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EFFECT OF SOME INTERMITTENT WARMING AND STORAGE TEMPERATURE TREATMENTS ON QUALITY AND STORAGABILITY OF BALADY AND NAB EL-GAMAL POMEGRANATE FRUITS

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ABSTRACT: The aim of the present work was to study the effect of different storage temperatures and intermittent warming (IW) on the physical and the chemical characteristics of Balady and Nab El-Gamal pomegranate fruits. IW cycles were applied by getting the fruits out from the cold room to room temperature (RT) for 12 h or for 24 h and then the fruits were returned to 10 °C. IW began to have a significant effect on fruit weight loss after 30 days of storage at 10 °C. The uppermost weight losses were obtained with the IW treatment for 24 h. Nab El-Gamal fruits had higher weight losses in both seasons and at both storage temperatures. Balady fruits had higher moisture content during the storage period than Nab El-Gamal fruits. There were no significant differences between treatments in juice weight and volume resulting from 100 gm arils at any storage period. However, the juice weight and volume were increased with the progress of the storage period at 10 °C. IW treatment for 24 h revealed the least soluble solid content (SSC) values in both seasons and for both cvs. Control fruits had significant lower titratable acidity (TA) values in comparison with IW treated fruits. Balady pomegranate had higher initial total phenols than Nab El-Gamal fruits. During the storage period there was a significant effect of IW on reducing total phenols. IW- treated fruits for 12 h had the highest anthocyanin content of both cvs. and in both seasons descendingly followed by control fruits.

Key words: Intermittent warming (IW), room temperature (RT), soluble solid content (SSC), titratable acidity (TA).

INTRODUCTION

The pomegranate *Punica granatum* L., belongs to the *Punicaceae* family and is one of the oldest known edible fruits. It is some times called Chinese apple, and has been cultivated extensively in Mediterranean countries, Iran, Afghanistan, India, California in USA, China, Japan and Russia (LaRue, 1980; Morton, 1987; Pierce and Kader, 2003).

Pomegranates are low in sodium and calories and good source of dietary fiber and potassium compared to many other fruits. They have low oil content and rich in polyunsaturated (n-3) fatty acids (Miguel *et al.*, 2004). Pomegranates have low ascorbate (0.49 to 30 mg per 100 g juice), depending on cultivar (Küpper, 1995). Juice content of pomegranates is 45 to 65 % of the whole fruit or 76 to 85 % of the arils. Skin contains 30 % tannin, which is used in medical and dye industries (Küpper, 1995) while juice tannin content is < 0.25 % (Crisosto *et al.*, 1996). The titratable acidity is < 1 % in sweet cvs., 1 to 2 % in sweet-sour cvs. and > 2 % in sour cultivars (Onur and Kaşka, 1985). Soluble solids consists of sugars, organic acids, amino acids, soluble pectins and other soluble compounds (Pierce and Kader, 2003). SSC varies from 8.3 to 20.5 % at harvest (Küpper, 1995).

Currently, there is a greater interest in pomegranate juice due to its high antioxidant activity that makes it appealing for the production of health supplements and nutraceuticals. Those activities are suggested to be related, in part, to the three major anthocyanidins found in fruit seeds extract (Noda *et al.*, 2002; Singh *et al.*, 2002; Pierce and Kader 2003 and Miguel *et al.*, 2004).

The pomegranate is equal to the apple in having a long storage life and the optimum storage temperature varies by cultivar, production area and post-harvest treatment (Hardenburg *et al.*, 1990; Snowdon,1995; Sea Land, 1991 and Onur *et al.*, 1992). It is best maintained at a temperature of 0 – 5 °C. The fruits are improved in storage; they become juicy and more flavorful, and may be kept for a period of seven months within the above temperature range and at 80 to 85 % RH, without shrinkage or spoiling. At 95 % RH, the fruit can be kept only for two months at 5 °C, and for longer period at 10 °C. After prolonged storage, internal breakdown is evidenced by faded, streaky pulp

of flat flavor (Kader *et al.*, 1984; Morton, 1987 and Gill *et al.*, 1996). Incidence and severity of chilling injury depend on temperature and duration. Storage of pomegranates at 5 °C or lower resulted in chilling injury occurrence (El-Yatem and Kader, 1984). On the other hand, Segal (1981) reported that the peel of Wonderful pomegranate fruits undergoes browning during storage at temperatures below 14 °C. The difference in the minimum safe temperature may be related to differences in pre-harvest temperatures and cultural practices (El-Yatem and Kader, 1984). Intermittent warming reduces low temperature injury and maintains fruit quality (Nyanjage *et al.*, 1998; Artés *et al.*, 2000 and Wang, 2000) by maintaining high levels of phospholipids, increasing the degree of unsaturation of fatty acids, increasing spermidine and spermine levels and stimulating free radical scavening enzymes (Wang, 2000).

The aims of the present work were to:

1. Compare the fruit quality and storagability of pomegranate cvs of Balady and Nab El-Gamal.
2. Study the effect of storage temperature on the fruit quality and the storagability of Balady and Nab El-Gamal pomegranates varieties.
3. Study the efficacy of intermittent warming (IW) on pomegranate fruits stored at 10 °C that is considered a safe temperature from chilling injury and study the cold storage disorders that may occur at this temperature by the accumulation of the low temperature with the progress of the storage period.
4. Study the effect of the above treatments (different storage temperatures and IW) on the physical (weight loss, moisture content and juice weight and volume of 100 g arils) and the chemical (SSC, titratable acidity, total phenols content and anthocyanin content) characteristics of the pomegranate fruits.

