Retardation of Chilling Injury Symptoms and Reducing Quality Loss of Cactus Pear Fruits During Cold Storage by Heat Treatments

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ABSTRACT

Cactus pear fruits had three ripening stages of light green (G), yellowish green (YG) and yellow (Y) were exposed to water steam (WS) at approximately 78 ?C for one min or dipped into hot water (HW) at 55 ?C for two min or washed with regular tap water(control). Each of the above nine (3 stages x 3 treatments) groups was divided into two sections, the first one was stored at 5 ?C and the other was stored at 10 ?C. Heat treatments prolonged the storage period of all ripening stages of fruits. At 5 and 10?C, respectively, the treated fruits were stored for 32 and 40 days compared with 28 and 32 days for the untreated one. Control fruits were the first to decay due to the chilling injury incidence specially the green stage at 5 ?C and became unattractive as a result of loss of its brightness. On the other hand, heated fruits kept its good appearance, free from decay and wrinkles for longer time. Heat treatments retard the appearance of chilling injury symptoms for the stored fruits at 5 ?C and the best appearance with less chilling symptoms was for the yellow fruits. The fruits stored at 10 ?C were free from chilling symptoms except of small red spots appeared on the control fruits. WS treatment reduced weight loss of cactus pear fruits and the differences were significant for the yellowish green fruits except of those stored at 5 ?C in the first season. On the other side, HW treatment increased the weight loss of all treatments with insignificant differences compared with the control fruits with exception of yellowish green fruits in the second season which reduced it. Green fruits had the highest initial color index (CI) and the heat treatments did not affect CI of all ripening stages of fruits stored at 5 and 10 ?C in the two seasons and there were no differences between heat treatments. Heat treatments had no significant effect on pulp weight percent, but generally heated fruits had lower percentages and the fruits stored at 10 ?C had higher percentages with significant increase by the duration of cold storage. At harvest in the two experimental seasons, yellow fruits had the highest contents of juice. Heat treatments had no significant effect on pulp juice weight at 5 and 10 ?C but generally the WS treated fruits had the highest juice weight which may be due to the water loss reduction. Except the green cactus pear fruits which lost its juiciness with the progress of the storage time. At harvest, yellow fruits had the highest values of SSC, V.C, water soluble pectin (WSP) and polyphenoloxidase (PPO) activity and the lowest percentages of acidity. Heat treatments had no significant effect on the SSC of cactus pear fruits except the higher significant content of heated fruits in some intervals. Heat treatments had significant effect on acidity and V.C especially the WS treatment which had the highest values at the two storage temperatures and in two seasons. Heat treatments had significant effect on reducing WSP pulp content and the activity of PPO. In both seasons, SSC of all treatments decreased by the advancing of cold storage and the highest values were obtained from yellow fruits. Fruit acidity increased by the end of the cold storage at 5 ?C and after the same period at 10 ?C (32 days), then decreased at the last two intervals at 10 ?C. WSP content increased with the loss of fruit firmness and the lowest changes were obtained with the yellow fruits and the fruits stored at 5 ?C. PPO activity increased, then decreased after 24 days at 5 and 10?C.

INTRODUCTION

Cactus pear or tuna fruit (*opuntia ficus indica*) is a berry fruits with a number of small hard seeds. The pericarp and the edible pulp may have soft green, greenish, white, canary yellow, lemon yellow, red or purple hues (Stinzing *et al.* 2001). The nutritional importance of cactus pear fruits is mainly due to its antioxidant properties and its contents of ascorbic acid (25 – 30 mg / 100g). The major components of the fruit pulp are water (85 %) and carbohydrates (10 – 15 %) with 12 - 15 % sugars; 0.6 % protein and 0.1 % lipids; 490 ppm calcium; 2200 ppm potassium and 850 ppm magnesium (Duru and Turker, 2005; Pérez *et al.,* 2005 and Cantwell, 1995).

Cactus pears are non climacteric fruits having at 20?C a low respiration rate (20 ml $CO_2.Kg^{-1}.h^{-1}$) and low ethylene production (0.2 µl $C_2 H_4$. Kg^{-1}. h^{-1}) and so, their physiological activity is low. Therefore, the perishability of fruits lies not in their physiology but mainly in physical damage. The low activity and the high sugar content of the pulp make the cactus pear fruit very susceptible to microbial invasion and limit its storage life.Under marketing conditions (20 ?C, 60 - 70 % RH) fruits have a shelf life of only few days which is mainly affected by decay at the stem end and related to physical damage during harvest and handling. Another problem during post-harvest handling of cactus pears is weight and water loss because it decrease saleable weight and appearance (Cantwell, 1995 and Garcia *et al.,* 1997).

