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Effect of surface coatings and storage conditions on shelf life and quality of pomegranate Cv. Bhagwa (*Punica granatum* L.)

Zafran and Veena Joshi

Abstract
An experiment was carried out to study the effect of surface coatings and storage conditions on quality and shelf life of Pomegranate during 2018-19 at College of Horticulture, SKLTSHU, Rajendranagar. The experiment was conducted in factorial completely randomized design with two factors Factor one includes surface coatings and factor two consists of storage conditions. With respect to physical parameters, among the treatments, C_4-Chitosan 2% recorded lowest Physiological loss in weight (15.550%) highest firmness of fruit (5.400), lowest spoilage (43.232%) followed by C_3-Chitosan 1%. Highest shelf life (30.650 days) was recorded in C_4-chitosan (2%) which was at par with C_3-chitosan 1% (29.667 days) and lowest shelf life (17.750 days) was recorded in C_9-without any treatment.
With respect to quality parameters, C_4-Chitosan 2% recorded highest Total soluble solids (11.743 ^oB), lowest acidity (0.380%) followed by C_5- Guar gum 1% (11.552 ^oB), (0.393%) respectively. C4-Chitosan 2% recorded highest total sugars, ascorbic acid content (4.250%) (7.897 mg/100 g) followed by C_3-Chitosan 1% (4.037%) (7.888 mg/100 g) and lowest was recorded in C_9- Control. Among the treatments Chitosan 2% cold storage is best followed by Chitosan 1%. Among both storage conditions fruits stored in cold storage (5 ºC) gave better results in terms of shelf life and quality. With respect to the interaction effect of surface coatings and storage conditions, Chitosan 2% + cold storage (5 ºC) was superior of all the treatments in terms of shelf life (41.533 days) and quality parameters followed by Chitosan 1% + cold storage over control fruits stored at room temperature (18.337 days).

Keywords: Pomegranate, surface coatings, storage conditions, shelf life and quality

Introduction
Pomegranate (*Punica granatum* L.) is an important fruit of tropical and sub-tropical regions of world and mainly grown in various countries due to its versatile adaptability to many soils and climates (Fawole and Opara, 2013) [5]. It is one of the commercial fruit crops of India. A number of treatments have been applied to improve quality and shelf life of pomegranate whole fruit which includes intermittent warming, curing, film wrapping, waxing, polyamines, low temperature and high relative humidity, modified atmospheric packaging and storage *etc.* (Nanda *et al*., 2001; Hess-Pierce and Kader, 2003; Mirdehghan *et al*., 2007; Waskar, 2011; Caleb *et al*., 2013) [11, 6, 9, 17, 4]. However each has advantages and disadvantages. The maintenance of quality of fresh produce is still a major challenge in the food industry. Research on edible coatings and films have been intense in recent years.
Edible coatings generate a modified atmosphere by creating a semipermeable barrier against O2, CO2, moisture, and solute movement, thus reducing respiration, water loss, and oxidation reaction rates (Ali *et al*., 2013) [1]. Different materials have been used as edible coatings and are commonly based on proteins, lipids, or polysaccharides. The great benefit conferred by edible coatings is that these are natural biodegradable products. Among this most commonly and widely used surface coatings are Aloe vera, Guar gum, bee wax, honey and Chitosan. (Milena *et al*., 2014) [10]. Very limited research is being conducted on the use of surface coatings on extending the shelf life of Pomegranate. Hence in view of the above, the present research experiment "Effect of surface coatings and storage conditions on shelf life and quality of pomegranate Cv. Bhagwa" is proposed on Pomegranate.

Materials and Methods
Pomegranate fruits (Cv. Bhagwa) used for investigation were obtained from farmers field located at Kalyanadurgam, Ananthapur district, Andhra Pradesh. Fruits were harvested at a stage when they produced metallic sound upon tapping and the total soluble solids reached 15.15 ^{0}Brix.

