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EFFECT OF DIFFERENT EDIBLE COATINGS AND STORAGE TEMPERATURES ON QUALITY PARAMETERS OF READY-TO-EAT ARILS OF POMEGRANATE CV. BHAGWA PACKED IN CLAMSHELLS

M. Viswanath*, B. Srinivasulu, K. Swarajya Lakshmi, K. Gopal, M. Balakrishna and M. L. N. Reddy

Department of Fruit Science, Horticultural College and Research Institute, Dist.-Kadapa - 516 105, Dr. Y.S.R. Horticultural University, Venkataramannagudem W. G. Dist (Andhra Pradesh), India.

Abstract

Pomegranate (*Punica granatum* L.) is an important fruit crop grown in tropical and sub-tropical regions of the world. In recent years, minimally processed ready-to-eat pomegranate arils have become popular due to their convenience, high value, unique sensory characteristics and health benefits. The present study on "Effect of different edible coatings and storage temperatures on quality parameters of ready-to-eat arils of pomegranate cv. Bhagwa packed in clamshells" was carried out to evaluate the effect of edible coatings and storage temperatures on various parameters *viz*. weight loss, TSS, TA, TSS/TA ratio, ascorbic acid, total sugars which are related to post-harvest quality. chitosan (1%) treated arils packed in clamshells and stored at cold temperature of 4±1°C was found to be promising to maintain several quality parameters, which recorded low physiological loss in weight (3.20%) with high TSS (14.61°Brix), titrable acidity (0.37%), per cent total sugars (10.53), ascorbic acid (6.37 mg $100g^{-1}$) during 20 days of storage.

Key words : Arils of pomegranate, edible coating, Chitosan, honey, aloevera gel and storage temperatures.

Introduction

Pomegranate (*Punica granatum* L.), which is regarded as the 'fruit of paradise' and 'elixir of life' is a rich source of minerals, vitamins and nutrients. It belongs to the family Punicaceae and originated from Iran. It is one of the choicest table fruits grown in tropical and sub-tropical regions of the world. Pomegranate fruits are large round berries called as – balusta and aril is the edible material. In recent years, minimally processed ready-to-eat pomegranate arils have become popular due to their convenience, high value, unique sensory characteristics, and health benefits. Scientific evidence has linked increasing consumption of pomegranate arils to improved human health as a result of active phenolic compounds which have potent pharmacological activities, including anti-oxidant, anti-mutagenic, anti-hypertension, anti-inflammatory and anti-atherosclerotic activities against osteoarthritis, prostate cancer, heart disease and HIV-1 (Viuda-Martos *et al*., 2010).

Recent advances in post-harvest treatments include, the use of organic edible coatings to increase the shelf life of fresh cut fruits and vegetables. Edible coatings are thin layers of material made from biodegradable ingredients that can be consumed as a part of the food product and can act as a selective barrier to gas transport.

Chitosan is a high molecular weight cationic polysaccharide, produced by the deacetylation of chitin, which is the second most abundant naturally occurring biopolymer after cellulose (Andrady and Xu, 1997). The effect of chitosan coating on preservation of fruits, such as litchi (De Reuck *et al*., 2009), strawberry, cucumber and bell pepper (Ghaouth *et al*., 1997) has been studied. Aloevera gel is the colourless mucilaginous gel obtained from the parenchymatous cells in the fresh leaves of Aloe spp. Currently, there is an increasing interest in the use of Aloe vera gel in the food industry as a resource of functional foods (Eshun and He, 2004). The possibility of honey application, as an organic thin layer of protective barrier, was investigated in pomegranate, table grapes, guava and papaya as an alternative mean for chemical-based treatments.

Storage temperatures significantly influence physical,

****Author for correspondence :*** E-mail : viswa.horti@gmail.com

physiological and biochemical parameters of fruits and their products. Identifying optimum storage temperature is of paramount importance to minimize physiological losses by retaining the quality of the stored produce.

The present investigation is planned to study the effect of different organic edible coatings and storage temperatures on physical, physiological and biochemical characters of arils of pomegranate cv. Bhagwa packed in clamshells.

