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Reducing Weight Loss and Keeping Fruit Quality of Wonderful Pomegranate Via Different Postharvest Treatments

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IN REGARD to maintain water content, fruit quality and reducing chilling injury symptoms of ripe Wonderful pomegranate during marketing in domestic or global markets the current study was applied in two successive seasons (2016 and 2017). Different treatments were conducted as postharvest treatments and it included, film wrapping, hot water at 45°C for 4 min., 2% $CaCl_2$, 1% chitosan, wrapping + hot water, wrapping + 2% $CaCl_2$, wrapping +1% chitosan, hot water + 2% $CaCl_2$, hot water + 1% chitosan, 2% $CaCl_2$ + 1% chitosan, combined treatment in addition to control. All treatments were stored at 5°C and 90-95% RH for 60 days followed by shelf life at 20°C for 14 days. $CaCl_2$ at 2% significantly maintained fruit weight, peel thickness and fruit firmness. Also, 1% chitosan alone or + 2% $CaCl_2$ showed the lowest significant decay percentages. Furthermore, 1% chitosan exhibited the lowest significant respiration rate, h° score and TSS value, it showed the highest significant general appearance scores, and maintained the higher contents of ascorbic acid and anthocyanin pigment compared with untreated ones.

Keywords: Film wrapping, Hot water, $CaCl_2$, Chitosan, Pomegranate, Water content.

Introduction

Pomegranate (*Punica granatum* L.) is an important fruit crop, it is considered one of the promising exportation fruits in Egypt in the last years (Abd-elghany et al., 2012). Wonderful pomegranate is late cultivar with high yield, large fruit, rich red aril, high juice, and good palatability (Palou et al., 2007). Wonderful is currently one of the most desired planted pomegranate cultivars in Egypt since it offers best balance combination yield and quality (Abd-elghany et al., 2012).

Pomegranate should be picked at ripening stage as it classified as non climacteric fruit (Kader et al., 1984). The optimum temperature for cold storage of pomegranate fruits ranged between 0-10°C depending on the cultivar (Koksal, 1989). The major storage obstacles are decay (Elyatem and Kader, 1984), shriveling of the fruit resulting in a brownish coloured tough peel and browning of arils (Kader et al., 1984) in addition to chilling injury symptoms (Gil et al., 1996). Aquino *et al*., (2010) stated that pomegranate fruits are sensitive to storage at low temperatures, once fruits are stored at temperatures below 5-6°C chilling injury appears as pitting of the husk, browning of the white segments separating the arils and discolouration of the arils, and husk surface scald, which is more clear when fruit transferred to markets (during shelf life).

Many procedures were followed to alleviate these problems and keeping fruit quality. Coating has been used as protection technique for fruits and vegetables (Jianglian and Shaoying, 2013), the main objectives of this practice are minimizing the water loss from the fruit cells and therefore it reduce weight loss, in this respect Baldwin et al. (1999) reported that coating can decrease fruit mass loss by up to 50%, and it can preserve fruit in high quality. Varasteh et al. (2012) reported that postharvest chitosan coating treatment delayed anthocyanin degradation and delayed colour changes in the pomegranate arils. Chitosan is considered a high molecular weight particle, it is valuable as antioxidant and eligible for maintaining fruit quality, for this reason chitosan is a highly suggested edible film (Tendaj and Tendaj, 1998). Varasteh et al. (2017) reported that pomegranate fruits ‘Rabbab-e-Neyriz’ dipping in 1 and 2% aqueous chitosan solutions retarded the respiration rate and weight loss of the fruit regardless of temperature during storage period with a higher total soluble solids content compared with uncoated fruits.

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In this respect Mirdehghan et al. (2007) reported that heat treatment via hot water dipping at 45°C for 4 min significantly decreased chilling injury symptoms in pomegranate fruit and have a role in keeping fruit hardness. In previous work for Mirdehghan and Rahemi (2005) on hot water effects on 'Malas Yazdi' pomegranate fruits as immersion in hot water at 35, 45, 55 and 65°C for 2 and 5 min, the results disclosed that increasing the water temperature to 45°C significantly minimized chilling injury disorders. Mirdehghan et al. (2006) declared that antioxidants activity of pomegranate fruits treated by different heat treatments were higher compared with untreated fruits, because of maintaining higher levels of, ascorbic acid, total phenolics content and anthocyanin pigment.

In this way, film wrapping of fresh fruits and vegetables greatly reduce weight loss via decreasing the transpiration rate and sustain fruit firmness (Ben-Yehoshua, 1985 and Risee, 1989). Aquino et al. (2010) mentioned that film wrapping diminished weight loss and peel scald and reduced fruit respiration rate during cold storage and shelf life. Also, Shaarawi and Nagy (2017) approved that polyethylene plastic films significantly reduced weight loss, decay incidence and maintained pomegranate fruit quality compared with control. Furthermore, film wrapping with polyolefin films of 'Ganesh' pomegranates retained peel thickness, freshness and firmness of the fruit, and reduced weight loss with lower changes in acidity, sugars and vitamin C (Nanada et al., 2001).

Pre-storage application of calcium chloride ($CaCl_2$) was widely applied to maintain fruit quality. The postharvest treatment of calcium in many horticultural crops has been revealed to maintain membrane hardness (Lester and Grusaak, 1999). Sayyarri et al. (2010) found that immersion of 'Malas Saveh' pomegranate fruits in $CaCl_2$ (135 and 270 mM) for 5 or 10 minutes significantly improved the calcium concentration in husk of fruits and reduced peel chilling injury symptoms such as pitting and browning. Also, dipping pomegranate fruits in $CaCl_2$ at 1 or 2% solutions for five minutes significantly reduced the chilling disorders and the total soluble solids of fruit juices was increased (Mirdehghan and Ghotbi, 2014). Also Kazemi et al. (2013) found that $CaCl_2$ at 4% retained maximum firmness, vitamin C of pomegranate fruits.

The main goals of this investigation were to evaluate the effects of different pre-storage treatments, chitosan, film wrapping, hot water treatment and $CaCl_2$ on the postharvest quality characteristics of 'Wonderful' pomegranate fruits during cold storage at 5°C and 90-95% RH for short time (60 days) and shelf life at 20°C for 14 days representing the average period for shipment and transportation during handling and marketing conditions.

Materials and Methods

Plant material and treatments

Wonderful pomegranate fruits were hand harvested according to indices cited by Kader (2006) from the Experimental Research Station of the Faculty of Agriculture, Cairo University at Wadi El Natrun, Egypt, which subjected to the recommended cultural practices in both successive seasons 2016 and 2017. Fruits were chosen to be similar as possible in colour and size, and free of any noticeable pathological or mechanical injuries. Fruits were instantly transported to the fruits handling laboratory, all fruits washed by tap water and air dried.

Fruits divided to twelve groups, every group was exposed to one of the following treatments,

Film wrapping.
Dipping at hot water (HWT) at 45°C for 4 min.
Dipping at $CaCl_2$ at 2% for 4 min.
Dipping at chitosan at 1% for 4 min.
HWT + Film wrapping.
$CaCl_2$ at 2% + Film wrapping.
Chitosan at 1% + Film wrapping.
HWT + $CaCl_2$ at 2%.
HWT + Chitosan at 1%.
$CaCl_2$ at 2% + Chitosan at 1%.
Combined treatment (HWT + $CaCl_2$ at 2% + Chitosan at 1% + Film wrapping).
Control.

Film wrapping was applied using polypropylene sheets (30 µm thickness) as a layer around the fruits inside the carton boxes. Fruits from each treatment were packed in carton boxes (12 fruits capacity). Three carton packages were used for each replicate, one package to determine decay, the second to determine weight loss and the third for fruits analysis, and each treatment was replicated three times. The investigation was conducted during two successive seasons (2016 and 2017). All fruits were stored at 5°C and 90-95% RH for 60 days followed by shelf life at

20°C for 14 days in laboratory of Refrigeration of Agricultural Systems Improvement Project, Ministry of Agriculture, Giza, Egypt.

All treatments were assessed for different chemical and physical properties at 15 days intervals during cold storage and 7 days intervals during shelf life.

Fruit physical and chemical characteristics

Weight loss percentage

The difference between the initial weight of fruits and that recorded at the date of sampling was translated as weight loss percentage and calculated as follows, weight loss % = (fruit initial weight - fruit weight at each sampling time) × 100 / fruit initial weight.

Decay percentage

The percentage of discarded fruits included all of the injured fruits, resulting from rots, fungus, bacteria, physiological disorders or chilling injury, were assessed and calculated as the number of discarded fruits /total number of fruits at the beginning × 100.

Fruit firmness (lbf)

According to Mitcham et al. (2003) fruit firmness was determined by fruit penetrometer (8 mm diameter probe) on the opposite surfaces of each fruit and data were recorded as lbf.