Mature, green fruits, without any visible blemish, were selected and the pedicels were removed.

The experiment was conducted in factorial completely randomized design with two factors. Factor one includes nine treatments of surface coatings, C_1 – Aloe vera gel (1:2), C_2 – Aloe vera gel (1:3), C_3– Chitosan 1%, C4 - Chitosan 2%, C_5 – Guar gum 1%, C_6 – Guar gum 21%, C_7 –Bee wax 1%, C_8 – Bee wax 2%, C_9 – Control (without any surface coatings), and factor two consists of storage conditions, S_1 – Cold storage (5 ºC) and S_2 – Room temperature (25 ºC). The fruits were then randomly divided into eight lots of twenty fruits each. Fresh fruits were dipped completely into the coatings solutions at room temperature for 25 min. The fruits were allowed to drain and then dried at room temperature to allow a thin film layer to be formed on the fruits. The treated fruits were then stored at room temperature and at cold storage (5 °C) respectively. Various parameters *viz*., physical, quality and organoleptic evaluation was analyzed at the end of shelf life.

Results and Discussions

1. Physiological Loss in Weight (%)

The effect of surface coatings and storage conditions on physiological loss in weight of pomegranate stored at both cold storage and room temperature is presented in the Table 1.There was a significant difference observed among all the treatments with respect to PLW at different storage conditions. Interaction effect between treatments and storage conditions was also found to be significant. With respect to the surface coatings, C_4-Chitosan 2% recorded lowest PLW (15.550%) followed by C_3-Chitosan 1% (16.383%) and C_5-Guar gum 1% (16.983%), while highest PLW was recorded in Control (20.867%). With respect to the storage conditions lowest PLW (14.922) was recorded in fruits stored at S_1-cold storage against S_2- room temperature (21.504). Among interactions, C_4S_1- Chitosan (2%) + cold storage recorded significantly least PLW (11.667%) followed by C_5S_1-Guar gum (1%) + cold storage (13.467%) while highest PLW in C_9S_2-Control + room temperature storage (24.567%). The primary mechanism of weight loss from fresh fruits and vegetables is by Vapour-phase diffusion driven by a gradient of water vapour pressure between inside and outside the fruit leading to an enhanced transpiration process. Among all the treatments, C_4-fruits treated with chitosan (2%) showed minimum loss of physiological loss of weight in fruits during storage compared to other treatments, as chitosan coating reduces the water loss and respiration rate of fruits during storage by acting as a protective layer between fruit surface and atmosphere. Though the chitosan coating show better results in room temperature, combination of cold storage (5 ºC) with chitosan show least PLW in pomegranate fruits with slow increase in loss of weight during storage period compared to room temperature. The results obtained in the present investigation are in close conformity with those of Manpreet *et al*. (2009) [8], Singh *et al*. (2005) [16] and Bhavana *et al*., (2018) [3].

2. Spoilage (%)

Spoilage per cent of pomegranate fruits stored in both cold storage and room temperature treated with surface coatings is presented in the Table 2. Significantly lowest spoilage was recorded in C_4-chitosan 2% (43.232), followed by C_5-Guar gum 1% (44.975) which was found to be on par with C_6- Guar gum 2% (45.457) and C_3-chitosan 1% (45.488) and highest spoilage was recorded in C9-control (49.87 0%). With respect to interactions least spoilage was recorded in C_4S_1- chitosan (1%) + cold storage (40.767) followed by C_6S_1-Guar gum (2%) + cold storage (42.190) and C_5S_1-Guar gum (1%) + cold storage (42.243) while highest was recorded in C_9S_2-Control + room temperature storage (54.377). There was significant difference between two storage conditions with lowest spoilage percent noticed in S_1 (43.926%), highest spoilage was seen in S_2 room temperature (49.387%) respectively. Among all the treatments, fruits treated with C_4-chitosan (2%) stored in cold storage recorded least spoilage in fruits during storage compared to other treatments, this may be due to low respiration rate and low ethylene synthesis in low temperature and chitosan coating helps in forming a barrier between fruit surface and outer atmosphere. Present results are in close conformity with the results obtained by Pandey *et al*. (2012) [14] in Ber fruits where fruits stored in room temperature spoiled till 12 days while refrigerated fruits were in good condition till 21 days.