Materials and Methods

Fruits of pomegranate variety, Bhagwa used in the experiment were obtained from AICRP centre on Arid Zone fruits, Horticulture Research Station, Rekulakunta, Ananthapuramu district, Andhra Pradesh, India. Well developed fruits at optimum stage of maturity, free from pest and disease attack were harvested from the field and brought to the laboratory. The arils from fruits were extracted manually after splitting the fruits with the help of sterilized knife. The entire process of aril extraction and packing was done under hygienic conditions. Edible coatings *viz.*, chitosan (1%), Aloe vera gel (100%) and honey (10%) were used for treating the arils. The treated arils packed in clamshells were kept at 4±1˚C, 7±1˚C and room temperature (26-29˚C).

Preparation of edible coating

Chitosan (1%) : Chitosan with 90% deacetylation and a molecular weight of 360 kDa was prepared at 1% (w/v) concentration in an aqueous solution of acetic acid (0.5% v/v). The solution was warmed to 45°C and stirred for complete dissolution of chitosan, adjusting its pH to 5.2 with NaOH. After cooling at 20°C, the arils were dipped in the chitosan solution for 60 seconds to generate a uniform film.

Aloe vera (100%) : Matured leaves from Aloe vera plant were harvested and washed with a mild chlorine solution of 25%. Aloe vera gel matrix was then separated from the outer cortex of leave and this colorless hydro parenchyma was ground in a blender. The resulting mixture was filtered to remove the fibres. The gel matrix was pasteurized at 70°C for 45min. For stabilization, the gel was cooled immediately to an ambient temperature.

Honey (10%) : Honey solution @ 10g was dissolved in one liter of warm water to get honey (10%) solution.

Estimation of various quality parameters

1) The PLW of arils was determined by using the following formula and expressed as percentage.

$$\text{PLW (\%)} = \frac{\text{Initials weight of arils (g)} - \text{Final weight of arils (g)}}{\text{Initials weight of arils (g)}} \times 100$$

2) The TSS content of arils was determined by using ERMA hand refractro-meter.
3) The ratio between total soluble solids and titratable acidity of the pomegranate juice was calculated and expressed as TSS/acid ratio.
4) The percentage of total sugars was estimated by A.O.A.C method (1980).
5) Ascorbic acid (mg $100g^{-1}$) was estimated as per the procedure outlined by Ranganna (1986).

$$\text{Ascorbic acid} = \frac{\text{Titre} \times \text{Dry factor} \times \text{Volume made up} \times 100}{10 \times \text{Weight of the sample}}$$

6) Acidity of pomegranate juice was determined by the method proposed by Ranganna (1986). The acidity of the fruit was expressed in per cent and calculated by using the formula.

$$\text{Titratable acidity (\%)} = \frac{1 \times \text{equivalent weight of acid (g)} \times \text{Normality of NaOH} \times \text{Titre volume}}{10 \times \text{Weight of sample (g)}} \times 100$$

Results and Discussion

Physiological loss in weight (PLW) (%) of arils

Significant differences were observed among edible coatings, storage temperatures and their interaction effects with respect to PLW (%) of arils of pomegranate cv. Bhagwa (table 1).

There was a gradual increase in PLW (%) of arils as the storage period progressed. The lowest PLW (%) of arils was recorded in C_1 (1% chitosan) (0.50, 1.27, 1.40, 2.41 and 3.20) on 4^{th}, 8^{th}, 12^{th}, 16^{th} and 20^{th} day of storage, respectively. The less PLW (%) in coated arils might be due to the formation of the semi permeable layer that blocked pores and reduced the loss of moisture and gases (Abbasi *et al.,* 2009 in mango and Zhelyazkov *et al*., 2014 in fresh-cut apple cubes). Its excellent film forming and anti-fungal, bio-safe and bio-chemical properties were also explained by Lin *et al*. (2008).

With regard to storage temperatures, $\mathbf{T_1}$ (4±1˚C) recorded the minimum PLW (%) of arils (0.38, 0.98, 1.89, 2.48 and 2.61) on 4^{th}, 8^{th}, 12^{th}, 16^{th} and 20^{th} day, respectively.

The minimum PLW (%) of arils can be attributed to low moisture loss due to minimum metabolic activity at low temperatures. These results are in agreement with the findings of Ayhan and Esturk (2009) in pomegranate.

Among interaction effects, C_1T_1 (1% chitosan and 4±1°C) recorded the lowest PLW (%) of arils (0.18, 0.65, 1.25, 1.97 and 2.58). These findings are in accordance with those reported in strawberry, coated with chitosan plus carrageenan (Ribeiro *et al.* 2007), brussel sprout with starch (Vina *et al.* 2007) and mango with chitosan (Zhu *et al.* 2008).

