increase in TSS with increase in storage has also been reported by Asrey *et al* (2008) [14] in strawberry; Dhatt *et al* (1991) [15] in Kinnow mandarin and Wijewardane and Guleria (2009) in apple [16].

Titratable acidity (%)

The data in Table 2 reveal non-significant effect on titratable acidity of stored Kinnow fruits with respect to different packaging materials, period of storage and interaction between packaging films and storage period during both the years of study. However, the decrease in titratable acidity during storage could be due to the increased catabolism of organic acids present in fruit as respiratory substrate during storage (Eccher Zerbini, 2002 and Hulme, 1971) [17, 18].

Table 2: Effect of different packaging films on titratable acidity (%) of Kinnow fruits stored at room temperature.

Treatments	Storage period (Days)											
	2019						2020					
	0	**7**	**14**	**21**	**28**	**Mean**	**0**	**7**	**14**	**21**	**28**	**Mean**
LDPE 25 micron	0.86	0.84	0.80	0.78	0.73	0.80	0.85	0.83	0.79	0.78	0.71	0.79
PP 25 micron	0.86	0.84	0.81	0.79	0.74	0.81	0.85	0.83	0.81	0.78	0.73	0.80
Cling film	0.86	0.83	0.80	0.77	0.70	0.79	0.85	0.83	0.79	0.77	0.70	0.79
Shrink wrap film	0.86	0.84	0.80	0.77	0.74	0.80	0.85	0.83	0.80	0.76	0.73	0.79
Control (Unwrapped)	0.86	0.80	0.76	0.72	0.67	0.76	0.85	0.81	0.77	0.73	0.69	0.77
Mean	0.86	0.83	0.80	0.77	0.72		0.85	0.83	0.79	0.77	0.71	
C.D. at 5%	T= NS, D= NS, T X D= NS						T= NS, D= NS, T X D= NS					

Film wrapped fruits maintained higher acidity due to decreased hydrolysis of organic acids and subsequent accumulation of organic acids which were oxidized at a slow rate because of decreased respiration (Pongener *et al*., 2011 and Soliva-Fortuny and Martín-Belloso, 2003) [11, 19]. The results are in accordance with the reports of Mahajan *et al.* (2013) [20] in Kinnow, Mahajan *et al*. (2015) [21] in peach, Nanda *et al*. (2001) [22] in pomegranate, Sharma *et al*. (2012) [23] in kiwi, Pongener *et al*. (2011) [11] in peach and Park (2002) [9] in pear.

Total sugars (%)

The total sugars of Kinnow fruits packed in different packaging films presented in Table 3 showed statistically significant variation with respect to the packaging films and period of storage. Minimum total sugars (8.49 and 8.57%) were noticed in fruits packed in shrink wrap film and maximum (9.24 and 9.25%) in unwrapped fruits during 2019 and 2020, respectively. The delayed increase in the sugar content under film packaging might be attributed to the inherent property of films in delaying the metabolic activities of fruits during storage (Abeles *et al.*, 2012) [24].This increase in total sugars during storage was also reported by Mahajan (1994) [25] in Red Delicious apples. The minimum total sugars (7.98 and 8.03%) were noticed on zero day of storage and maximum (9.40 and 9.37%) on 28th day of storage during 2019 and 2020, respectively. The increase in total sugars during storage might be due to breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch into mono-and-disaccharides (Pongener *et al*., 2011 [11] and Kaur *et al*., 2013) [26].

Table 3: Effect of different packaging films on total sugars (%) of Kinnow fruits stored at room temperature.

Treatments	Storage period (Days)											
	2019						2020					
	0	**7**	**14**	**21**	**28**	**Mean**	**0**	**7**	**14**	**21**	**28**	**Mean**
LDPE 25 micron	7.98	8.51	9.03	9.24	9.56	8.87	8.03	8.52	9.07	9.26	9.49	8.88
PP 25 micron	7.98	8.57	8.61	8.95	9.05	8.63	8.03	8.75	8.80	9.09	9.12	8.76
Cling film	7.98	8.84	9.21	9.30	9.54	8.97	8.03	8.74	9.10	9.20	9.40	8.90
Shrink wrap film	7.98	8.16	8.56	8.76	8.98	8.49	8.03	8.27	8.67	8.87	9.00	8.57
Control (Unwrapped)	7.98	9.18	9.50	9.65	9.88	9.24	8.03	9.22	9.54	9.64	9.81	9.25
Mean	7.98	8.65	8.98	9.18	9.40		8.03	8.70	9.04	9.21	9.37	
C.D. at 5%	T= 0.04, D= 0.04, T X D= 0.09						T= 0.04, D= 0.04, T X D= 0.09					

Similar results were recorded by Kishor *et al.* (2018) [27] in apple. The interaction between packaging films and storage period significantly affected the total sugars in Kinnow during 2019 and 2020, respectively. Minimum total sugars (7.98 and 8.03%) were recorded on zero day of storage and maximum (9.88 and 9.81%) on 28th day of storage in control during 2019 and 2020, respectively.