3. Shelf life (days)

Shelf life of pomegranate fruits treated with surface coatings, stored at different storage conditions is depicted in the Table 3. Highest shelf life was (30.650) recorded in C_4-chitosan (2%) which was at par with C_3-chitosan 1% (29.667), C_5-Guar gum 1% (28.767), C_6-Guar gum 2% (27.600) and lowest shelf life (17.750) was recorded in C_9-control which was on par with C_7 & C_8. Pomegranate fruits treated with chitosan (2%) stored in cold storage- C_4S1 recorded significantly higher shelf life of (41.533) which was at par with fruits pretreated with C_5S_1-Guar gum (1%) + cold storage (39.433) and C_6S_1-Guar gum (2%) + cold storage with shelf life of (39.100) and least shelf life of was recorded in C_9S_2-control (12.667) fruits at room temperature. Among the storage conditions, significantly highest shelf life was recorded in S_1-cold storage of (32.089) and lowest shelf life was in S_2-room temperature with (18.337). Chitosan coating scored well and found satisfactory in maintaining high shelf life. Chitosan coating reduces shrinkage by reducing loss of moisture and thereby retains freshness of fruits. Low temperature of 5 ºC is very much favorable for pomegranate fruits to extend its shelf life as it reduces ethylene synthesis, if temperature is reduced further there may be a problem of chilling injury. The application of chitosan coating could beneficial in retarding the ripening process of Cavendish banana, maintaining quality and controlling decay of banana. The shelf life of banana fruits could be prolonged up to several days upon the application of chitosan edible coating as reported by Natalia *et al*., 2013 [12]. Bhavana *et al.,* (2018) [3] also reported that apple Ber fruits can be stored economically for 12 days in ambient conditions and 21 days in cold storage of 10± 2 ºC when treated with Chitosan 1% respectively.

4. Total soluble solids (ºB)

The effect of surface coatings at different storage conditions of pomegranate on total soluble solids is presented in the Table. 4. With respect to the effect of surface coatings on total soluble solids of fruits, C4-Chitosan 2% recorded highest TSS (11.743) which was on par with C6- Guar gum 2% (11.552) and C_3-Chitosan 1% (11.510) followed by C_1- Aloe vera gel (1:2) (11.185) While lowest total soluble solids was recorded in C_9- Control (9.917). Among the storage conditions S_1-cold storage condition recorded highest total soluble solids of fruits

(11.932) over fruits stored at S_2- room temperature (9.964). With respect to interactions highest total soluble solids was recorded by C_4S_1-chitosan (2%) + cold storage (13.197) followed by C_3S_1-chitosan (1%) + cold storage (12.340) while lowest was recorded with C_9S_2- Control + room temperature (8.527). Chitosan coating on pomegranate fruit modifies internal atmosphere caused decrease in usage of sugars and organic acids due to reduction of respiration and metabolism. In addition, low storage temperature could reduce respiration and metabolism. (Nanda *et al*., 2001) [11]. Coated papaya retarded TSS development because aloe gel decreases the respiration and eventually matabolism of sugars. This may be due to the effect of aloe vera gel coating on the reduction of α-galactosidase, poly galacturonase and pectinmethyl-esterase activities (Nunan *et al*. 1998) [13].