MATERIALS AND METHODS

The present investigation was carried out during 2003 and 2004 seasons on fresh Balady and Nab El-Gamal pomegranate fruits harvested from a private orchard in Assiout Governorate.

The fruits were delivered to the Post-Harvest Center of Horticulture Crops, Faculty of Agriculture Alexandria University. The fruits had the initial quality as shown in Table 1.

Sound selected pomegranate fruits (uniform in size and free of mechanical damage, physiological crashing or pathological disorders) were washed then dried by electric fan. Dried fruits were packed in plastic boxes and divided into four sections of each cv. (65 fruits for each of the first three sections and 20 fruits for the fourth one). The first three sections were stored at 10 °C and 85 - 90 % RH and the fourth one was stored at room temperature (RT).

IW treatments were applied on two of the three sections that were stored at 10 °C and the third one was treated as the control. IW cycles were applied by removing the corresponding boxes every ten days from the cold room to RT for 12 h for the first section and for 24 h for the second one and then the fruits were returned to 10 °C.

Nine pomegranate fruits of each cv were taken to determine the initial physio-chemical properties of the fruits. Changes in such properties were followed up in ten days intervals throughout the experimental working period as follows:

Table 1: The initial quality of the fruits

Parameters	2003 Season		2004 Season	
	Balady	Nab El-Gamal	Balady	Nab El-Gamal
Fruit Weight (g)	792.87	448.60	637.37	369.50
Fruit Size (cm):				
Height	12.83	9.80	10.70	10.20
Diameter	11.97	9.70	11.20	9.40
Juice Weight /100 g Arils	59.80	57.07	62.80	63.67
Juice Volume /100 g	56.67	52.67	58.67	62.00
Arils	15.33	15.27	15.87	15.33
SSC (%)	1.22	1.32	1.34	1.33
Titratable Acidity (%)	0.82	0.66	0.73	0.55
Arils Total Phenol (%)				
Anthocianine Content	0.52	0.43	0.54	0.32
(mg/100g arils)	Red	Rose	Red	Rose
Peel Colour	Red	Rose	Red	Rose
Arils Colour				

Weight Loss (%)

Ten labeled pomegranate fruits for every treatment were initially weighed to calculate fruit weight loss percent during the storage period in relation to its original weight.

Arils Moisture Content (%)

Three recorded weights of each treatment arils were dried and subsequent periodical weight determinations were carried out to obtain a constant dry weight then the percentage of water content was calculated in relation to the initial recorded weight.

Weight and Volume of 100 g Arils Juice

Pomegranate fruits were hand-peeled then three samples of 100 g of each treatment arils were taken (one sample from each 3 fruits). Each sample was squeezed to obtain the pomegranate juice. The weight and the volume of the above obtained juice were recorded.

Soluble Solid Content SSC (%)

SSC of pomegranates was determined in the above obtained juice by the use of a hand refractometer according to Chen and Mellenthin (1981).

Titratable Acidity (TA)

The above obtained juice was used to determine the titratable acidity of pomegranates as g citric acid / 100 ml fruit juice (Chen and Mellenthin, 1981).

Arils Total Phenols (%)

Three samples of one g were taken from each treatment arils to determine its total phenol contents according to the colourmetric method of Resenblatt and Peluso (1941). The extraction was carried out by 95 % ethanol at 25 °C on a hotplate, then the colourmetric determination was carried out and the optical density of the samples was read at 725 nm and the amount of total phenol percentages were calculated against a standard curve of tannic acid.

Arils Anthocyanin Content (mg/ 100 g arils)

Arils anthocyanin content was determined following the method of Fuleki and Francis (1968). Three samples of 50 g of each treatment arils were extracted in 100 ml mixture of ethanol and HCl (85: 15). Five millileters of the above extraction were centrifugated for 10 min. then the

obtained supernatant was measured spectrophotometrically at 535 nm, and the aril anthocyanin content was calculated as mg / 100 g sample.

The termination of the experiment was done by the occurrence of peel disorders (shrinkage, drying and off shining). All data were statistically analyzed according to Snedecor and Cochran (1980). The individual comparisons were carried out by using the Least Significant Difference (LSD) according to SAS Institute (1985). Simple regression coefficient between storage period and studied properties was calculated as referred by SAS Institute (1985).

RESULTS AND DISCUSSION

Fruit Weight Loss (%)

The storage temperature had a significant effect on pomegranate fruit weight loss (Table 2). This effect reflected on the high weight loss of the fruits stored at RT. After 10 days of storage at RT, Balady pomegranates lost 10.25 and 11.27 % of the fruit weight in 2003 and 2004 seasons, respectively and those values were about four folds of the loss for the fruits stored at 10 °C. After the same period at RT, Nab El-Gamal pomegranate fruits had higher weight loss percentages of 13.03 and 11.87 % in the two seasons, respectively and those values were five and four folds, approximately, of the fruit weight loss at 10 °C. After 20 days, weight loss values were approximately six and four folds for Balady cv. and six and four folds of that at 10 °C for Nab El-Gamal cv. in the two seasons, respectively. The above results were in agreement with those of El-Yatem and Kader (1984) on Wonderful pomegranate and Nanda *et al.* (2001) on Ganesh pomegranate.