TSS (°Brix)

The TSS (°Brix) of arils of pomegranate cultivar, Bhagwa was significantly influenced by edible coatings and storage temperatures as depicted in table 2.

Maximum TSS (°Brix) of arils was recorded in C_1 (1% chitosan) (16.40, 16.62) during initial 4th and 8th day of storage, respectively. However, on 12th (15.24), 16th (14.90) and 20th (14.61) day of storage, the minimum TSS (°Brix) was recorded in C_1 (1% chitosan). These observations were similar to the findings of Zhelyazkov *et al*. (2014) in fresh-cut apple.

Among the storage temperatures, $\mathbf{T_1}$ (4±1°C) recorded the maximum TSS (°Brix), on 4th (16.21) and 8th (16.41) day of storage and minimum TSS (°Brix) values were observed with 12th (15.05), 16th (14.79) and 20th (14.41) day of storage.

The results of interaction effect indicated that, edible coatings and storage temperatures on TSS (°Brix) of arils of Bhagwa variety was found to be significant on all the days of storage except, on 4th and 12th day of storage. Whereas, on 8th day of storage, C_1T_1 (1% chitosan and 4±1°C) recorded the maximum TSS (°Brix) (16.31). The results obtained in the present study might be indirectly attributed to chitosan's inhibitory effect on respiration and other bioactivities occurring in arils that consume sugars which are a main constituent of TSS (Zahran *et al*., 2015 in pomegranate).

Titratable acidity (%)

The data on per cent titratable acidity of arils of pomegranate cv. Bhagwa as influenced by different edible coatings and storage temperatures were presented in fig. 1.

In general, the per cent titratable acidity of arils was found to decrease during storage irrespective of edible coatings and storage temperatures. Acidity reductions during storage may be due to the conversion of organic acids to sugars and their further utilization in respiration and metabolic processes (Abbasi *et al*., 2009 in mango and Ibrahim *et al.,* 2014 in pineapple).

Significant differences were observed among edible coatings with respect to titratable acidity (%) throughout the storage period. The higher values of titratable acidity (%) in arils of pomegranate were recorded in C_1 (1% chitosan) on 4th (0.46), 8th (0.44), 12th (0.43), 16th (0.41) and 20th (0.37) day of storage. Very high or very low values of acidity are not recommended for good quality fruits. Chitosan coating can develop an oxygen barrier on aril surface leading to reduced metabolic rates and consequently, less acidity variation in chitosan-treated fruits (Ibrahim *et al*., 2014 in pineapple).

The titratable acidity of arils stored at (4±1°C) $\mathbf{T_1}$ recorded higher per cent acidity values (0.48, 0.46, 0.42, 0.40 and 0.36) on 4th, 8th, 12th, 16th and 20th day of storage, respectively as opined by Gil *et al*. (1996), Artes *et al*. (2000) and Martinez *et al*. (2012) in pomegranate. Among interaction effects, C_1T_1 (1% chitosan and 4±1°C) recorded the highest values of titratable acidity (0.50, 0.49, 0.44, 0.42 and 0.39).

TSS/acid ratio

The influence of different edible coatings and storage temperatures on TSS/acid ratio of arils of pomegranate cv. Bhagwa were presented in Table 3.

The increase in TSS/acid ratio irrespective of storage time, edible coatings and storage temperatures might be due to the increase in TSS and decrease in titratable acidity. These findings are in conformity with those of Singh and Mondal (2006) in peach, Jadhao *et al*. (2007) in Kagzi lime and Petriccione *et al*. (2015) in strawberry.

With respect to storage temperatures, 4±1°C ($\mathbf{T_1}$) recorded low TSS/acid ratio of 33.66, 35.66 and 39.66 on 4th, 8th and 12th day of storage, respectively. Though high TSS/acid ratios (43.48 on 4th day and 49.21 on 8th day) were recorded at room temperature of 26-29°C (C_4), spoilage of arils noticed after 8 days of storage. The calculated TSS/acid ratios obtained in the present study were similar to those reported by Ben-Ariee *et al.* (1984) in pomegranate cv. Wonderful. The low TSS/ acid ratio was recorded in C_1T_1 (32.34, 33.28, 38.75, 35.85 and 34.01) on 4th, 8th, 12th, 16th and 20th day of storage, respectively. While, high TSS/acid ratio was recorded in C_4T_3 (48.60) on 4th day. The spoilage of arils observed after 4 days of storage.