5. Titrable acidity (%)

Results on titrable acidity of pomegranate stored at both cold storage and room temperature as affected by surface coatings is presented in the Table 5. With respect to the effect of surface coatings on titrable acidity, C4-Chitosan 2% recorded lowest acidity (0.380) followed by C_5-Guar gum 1% (0.393), C_3-Chitosan 1% (0.412) and C_6-Guar gum 2% (0.422)and were at par to each other while highest acidity was recorded in C_9-Control (0.517). Among the storage conditions S_1-cold storage condition recorded lowest acidity of fruits over fruits stored at room temperature (S_2). With respect to interactions lowest acidity was recorded by C_4S_1-chitosan (2%) + cold storage (0.223) followed by C_5S_1- Guar gum 1% + cold storage (0.233) while highest was recorded with C_9S_2- Control + room temperature (0.610). Titrable acidity of fruits decreases due to increase of soluble sugars during course of storage. This decrease was observed less in fruits coated with surface coating compared to control due to edible coatings and low temperature. C_4S_1- chitosan (2%) + cold storage is the best treatment with least acidity, similar findings were reported by Baviskar *et al*. (1995) [2] in Ber fruits.

6. Total sugars (%)

The data pertaining to the effect of surface coatings and storage conditions of Pomegranate on total sugars is presented in the Table.6. C_4-Chitosan 2% recorded highest total sugars (4.250) and was at par with C_5-Guar gum 1% (4.205) and C_3-Chitosan 1% (4.037) and lowest total sugar was recorded in C_9- Control (3.478). Among the storage conditions S_1-cold storage condition recorded highest total sugar content (4.909) over fruits stored at S2- room temperature (2.317). With respect to interactions highest total sugars was recorded by C_4S_1- chitosan (2%) + cold storage (5.313) followed by C_5S_1- Guar gum 1% + cold storage (5.297) and C_6S_1- Guar gum 2% + cold storage (5.167) while highest was recorded with C_9S_2- Control + room temperature (2.317). Treated fruits show slow buildup of sugars compared to control due to exposure of fruit to atmosphere without any increase in respiration. (Ramachandran and Ashok, 1997) [15]. C_4S_1 – chitosan + cold storage was the best treatment with maximum total sugars during storage period. Similar trends of total and reducing sugars content were reported by Ramachandra and Ashok (1997) [15] in ber cultivars.

7. Ascorbic acid content (mg/100 g)

Results of ascorbic acid content of Pomegranate influenced by surface coatings and storage conditions is presented in the Table.7. C_4-Chitosan 2% recorded highest ascorbic acid content (7.897) and was at par with C_3-Chitosan 1% (7.888) C_6-Guar gum 2% (7.800) and C_5-Guar gum 1% (7.797) and lowest ascorbic acid was recorded in C_9-Control (7.523). Among the storage conditions S_1-cold storage condition recorded highest ascorbic acid content (7.949) over fruits stored at room temperature (7.491). With respect to interactions, it was found to be non-significant. C_4S_1-chitosan + cold storage recorded highest ascorbic acid content (8.183) followed by C_5S_1-chitosan (1%) + cold storage (8.153). The decrease trend of ascorbic acid is less in surface coated and low temperature stored fruits compared to control where there is a rapid decrease of ascorbic acid. This may be due to increase in total soluble solids in the fruits. The results obtained were in close conformity with Jagtar Singh *et al*., 1978 in his studies on storage behavior of ber fruits at room temperature and refrigerated temperatures.

Table 1: Effect of surface coatings and storage conditions on PLW (%) at the end of shelf life of Pomegranate Cv. Bhagwa.

Treatments	**Storage conditions (S)**		
Surface coatings (C)	**S_1 -Cold storage (5 ºC)**	**S_2 -Room temperature (25 ºC)**	**Mean**
C_1- Aloe vera gel (1:2)	15.167	21.200	18.183
C_2 -Aloe vera gel (1:3)	15.600	21.767	18.683
C_3 -Chitosan 1%	14.533	18.233	16.383
C_4 -Chitosan 2%	11.667	19.433	15.550
C_5 -Guar gum 1%	13.467	20.500	16.983
C_6 -Guar gum 2%	14.033	20.733	17.383
C_7 -Bee wax 1%	16.167	23.100	19.633
C_8 -Bee wax 2%	17.167	24.000	20.583
C_9 -Control	16.500	24.567	20.533
Mean	14.922	21.504	
	F-test	SE (m)±	CD at 5%
Factor (C)	*	0.20	0.58
Factor (S)	*	0.09	0.27
C × S	*	0.29	0.83

Table 2: Effect of surface coatings and storage conditions on spoilage percentage at the end of shelf life of Pomegranate Cv. Bhagwa.