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Received June 29, 2009, Accepted August 24, 2009

Cold storage reduces water loss by reducing the vapor pressure deficit and increases the post-harvest life of most horticultural crops by retarding respiration, ethylene production, ripening, senescence, undesirable metabolic changes and decay. However, cactus pears are susceptible to chilling injury when stored at temperature below 10 ?C depending on cultivar, environmental growth condition and fruit age (Cantwell, 1995; Garcia *et al.,* 1997 and Schirra *et al.*, 1999).

Post-harvest decay losses are commonly controlled by fungicides but public concern on possible food poisoning by chemical residues has led to the using of the physical methods that are less hazardous to human health such as heat treatments which controlled both of decay and chilling injury. The beneficial effects of heat treatments on keeping quality of fruits are associated with induction of heat shock proteins (Paull and McDonald, 1994), increasing in internal CO_2, decreasing in internal O_2 and decreasing in ethylene forming enzyme activity (Mitcham and McDonald, 1993 and Zainon *et al.,* 2000). Also, reducing the rate of fruit texture changes as a result of reducing the activity of softening enzymes (Zainon *et al.*, 2000), maintaining membrane stability (Chein, 2000) and reducing the solubility of polyuronide (Lazan *et al.,* 1989 and Shalom *et al.*, 1993).

The objectives of this study were to investigate the influence of pre-storage heat treatments (hot water and water steam) and the following different cold storage temperatures on the chilling injury, decay incidence and other quality attributes (fruit quality and storagability, external color index, weight loss, pulp juice weight, SSC, acidity, water soluble pectin and pulp PPO activity) of cactus pear fruits at different ripening stages.

MATERIALS AND METHODS

Cactus pear fruits had three ripening stages of light green (G), yellowish green (YG) and yellow (Y) were manually and carefully harvested on the last days of July in 2007 and 2008 seasons from a private orchard that located in EL-Nobaria, Alexandria province. Cactus pears were immediately transported to the Post-harvest Center of Horticulture Crops, Faculty of Alexandria, Alexandria University.

Fruits were sorted for size uniformity and absence of defects. Sound selected fruits of each ripening stage (fig. 1) were divided into three groups (150 fruits of each). The first group was exposed to water steam (WS) at approximately 78 ?C for one min then dried. The second group was dipped in hot water (HW) at 55 ?C for two min then dried. The peel area temperature was recorded each 15 sec. during WS and HW treatments and it reached the values (a range of 5 records) of 43, 45 and 46.2 ?C for WS heated fruits and 40.4, 60.2 and 70.0 ?C for HW treated fruits respectively for the G, YG and Y stages. The third group of fruits was washed using regular tap water then dried (control). Each of the above nine (3 stages x 3 treatments) groups was divided into two sections, packed in open plastic boxes, for each treatment represented 3 replicates. Each one contained 30 fruits and the dimensions of the boxes were 60 x 40 x 20 cm., the first one was stored at 5 ?C and the other was stored at 10 ?C.

Ten cactus pear fruits from each ripening stage were taken to determine the initial physical and chemical properties of the fruits. Changes in such properties were followed up each four days intervals through the experimental period. 15 fruits were labeled in every treatment and were initially weighed to calculate the fruits weight loss percent during the cold storage in relation to its original weight.

Chilling injury incidence and external fruit appearance were estimated visually at each sampling interval. External color of the fruits was estimated visually and measured with Minolta colorimeter. L, a and b values were used to calculate a color index (CI) of each fruit in the sample of each treatment according to Dominguez, (1992) as follow:

CI = ab / L (a,b and L were Minolta's reading)

Each fruit in the sample was weighed then peeled. The pulp of each fruit was weighed then squeezed and the obtained juice was weighed. The obtained juice was used to determine the percentage of soluble solids content (SSC) by the use of a hand refractometer and the titratable acidity was determined in the obtained juice as g citric acid /100 ml juice according to Chen and Mellenthin (1981).

Water soluble pectin (WSP) of fruit pulp was estimated as Ca pectate according to AOAC, (1980).

Polyphynoloxidase (PPO) activity was determined in the crude extracts (Brenneman and Black, 1979) of three samples of fruit pulp in each replicate, each treatment and the activity was measured using the method of Matta and Dimond (1963).