Although the pomegranate peel appears to be thick, it has numerous minute openings that permit free movement of water vapor, making the fruit highly susceptible to water loss (Kader *et al.*, 1984). Further, the storage temperature recommended for pomegranate varied from 0 to 10 °C with a shelf life ranging from two weeks to seven months depending on the cultivar (Kader *et al.*, 1984;

Table 2: Effect of some intermittent warming and storage temperature treatments on weight loss (%) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatments	Storage period (days)								r^2
	0	10	20	30	40	50	60	70	
2003 Season									
Balady									
12 h IW+10°C	0.00 a	2.82c	4.95c	6.82bc	8.56ab	10.36abc	11.62abc	13.13ab	0.99**
24 h IW+10°C	0.00 a	3.38c	6.09c	8.80a	10.70a	12.74a	14.15a	15.97a	0.99**
Control+10°C	0.00 a	2.29c	3.72c	5.28c	6.70b	8.09c	9.08c	10.31b	0.98**
RT	0.00 a	10.25b	21.77b						
Nab El-Gamal									
12 h IW+10°C	0.00 a	3.10c	6.05c	8.10ab	10.13a	12.10ab	13.54ab	15.13a	0.99**
24 h IW+10°C	0.00 a	2.86c	6.53c	9.05a	10.66a	12.78a	14.18a	15.96a	0.98**
Control+10°C	0.00 a	2.60c	4.51c	6.50bc	8.44ab	10.09bc	11.25bc	11.85b	0.96**
RT	0.00 a	13.03a	26.13a						
LSD at 0.05 level		1.30	3.55	1.90	2.34	2.59	2.73	3.03	
2004 Season									
Balady									
12 h IW+10°C	0.00 a	2.86b	4.72c	6.87b	8.63b	10.43bc	11.74bc	13.36bc	0.98**
24 h IW+10°C	0.00 a	3.13b	5.87bc	8.56ab	10.18ab	12.33ab	13.74ab	15.66ab	0.99**
Control+10°C	0.00 a	3.12b	4.84c	6.36b	7.95b	9.32c	10.37c	11.78c	0.98**
RT	0.00 a	11.27a	21.27a						
Nab El-Gamal									
12 h IW+10°C	0.00 a	3.30b	6.29bc	8.43ab	10.43ab	12.49ab	13.83ab	15.50ab	0.98**
24 h IW+10°C	0.00 a	3.73b	7.54b	10.37a	12.13a	14.38a	15.86a	17.80a	0.98**
Control+10°C	0.00 a	3.08b	5.40c	7.51b	9.47b	11.20bc	12.47bc	13.74bc	0.97**
RT	0.00 a	11.87a	22.13a						
LSD at 0.05 level		1.18	1.90	2.32	2.61	2.90	3.06	3.25	

Means within columns (in same season) having a common letter are not significantly different. r^2 =Determination coefficient RT= room temperature.

Salunke and Desai, 1986; Koksal, 1989; Gill *et al.*, 1996). However, El-Yatem and Kader (1984) showed that storage of pomegranates at 5 °C or lower resulted in chilling injury with symptoms of brown discoloration of the skin, surface pitting and susceptibility to decay organisms.

The effect of IW in increasing weight losses began to be significant after 30 days of storage at 10 °C and the higher significant effect was, in general, for the IW treatment for 24 h in both seasons and for both cvs. With the advancing of the storage period, IW treated fruits had higher weight loss especially for the treatment of 24 h IW. Treatment of 12 h IW had higher fruit weight loss but the differences were not significant compared with the control fruits and that was in both seasons and for both cvs. The increase in fruit weight loss by IW was previously reported by Artés *et al.* (2000) on Sweet pomegranates and Tayel (2001) on peaches.

Nab El-Gamal fruits had slightly higher weight loss in both seasons and at both storage temperatures as compared with Balady cv. fruits, but the differences were not significant except for the fruits stored at RT in the first season. With the progress of the storage period at 10 °C, pomegranate fruits gradually lost more weight (r^2 values are highly significant). The weight loss is mainly a result of water loss from the fruit tissues and partially of the respiration process and the higher the storage temperature the higher the respiration rate and the higher the weight loss is (El-Yatem and Kader, 1984).

Arils Moisture Content

After 10 days of storage, there were no significant differences between treatments (Table 3). After 20 days, there were no significant differences in Balady cv. but Nab El-Gamal fruits of IW treatment and that at RT had significantly lower moisture content as compared with control fruits stored at 10 °C.

There were no significant differences between treatments of Balady fruits in the first 50 days of storage in both seasons. But after this period the higher moisture content of control fruits began to be significant and the IW for 24 h had the lowest values. For Nab El-Gamal fruits, the differences between treatments began after 20 days and also the control fruits had the highest moisture content values

Table 3: Effect of some intermittent warming and storage temperature temperatures on arils moisture content (%) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatment	Storage period (days)								r^2
	0	10	20	30	40	50	60	70	
				2003 Season					
Balady									
12 h IW+10°C	80.17a	79.33a	78.67ab	78.17ab	80.67a	80.50ab	79.33ab	79.83a	0.03
24 h IW+10°C	80.17a	79.17a	78.83ab	78.50a	80.67a	80.17abc	78.83b	78.83b	0.03
Control+10°C	80.17a	79.17a	79.00ab	78.83a	81.00a	80.67a	80.50a	80.00a	0.02
RT	80.17a	79.83a	78.67ab						
Nab El-Gamal									
12 h IW+10°C	80.83a	79.83a	77.33bc	77.50bc	78.53b	78.67d	79.16b	79.00b	0.08
24 h IW+10°C	80.83a	78.67a	76.83bc	77.17c	78.67b	78.83cd	78.33b	78.00c	0.11
Control+10°C	80.83a	80.17a	79.67a	78.50a	78.51b	79.17bcd	79.17b	79.00b	0.48
RT	80.83a	79.83a	76.33c						
LSD at 0.05 level	1.04	2.07	2.17	0.89	1.61	1.48	1.19	0.63	
				2004 Season					
Balady									
12 h IW+10°C	80.33a	80.50a	78.83a	78.83a	80.67a	80.33a	79.83ab	79.67ab	0.004
24 h IW+10°C	80.33a	79.33ab	78.50a	78.67a	79.83a	79.83ab	79.00bcd	79.33b	0.03
Control+10°C	80.33a	80.17a	79.17a	79.17a	81.00a	80.50a	80.33a	80.03a	0.04
RT	80.33a	79.83ab	78.17a						
Nab El-Gamal									
12 h IW+10°C	80.67a	79.83ab	76.83b	77.83a	78.50b	78.83bc	78.83cd	79.17b	0.05
24 h IW+10°C	80.67a	78.50b	76.67b	77.83a	78.17b	78.50c	78.10d	78.57c	0.08
Control+10°C	80.67a	80.00ab	79.17a	78.33a	78.50b	80.00a	79.33bc	79.17b	0.17
RT	80.67a	79.00ab	76.17b						
LSD at 0.05 level	1.04	1.54	1.12	1.54	1.20	1.03	0.92	0.51	