Respiration rate (ml CO_2/kg fruits/hr)

Respiration rate was measured by gas analyzer (Model 1450 - Servomex 1400) according to McCollum et al. (1993), airtight glass jars (4 liter) were used to fruit incubation under the same storage circumstances for 24 hr, respiration rate was measured as ml of CO_2/kg fruits/hr.

General appearance score

General appearance of fruits was observed visually using the described procedure by Mitcham et al. (2003), on a scale from one to nine with 1= unacceptable, 3= poor, 5= fair, 7= good, and 9= excellent.

Instrumental colour

Instrumental colour was measured in the CIE L^* a^* b^* on different places of husk layer surface of fruit objectively using a Minolta CR-400 chroma meter (Minolta, Osaka, Japan) according to McGuire (1992).

Peel thickness (mm)

Peel layer thickness was evaluated and expressed in mm.

Total soluble solids (TSS %)

Total soluble solids were measured using drops of pomegranate fruit arils juice via refractometer and expressed as TSS %.

Ascorbic acid (mg/ 100g FW)

Ascorbic acid was measured according to Mazumdar and Majumder (2003) using titration method against 2,6 dicholorophenol indophenol solution, the obtained results were indicated as mg ascorbic acid per 100 g fruit fresh weight (FW).

Anthocyanin (mg/ 100g FW)

Total anthocyanins were extracted from ten gram aril fresh weight with 100 mm 0.1% methanolic HCL, the solution filtered and was measured colourimetrically at 520 nm (Geza et al., 1984)

Statistical analysis procedure

All data parameters studied were analyzed as randomized complete block design in factorial arrangement with three replication. The differences between means were compared by LSD range test at the 5% level of probability in the two investigated seasons as described by Snedecor and Cochran (1989).

Results and Discussion

Weight loss percentage

Table 1. presents the effect of the different conducted postharvest treatments on weight loss percentage of Wonderful pomegranate fruits in 2016 and 2017 seasons. Weight loss percentage increased gradually under all circumstances, all treatments showed lower significant weight loss values compared with control that showed the highest significant weight loss values during cold storage and shelf life periods in both seasons. On the other hand, $CaCl_2$ treatment at 2% and combined treatment showed the lowest significant weight loss values.

By the end of storage period, control showed the highest significant weight loss (9.98 and 9.06%) in both seasons, respectively while the lowest values were obtained from combined treatment (7.39%) in the first season and obtained from 2% $CaCl_2$ treatment (5.87%) in the second one. Whereas, by the end of shelf life period control showed the highest significant weight loss (6.91 and 6.07%) in 2016 and 2017 seasons, respectively while combined treatment showed the lowest significant weight loss (4.17%) in the first season whereas that chitosan at 1% showed the lowest significant weight loss (3.96%) in the second one .

Fresh pomegranate fruits transpiration leads to significant weight loss and finally causing to the softening of flesh, the decrease of juiciness, and husk shriveling (Kader et al., 1984). Weight loss is largely due to water loss through natural porosity of the skin, Varasteh et al. (2017) revealed that postharvest weight losses in pomegranate fruits primarily associated with weight loss in the fruit husk compared with arils. Shriveling symptoms on fruit are noticeable only when weight loss exceeds 5% or more of the initial weight in accordance with investigations of Ben-Arie and Or, (1986) and Holcroft et al. (1998).

The role of applied treatments especially $CaCl_2$ treatment compared with control on decreasing weight loss was clear. The obtained results was in line with Nanada et al. (2001) using film wrapping in 'Ganesh' pomegranates in regard to reduction in transpiration and respiration rate, Mirdehghan et al. (2007) using hot water dip at 45°C for 4 min because of increment in putrescine and spermidine during storage that could have a role in the lower rate of fruit softening as well as maintenance of the fatty acid ratio which maintain membrane integrity and fluidity, in addition to Varasteh *et al*. (2017) using aqueous chitosan solutions at 1 and 2% on Rabbab-e-Neyriz pomegranate fruits due to coating role in providing thin film to fruit peel that consider a semi permeable barrier against gas exchange, and evaporation.

Also, the valuable role of calcium treatment was in agreement with the previous work in pomegranate (Kazemi et al., 2013), Lester and Grusaak (1999) have shown that calcium treatment in fruits was effective in terms of membrane functionality and integrity maintenance, with lower losses of proteins and phospholipids and reduced ion leakage, which resulted in lower respiration and lower water loss.

Decay (%)

Table 2. presents the influence of the different applied treatments on decay percentage of Wonderful pomegranate fruits in both seasons, decay percentage increased gradually with the prolongation of cold storage period and simulated marketing life period. 1% chitosan alone or + 2% $CaCl_2$ showed the lowest significant decay percentages compared with untreated ones that showed the highest significant decay percentages

In the first season, control showed the highest significant decay percentage (11.11%) while treatments of 1% chitosan, 2% $CaCl_2$ + 1% chitosan, Wrapping + 1% chitosan and HWT + 2% $CaCl_2$ showed the lowest significant decay percentages (2.78%) by the end of storage period. Moreover, control showed the highest significant decay percentage (19.44%) while 2% $CaCl_2$ + 1% chitosan showed the lowest significant decay percentage (8.33%) by the end of shelf life period.

In the second season, control showed the highest significant decay percentage (8.33%) while treatments of 1% chitosan, 2% $CaCl_2$ + 1% chitosan and combined treatment showed the lowest significant decay percentages (1.39%) by the end of storage period. Also, control showed the highest significant decay percentage (16.67%) while 1% chitosan and HWT + 1% chitosan showed the lowest significant decay percentages (6.94%) by the end of shelf life period.

Chitosan and $CaCl_2$ showed significant impact on fruit preservation that reduce decay percentage. Sayyarri et al. (2010) explained the effect of pre-storage application of calcium chloride ($CaCl_2$) on chilling resistance and calcium (Ca) concentration of arils and peel of pomegranate (*Punica granatum*) 'Malas Saveh'. They found that postharvest $CaCl_2$ treatments at 135 and 270 mM limited the intense of peel chilling injury symptoms such as browning and pitting on segment separating thin layer browning because of accumulation of calcium ions in husk.

Wang (2009) approved that the main key to reduce chilling injury via its effect on antioxidant activity and changes in enzymes activity such as ascorbic acid oxidase, polypenoloxidase, peroxidase, catalase, which may be related to membrane integrity and electrolyte leakage (Zhang and Zhang, 2008).

Also, calcium enhanced the natural resistance against different rots and the growth of fungus by reducing the fungus from reaching its active sites in the cells, also high levels of Ca concentrations in husk reduced the soft rot disease, in addition to delayed in senescence and ripening (Kazemi et al., 2013).

TABLE 1. Effect of different postharvest treatments on weight loss percentage of pomegranate fruits cv. Wonderful in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
	2016 season									
Film wrapping	0.00	2.98	5.20	6.74	8.78	4.74	0.00	2.60	5.44	2.68
Hot water (HWT)	0.00	3.10	5.20	6.66	9.05	4.80	0.00	2.53	4.88	2.47
$CaCl_2$ at 2%	0.00	2.59	4.80	6.40	8.92	4.54	0.00	1.93	4.23	2.05
Chitosan at 1%	0.00	2.60	4.86	6.45	8.85	4.55	0.00	2.11	4.42	2.18
Wrapping + HWT	0.00	3.12	5.58	7.51	9.94	5.23	0.00	2.62	5.02	2.55
Wrapping + 2% $CaCl_2$	0.00	2.75	5.25	6.94	9.50	4.89	0.00	3.18	5.17	2.78
Wrapping + 1% Chitosan	0.00	2.93	5.49	7.34	9.97	5.15	0.00	2.72	5.95	2.89
HWT + $CaCl_2$ at 2%	0.00	3.05	5.46	7.20	9.93	5.13	0.00	2.76	5.51	2.76
HWT + Chitosan at 1%	0.00	3.01	5.41	7.03	9.56	5.00	0.00	2.41	4.45	2.28
2% $CaCl_2$ + 1% Chitosan	0.00	3.07	5.49	7.05	9.38	5.00	0.00	2.58	5.06	2.55
Combined treatment	0.00	2.18	4.13	5.69	7.39	3.88	0.00	1.85	4.17	2.01
Control	0.00	3.59	6.47	8.29	9.98	5.67	0.00	4.55	6.91	3.82
Mean	0.00	2.91	5.28	6.94	9.27		0.00	2.65	5.10	
L.S.D at 0.05	(A) = 0.59, (B) = 0.38, (A×B) = 1.32						(A) = 0. 69, (B) = 0.35, (A×B) = 1.20			
	2017 season									
Film wrapping	0.00	2.20	3.85	5.14	7.45	3.73	0.00	2.52	4.60	2.37
Hot water (HWT)	0.00	1.95	3.82	5.23	7.56	3.71	0.00	2.64	4.73	2.46
$CaCl_2$ at 2%	0.00	1.52	3.04	4.03	5.87	2.89	0.00	1.88	4.06	1.98
Chitosan at 1%	0.00	1.75	3.20	4.28	6.21	3.09	0.00	2.44	3.96	2.13
Wrapping + HWT	0.00	2.77	4.74	5.89	8.00	4.28	0.00	2.41	6.01	2.81
Wrapping + 2% $CaCl_2$	0.00	2.25	3.49	4.54	6.71	3.40	0.00	2.50	4.81	2.44
Wrapping + 1% Chitosan	0.00	2.25	4.29	5.72	8.28	4.11	0.00	2.89	5.88	2.92
HWT + $CaCl_2$ at 2%	0.00	1.88	3.79	4.97	7.17	3.56	0.00	2.22	5.24	2.49
HWT + Chitosan at 1%	0.00	2.45	4.33	5.50	7.78	4.01	0.00	2.32	4.13	2.15
2% $CaCl_2$ + 1% Chitosan	0.00	2.31	4.09	5.30	7.33	3.81	0.00	3.11	5.25	2.79
Combined treatment	0.00	1.50	3.08	4.21	6.01	2.96	0.00	1.25	4.21	1.82
Control	0.00	2.96	5.24	6.56	9.06	4.76	0.00	3.04	6.07	3.04
Mean	0.00	2.15	3.91	5.11	7.29		0.00	2.43	4.91	
L.S.D at 0.05	(A) = 0.65, (B) = 0.42, (A×B) = 1.46						(A) = 0.63, (B) = 0.32, (A×B) = 1.09			