Total sugars (%)

The perusal of data regarding the changes in per cent total sugars of arils of pomegranate cv. Bhagwa indicates significant differences among edible coatings, storage temperatures and their interaction effects (table 4).

On 4th, 8th, 12th day of storage, per cent total sugars (11.47, 12.06 and 12.16) was less in C_1 (1% chitosan)

Table 1 : Effect of different edible coatings and storage temperatures on physiological loss in weight (PLW) (%) of arils of pomegranate cv. Bhagwa.

PLW (%)																										
Storage period (days)																										
	0	4					8					12					16					20				
		C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean
T_1	0.0	0.18	0.19	0.18	0.98	0.38	0.65	0.68	0.67	1.84	0.98	1.25	1.38	1.35	3.58	1.89	1.97	1.99	1.98	3.98	2.48	2.58	2.64	2.61	*	2.61
T_2	0.0	0.21	0.22	0.21	1.23	0.47	0.78	0.81	0.80	2.20	1.15	1.55	1.63	1.61	3.98	2.19	2.85	2.89	2.86	*	2.86	3.83	3.98	3.96	*	3.92
T_3	0.0	1.10	1.15	1.14	3.68	1.77	2.37	2.39	2.38	*	2.38	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Mean	0.0	0.50	0.52	0.51	1.96		1.27	1.29	1.28	2.02		1.40	1.50	1.48	3.78		2.41	2.43	2.42	3.98		3.20	3.31	3.28	*	
Statistics		SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05		
C		0.01		0.03			0.02		0.05			0.02		0.06			0.02		0.06			0.02		0.06		
T		0.01		0.02			0.01		0.04			0.02		0.06			0.02		0.06			0.02		0.05		
C×T		0.02		0.05			0.03		0.09			0.04		0.11			0.04		0.11			0.03		0.10		

C_1 : Chitosan (1%) C_2 : Aloe vera gel (100%) C_3 : Honey (10%) C_4 : Control (Un-treated) * Decayed arils
T_1 : 4±1⁰C T_2 : 7±1⁰C T_3 : Room temperature (26-29⁰C)

Table 2 : Effect of different edible coatings and storage temperatures on TSS (⁰Brix) of arils of pomegranate cv. Bhagwa.

TSS (⁰Brix)																										
Storage period (days)																										
	0	4					8					12					16					20				
		C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean
T_1	15.83	16.17	16.21	16.19	16.29	16.21	16.31	16.38	16.33	16.61	16.41	15.29	15.20	15.27	14.45	15.05	15.06	15.03	15.04	14.04	14.79	14.88	14.72	14.83	*	14.41
T_2	15.83	16.22	16.30	16.23	16.45	16.30	16.36	16.40	16.38	16.82	16.49	15.19	15.13	15.16	14.18	14.91	14.74	14.62	14.71	*	14.69	14.34	14.23	14.31	*	14.29
T_3	15.83	16.80	16.89	16.83	17.01	16.88	17.19	17.26	17.20	*	17.22	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Mean	15.83	16.40	16.47	16.42	16.58		16.62	16.68	16.64	16.71		15.24	15.16	15.21	14.31		14.90	14.82	14.87	14.04		14.61	14.47	14.57	*	
Statistics		SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05		
C		0.15		0.44			0.15		0.44			0.12		0.34			0.10		0.30			0.08		0.25		
T		0.13		0.38			0.13		0.38			0.10		0.30			0.09		0.26			0.07		0.21		
C×T		0.26		NS			0.26		0.76			0.20		NS			0.18		0.52			0.15		0.42		

C_1 : Chitosan (1%) C_2 : Aloe vera gel (100%) C_3 : Honey (10%) C_4 : Control (Un-treated) * Decayed arils
T_1 : 4±1⁰C T_2 : 7±1⁰C T_3 : Room temperature (26-29⁰C)

Table 3 : Effect of different edible coatings and storage temperatures on TSS/acid ratio of arils of pomegranate cv.Bhagwa.