The termination of the experiment was done by the incidence of chilling injury symptoms and the loss of good fruit appearance. All data obtained were statistically analyzed according to the methods described by 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 using SAS program (1985).

RESULTS AND DISCUSSIONS

Fruit Quality and Storability:

Fig.1 howed the initial quality of cactus pear fruits. In the first season, the fruits had the initial weight of 131.9, 133.7 and 138.0 g ,the diameter of 5.5, 5.4 and 5.7 cm and the height of 7.45, 8.4 and 8.9 cm, respectively for the green, yellowish green and yellow fruits. Those values in the second season respectively were 147.7, 150.3 and 156.9 g for weight, 5.5, 5.5 and 5.7 cm for diameter and 8.5, 9.0 and 9.0 cm for height.

Heat treatments prolonged the storage period of all ripening stages of cactus pear fruits compared with untreated fruits. At 5 and 10?C, respectively the treated fruits stored for 32 and 40 days compared with 28 and 32 days for the control. Control fruits were the first to decay (fig 5) due to the chilling injury incidence, specially the green one at 5 ?C. Untreated fruits became unattractive as a result of loss its brightness in color and the formation of wrinkles with the drying of the fruit ends and the flatness loss of the rose end (fig 6). On the other hand, heated fruits kept its good appearance free from decay and wrinkles for longer time.

Harvest damages to the peel and stem end of cactus fruits lead to attack by numerous pathogens and result in fruit decay. Common post-harvest pathogens on cactus fruits are mostly fungi and include *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp. Heat treatment reduce that decay by killing pathogens spores and furthermore, the partial melting of the epicuticular wax layer in wounded areas with concomitant occlusion of possible entry points for wounded pathogens may have produced additional protection against decay in cactus pear fruits (Cantwell 1995; Piga *et al.,* 1996 and Schirra *et al.,* 1999).

Chilling Injury Incidence:

Cactus pear fruits are chilling sensitive when exposed to temperature below 9-10 ?C for longer than a few days. Chilling injury symptoms include pitting, surface bronzing and dark spots on the peel and increased susceptibility to decay (Cantwell 1995 and Garcia *et al.,* 1997).

In this experiment, heat treatments retard the appearance of chilling injury symptoms for the stored fruits at 5 ?C. Chilling injury incidence began after 12 days at 5 ?C first on the control as bronze pitting (fig 2). After 16 days, those symptoms area increased (1-2 mm) and began to appear on the heated green fruits and the best appearance with less symptoms was obtained for the WS treated fruits. Chilling injury symptoms appeared later (24 days) on the yellowish green and the yellow fruits and the control fruits were the most sensitive to low temperature. With the advancing of the storage period Chilling symptoms increased (fig 3) to include all the control fruit surface and 100% of the fruits. Those symptoms include less area of the fruit surface of the treated green fruits (50%) on less number of the fruits (75%). The yellowish green treated fruits had better appearance of the fruit surface (25%) on less number (50%) and the best appearance with less chilling symptoms (>25% of the fruit surface on > 30 of the fruit number) was for the yellow fruits.

The fruits stored at 10 ?C were free from chilling symptoms except of small red spots (1-2 mm) appeared on the control fruits (fig 4). The chilled areas were suitable places to decaying pathogens with the progress of the storage period (fig 5).

Chilling injury of cactus pears varies depending on species, cultivars, fruit maturity, environmental growth conditions and storage humidity (Schirra *et al.,* 1999). Chilling injury appeared after 14 days at 9 ?C on *O. ficus-indica* Gialla fruits (Chessa and Barbera, 1984) and the occurrence of chilling injury decreased when the fruits get its orange color (Gorini *et al.,* 1993) where the ripe fruits is less susceptible to chilling injury than the fruits harvested at the green or breaker stage (Schirra *et al.,*1999).

Cactus pear fruits are reported to be relatively less sensitive to chilling injury and they could be stored at 0?C for up two months (Berger *et al.,*1978 and Cantwell, 1995) while Copena-Torreoja fruits had 100 % injury from chilling after the first month of cold storage at 9 ?C (Garcia, 1997).

Several post-harvest treatments have shown to reduce chilling injury during storage. Those fore cactus pears include post-harvest heat treatments (Felix, 2002) which reduce the incidence of chilling injury as a result of inducing of heat shock proteins, suppressing oxidative activity and maintaining membrane stability (Chein, 2000 and Zainon *et al.,* 2000).