Means within columns (in same season) having a common letter are not significantly different. r^2 =Determination coefficient. RT=Room temperature.

and the least were for the treatment of IW for 24 h. Balady fruits had higher moisture content compared with Nab El-Gamal fruits during the storage period.

There was a trend of moisture content decreasing with the progress of the storage period in both seasons for both cvs. (r^2 values were not significant). Koksal (1989) reported the decreasing in moisture content of Gok Bahce pomegranate fruits during storage. However, Nanda *et al.* (2001) observed that the moisture loss during storage was mainly from the rind and not from the arils of Ganesh pomegranate.

Juice Weight (g / 100 g arils)

Balady pomegranate fruits had initially juice weight of 59.80 and 62.80 g, respectively in 2003 and 2004 seasons (Table 4). The corresponding values for Nab El-Gamal fruits were 57.07 and 63.67 g, respectively. Those values were decreased at the end of the storage period at RT (20 days). On the other hand, juice weight was significantly increased by the storage at 10 °C for both cvs. and in both seasons (r^2 values were significant except IW + 24 h treatment for Balady cv. in the first season). Similar results were found by Nanda *et al.*, 2001.

There were no significant differences between treatments in both seasons except for the high significant increase in juice weight value of Nab El-Gamal fruits after 40 days of storage at 10 °C in the first season.

Veres (1976) reported that the juice content amounts to 45 – 61 % of the whole fruit or 76 – 85.51 % expressed in relation to the weight of arils. On the other hand, Küpper (1995) reported that juice content of pomegranates is 45 – 65 % of the whole fruit or 76 – 85 % of the arils.

Juice Volume (ml / 100 g arils)

From the tabulated data in Table 5, it was noticed that pomegranate juice volume had the same trend of the juice weight. There were no significant differences in fruit juice volume between treatments or cvs. in both seasons except for the control and IW (of 24 h) after 10 days in the first season with Balady cv. and the significant increase in juice volume of Nab El-Gamal after 40 days of storage at 10 °C in the first season.

Juice volume was slightly decreased by the fruit storage at RT. On the other hand, fruit juice volume increased slightly for

Table 4: Effect of some intermittent warming and storage temperature treatments on juice weight (g / 100g arils) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatments	Storage period (days) 0	10	20	30	40	50	60	70	r^2
				2003 Season					
Balady									
12 h IW+10°C	59.80a	56.47a	58.73a	57.47a	65.00b	63.80a	62.20a	65.40a	
24 h IW+10°C	59.80a	63.47a	53.60a	71.90a	64.67b	69.53a	69.73a	67.40a	0.58*
Control+10°C	59.80a	54.07a	47.60a	66.87a	68.27ab	69.07a	67.07a	70.27a	0.36
RT	59.80a	62.63a	52.47a						0.52*
Nab El-Gamal									
12 h IW+10°C	57.07a	59.27a	59.87a	65.80a	66.47b	70.93a	69.60a	66.27a	
24 h IW+10°C	57.07a	61.60a	57.00a	61.00a	66.73b	68.67a	70.07a	69.33a	0.74**
Control+10°C	57.07a	57.67a	55.53a	63.40a	73.87a	73.93a	67.40a	70.87a	0.82**
RT	57.07a	60.13a	56.80a						0.64*
LSD at 0.05 level	8.93	11.15	13.69	23.21	6.98	11.33	10.09	9.08	
				2004 Season					
Balady									
12 h IW+10°C	62.80a	59.07a	53.13a	60.40a	67.33a	70.00a	67.60a	70.80a	
24 h IW+10°C	62.80a	60.67a	54.27a	64.53a	70.67a	69.93a	72.07a	71.67a	0.55*
Control+10°C	62.80a	62.87a	54.53a	61.73a	72.33a	71.73a	69.07a	71.33a	0.62*
RT	62.80a	61.03a	56.40a						0.50*
Nab El-Gamal									
12 h IW+10°C	63.67a	62.07a	57.00a	67.13a	69.73a	72.40a	70.93a	69.13a	
24 h IW+10°C	63.67a	55.33a	56.13a	60.60a	70.13a	73.47a	71.13a	71.60a	0.54*
Control+10°C	63.67a	59.40a	57.07a	68.13a	70.27a	72.93a	71.73a	71.83a	0.62*
RT	63.67a	64.80a	56.87a						0.65*
LSD at 0.05 level	7.07	11.76	10.19	11.63	9.93	3.85	5.18	7.18	