TSS/acid ratio																										
Storage period (days)																										
	0	4					8					12					16					20				
		C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean
T_1	32.06	32.34	33.08	33.04	36.20	33.66	33.28	34.85	34.02	40.51	35.66	38.75	39.88	38.78	41.26	39.66	35.85	36.65	35.80	45.11	37.10	34.01	34.10	34.08	*	34.06
T_2	32.06	33.79	34.68	34.53	40.12	35.78	35.56	36.44	36.40	48.05	39.11	40.16	40.45	40.23	49.56	42.60	36.85	38.47	37.71	*	37.67	35.22	35.35	35.28	*	35.28
T_3	32.06	40.97	43.31	41.04	48.60	43.48	47.75	50.76	49.14	*	49.21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Mean	32.06	35.70	37.02	36.20	41.64		38.86	40.57	39.85	44.28		39.45	39.67	39.50	45.41		36.35	37.56	36.75	45.11		34.61	34.71	34.67	*	
Statistics		SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05		
C		0.34		1.00			0.38		1.11			0.34		0.98			0.28		0.72			0.20		0.59		
T		0.30		0.87			0.33		0.96			0.29		0.85			0.28		0.83			0.17		0.51		
C×T		0.59		1.73			0.66		1.92			0.58		1.69			0.49		1.43			0.35		1.02		

C_1 : Chitosan (1%) C_2 : Aloe vera gel (100%) C_3 : Honey (10%) C_4 : Control (Un-treated) * Decayed arils
T_1 : 4±1⁰C T_2 : 7±1⁰C T_3 : Room temperature (26-29 ⁰C)

Table 4 : Effect of different edible coatings and storage temperatures on total sugars (%) of arils of pomegranate cv. Bhagwa.

Total Sugars (%)																										
Storage period (days)																										
	0	4					8					12					16					20				
		C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean
T_1	10.56	11.04	11.10	11.03	11.22	11.10	11.26	11.30	11.28	11.85	11.42	11.80	11.89	11.86	12.31	11.96	10.96	10.91	10.93	10.04	10.71	10.64	10.58	10.61	*	10.61
T_2	10.56	11.31	11.38	11.36	11.58	11.40	11.81	11.91	11.86	12.62	12.05	12.53	12.60	12.58	13.08	12.70	10.78	10.71	10.74	*	10.74	10.42	10.32	10.39	*	10.38
T_3	10.56	12.05	12.15	12.08	12.79	12.27	13.10	13.18	13.16	*	13.15	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Mean	10.56	11.47	11.54	11.49	11.86		12.06	12.13	12.10	12.23		12.16	12.24	12.22	12.69		10.87	10.81	10.83	10.04		10.53	10.45	10.50	*	
Statistics		SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05			SE.m±		CD @ P=0.05		
C		0.11		0.31			0.11		0.32			0.10		0.29			0.07		0.22			0.06		0.18		
T		0.09		0.27			0.10		0.28			0.09		0.25			0.06		0.19			0.05		0.15		
C×T		0.18		NS			0.19		0.56			0.17		NS			0.13		0.38			0.11		0.31		

C_1 : Chitosan (1%) C_2 : Aloe vera gel (100%) C_3 : Honey (10%) C_4 : Control (Un-treated) * Decayed arils
T_1 : 4±1⁰C T_2 : 7±1⁰C T_3 : Room temperature (26-29⁰C)