Reducing sugars (%)

The analysis of variance of reducing sugars of stored Kinnow fruits packed in different packaging materials presented in Table 4 followed significant variation with respect to different packaging films and storage period.

Table 4: Effect of different packaging films on reducing sugars (%) of Kinnow fruits stored at room temperature.

Treatments	Storage period (Days)											
	2019						2020					
	0	**7**	**14**	**21**	**28**	**Mean**	**0**	**7**	**14**	**21**	**28**	**Mean**
LDPE 25 micron	3.84	4.10	4.36	4.48	4.68	4.29	3.87	4.11	4.39	4.50	4.65	4.30
PP 25 micron	3.84	4.13	4.16	4.34	4.42	4.18	3.87	4.22	4.25	4.42	4.46	4.24
Cling film	3.84	4.27	4.45	4.51	4.66	4.35	3.87	4.21	4.40	4.47	4.60	4.31
Shrink wrap film	3.84	3.94	4.14	4.25	4.39	4.11	3.87	3.98	4.19	4.31	4.41	4.15
Control (Unwrapped)	3.84	4.43	4.59	4.68	4.83	4.47	3.87	4.46	4.63	4.70	4.81	4.50
Mean	3.84	4.17	4.34	4.45	4.60		3.87	4.19	4.37	4.47	4.58	
C.D. at 5%	T= 0.02, D= 0.02, T X D= 0.04						T= 0.02, D= 0.02, T X D= 0.04					

Reducing sugars were observed minimum (4.11 and 4.15%) in fruits packed in shrink wrap film, whereas maximum (4.47 and 4.50%) was recorded in unwrapped control fruits during 2019 and 2020, respectively. The reducing sugars of Kinnow fruits packed in different packaging films went on increasing with the advancement of storage period at room temperature, where minimum reducing sugars (3.84 and 3.87%) were recorded on zero day of storage and maximum (4.60 and 4.58%) on 28th day of storage during 2019 and 2020, respectively. The increase in sugars during storage period might be due to hydrolysis of polysaccharides and concentrations of juice as a result of dehydration (Kaur *et al*., 2013) [26]. Similar results were recorded by Kishor *et al.* (2018) [27] in apple, Kahlon and Bajwa (1991) [28] in litchi and Waskar *et al.* (1999) [29] in sapota. Reducing sugars in Kinnow fruits varied significantly due to interaction between packaging films and storage period. Minimum reducing sugars (3.84 and 3.87%) were recorded on zero day of storage and maximum (4.83 and 4.81%) were obtained on 28th day of storage in unwrapped fruits during 2019 and 2020, respectively.

Non-reducing sugars (%)

The data pertaining to non-reducing sugars of Kinnow fruits are presented in Table 5 exhibited the significant effect due to the packaging films and the storage period. Minimum non-reducing sugars (4.38 and 4.42%) were noticed in fruits packed in shrink wrap film and maximum (4.77 and 4.77%) in unwrapped fruits during 2019 and 2020, respectively.

Table 5: Effect of different packaging films on non-reducing sugars (%) of Kinnow fruits stored at room temperature.

Treatments	Storage period (Days)											
	2019						2020					
	0	**7**	**14**	**21**	**28**	**Mean**	**0**	**7**	**14**	**21**	**28**	**Mean**
LDPE 25 micron	4.14	4.40	4.67	4.76	4.89	4.57	4.16	4.42	4.69	4.76	4.85	4.57
PP 25 micron	4.14	4.43	4.45	4.61	4.63	4.45	4.16	4.53	4.55	4.68	4.66	4.52
Cling film	4.14	4.57	4.76	4.79	4.88	4.63	4.16	4.53	4.71	4.73	4.80	4.59
Shrink wrap film	4.14	4.22	4.43	4.51	4.59	4.38	4.16	4.29	4.48	4.57	4.60	4.42
Control (Unwrapped)	4.14	4.75	4.91	4.97	5.06	4.77	4.16	4.78	4.93	4.96	5.01	4.77
Mean	4.14	4.48	4.64	4.73	4.81		4.16	4.51	4.67	4.74	4.78	
C.D. at 5%	T= 0.02, D= 0.02, T X D= 0.04						T= 0.02, D= 0.02, T X D= 0.05					

It was recorded minimum (4.14 and 4.16%) on zero day of storage and maximum (4.81 and 4.78%) on 28th day of storage during 2019 and 2020, respectively. Similar results were recorded by Kishor *et al.* (2018) [27] in apple and Kumar *et al*. (2012) [30] in guava cv. Sardar. The interaction between the packaging materials and the storage period also had significant effect on the non-reducing sugars in Kinnow fruits and minimum non-reducing sugars (4.14 and 4.16%) were noticed on zero day of storage and maximum (5.06 and 5.01%) in unwrapped fruits on 28th day of storage during 2019 and 2020, respectively.

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