TABLE 2. Effect of different postharvest treatments on decay (%) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
	2016 season									
Film wrapping	0.00	0.00	2.78	2.78	6.94	2.50	0.00	6.94	13.89	6.94
Hot water (HWT)	0.00	0.00	0.00	1.39	4.17	1.11	0.00	4.17	13.89	6.02
$CaCl_2$ at 2%	0.00	0.00	0.00	1.39	4.17	1.11	0.00	5.55	12.50	6.02
Chitosan at 1%	0.00	0.00	0.00	0.00	2.78	0.56	0.00	2.78	9.72	4.17
Wrapping + HWT	0.00	0.00	1.39	4.17	6.94	2.50	0.00	6.94	15.28	7.41
Wrapping + 2% $CaCl_2$	0.00	0.00	1.39	2.78	4.17	1.67	0.00	5.55	12.50	6.02
Wrapping + 1% Chitosan	0.00	0.00	0.00	2.78	2.78	1.11	0.00	5.55	11.11	5.55
HWT + $CaCl_2$ at 2%	0.00	0.00	0.00	1.39	2.78	0.83	0.00	4.17	13.89	6.02
HWT + Chitosan at 1%	0.00	0.00	0.00	1.39	4.17	1.11	0.00	5.55	9.72	5.09
2% $CaCl_2$ + 1% Chitosan	0.00	0.00	0.00	0.00	2.78	0.56	0.00	4.17	8.33	4.17
Combined treatment	0.00	0.00	0.00	0.00	4.17	0.83	0.00	4.17	11.11	5.09
Control	0.00	0.00	4.17	4.17	11.11	3.89	0.00	11.11	19.44	10.18
Mean	0.00	0.00	0.81	1.85	4.75		0.00	5.56	12.62	
L.S.D at 0.05	(A) = 1.49, (B) = 0.96, (A×B) = 3.35						(A) = 2.79, (B) = 1.40, (A×B) = 4.84			
	2017 season									
Film wrapping	0.00	0.00	0.00	1.39	2.78	0.83	0.00	4.17	13.89	6.02
Hot water (HWT)	0.00	0.00	0.00	1.39	2.78	0.83	0.00	4.17	12.50	5.56
$CaCl_2$ at 2%	0.00	0.00	0.00	1.39	4.17	1.11	0.00	5.55	9.72	5.09
Chitosan at 1%	0.00	0.00	0.00	0.00	1.39	0.28	0.00	2.78	6.94	3.24
Wrapping + HWT	0.00	0.00	1.39	4.17	5.55	2.22	0.00	6.94	13.89	6.94
Wrapping + 2% $CaCl_2$	0.00	0.00	0.00	2.78	5.55	1.67	0.00	5.55	12.50	6.02
Wrapping + 1% Chitosan	0.00	0.00	0.00	2.78	4.17	1.39	0.00	5.55	11.11	5.55
HWT + $CaCl_2$ at 2%	0.00	0.00	0.00	1.39	2.78	0.83	0.00	4.17	12.50	5.56
HWT + Chitosan at 1%	0.00	0.00	0.00	1.39	2.78	0.83	0.00	5.55	6.94	4.17
2% $CaCl_2$ + 1% Chitosan	0.00	0.00	0.00	0.00	1.39	0.28	0.00	4.17	8.33	4.17
Combined treatment	0.00	0.00	0.00	0.00	1.39	0.28	0.00	4.17	9.72	4.63
Control	0.00	0.00	2.78	5.55	8.33	3.33	0.00	11.11	16.67	9.26
Mean	0.00	0.00	0.35	1.85	3.59		0.00	5.32	11.23	
L.S.D at 0.05	(A) = 1.22, (B) = 0.78, (A×B) = 2.72						(A) = 3.06, (B) = 1.53, (A×B) = 5.30			

Firmness (lbf)

Data tabulated in Table 3. declare the impact of different postharvest treatments on firmness of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Cell wall turgid decreased continuously in both seasons of this study, 2% $CaCl_2$ was the most effective treatment in maintaining fruit firmness compared with untreated fruits that showed the lowest firmness values in both seasons.

$CaCl_2$ at 2% showed the highest significant firmness values 28.96 and 27.30 lbf by the end of storage period in the first and the second season respectively. Also, it showed the highest significant firmness values 22.60 and 21.76 lbf by the end of shelf life period in the first and the second season respectively. On the other hand, untreated fruits exhibited the lowest significant firmness values as 27.69 and 26.30 lbf by the end of storage period in the first and the second season respectively, and it recorded 21.87 and 21.00 lbf by the end of shelf life period in the first and the second season respectively.

El-Kassas et al. (1995) also obtained agreeable results on postharvest $CaCl_2$ treatments effects on 'Manfalouty' pomegranate. Calcium treatments have known to be effective in terms of membrane hardness, Mahajan and Dhat (2004) reported that, $CaCl_2$ significantly reduced pear fruit softening.

The maintenance of firmness in calcium treated pomegranate fruits might be due its aggregation in the cell walls which resulted in acceleration in the cross linking of the pectic polymers that finally enhance wall strength and cell integrity (White and Broadly, 2003). These results are also in agreement with those found by Shuiliang et al. (2002) and Arhttar *et al*., (2010). Calcium has been used widely for its potential role in maintaining postharvest quality of fruit and vegetable crops by participating to the linkage between pectic substances within the cell wall (Demarty et al., 1984, Kirkby and Pilbeaam, 1984, Arhttar et al., 2010). The existence of Ca^{2+} ions increases the integrity of cell walls (Kazemi et al., 2011). It is also involved in delaying the incidence of deterioration and fruit senescence (Ferguson, 1984, White and Broadly, 2003, Mahajan and Dhat, 2004). In this way, Picchioni et al. (1998) indicated that postharvest calcium application maintains cell stability, membrane hardness, tissue firmness, delays membrane lipid destruction, prolongation storage lifetime of fresh fruits and reducing physiological disorders.

Respiration rate (ml CO_2 / kg fruit / hr)

The changes of respiration rate of Wonderful pomegranate fruits in response for the conducted treatments in 2016 and 2017 seasons are presented in Table 4. Respiration rate decreased in the beginning of cold storage then it increased gradually with the prolongation of storage period.

During cold storage period, control showed the highest significant respiration rate while 1% chitosan showed the lowest significant respiration rate in both seasons. By the end of storage period, control showed the highest significant respiration rates (8.23 and 7.91 ml CO_2 / kg fruit / hr), while wrapping + 1% chitosan showed the lowest significant respiration rates (7.20 and 7.08 ml CO_2 / kg fruit / hr) in the first and the second season respectively.

During shelf life period, control showed the highest significant respiration rates while 1% chitosan and wrapping + 1% chitosan showed the lowest significant respiration rates. By the end of shelf life period, control showed the highest significant respiration rates 18.51 and 19.70 ml CO_2 / kg fruit / hr in both seasons respectively, while wrapping + 1% chitosan recorded 16.34 ml CO_2 / kg fruit / hr in 2016 season, and 1% chitosan recorded 18.19 ml CO_2 / kg fruit / hr in 2017 season that were the lowest significant respiration rates.