Treatments	Storage conditions (S)		
Surface coatings (C)	**S_1 -Cold storage (5 ºC)**	**S_2 -Room temperature (25 ºC)**	**Mean**
C_1- Aloe vera gel (1:2)	44.240	49.483	46.862
C_2 -Aloe vera gel (1:3)	44.900	49.487	47.193
C_3 -Chitosan 1%	43.960	46.953	45.457
C_4 -Chitosan 2%	40.767	45.697	43.232
C_5 -Guar gum 1%	42.243	47.707	44.975
C_6 -Guar gum 2%	42.190	48.787	45.488
C_7 -Bee wax 1%	45.767	50.637	48.202
C_8 -Bee wax 2%	45.903	51.353	48.628
C_9 –Control	45.363	54.377	49.870
Mean	43.926	49.387	
	F test	SE (m)±	CD at 5%
Factor (C)	*	0.27	0.78
Factor (S)	*	0.12	0.36

Table 3: Effect of surface coatings and storage conditions on shelf life (days) of Pomegranate Cv. Bhagwa.

Treatments	Storage conditions (S)	
Surface coatings (C)	**S_1 -Cold storage (5 ºC)**	**S_2 -Room temperature (25 ºC)**
C_1- Aloe vera gel (1:2)	33.267	17.900
C_2 -Aloe vera gel (1:3)	29.433	19.667
C_3 -Chitosan 1%	30.900	28.433
C_4 -Chitosan 2%	41.533	19.767
C_5 -Guar gum 1%	39.433	18.100
C_6 -Guar gum 2%	39.100	16.100
C_7 -Bee wax 1%	26.867	17.333
C_8 -Bee wax 2%	25.433	12.667
C_9 -Control	22.833	15.067
Mean	32.089	18.337
	F test	SE (m)±
Factor (C)	*	1.66
Factor (S)	*	0.78
C × S	*	2.35

Table 4: Effect of surface coatings and storage conditions on TSS (^{0}B) at the end of shelf life of Pomegranate Cv. Bhagwa.

Treatments	Storage conditions (S)			
Surface coatings (C)	**Initial TSS (0 B) At 0th day**	**S_1 -Cold storage (5 ºC)**	**S_2 -Room temperature (25 ºC)**	**Mean**
C_1- Aloe vera gel (1:2)	16.242	12.133	10.237	11.185
C_2 -Aloe vera gel (1:3)	16.201	11.793	9.733	10.763
C_3 -Chitosan 1%	16.325	12.340	10.680	11.510
C_4 -Chitosan 2%	16.264	13.197	10.290	11.743
C_5 -Guar gum 1%	16.226	11.643	10.133	10.888
C_6 -Guar gum 2%	16.208	12.250	10.853	11.552
C_7 -Bee wax 1%	16.232	11.577	9.660	10.618
C_8 -Bee wax 2%	16.360	11.150	9.567	10.358
C_9 -Control	16.304	11.307	8.527	9.917
Mean		11.932	9.964	
		F test	SE (m)±	CD at 5%
Factor (C)		*	0.12	0.35
Factor (S)		*	0.08	0.16
C × S		*	0.24	0.49

Table 5: Effect of surface coatings and storage conditions on Titrable Acidity (%) at the end of shelf life of Pomegranate Cv. Bhagwa.