Means within columns (in same season) having a common letter are not significantly different. r^2 = Determination coefficient, RT=Room temperature

Table 5 : Effect of some intermittent warming and storage temperature treatments on juice volume (ml / 100 g arils) of Balady and Nab El-Gamal pomegranate cvs. fruits in 2003 and 2004 seasons

Treatments	Storage period (days) 0	10	20	30	40	50	60	70	r^2
2003 Season									
Balady									
12 h IW+10°C	56.67a	48.67b	52.00a	54.67a	62.67b	58.67a	56.00a	60.00a	
24 h IW+10°C	56.67a	59.00a	50.00a	58.67a	62.67b	64.67a	64.00a	61.33a	0.33
Control+10°C	56.67a	49.00b	44.00a	64.00a	66.00ab	64.67a	65.33a	64.67a	0.42
RT	56.67a	59.00a	49.33a						0.48
Nab El-Gamal									
12 h IW+10°C	52.67a	56.67ab	55.33a	62.00a	64.00b	66.00a	63.33a	61.33a	0.63*
24 h IW+10°C	52.67a	59.33a	53.33a	57.33a	63.33b	63.33a	61.00a	63.33a	0.51*
Control+10°C	52.67a	54.00ab	53.33a	60.00a	70.67a	68.67a	64.33a	63.33a	0.48
RT	52.67a	55.33ab	51.33a						
LSD at 0.05 level	8.28	9.43	12.10	12.41	7.41	11.41	9.85	8.04	
2004 Season									
Balady									
12 h IW+10°C	58.67a	57.33a	48.00a	57.33a	65.33a	65.33a	61.33b	64.67a	0.37
24 h IW+10°C	58.67a	56.67a	50.67a	58.00a	67.33a	65.33a	67.33a	66.67a	0.58*
Control+10°C	58.67a	56.67a	50.00a	61.33a	69.33a	66.67a	62.67b	66.00a	0.42
RT	58.67a	57.00a	52.67a						
Nab El-Gamal									
12 h IW+10°C	62.00a	60.00a	52.67a	62.67a	66.67a	67.33a	64.67ab	63.33a	0.26
24 h IW+10°C	62.00a	52.67a	52.00a	56.67a	66.33a	68.00a	65.33ab	66.00a	0.45
Control+10°C	62.00a	54.67a	53.33a	63.33a	69.67a	68.00a	65.00ab	66.33a	0.42
RT	62.00a	60.00a	53.33a						
LSD at 0.05 level	8.26	10.65	9.94	10.64	10.06	3.36	4.59	7.25	

Means within columns (in same season) having a common letter are not significantly different. r^2 = Determination coefficient, RT=Room temperature.

control pomegranate fruits stored at 10 °C. Pomegranate fruits become juicy and more flavorful by storage (Morton, 1987 and Waskar *et al.*, 1999).

Soluble Solid Content (SSC %)

SSC values of Balady and Nab El-Gamal pomegranate fruits stored at RT were not altered after 10 or 20 days in comparison with the initial values in both seasons (Table 6). But SSC values were increased after the same period at 10 °C where the cooled fruits had significant higher SSC values. These results agree with that of El-Yatem and Kader (1984) on Wonderful pomegranate and Waskar *et al.* (1999) on Ganesh pomegranate.

In the first season, there was no significant effect of IW on SSC in the first 30 days in both cvs. This was in agreement with Kader *et al.* (1984) and Artés *et al.*(2000). In the second season, IW was slightly increased SSC values in both cvs. after the same period at 10 °C. These results associated with the results of Tayel (2001).

With the progress of the storage period, there was no significant effect of IW for 12 h on SSC values in comparison with the control, but IW treatment for 24 h had the least significant values of SSC in both seasons and for both cvs. The effect of IW on reducing SSC values was found by Trujillo and Artes (1997) and Sungbok *et al.* (1998).

SSC values of both cvs and in both seasons were slightly increased (r^2 values were not significant) with the advance of the storage period. This was in agreement with the results of Koksal (1989) who attributed the SSC increasing to the loss of moisture leading to concentration of the soluble solids in Gok Bahce pomegranate fruits. However, Padule and Keskar (1988); Nanda *et al.* (2001) and Pierce and Kader (2003) observed decreases in SSC after cold storage of Ganesh, and Wonderful pomegranates, respectively.

Titratable Acidity (%)

Organic acids found in pomegranates include citric, malic, fumaric, tartaric and lactic acids; however, the major acid accounting for titratable acidity in pomegranate arils is citric acid (Kulkarni and Aradhya 2004).

After 10 days of storage there was no significant difference between cooled control fruits and RT stored fruits in titratable acidity