These results are in line with those illustrated by Aquino et al. (2010) who found that film wrapping decreased respiration rate during cold storage and shelf life. As well, Nanada et al. (2001) and Abd-elghany et al. (2012) found similar results in pomegranates cv. Ganesh that were wrapped by polyolefin films, Elyatem and Kader (1984) reported a relatively low respiration rate for Wonderful fruits stored at 0ºC and 10ºC for 3 months.

In similar way, Chitosan coatings showed ultimate inhibition of the respiration rates in terms of both O_2 consumption and CO_2 generation (Sanchez-Gonzalez et al. 2011). Chitosan resulted in thin film of the coating substance to the external surface of the fruit, which can act as a semi permeable barrier against oxygen, carbon dioxide, moisture and solute movements (Varasteh et al. 2017).

TABLE 3. Effect of different postharvest treatments on firmness (lbf) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
2016 season										
Film wrapping	34.62	33.75	32.50	29.88	28.28	31.81	28.28	24.19	22.44	24.97
Hot water (HWT)	34.62	33.52	32.37	29.65	28.39	31.71	28.39	24.02	22.26	24.89
$CaCl_2$ at 2%	34.62	34.13	32.82	30.09	28.96	32.12	28.96	24.36	22.60	25.31
Chitosan at 1%	34.62	33.76	32.56	29.89	28.69	31.90	28.69	24.22	22.45	25.12
Wrapping + HWT	34.62	33.72	32.44	29.86	28.61	31.85	28.61	24.13	22.40	25.05
Wrapping + 2% $CaCl_2$	34.62	33.83	32.64	29.86	28.64	31.92	28.64	24.16	22.43	25.08
Wrapping + 1% Chitosan	34.62	33.70	32.49	29.83	28.61	31.85	28.61	24.16	22.38	25.05
HWT + $CaCl_2$ at 2%	34.62	33.67	32.50	29.80	28.51	31.82	28.51	24.12	22.38	25.00
HWT + Chitosan at 1%	34.62	33.63	32.42	29.79	28.51	31.79	28.51	24.18	22.44	25.04
2% $CaCl_2$ + 1% Chitosan	34.62	33.93	32.80	30.04	28.78	32.03	28.78	24.32	22.58	25.23
Combined treatment	34.62	33.93	32.71	29.99	28.76	32.00	28.76	24.29	22.56	25.21
Control	34.62	32.99	31.44	29.16	27.69	31.18	27.69	23.59	21.87	24.38
Mean	34.62	33.71	32.47	29.82	28.54		28.54	24.15	22.40	
L.S.D at 0.05	(A) = 0.26, (B) = 0.17, (A×B) = 0.58						(A) = 0.21, (B) = 0.10, (A×B) = 0.36			
2017 season										
Film wrapping	35.31	33.85	33.11	29.32	26.96	31.71	26.96	23.85	21.45	24.09
Hot water (HWT)	35.31	33.27	32.59	28.82	26.54	31.31	26.54	23.52	21.13	23.73
$CaCl_2$ at 2%	35.31	34.23	33.53	29.69	27.30	32.01	27.30	24.16	21.76	24.41
Chitosan at 1%	35.31	33.89	33.26	29.38	27.02	31.77	27.02	23.90	21.48	24.13
Wrapping + HWT	35.31	33.30	32.54	28.89	26.51	31.31	26.51	23.47	21.10	23.69
Wrapping + 2% $CaCl_2$	35.31	34.02	33.25	29.55	27.13	31.85	27.13	24.00	21.59	24.24
Wrapping + 1% Chitosan	35.31	33.74	33.01	29.28	26.86	31.64	26.86	23.79	21.38	24.01
HWT + $CaCl_2$ at 2%	35.31	33.55	32.88	29.06	26.76	31.51	26.76	23.75	21.30	23.94
HWT + Chitosan at 1%	35.31	33.36	32.68	28.98	26.59	31.38	26.59	23.53	21.18	23.77
2% $CaCl_2$ + 1% Chitosan	35.31	34.16	33.45	29.66	27.28	31.97	27.28	24.17	21.72	24.39
Combined treatment	35.31	34.07	33.39	29.55	27.19	31.90	27.19	24.08	21.63	24.30
Control	35.31	33.08	32.32	28.67	26.30	31.14	26.30	23.32	21.00	23.54
Mean	35.31	33.71	33.00	29.24	26.87		26.87	23.79	21.39	
L.S.D at 0.05	(A) = 0.28, (B) = 0.18, (A×B) = 0.62						(A) = 0.24, (B) = 0.12, (A×B) = 0.42			

TABLE 4. Effect of different postharvest treatments on respiration rate (ml CO_2 / kg fruit / hr) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
2016 season										
Film wrapping	7.06	4.48	4.61	5.08	7.32	5.71	7.32	11.76	16.56	11.88
Hot water (HWT)	7.06	4.49	4.66	5.54	7.98	5.95	7.98	12.75	18.04	12.92
$CaCl_2$ at 2%	7.06	4.58	4.70	5.17	7.45	5.79	7.45	11.88	16.90	12.08
Chitosan at 1%	7.06	4.45	4.57	5.03	7.23	5.67	7.23	11.51	16.42	11.72
Wrapping + HWT	7.06	4.73	4.89	5.47	7.89	6.01	7.89	12.59	17.86	12.78
Wrapping + 2% $CaCl_2$	7.06	4.64	4.68	5.43	7.87	5.93	7.87	12.56	17.76	12.73
Wrapping + 1% Chitosan	7.06	4.60	4.77	5.00	7.20	5.73	7.20	11.50	16.34	11.68
HWT + $CaCl_2$ at 2%	7.06	4.65	4.75	5.12	7.40	5.80	7.40	11.74	16.73	11.96
HWT + Chitosan at 1%	7.06	4.58	4.65	5.38	7.77	5.89	7.77	12.39	17.46	12.54
2% $CaCl_2$ + 1% Chitosan	7.06	4.67	4.75	5.32	7.64	5.89	7.64	12.18	17.32	12.38
Combined treatment	7.06	4.62	4.72	5.24	7.59	5.85	7.59	12.05	17.11	12.25
Control	7.06	4.75	4.85	5.67	8.23	6.11	8.23	13.06	18.51	13.27
Mean	7.06	4.60	4.72	5.29	7.63		7.63	12.16	17.25	
L.S.D at 0.05	(A) = 0.25, (B) = 0.16, (A×B) = 0.55						(A) = 0.42, (B) = 0.21, (A×B) = 0.73			
2017 season										
Film wrapping	7.17	4.70	5.71	5.80	7.35	6.15	7.35	12.11	18.77	12.74
Hot water (HWT)	7.17	4.79	5.80	6.19	7.82	6.35	7.82	12.25	18.51	12.86
$CaCl_2$ at 2%	7.17	4.83	5.83	5.86	7.44	6.22	7.44	12.38	18.82	12.88
Chitosan at 1%	7.17	4.70	5.72	5.74	7.26	6.12	7.26	12.15	18.19	12.53
Wrapping + HWT	7.17	5.01	6.09	6.14	7.88	6.46	7.88	13.09	19.57	13.51
Wrapping + 2% $CaCl_2$	7.17	4.79	5.84	6.11	7.79	6.34	7.79	12.38	19.24	13.13
Wrapping + 1% Chitosan	7.17	4.88	5.75	5.80	7.08	6.14	7.08	12.22	18.99	12.76
HWT + $CaCl_2$ at 2%	7.17	4.87	5.80	5.81	7.39	6.21	7.39	12.38	19.13	12.97
HWT + Chitosan at 1%	7.17	4.77	5.84	6.06	7.74	6.31	7.74	12.42	19.22	13.13
2% $CaCl_2$ + 1% Chitosan	7.17	4.85	5.91	5.97	7.72	6.32	7.72	12.54	19.14	13.13
Combined treatment	7.17	4.83	5.84	5.89	7.65	6.27	7.65	12.46	19.17	13.09
Control	7.17	4.93	5.99	6.40	7.91	6.48	7.91	12.92	19.70	13.51
Mean	7.17	4.83	5.84	5.98	7.58		7.58	12.44	19.04	
L.S.D at 0.05	(A) = 0.24, (B) = 0.16, (A×B) = 0.54						(A) = 0.56, (B) = 0.28, (A×B) = 0.97			

General appearance score

Fruit general appearance score decreased gradually, the decrement was significant after 30 days of cold storage as shown in Table 5. Chitosan at 1% alone and HWT + chitosan at 1% showed the highest significant general appearance scores, while control showed the lowest during cold storage and shelf life periods in both seasons.

By the end of storage period, 1% chitosan and HWT + 1% chitosan showed the highest significant general appearance score (8.78) in 2016 season and chitosan at 1% showed the highest significant general appearance score (8.33) in 2017 season. While control showed the lowest significant general appearance scores 6.78 and 6.56 in the first and the second season in that order.