Treatments	Storage conditions (S)			
Surface coatings (C)	**Initial Titrable acidity (%)at 0th day**	**Cold storage (4-5 ºC)**	**Room temperature**	**Mean**
Aloe vera gel (1:2)	0.611	0.337	0.567	0.452
Aloe vera gel (1:3)	0.632	0.367	0.573	0.470
Chitosan 1%	0.601	0.317	0.507	0.412
Chitosan 2%	0.582	0.223	0.537	0.380
Guar gum 1%	0.616	0.233	0.553	0.393
Guar gum 2%	0.620	0.273	0.570	0.422
Bee wax 1%	0.624	0.373	0.573	0.473
Bee wax 2%	0.612	0.437	0.563	0.500
Control	0.605	0.423	0.610	0.517

Mean		0.331	0.561	
		F test	SE (m)±	CD at 5%
Factor (C)		*	0.013	0.03
Factor (S)		*	0.006	0.01
C × S		*	0.018	0.05

Table 6: Effect of surface coatings and storage conditions on Total sugar content (%) at the end of shelf life of Pomegranate Cv. Bhagwa.

Treatments	**Storage conditions (S)**			
Surface coatings (C)	**Initial total sugar (%) At 0th day**	**S_1 -Cold storage (5 ºC)**	**S_2 -Room temperature (25 ºC)**	**Mean**
C_1- Aloe vera gel (1:2)	10.120	4.867	2.800	3.833
C_2 -Aloe vera gel (1:3)	10.130	4.753	2.713	3.733
C_3 -Chitosan 1%	10.114	4.880	3.193	4.037
C_4 -Chitosan 2%	10.144	5.313	3.187	4.250
C_5 -Guar gum 1%	10.156	5.297	3.113	4.205
C_6 -Guar gum 2%	10.141	5.167	2.860	4.013
C_7 -Bee wax 1%	10.201	4.713	2.640	3.677
C_8 -Bee wax 2%	10.325	4.547	2.567	3.557
C_9 -Control	10.285	4.640	2.317	3.478
Mean		4.909	2.317	
		F test	SE (m)±	CD at 5%
Factor (C)		*	0.034	0.10
Factor (S)		*	0.016	0.04
C × S		*	0.049	0.14

Table 7: Effect of surface coatings and storage conditions on Ascorbic acid content (mg/100g) at the end of shelf life of Pomegranate Cv. Bhagwa.

Treatments	**Storage conditions (S)**			
Surface coatings (C)	**Initial ascorbic acid content at 0th day**	**S_1-Cold storage (5 ºC)**	**S_2 -Room temperature (25 ºC)**	**Mean**
C_1- Aloe vera gel (1:2)	8.423	7.927	7.567	7.747
C_2 -Aloe vera gel (1:3)	8.865	7.840	7.503	7.672
C_3 -Chitosan 1%	8.654	8.153	7.623	7.888
C_4 -Chitosan 2%	8.513	8.183	7.610	7.897
C_5 -Guar gum 1%	8.845	8.100	7.493	7.797
C_6 -Guar gum 2%	8.754	8.067	7.533	7.800
C_7 -Bee wax 1%	8.514	7.737	7.473	7.605
C_8 -Bee wax 2%	8.314	7.760	7.347	7.553
C_9 -Control	8.625	7.773	7.273	7.523
Mean		7.949	7.491	
		F test	SE (m)±	CD at 5%
Factor (C)		*	0.018	0.053
Factor (S)		*	0.008	0.025
C × SS		N S	0.026	-

Conclusion

In conclusion surface coatings has profound influence on the shelf life and quality of Pomegranate. Chitosan 2% was superior in terms of shelf life and quality followed by Chitosan 1%. Among both storage conditions fruits stored in cold storage gave better results with increase in shelf life and quality of pomegranate fruits. Chitosan 1% + cold storage was best of all the treatments with a shelf life of 41.53 days with superior results in maximum parameters *viz*., highest ascorbic acid content and sugars, least acidity, spoilage and physiological loss in weight followed by Chitosan 1% + cold storage with shelf life of 30.90 days.

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