Table 6: Effect of some intermittent warming and storage temperature treatments on SSC (%) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatments	Storage period (days) 0	10	20	30	40	50	60	70	r^2
					2003 Season				
Balady									
12 h IW+10°C	15.33a	15.93ab	16.40a	15.47a	15.40a	16.13ab	15.73ab	16.53a	0.17
24 h IW+10°C	15.33a	16.07a	16.20ab	13.67a	13.67b	15.07c	15.00b	16.07b	0.01
Control+10°C	15.33a	15.73ab	16.53a	13.73a	14.47ab	15.80bc	15.47ab	16.40ab	0.02
RT	15.33a	15.60ab	15.67c						
Nab El-Gamal									
12 h IW+10°C	15.27a	15.93ab	15.80bc	14.40a	15.47a	17.00a	16.00a	16.40ab	0.24
24 h IW+10°C	15.27a	16.20a	16.60a	15.07a	14.07b	16.13ab	15.73ab	16.33ab	0.01
Control+10°C	15.27a	15.93ab	15.87bc	15.33a	14.53ab	16.40ab	15.87a	16.33ab	0.14
RT	15.27a	15.20b	15.13d						
LSD at 0.05 level	0.26	0.74	0.52	2.30	1.01	1.03	0.77	0.37	
					2004 Season				
Balady									
12 h IW+10°C	15.87a	16.13a	16.47a	15.73abc	15.27a	16.27bc	15.20b	16.60a	0.001
24 h IW+10°C	15.87a	15.80ab	16.27a	15.60bc	14.40b	15.67d	15.67ab	16.07a	0.01
Control+10°C	15.87a	15.87ab	15.88b	15.33cd	14.67b	15.60d	15.33b	16.40a	0.001
RT	15.87a	15.67abc	15.87b						
Nab El-Gamal									
12 h IW+10°C	15.33b	15.67abc	16.33a	16.20a	15.53a	17.07a	16.20a	16.40a	0.37
24 h IW+10°C	15.33b	16.07a	16.47a	15.93ab	15.20a	15.93cd	15.80ab	16.20a	0.04
Control+10°C	15.33b	15.27c	14.93c	15.07d	15.27a	16.47b	16.07a	16.47a	0.24
RT	15.33b	15.53bc	15.67b						
LSD at 0.05 level	0.33	0.50	0.35	0.47	0.49	0.50	0.62	0.56	

Means within columns (in same season) having a common letter are not significantly different. r^2 =Determination coefficient, RT=Room temperature.

(TA) content for both cvs and in both seasons (Table 7). However, the trend of TA was different for the RT stored fruits of both cvs. after 20 days. Waskar *et al.,* (1999) and El-Yatem and Kader (1984) reported that the cooled fruits showed higher values of TA than RT ones. Moreover, the juice of Balady cv., Generally, revealed lower TA in comparison with Nab El-Gamal juice.

During the storage period at 10 °C, control fruits had significant lower TA values in comparison with IW treated fruits and that was in both seasons for both cvs. In addition, IW for 12 h indicated higher TA values as compared with IW for 24 h. The obtained results agree with those of Trujilo and Artés (1997) and Artés *et al.,* (2000). The higher TA values of IW treated fruits may be a result of the higher weight loss that concentrates citric acid.

With the advance in the storage period, the juice TA decreased (r^2 values were significant for control fruits and IW-treated fruits for 24 h of Balady cv. in both seasons) and the highest values were reported for Nab El-Gamal cv. These results are in agreement with those of El-Yatem and Kader (1984), Artés *et al.* (2000), Nanda *et al.* (2001) and Pierce and Kader (2003). As pomegranate is non-climacteric fruit, loss in acid occurred with ongoing metabolism (Nanda, 2001 and Kader *et al.,* 1984).

The above compositional changes; i.e., the increase in SSC and the reduction in TA may have some effect on the taste due to lower acidity and sweetness (Pierce and Kader, 2003; Kulkarni and Aradhya, 2004).

Arils Total Phenols (%)

Balady pomegranates had slightly (insignificant) higher initial total phenols of arils in comparison with the fruits of Nab El-Gamal (Table 8). However, in both cvs. the phenols content decreased after 20 days of storage at RT or at 10 °C in both seasons. Such reductions continued during the storage periods (r^2 values were highly significant for Balady cv. and significant for Nab El-Gamal cv.). A decrease in phenolic compounds with cold storage has, also, been reported in grapes (Takeda *et al.,* 1983) and pears (Mann and Baljit, 1990).

During the storage period there was a significant effect of IW on reducing total phenols of Balady fruits at the first intervals

Table 7: Effect of some intermittent warming and storage temperature treatments on titratable acidity (%) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatments	Storage period (days) 0	10	20	30	40	50	60	70	r^2
					2003 Season				
Balady									
12 h IW+10°C	1.22a	0.85c	1.16bc	1.03bc	1.04b	1.23b	0.78d	1.11ab	0.03
24 h IW+10°C	1.22a	1.09bc	1.12bc	0.94c	1.10b	0.94c	0.85d	0.96bc	0.65*
Control+10°C	1.22a	1.25abc	1.26abc	1.10abc	0.99b	0.94c	1.01c	0.80c	0.84**
RT	1.22a	1.29ab	1.10c						
Nab El-Gamal									
12 h IW+10°C	1.32a	1.53a	1.22bc	1.27ab	1.52a	1.59a	1.35a	1.27a	0.001
24 h IW+10°C	1.32a	1.57a	1.32abc	1.39a	1.52a	1.43ab	1.31ab	1.17a	0.19
Control+10°C	1.32a	1.17abc	1.34ab	1.18abc	1.45a	1.32ab	1.17b	1.12ab	0.09
RT	1.32a	1.17abc	1.48a						
LSD at 0.05 level	0.60	0.43	0.23	0.32	0.34	0.28	0.16	0.19	
					2004 Season				
Balady									
12 h IW+10°C	1.34a	0.83e	1.29bc	1.37a	1.07d	0.93d	0.97d	1.05b	
24 h IW+10°C	1.34a	1.55ab	1.47a	1.17ab	1.18c	1.01d	0.86e	1.02b	0.15
Control+10°C	1.34a	1.26cd	1.22c	0.98b	1.03d	1.20c	0.82e	0.86c	0.74**
RT	1.34a	1.26cd	1.03d						0.71**
Nab El-Gamal									
12 h IW+10°C	1.33a	1.74a	1.28bc	1.35a	1.70a	1.57a	1.45a	1.28a	
24 h IW+10°C	1.33a	1.42bc	1.42ab	1.35a	1.59b	1.44ab	1.30b	1.28a	0.01
Control+10°C	1.33a	1.00de	1.27bc	1.16ab	1.51b	1.40b	1.12c	1.19a	0.04
RT	1.33a	1.25cd	1.49a						0.004
LSD at 0.05 level	0.06	0.26	0.18	0.24	0.10	0.17	0.08	0.13	

Means within columns (in same season) having a common letter are not significantly different. r^2 =Determination coefficient, RT=Room temperature.