By the end of shelf life period, 1% chitosan and HWT + 1% chitosan showed the highest significant general appearance score (7.00), while control showed the lowest significant general appearance value (2.78) in the first season. Moreover that, 1% chitosan showed the highest significant general appearance score (7.67) while control showed the lowest significant general appearance score (2.78) in the second season.

The presented data declared that chitosan treatment maintained good appearance after 60 days of cold storage and 14 days of shelf life. The obtained data were in harmony with Mirdehghan et al. (2006) who declared that heat-treated pomegranate fruits revealed higher total antioxidant activity than untreated fruits that was correlated primarily to the high levels of total phenolics and to remain ascorbic acid and anthocyanin contents, which finally decreased browning and shriveling and retain good fruit appearance.

Furthermore, Varasteh et al. (2017) found that chitosan coating at 1 and 2% kept pomegranate fruits ‘Rabbab-e-Neyriz’ quality, as chitosan add a thin shiny layer to fruit surface, in addition to its role in maintaing husk colour and decreasing browning.

Instrumental colour

Table 6. presents the effect of various postharvest treatments on h° of Wonderful pomegranate fruits peel in 2016 and 2017 seasons. In general, hue angle values increased gradually during cold storage period but decreased during shelf life period in both seasons.

In the first season, control showed the highest significant h° while 1% chitosan showed the lowest significant h° score during cold storage, and control showed the highest significant h° while HWT + 1% chitosan and 1% chitosan showed the lowest significant h° score during shelf life. By the end of storage period, HWT showed the highest h° (35.79) while HWT + 1% chitosan showed the lowest significant h° value (28.39), in addition by the end of shelf period control showed the highest h° (31.08) while 1% chitosan showed the lowest significant h° value (25.15).

In the second season, control showed the highest significant h° while 1% chitosan showed the lowest significant h° score during cold storage, and control showed the highest significant h° while HWT + 1% chitosan showed the lowest significant h° score during shelf life. By the end of storage period, wrapping + HWT showed the highest h° (37.08) while HWT + 1% chitosan showed the lowest significant h$^\circ$ value (28.54). By the end of shelf life period, control showed the highest h° (32.26), while HWT + 1% chitosan showed the lowest significant h° value (27.52).

Peel colour of pomegranate is the most essential quality index, directly attracting consumer attention (Barman et al., 2011). Hermandz-Munoz et al. (2008) suggested that coating led to the control of water loss that minimize external colour changes. Previous investigations indicated similar outcomes under long-term storage of sweet pomegranate fruits (Selcuk and Erkan, 2014) and ‘Mollar’ pomegranates (Artés et al., 1998).

Colour changes in husk surface were in line with fruit general appearance, fruits treated by HWT and 1% chitosan showed hue angel values indicate to higher shiny colour compared with control that changed to dull colour rapidly.

In this respect, Varasteh et al. (2012) found similar findings in pomegranate (cv. Rabbab-e-Neyriz) and reported that chitosan delayed anthocyanin degradation and prevented colour deterioration in pomegranate.

TABLE 5. Effect of different postharvest treatments on general appearance[z] of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
					2016 season					
Film wrapping	9.00	9.00	9.00	8.55	8.11	8.73	8.11	7.00	5.67	6.93
Hot water (HWT)	9.00	9.00	9.00	8.33	7.00	8.47	7.00	6.33	5.00	6.11
$CaCl_2$ at 2%	9.00	9.00	9.00	8.55	8.33	8.78	8.33	7.00	5.45	6.93
Chitosan at 1%	9.00	9.00	9.00	9.00	8.78	8.96	8.78	7.67	7.00	7.82
Wrapping + HWT	9.00	9.00	9.00	8.33	8.11	8.69	8.11	6.78	5.22	6.70
Wrapping + 2% $CaCl_2$	9.00	9.00	9.00	8.55	8.11	8.73	8.11	6.78	5.45	6.78
Wrapping + 1% Chitosan	9.00	9.00	9.00	8.78	8.55	8.87	8.55	7.22	6.11	7.30
HWT + $CaCl_2$ at 2%	9.00	9.00	9.00	8.33	8.11	8.69	8.11	6.55	5.22	6.63
HWT + Chitosan at 1%	9.00	9.00	9.00	9.00	8.78	8.96	8.78	7.67	6.78	7.74
2% $CaCl_2$ + 1% Chitosan	9.00	9.00	9.00	8.78	8.55	8.87	8.55	7.22	5.89	7.22
Combined treatment	9.00	9.00	9.00	9.00	8.55	8.91	8.55	7.22	6.33	7.37
Control	9.00	8.78	7.89	7.67	6.78	8.02	6.78	4.56	2.78	4.70
Mean	9.00	8.98	8.91	8.57	8.15		8.15	6.83	5.57	
L.S.D at 0.05	(A) = 0.22, (B) = 0.14, (A×B) = 0.51						(A) = 0. 45, (B) = 0.22, (A×B) = 0.78			
					2017 season					
Film wrapping	9.00	9.00	8.78	8.78	7.67	8.64	7.67	6.55	5.67	6.63
Hot water (HWT)	9.00	9.00	8.78	8.78	7.22	8.56	7.22	6.11	5.45	6.26
$CaCl_2$ at 2%	9.00	9.00	9.00	8.78	7.89	8.73	7.89	6.55	6.11	6.85
Chitosan at 1%	9.00	9.00	9.00	9.00	8.33	8.87	8.33	7.89	7.67	7.96
Wrapping + HWT	9.00	9.00	8.78	8.55	7.00	8.47	7.00	5.89	5.00	5.96
Wrapping + 2% $CaCl_2$	9.00	9.00	8.78	8.78	7.22	8.56	7.22	6.11	5.22	6.19
Wrapping + 1% Chitosan	9.00	9.00	9.00	8.78	7.67	8.69	7.67	6.78	6.33	6.93
HWT + $CaCl_2$ at 2%	9.00	9.00	8.78	8.78	7.45	8.60	7.45	6.33	5.45	6.41
HWT + Chitosan at 1%	9.00	9.00	9.00	9.00	8.11	8.82	8.11	7.67	7.22	7.67
2% $CaCl_2$ + 1% Chitosan	9.00	9.00	9.00	8.78	7.89	8.73	7.89	7.22	7.00	7.37
Combined treatment	9.00	9.00	9.00	9.00	8.11	8.82	8.11	7.00	6.78	7.30
Control	9.00	9.00	7.67	7.00	6.56	7.84	6.56	4.78	2.78	4.70
Mean	9.00	9.00	8.80	8.67	7.59		7.59	6.57	5.89	
L.S.D at 0.05	(A) = 0.18, (B) = 0.12, (A×B) = 0.41						(A) = 0.34, (B) = 0.17, (A×B) = 0.58			

[z] General appearance on a scale from one to nine with 1= unacceptable, 3= poor, 5= fair, 7= good, and 9= excellent.