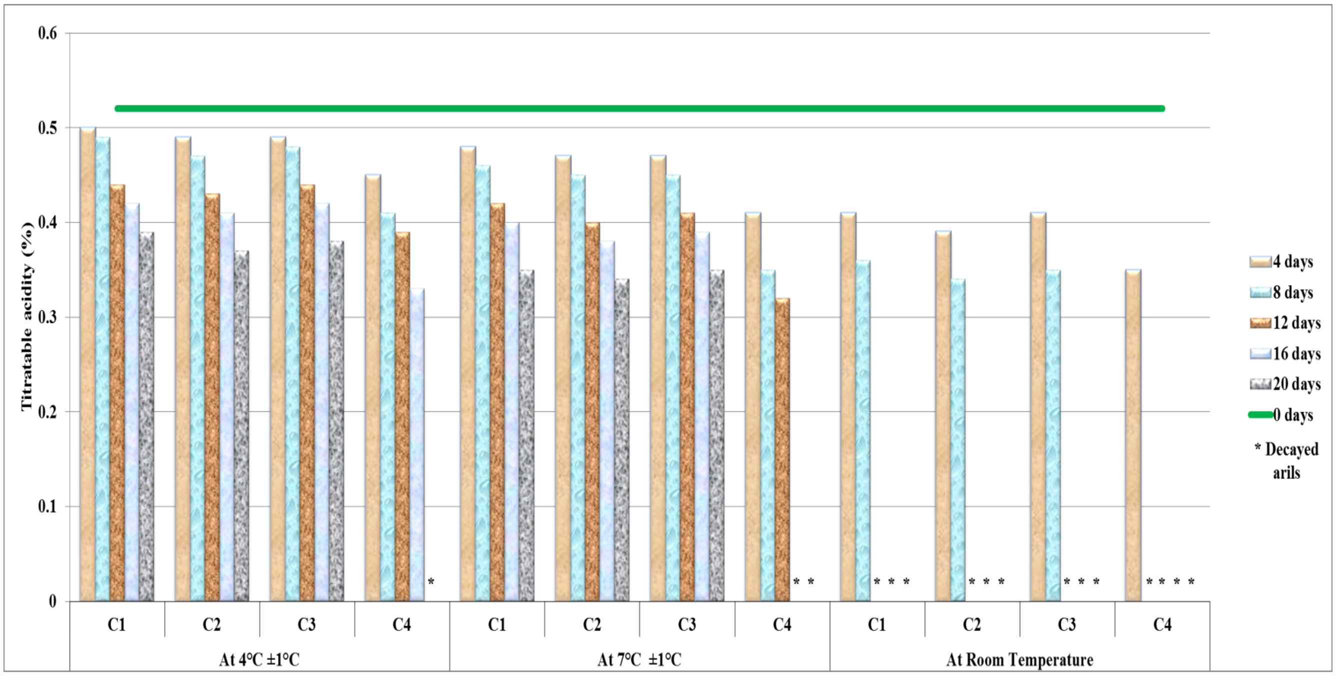

Fig. 3 : Effect of different edible coatings and storage temperatures on titratable acidity (%) of arils of pomegranate cv. Bhagwa.