Table 8: Effect of some intermittent warming and storage temperature treatments on arils total phenols (%) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatment	Storage period (days)								r^2
	0	10	20	30	40	50	60	70	
					2003 Season				
Balady									
12 h IW+10°C	0.82a	0.98a	0.56a	0.40bc	0.44ab	0.23a	0.18a	0.19ab	0.85**
24 h IW+10°C	0.82a	0.59a	0.28c	0.45b	0.29c	0.17a	0.14ab	0.16bc	0.79**
Control+10°C	0.82a	0.67a	0.47ab	0.62a	0.54a	0.22a	0.18a	0.20ab	0.84**
RT	0.82a	0.97a	0.32bc						
Nab El-Gamal									
12 h IW+10°C	0.66a	0.81a	0.23c	0.30cd	0.29c	0.15a	0.10ab	0.20a	0.65*
24 h IW+10°C	0.66a	0.77a	0.18c	0.24d	0.25c	0.13a	0.07b	0.15c	0.65*
Control+10°C	0.66a	0.90a	0.30c	0.32cd	0.33bc	0.17a	0.10ab	0.20ab	0.67*
RT	0.66a	0.70a	0.16c						
LSD at 0.05 level	0.35	0.53	0.16	0.12	0.15	0.15	0.09	0.04	
					2004 Season				
Balady									
12 h IW+10°C	0.73a	0.73a	0.40a	0.45ab	0.42a	0.21b	0.17b	0.18ab	0.88**
24 h IW+10°C	0.73a	0.58abcd	0.32ab	0.42ab	0.32a	0.18b	0.20ab	0.15b	0.85**
Control+10°C	0.73a	0.62abc	0.37a	0.47a	0.44a	0.30a	0.18b	0.20ab	0.86**
RT	0.73a	0.52cd	0.15c						
Nab El-Gamal									
12 h IW+10°C	0.55a	0.57bcd	0.21c	0.38ab	0.39a	0.18b	0.15b	0.23a	0.61*
24 h IW+10°C	0.55a	0.58abcd	0.23bc	0.30b	0.29a	0.15b	0.14b	0.21ab	0.67*
Control+10°C	0.55a	0.68ab	0.24bc	0.54a	0.47a	0.18b	0.26a	0.25a	0.49
RT	0.55a	0.46d	0.18c						
LSD at 0.05 level	0.22	0.15	0.11	0.16	0.21	0.07	0.06	0.08	

Means within columns (in same season) having a common letter are not significantly different. r^2 =Determination coefficient, RT=Room temperature

(20, 30 and 40 days) in the first season and after 50 days in the second season. For Nab El-Gamal fruits, there were no significant differences among treatments in both seasons except for the final interval in the first season and after 30 days in the second season. Generally, control fruits had the highest total phenols content in both cvs. and in both seasons.

The main phenolic compounds present in pomegranate juice can be arranged into four groups (Gill *et al.*, 2000). A first group includes the anthocyanin pigments. The Second group includes the hydrolyzable tannins of the gallagyl type. The third group of pomegranate juice phenolics includes ellagic acid and its glycosides. The fourth group includes a very wide group of hydrolyzable tannins with undefined UV spectra (these compounds are different combinations of glucose, gallic acid, hexahydroxy diphenic acid and tertgallic acid).

Arils Anthocyanin Content (mg/100 g arils)

IW treatments clearly affected total anthocyanin content of pomegranate arils and there was a difference between cvs. response (Table 9). Generally, IW treated fruits for 12 h had the highest anthocyanin content for both cvs. and in both seasons, discendingly followed by control fruits at the end of storage. The above results agree with those of Artés *et al.* (1998) who declared that red colour of the pomegranate arils (Mollar cv.) was kept better under IW treatment. Also, Artés *et al.* (2000) reported that only some increases in total anthocyanin content were detected in IW and control fruits after cold storage period of Sweet pomegranates.

Initially, Balady pomegranate revealed slightly higher (insignificant) anthocyanin content as compared with Nab El-Gamal fruits. However, the values were, generally, increased after 20 days of storage at 10 °C then decreased gradually with the advance in storage period (r^2 values were not significant except the 12 h IW treatment for Balady cv. in the second season). The above results agree with the results of Miguel *et al.* (2004) who reported that the variation was more evident between the harvesting time and the first month of storage, when a great increase of anthocyanin level was monitored, followed by gradual reductions until the end of the storage period of Assaria

Table 9: Effect of some intermittent warming and storage temperature treatments on arils anthocyanin content (mg /100 g arils) of cvs. Balady and Nab El-Gamal pomegranate fruits in 2003 and 2004 seasons