TABLE 6. Effect of different postharvest treatments on $h°$ of Wonderful pomegranate fruits peel in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
					2016 season					
Film wrapping	24.10	26.61	27.63	32.34	32.50	28.64	32.50	27.99	28.26	29.59
Hot water (HWT)	24.10	25.71	29.15	33.13	35.79	29.58	35.79	29.27	27.83	30.97
$CaCl_2$ at 2%	24.10	24.88	28.73	30.89	32.13	28.15	32.13	28.41	27.29	29.28
Chitosan at 1%	24.10	24.23	23.41	27.13	30.51	25.88	30.51	26.97	25.15	27.54
Wrapping + HWT	24.10	26.23	28.27	37.13	35.13	30.17	35.13	30.34	29.63	31.70
Wrapping + 2% $CaCl_2$	24.10	24.65	28.71	32.44	35.23	29.03	35.23	28.99	28.30	30.84
Wrapping + 1% Chitosan	24.10	25.94	26.67	30.34	30.92	27.59	30.92	27.74	27.10	28.59
HWT + $CaCl_2$ at 2%	24.10	26.42	26.66	33.28	35.57	29.21	35.57	28.95	28.44	30.99
HWT + Chitosan at 1%	24.10	26.40	27.62	27.78	28.39	26.86	28.39	27.48	26.50	27.46
2% $CaCl_2$ + 1% Chitosan	24.10	24.80	26.54	29.63	31.07	27.23	31.07	27.42	26.91	28.47
Combined treatment	24.10	27.70	28.20	28.66	28.76	27.48	28.76	29.96	26.74	28.49
Control	24.10	28.63	31.76	34.74	33.55	30.56	33.55	32.07	31.08	32.23
Mean	24.10	26.02	27.78	31.46	32.46		32.46	28.80	27.77	
L.S.D at 0.05	(A) = 2.13, (B) = 1.37, (A×B) = 4.76						(A) = 3.42, (B) = 1.71, (A×B) = 5.92			
					2017 season					
Film wrapping	24.23	26.77	27.66	32.33	32.58	28.71	32.58	32.53	31.51	32.21
Hot water (HWT)	24.23	25.80	28.93	33.19	35.87	29.60	35.87	31.92	30.72	32.83
$CaCl_2$ at 2%	24.23	24.99	28.52	30.93	32.27	28.19	32.27	32.00	31.13	31.80
Chitosan at 1%	24.23	24.36	23.28	27.17	30.60	25.93	30.60	30.34	29.56	30.17
Wrapping + HWT	24.23	26.30	28.13	35.18	37.08	30.18	37.08	31.18	30.52	32.93
Wrapping + 2% $CaCl_2$	24.23	24.78	28.55	32.50	35.37	29.09	35.37	32.73	31.38	33.16
Wrapping + 1% Chitosan	24.23	26.07	26.57	30.36	31.03	27.65	31.03	30.79	29.92	30.58
HWT + $CaCl_2$ at 2%	24.23	26.53	26.53	33.34	35.71	29.27	35.71	31.42	31.40	32.84
HWT + Chitosan at 1%	24.23	26.53	27.52	27.87	28.54	26.94	28.54	28.38	27.52	28.15
2% $CaCl_2$ + 1% Chitosan	24.23	24.93	26.41	29.69	31.19	27.29	31.19	30.94	30.05	30.73
Combined treatment	24.23	27.84	28.12	28.79	28.85	27.56	28.85	28.59	27.79	28.41
Control	24.23	28.81	31.60	34.48	33.29	30.48	33.29	33.40	32.26	32.98
Mean	24.23	26.14	27.65	31.32	32.70		32.70	31.19	30.31	
L.S.D at 0.05	(A) = 2.11, (B) = 1.36, (A×B) = 4.72						(A) = 3.69, (B) = 1.84, (A×B) = 6.39			

Fruit peel thickness (mm)

The results in Table 7. illustrate the effect of different postharvest treatments on peel thickness of Wonderful pomegranate fruits in 2016 and 2017 seasons, peel thickness decreased gradually. In the first season, 2% $CaCl_2$ and combined treatment showed the highest significant peel thickness while control showed the lowest significant peel thickness during cold storage and shelf life. By the end of storage period, combined treatment showed the highest peel thickness (4.81 mm) while control showed the lowest significant peel thickness (4.47 mm), by the end of shelf life period, combined treatment showed the highest peel thickness (4.28 mm) while control showed the lowest significant peel thickness (4.00 mm).

In the second season, 1% chitosan, combined treatment and 2% $CaCl_2$ showed the highest significant peel thickness values while control showed the lowest significant peel thickness. By the end of storage period, combined treatment showed the highest peel thickness (4.80 mm) while control showed the lowest significant peel thickness (4.44 mm). By the end of shelf life period, wrapping treatment showed the highest peel thickness (3.88 mm) while control showed the lowest significant peel thickness (3.57 mm).

Peel thickness indicate to the chemical changes in pomegranate fruit composition, and it is related to water content and cell wall integrity, our findings approved the role of $CaCl_2$ in maintaining peel turgidity. Nanada et al. (2001) found similar data in 'Ganesh' pomegranates in concern with firmness, also Abd-elghany et al. (2012) found similar data in 'Wonderful' pomegranates.

Moreover that, the accumulation effect for the combined treatment could be due to the effect of wrapping treatment (Abd-elghany et al., 2012) and chitosan treatment (Varasteh et al., 2012) on respiration rate reduction and higher firmness that preserve peel soluble content.

TSS (%)

Table 8. presents the effect of different postharvest treatments on TSS percentage of Wonderful pomegranate fruits in 2016 and 2017 seasons. TSS increased gradually during cold storage, whereas it vary during shelf life in both season.

In the first season, control showed the highest significant TSS value whereas chitosan at 1% showed the lowest significant TSS value during cold storage, in addition wrapping + 2% $CaCl_2$ showed the highest significant TSS value while 1% chitosan showed the lowest significant TSS value during shelf life. By the end of cold storage period, control showed the highest TSS (13.21%) while 1% chitosan showed the lowest significant TSS (12.63%). By the end of shelf life period, combined treatment showed the highest TSS value (14.39%) while control showed the lowest significant TSS value (13.55%).

In the second season, untreated fruits showed the highest significant TSS value while 1% chitosan showed the lowest significant TSS value during cold storage, in addition wrapping + 2% $CaCl_2$ showed the highest significant TSS value while 1% chitosan showed the lowest significant TSS value during shelf life. By the end of storage period, control showed the highest TSS (13.68%) while 1% chitosan showed the lowest significant TSS (12.92%). By the end of shelf life period, combined treatment showed the highest TSS (14.01%) while control showed the lowest significant TSS (13.38%).

The obtained data declared that chitosan delayed TSS increment, which mean it delayed fruit over ripening and deterioration. The outcomes of this experiment are in line with those illustrated by Abd-elghany et al. (2012).

Sanchez-Gonzalez et al. (2011) reported that the change in soluble solids in fruits is generally associated with the hydrolytic enzymes for starch, the advanced activity of enzymes is responsible for the changes of starch to sugars. Also, deterioration of acids lead to more TSS because of the chemical formula of acids is related to glucose (Baldwin et al., 1999).

Ascorbic acid (mg/ 100g FW)

Ascorbic acid of Wonderful pomegranate fruits decreased gradually as it shown in Table 9. in 2016 and 2017 seasons. Chitosan at 1% showed the highest significant ascorbic acid values while control showed the lowest significant ones during cold storage and shelf life in both seasons.

By the end of cold storage period, 1% chitosan showed the highest ascorbic acid values (9.34 and 9.47 mg/ 100g FW) while control showed the lowest significant ascorbic acid values (7.97 and 8.01 mg/ 100g FW) in 2016 and 2017 seasons respectively.

TABLE 7. Effect of different postharvest treatments on peel thickness (mm) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
					2016 season					
Film wrapping	5.16	5.14	5.10	5.08	4.75	5.05	4.75	4.45	4.23	4.48
Hot water (HWT)	5.16	5.13	5.09	5.07	4.74	5.04	4.74	4.44	4.22	4.47
$CaCl_2$ at 2%	5.16	5.15	5.11	5.10	4.80	5.07	4.80	4.46	4.27	4.51
Chitosan at 1%	5.16	5.15	5.10	5.08	4.79	5.06	4.79	4.45	4.25	4.50
Wrapping + HWT	5.16	5.09	5.04	5.02	4.66	5.00	4.66	4.35	4.12	4.38
Wrapping + 2% $CaCl_2$	5.16	5.13	5.08	5.08	4.72	5.03	4.72	4.43	4.20	4.45
Wrapping + 1% Chitosan	5.16	5.10	5.04	5.03	4.67	5.00	4.67	4.36	4.15	4.39
HWT + $CaCl_2$ at 2%	5.16	5.10	5.05	5.04	4.68	5.01	4.68	4.40	4.18	4.42
HWT + Chitosan at 1%	5.16	5.12	5.06	5.05	4.70	5.02	4.70	4.42	4.19	4.44
2% $CaCl_2$ + 1% Chitosan	5.16	5.13	5.07	5.04	4.71	5.02	4.71	4.41	4.20	4.44
Combined treatment	5.16	5.15	5.12	5.10	4.81	5.07	4.81	4.47	4.28	4.52
Control	5.16	5.09	5.03	4.98	4.47	4.95	4.47	4.13	4.00	4.20
Mean	5.16	5.12	5.07	5.06	4.71		4.71	4.40	4.19	
L.S.D at 0.05	(A) = 0.02, (B) = 0.01, (A×B) = 0.05						(A) = 0. 03, (B) = 0.01, (A×B) = 0.05			
					2017 season					
Film wrapping	5.22	5.17	5.10	5.07	4.75	5.06	4.75	4.28	3.88	4.30
Hot water (HWT)	5.22	5.19	5.10	5.07	4.75	5.07	4.75	4.23	3.86	4.28
$CaCl_2$ at 2%	5.22	5.20	5.12	5.09	4.78	5.08	4.78	4.28	3.87	4.31
Chitosan at 1%	5.22	5.20	5.12	5.10	4.79	5.09	4.79	4.27	3.86	4.31
Wrapping + HWT	5.22	5.15	5.06	5.02	4.68	5.03	4.68	4.21	3.85	4.25
Wrapping + 2% $CaCl_2$	5.22	5.16	5.10	5.08	4.73	5.06	4.73	4.24	3.67	4.22
Wrapping + 1% Chitosan	5.22	5.14	5.05	5.02	4.69	5.03	4.69	4.22	3.80	4.24
HWT + $CaCl_2$ at 2%	5.22	5.15	5.07	5.02	4.70	5.03	4.70	4.20	3.79	4.23
HWT + Chitosan at 1%	5.22	5.18	5.08	5.07	4.69	5.05	4.69	4.23	3.83	4.25
2% $CaCl_2$ + 1% Chitosan	5.22	5.19	5.11	5.06	4.72	5.06	4.72	4.24	3.86	4.27
Combined treatment	5.22	5.19	5.13	5.09	4.80	5.09	4.80	4.24	3.85	4.29
Control	5.22	5.14	5.04	4.93	4.44	4.95	4.44	4.20	3.57	4.07
Mean	5.22	5.17	5.09	5.05	4.71		4.71	4.24	3.81	
L.S.D at 0.05	(A) = 0.03, (B) = 0.02, (A×B) = 0.07						(A) = 0.06, (B) = 0.03, (A×B) = 0.11			