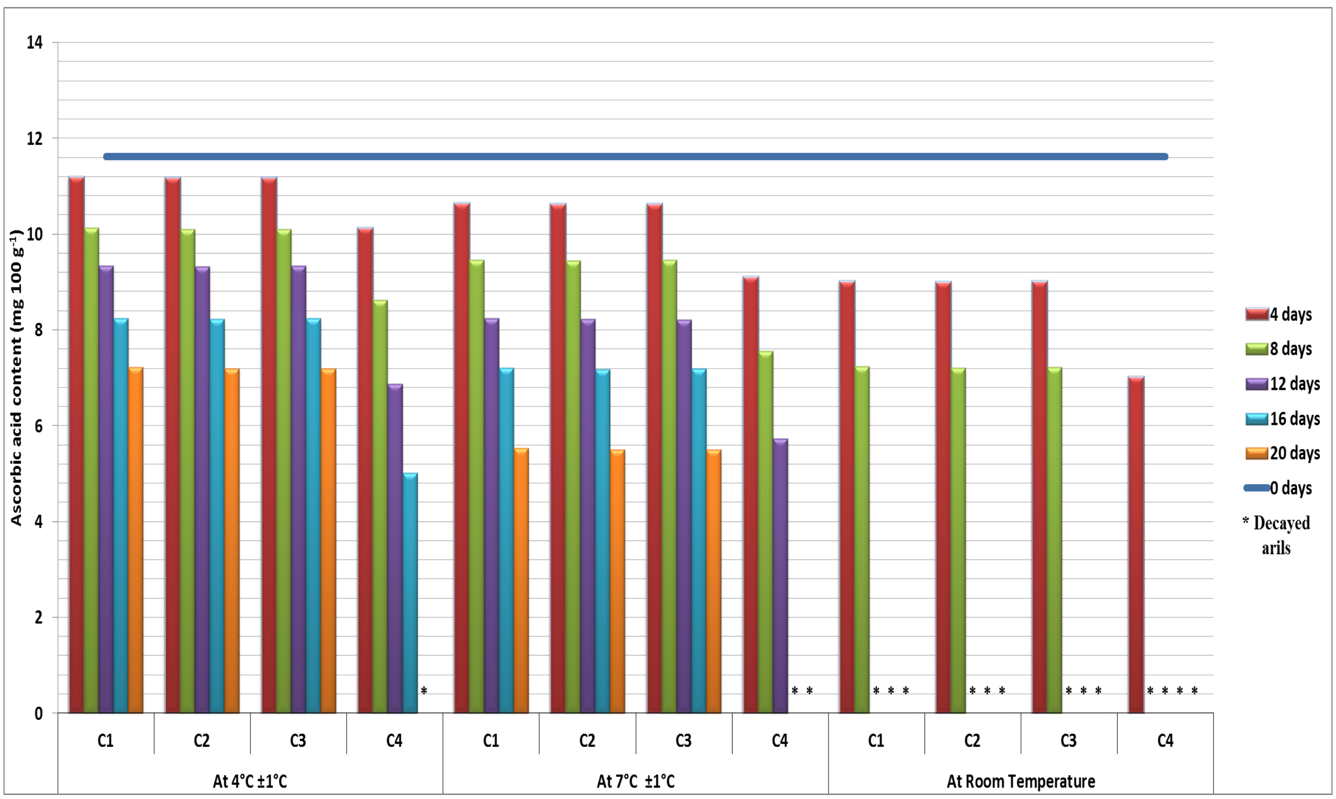

Fig. 6 : Effect of edible coatings and storage temperatures on ascorbic acid content (mg 100 g^{-1}) of arils of pomegranate cv. Bhagwa.

treated arils compared to per cent total sugars in C_4 (control) (11.86, 12.23, 12.69), respectively. On 16th (10.87) and 20th (10.53) day of storage, more per cent total sugars were observed in C_1 (1% chitosan) whereas, less per cent total sugars were recorded in C_4 (control) on 16th (10.04) day of storage. The slow increase in sugar content in coated arils was because of the fact that the thin layer of chitosan on the surface of arils delayed the degradation process as reported by Trung *et al*. (2011) in sugar-apples.

The results of interaction effect of edible coatings and storage temperatures on total sugars (%) of arils of Bhagwa was found to be significant on all the days of storage except, on 4th and 12th day of storage. Whereas, on 8th, 16th and 20th day of storage, significantly lowest total sugars (%) (11.26, 10.96 and 10.64) was recorded in C_1T_1 (1% chitosan and 4±1°C). The declining trend of sugars in later phase is possibly due to utilization of sugars as a substrate in metabolic process as reported by Rocha *et al*. (2003) in apple.

Ascorbic acid (mg 100g^{-1})

Observations on ascorbic acid content (mg/100g^{-1}) of arils of pomegranate cv. Bhagwa showed significant variation among different edible coatings and storage temperatures (fig. 2).

The ascorbic acid content (mg/100g^{-1}) in pomegranate arils showed a declining trend irrespective of edible coatings and storage temperatures during storage period. The arils coated with C_1 (1% chitosan) recorded the highest ascorbic acid content (mg 100g^{-1}) (10.29, 8.94, 8.79, 7.73 and 6.37) on 4th, 8th, 12th, 16th and 20th day of storage, respectively. The reason for high ascorbic acid content in chitosan treatments can be attributed to limited oxygen supply caused by the barrier effect imposed by chitosan as reported by Malundo *et al.* (1997) in mango.

Among the storage temperatures, the higher ascorbic acid (mg 100g^{-1}) in arils was recorded in $\mathbf{T_1}$ (4±1°C) on 4th (10.92), 8th (9.74), 12th (8.72), 16th (7.43) and 20th (7.21) day of storage. Similar findings of increased ascorbic acid with low temperatures were observed by Ram *et al*. (1970) in kagzi lime.C_1T_1 (1% chitosan and 4±1°C) recorded the highest ascorbic acid content (mg 100g^{-1}) (11.20, 10.13, 9.35, 8.25 and 7.22) on 4th, 8th, 12th, 16th and 20th day of storage, respectively.

Conclusion

Based on the results obtained from the study, it is concluded that chitosan (1%) edible coating to arils of pomegranate cv. Bhagwa proved to be beneficial in reducing weight loss and maintaining the quality of arils during storage period of twenty days. Integrating chitosan (1%) treated arils with cold storage temperature of 4±1°C, was found to be promising to several quality parameters such as TSS, titratable acidity, TSS/TA, total soluble solids and total sugars.

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