Treatment	Storage period (days)								r^2
	0	10	20	30	40	50	60	70	
					2003 Season				
Balady									
12 h IW+10°C	1.23a	1.20b	2.78ab	1.36a	0.41a	0.51a	0.49a	0.38a	0.38
24 h IW+10°C	1.23a	0.86bc	2.75ab	1.02ab	0.23b	0.29b	0.35bc	0.21c	0.37
Control+10°C	1.23a	1.76a	3.30a	1.10ab	0.24b	0.32b	0.43ab	0.29b	0.41
RT	1.23a	0.84c	1.39de						
Nab El-Gamal									
12 h IW+10°C	0.82a	0.86bc	1.57c	1.08ab	0.28b	0.27b	0.26c	0.20c	0.50
24 h IW+10°C	0.82a	0.54c	1.45cd	0.35c	0.22b	0.23b	0.25c	0.16d	0.43
Control+10°C	0.82a	0.56c	1.94bc	0.59bc	0.25b	0.25b	0.27c	0.19cd	0.32
RT	0.82a	0.52c	0.65d						
LSD at 0.05 level	1.16	0.35	0.88	0.52	0.08	0.14	0.12	0.03	
					2004 Season				
Balady									
12 h IW+10°C	1.33a	2.68a	3.09ab	1.42a	0.33a	0.42a	0.50a	0.28a	0.52*
24 h IW+10°C	1.33a	1.02b	2.68bc	0.98b	0.24b	0.34ab	0.43ab	0.24ab	0.42
Control+10°C	1.33a	1.07b	3.55a	1.08b	0.25b	0.43a	0.50a	0.24ab	0.31
RT	1.33a	0.93b	1.05ef						
Nab El-Gamal									
12 h IW+10°C	0.67a	0.64b	1.91cd	0.80bc	0.26b	0.35ab	0.36b	0.21b	0.27
24 h IW+10°C	0.67a	0.47b	1.70de	0.24d	0.17c	0.17c	0.20c	0.14c	0.31
Control+10°C	0.67a	0.49b	1.90cd	0.58c	0.26b	0.20bc	0.31bc	0.17c	0.26
RT	0.67a	0.44b	0.89f						
LSD at 0.05 level	0.78	1.16	0.78	0.28	0.06	1.56	0.14	0.04	

Means within columns (in same season) having a common letter are not significantly different. r^2 =Determination coefficient, RT=Room temperature.

pomegranates. Also, Artés *et al.* (1998) reported that although significant changes in the individual anthocyanins (Mollar cv.) were observed, particularly after the shelf-life period, the total anthocyanin content of the juice at harvest was maintained. Artés *et al.* (2000) reported a slightly decrease in the total anthocyanin concentration of Sweet pomegranates at the end of shilf life.

The increase in the total amount of anthocyanin during the first month of storage may be due to the continued biosynthesis of phenolic compounds after harvest, related to the ripening process (Miguel *et al.,* 2004). The increase of anthocyanin concentration after harvest was reported previously in pomegranates (Gill *et al.,* 1995; Holcroft *et al.,* 1998) and that was correlated with the activity of the enzymes of the anthocyanin biosynthetic pathway.

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تأثير بعض معاملات التبريد المتقطع و درجة حرارة التخزين على الجودة والقابلية للتخزين لثمار الرمان البلدى و ناب الجمل

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تهدف الدراسة الحالية الى إلقاء الضوء على تأثير درجة حرارة التخزين و كذلك تأثير التخزين تحت ظروف تبادل فترات التبريد و الدفء على جودة ثمار الرمان من صنفي البلدى، وناب الجمل من حيث الخواص الطبيعية و الكيماوية، وقد تم تبادل التبريد و الدفء أثناء التخزين بإخراج الثمار من الثلاجة (١٠° م) الى درجة حرارة الغرفة لمدة ١٢ أو ٢٤ ساعة كل ١٠ أيام ثم إعادتها للثلاجة مرة أخرى.

وأظهرت النتائج أن التبريد المتقطع بدأ يؤثر بدرجة ملحوظة على فقد الوزن فى الثمار بعد ٣٠ يوماً من التخزين على ١٠°م، و قد لوحظ أن أكبر فقد للوزن كان تحت ظروف التبريد المتقطع لمدة ٢٤ ساعة، كما أن ثمار الصنف ناب الجمل أظهرت فقدا أكبر فى الوزن فى الموسمين، و تحت ظروف التخزين المبرد، و فى درجة حرارة الغرفة، وكان من الواضح أن ثمار الرمان البلدى كانت أعلى فى محتوى الرطوبة خلال فترة التخزين عن ثمار الصنف ناب الجمل، ولم تلاحظ فروقا معنوية بين المعاملات فى وزن أو حجم العصير الناتج من ١٠٠جم من حبوب الرمان فى أى فترة من فترات التخزين. ومع ذلك فقد زاد وزن و حجم العصير مع التقدم فى فترة التخزين على درجة١٠° م . وقد تبين أن معاملة التبريد المتقطع لمدة ٢٤ ساعة سببت نقصا فى نسبة المواد الصلبة الكلية فى العصير فى كلا الموسمين و الصنفين، وبالإضافة الى ذلك فقد أظهرت ثمار المقارنة نقصا واضحا فى محتوى الحموضة الكلى بالعصير مقارنة بثمار التدفئة المتقطعة. كما بينت النتائج أن ثمار الرمان البلدى قبل التخزين احتوت على كمية أكبر من الفينولات عن ثمار الصنف ناب الجمل.كما تبين أن التخزين بنظام التبريد المتقطع يقلل من محتوى الثمار من الفينولات. وأظهرت النتائج أيضا أن التخزين بنظام التبريد المتقطع لمدة ١٢ ساعة سبب زيادة واضحة فى محتوى الانثوسيانين فى الصنفين و فى موسمى التجربة، كما ظهرت زيادة فى محتوى الانثوسيانين فى ثمار المقارنة و لكن بدرجة أقل.