TABLE 8. Effect of different postharvest treatments on TSS (%) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
					2016 season					
Film wrapping	12.02	12.23	12.26	12.56	12.76	12.37	12.76	13.45	14.20	13.47
Hot water (HWT)	12.02	12.55	12.59	12.76	13.04	12.59	13.04	13.85	13.91	13.60
$CaCl_2$ at 2%	12.02	12.34	12.35	12.54	12.86	12.42	12.86	13.66	14.25	13.59
Chitosan at 1%	12.02	12.13	12.15	12.44	12.63	12.27	12.63	13.44	14.20	13.42
Wrapping + HWT	12.02	12.48	12.53	12.71	12.94	12.54	12.94	13.80	14.34	13.69
Wrapping + 2% $CaCl_2$	12.02	12.51	12.54	12.75	13.02	12.57	13.02	13.87	14.27	13.72
Wrapping + 1% Chitosan	12.02	12.20	12.24	12.47	12.70	12.33	12.70	13.43	14.22	13.45
HWT + $CaCl_2$ at 2%	12.02	12.37	12.40	12.62	12.85	12.45	12.85	13.62	14.18	13.55
HWT + Chitosan at 1%	12.02	12.28	12.31	12.57	12.79	12.39	12.79	13.59	14.24	13.54
2% $CaCl_2$ + 1% Chitosan	12.02	12.41	12.45	12.58	12.90	12.47	12.90	13.69	14.27	13.62
Combined treatment	12.02	12.49	12.53	12.77	12.93	12.55	12.93	13.77	14.39	13.69
Control	12.02	12.57	12.64	12.83	13.21	12.65	13.21	13.72	13.55	13.50
Mean	12.02	12.38	12.42	12.63	12.88		12.88	13.66	14.17	
L.S.D at 0.05	(A) = 0.07, (B) = 0.04, (A×B) = 0.15						(A) = 0.11, (B) = 0.06, (A×B) = 0.20			
					2017 season					
Film wrapping	11.96	12.04	12.31	12.58	12.99	12.38	12.99	13.69	13.74	13.48
Hot water (HWT)	11.96	12.45	12.72	13.06	13.54	12.75	13.54	13.60	13.63	13.59
$CaCl_2$ at 2%	11.96	12.09	12.36	12.62	13.06	12.42	13.06	13.74	13.77	13.52
Chitosan at 1%	11.96	12.03	12.30	12.56	12.92	12.35	12.92	13.68	13.72	13.44
Wrapping + HWT	11.96	12.30	12.50	12.84	13.18	12.55	13.18	13.97	13.99	13.71
Wrapping + 2% $CaCl_2$	11.96	12.38	12.58	12.93	13.22	12.61	13.22	14.06	13.98	13.75
Wrapping + 1% Chitosan	11.96	12.05	12.37	12.60	12.97	12.39	12.97	13.69	13.71	13.46
HWT + $CaCl_2$ at 2%	11.96	12.19	12.47	12.73	13.14	12.50	13.14	13.89	13.96	13.66
HWT + Chitosan at 1%	11.96	12.06	12.29	12.60	13.02	12.39	13.02	13.71	13.74	13.49
2% $CaCl_2$ + 1% Chitosan	11.96	12.11	12.32	12.65	13.10	12.43	13.10	13.82	13.83	13.58
Combined treatment	11.96	12.21	12.40	12.71	13.20	12.50	13.20	13.95	14.01	13.72
Control	11.96	12.50	12.76	13.12	13.68	12.80	13.68	13.52	13.38	13.53
Mean	11.96	12.20	12.45	12.75	13.17		13.17	13.78	13.79	
L.S.D at 0.05	(A) = 0.07, (B) = 0.04, (A×B) = 0.16						(A) = 0.07, (B) = 0.03, (A×B) = 0.12			

By the end of shelf life period, chitosan at 1% maintained the highest ascorbic acid content of fruit (7.04 and 7.21 mg/ 100g FW) while control showed the lowest significant ascorbic acid content (4.15 and 5.24 mg/ 100g FW) in 2016 and 2017 seasons respectively.

The degradation in ascorbic acid during storage was in accordance with the previous study of Abd-elghany et al. (2012). This degradation might be due to indirect dissolution through polyphenol oxidase and peroxidase activity (Lee and Kader, 2000). Manzano and Diaz (2001) mentioned that ascorbic acid is sensitive to oxidative degradation lead to the formation of dehydroascorbic acid.

Results revealed to the valuable effect of combined treatment and chitosan on ascorbic acid preservation, as it is reducing the degradation of ascorbic acid by hydrolysis enzymes (Zhang and Zhang 2008).

Anthocyanin (mg/ 100g FW)

Table 10. presents the influence of different conducted treatments on anthocyanin pigment of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Anthocyanin content increased in the beginning of cold storage then it decreased gradually. Chitosan at 1% showed the highest significant anthocyanin pigment content of pomegranate fruits while control showed the lowest significant anthocyanin content during cold storage and shelf life period in both trial seasons.

By the end of cold storage period, 1% chitosan treatment showed the highest anthocyanin content (11.52 and 10.37 mg/ 100g FW) while control showed the lowest significant anthocyanin content (9.40 and 9.56 mg/ 100g FW) in both seasons. Also by the end of shelf life period, chitosan at 1% showed the highest anthocyanin values (7.69 and 8.17 mg/ 100g FW), while control showed the lowest significant anthocyanin values (6.24 and 6.66 mg/ 100g FW) in both seasons.

The obtained data showed that chitosan was the most effective in maintaining colour of ‘Wonderful’ pomegranate. In this respect Varasteh *et al*., (2012) reported that ‘Rabbab-e-Neyriz’ pomegranate treated by chitosan at 1% and 2% showed higher anthocyanin content in pomegranate arils because of the higher immutability of di-glucoside anthocyanins compared with mono-glucosides. Also chitosan coating delayed anthocyanin degradation and prevented colour deterioration in the pomegranate arils (Jianglian and Shaoying, 2013).

Conclusion

In summary, conclusions of the present work are that all treatments were effective in maintaining fruit quality of Wonderful pomegranate compared with control. $CaCl_2$ at 2% and combined treatment maintained fruit weight and showed the highest significant peel thickness. $CaCl_2$ at 2% was the most effective treatment in maintaining fruit firmness, also, 1% chitosan alone or + 2% $CaCl_2$ showed the lowest significant decay percentages.

Moreover, chitosan at 1% showed the lowest significant respiration rate, h° score and TSS value. In this respect, 1% chitosan showed the highest significant general appearance scores, and maintained the higher contents of ascorbic acid and anthocyanin pigment, which suggested the valuable effect of chitosan at 1% and $CaCl_2$ at 2% in maintaining water content and fruit quality of Wonderful pomegranate during cold storage at 5°C for 60 days followed by shelf life at 20°C for 14 days.

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TABLE 9. Effect of different postharvest treatments on ascorbic acid (mg/ 100g FW) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
					2016 season					
Film wrapping	11.12	11.05	10.94	10.62	9.23	10.59	9.23	7.48	6.94	7.88
Hot water (HWT)	11.12	10.82	10.51	10.21	8.67	10.27	8.67	7.09	6.09	7.28
$CaCl_2$ at 2%	11.12	10.99	10.90	10.57	9.12	10.54	9.12	7.32	6.84	7.76
Chitosan at 1%	11.12	11.10	11.03	10.84	9.34	10.69	9.34	7.65	7.04	8.01
Wrapping + HWT	11.12	10.86	10.66	10.38	9.02	10.41	9.02	7.21	6.53	7.59
Wrapping + 2% $CaCl_2$	11.12	10.85	10.60	10.29	8.93	10.36	8.93	7.16	6.37	7.49
Wrapping + 1% Chitosan	11.12	11.08	10.98	10.78	9.27	10.64	9.27	7.56	7.01	7.95
HWT + $CaCl_2$ at 2%	11.12	10.94	10.79	10.43	9.09	10.47	9.09	7.23	6.67	7.66
HWT + Chitosan at 1%	11.12	11.02	10.95	10.64	9.14	10.57	9.14	7.41	6.92	7.82
2% $CaCl_2$ + 1% Chitosan	11.12	10.97	10.84	10.50	9.15	10.52	9.15	7.26	6.71	7.70
Combined treatment	11.12	10.91	10.72	10.41	9.07	10.45	9.07	7.26	6.68	7.67
Control	11.12	10.74	10.33	10.01	7.97	10.04	7.97	5.37	4.15	5.83
Mean	11.12	10.94	10.77	10.47	9.00		9.00	7.17	6.50	
L.S.D at 0.05	(A) = 0.12, (B) = 0.07, (A×B) = 0.26						(A) = 0. 24, (B) = 0.12, (A×B) = 0.42			
					2017 season					
Film wrapping	11.19	11.06	10.96	10.83	9.37	10.68	9.37	8.03	7.09	8.16
Hot water (HWT)	11.19	10.61	10.35	9.88	8.23	10.05	8.23	7.10	6.25	7.19
$CaCl_2$ at 2%	11.19	10.87	10.79	10.48	9.31	10.53	9.31	7.92	7.00	8.07
Chitosan at 1%	11.19	11.17	11.02	10.86	9.47	10.74	9.47	8.12	7.21	8.27
Wrapping + HWT	11.19	10.84	10.72	10.07	9.07	10.38	9.07	7.52	6.35	7.65
Wrapping + 2% $CaCl_2$	11.19	10.70	10.66	9.96	8.88	10.28	8.88	7.22	6.51	7.54
Wrapping + 1% Chitosan	11.19	11.09	10.94	10.82	9.42	10.69	9.42	8.04	7.19	8.22
HWT + $CaCl_2$ at 2%	11.19	10.84	10.72	10.28	9.21	10.45	9.21	7.83	6.92	7.99
HWT + Chitosan at 1%	11.19	10.95	10.87	10.77	9.29	10.61	9.29	8.00	7.03	8.11
2% $CaCl_2$ + 1% Chitosan	11.19	10.86	10.77	10.47	9.27	10.51	9.27	7.87	6.95	8.03
Combined treatment	11.19	10.80	10.69	10.24	9.13	10.41	9.13	7.78	6.76	7.89
Control	11.19	10.40	10.17	9.46	8.01	9.85	8.01	6.32	5.24	6.52
Mean	11.19	10.85	10.72	10.34	9.05		9.05	7.65	6.71	
L.S.D at 0.05	(A) = 0.19, (B) = 0.12, (A×B) = 0.42						(A) = 0.37, (B) = 0.18, (A×B) = 0.65			

TABLE 10. Effect of different postharvest treatments on anthocyanin (mg/ 100g FW) of Wonderful pomegranate fruits in 2016 and 2017 seasons.

Treatment (A)	Days of storage at 5°C (B)						Days of shelf life at 20°C (B)			
	Initial	15	30	45	60	Mean	Initial	7	14	Mean
					2016 season					
Film wrapping	12.28	12.33	12.19	11.89	11.03	11.94	11.03	9.32	7.62	9.32
Hot water (HWT)	12.28	12.43	11.78	11.17	10.12	11.56	10.12	8.95	6.99	8.69
$CaCl_2$ at 2%	12.28	12.36	12.13	11.74	10.81	11.86	10.81	9.22	7.46	9.16
Chitosan at 1%	12.28	12.30	12.26	11.97	11.52	12.07	11.52	9.36	7.69	9.52
Wrapping + HWT	12.28	12.40	11.99	11.45	10.50	11.72	10.50	8.98	7.13	8.87
Wrapping + 2% $CaCl_2$	12.28	12.42	11.89	11.32	10.34	11.65	10.34	9.00	7.06	8.80
Wrapping + 1% Chitosan	12.28	12.32	12.23	11.96	11.47	12.05	11.47	9.37	7.63	9.49
HWT + $CaCl_2$ at 2%	12.28	12.35	12.06	11.51	10.52	11.74	10.52	9.16	7.27	8.98
HWT + Chitosan at 1%	12.28	12.35	12.16	11.81	10.85	11.89	10.85	9.28	7.54	9.22
2% $CaCl_2$ + 1% Chitosan	12.28	12.36	12.08	11.64	10.73	11.82	10.73	9.19	7.40	9.11
Combined treatment	12.28	12.37	11.96	11.36	10.45	11.69	10.45	9.10	7.17	8.91
Control	12.28	12.46	11.44	10.91	9.40	11.30	9.40	8.61	6.24	8.08
Mean	12.28	12.37	12.01	11.56	10.65		10.65	9.13	7.27	
L.S.D at 0.05	(A) = 0.17, (B) = 0.11, (A×B) = 0.37						(A) = 0. 28, (B) = 0.14, (A×B) = 0.49			
					2017 season					
Film wrapping	12.13	12.31	11.99	11.50	10.30	11.65	10.30	9.57	8.02	9.30
Hot water (HWT)	12.13	12.40	11.46	10.99	9.87	11.37	9.87	9.08	7.43	8.80
$CaCl_2$ at 2%	12.13	12.33	11.90	11.47	10.17	11.60	10.17	9.48	7.96	9.20
Chitosan at 1%	12.13	12.27	12.05	11.57	10.37	11.68	10.37	9.64	8.17	9.39
Wrapping + HWT	12.13	12.39	11.68	11.25	9.94	11.48	9.94	9.24	7.69	8.96
Wrapping + 2% $CaCl_2$	12.13	12.39	11.56	11.11	9.87	11.41	9.87	9.17	7.60	8.88
Wrapping + 1% Chitosan	12.13	12.28	12.03	11.53	10.34	11.66	10.34	9.61	8.09	9.35
HWT + $CaCl_2$ at 2%	12.13	12.34	11.81	11.36	10.10	11.55	10.10	9.33	7.82	9.09
HWT + Chitosan at 1%	12.13	12.34	11.94	11.53	10.28	11.64	10.28	9.54	8.00	9.27
2% $CaCl_2$ + 1% Chitosan	12.13	12.36	11.84	11.42	10.13	11.58	10.13	9.41	7.89	9.14
Combined treatment	12.13	12.36	11.74	11.33	10.06	11.53	10.06	9.28	7.85	9.06
Control	12.13	12.48	11.39	10.72	9.56	11.26	9.56	8.66	6.66	8.29
Mean	12.13	12.35	11.78	11.32	10.08		10.08	9.33	7.76	
L.S.D at 0.05	(A) = 0.17, (B) = 0.11, (A×B) = 0.39						(A) = 0.23, (B) = 0.11, (A×B) = 0.40			

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خفض الفاقد في الوزن والحفاظ على جودة ثمار الرمان صنف الوندرفل باستخدام بعض المعاملات المختلفة بعد الحصاد

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بهدف الحفاظ على جودة الثمار و محتواها الرطوبى و خفض اضرار البرودة للثمار المكتملة النضج لصنف الرمان الوندرفل خلال التسويق المحلى او الخارجي أجريت الدراسة الحالية خلال موسمين متتاليين (٢٠١٦ و ٢٠١٧). و قد تضمنت المعاملات التي أجريت بعد الحصاد كلا مما يلى؛ أفلام التغطية، الماء الساخن على ٤٥°م لمدة ٤ ق، كلوريد الكالسيوم بتركيز ٢٪ ، الشيتوزان بتركيز ١٪ ، التغطية + الماء الساخن، التغطية + ٢٪ كلوريد كالسيوم، التغطية + ١٪ شيتوزان، الماء الساخن + ٢٪ كلوريد كالسيوم، الماء الساخن + ١٪ شيتوزان، ٢٪ كلوريد كالسيوم + ١٪ شيتوزان، المعاملة المجمعة بالإضافة الى الكنترول. جميع المعاملات تم تخزينها على ٥°م و رطوبة نسبية ٩٠-٩٥٪ لمدة ٦٠ يوم متبوعة بالتخزين على ٢٠°م لمدة ١٤ يوم (لدراسة العمر التسويقى). المعاملة بكلوريد الكالسيوم بتركيز ٢٪ حافظت معنويا على وزن الثمار، سمك القشرة و صلابة الثمار. كذلك المعاملة بالشيتوزان بتركيز ١٪ منفردا او مع ٢٪ كلوريد كالسيوم أظهرت اقل نسب معنوية من الثمار التالفة. فضلا عن ذلك أدت المعاملة بالشيتوزان بتركيز ١٪ الى تقليل معدلات التنفس، كما كان لها تاثير معنوى على اللون و المحتوى من المواد الكلية الصلبة الذائبة، و الاحتفاظ بمعدلات اعلى من حامض الاسكوربيك و كذلك صبغة الانثوسيانين مقارنة بالثمار الغير معاملة.