Moisture loss may be an important factor involved in cactus pear chilling injury development. A reduction in water loss result in a delay of membrane collapse occurring in chilling sensitive fruits when exposed to low temperature (Piga *et al.,*1996 and 1997).

Fruit Weight Loss %:

The obtained data in the two seasons (Tables 1 and 2) showed that WS treatment reduced weight loss of cactus pear fruits and the differences were significant for the yellowish green fruits except of those stored at 5

?C in the first season. On the other hand, HW treatment increased the percentage of fruit weight loss of all treatments with insignificant differences compared with the control fruits but the same treatments reduced the weight loss of yellowish green fruits in the second

Fig 1. Initial quality of cactus pear fruits

Fig 2. Initial symptoms of chilling injury of control fruits stored at 5?C

Fig 3. Advanced chilling injury symptoms of control fruits stored at 5?C

Fig 4. Red spots appearance of control fruits stored at 10?C

Fig 5. Decay incidence on chilled areas of fruits stored at 5?C

Fig 6. Rose end wrinkles on fruits stored at 10 wrinkles ?C.

season. The stored fruits at 10?C had the significant higher weight loss compared with those stored at 5 ?C. By the progress of the storage period in two seasons, there was a significant increase (r^2 values were highly significant) of weight loss of all treatments.

Weight loss or water loss is a serious problem for cactus pear fruits because it decreases saleable weight and appearance (Cantwell 1995 and Garcia *et al.*, 1997) and a weight loss of about 8 % was necessary to affect visual appearance of cactus pear fruits (Félix *et al.*, 1992 and Lopez *et al*., 2003). The resulting increase of weight loss in water heated fruits is due to the stress condition of the treatment on fruits (Philips, 1982). Storage at lower temperature (5 ?C) reduces water loss by reducing the vapor pressure deficit (Cantwell, 1986) and that loss increases by the duration of cold storage (Schirra *et al.* ,1999 and Lopez *et al.*, 2003) with the decrease of its rate may be due to changes in structure and morphology of epicuticular waxes (Chessa et al., 1992 and Lopez *et al*., 2003**)**.

External Color Index:

The tabulated data (Table 3 and 4) showed the tendencies of external color changes as color index (CI) of heated cactus pear fruits compared with control ones. Heat treatments did not affect CI of all ripening stages of fruits stored at 5 and 10 ?C in two seasons and there were no differences between heat treatments. Green fruits had the highest initial CI and its change percentages after 28 days ranged from 33.58 to 65.23%. On the other hand, yellow fruits had the lowest initial CI and the highest change percentages after 28 days ranged from 28.57 to 77.55 %. The above data are associated with those of Schirra *et al.,* (1997); Ortùzar, (1976); Castillo, (1997).

The visual observations of the fruits external color in this work showed that peel color changed with the

Table 1. Effect of heat treatments and the following storage temperature on weight loss (%) of cactus pear fruits in 2007 season

Treatment			Storage Period (days)											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
5°C	G	Steam	0.00a	0.77ef	1.35fg	2.03ef	2.47e	2.79e	3.51ef	3.97ef	4.28de			0.990**
		Water	0.00a	1.13cd	1.85ef	2.80de	3.39cd	3.94cd	4.90cd	5.62bcd	6.32bc			0.995**
		Cont.	0.00a	0.80ef	1.33fg	2.08ef	2.52de	2.86e	3.66ef	4.26def				0.993**
	YG	Steam	0.00a	0.56f	0.99g	1.56f	1.96e	2.23e	3.00f	3.44f	3.71e			0.994**
		Water	0.00a	0.91de	1.47fg	2.10ef	2.62de	2.90e	3.72ef	4.26def	4.61de			0.991**
		Cont.	0.00a	0.80ef	1.26g	1.73f	2.22e	2.32e	3.09f	3.52f				0.983**
	Y	Steam	0.00a	0.75ef	1.23g	1.66f	2.02e	2.24e	2.71f	3.02f	3.29e			0.979**
		Water	0.00a	0.91ed	1.54fg	2.12ef	2.62de	3.02de	3.74ef	4.15ef	4.62de			0.991**
		Cont.	0.00a	0.83def	1.38fg	2.02ef	2.49de	2.83e	3.63ef	4.08ef				0.992**
10°C	G	Steam	0.00a	1.42abc	2.82abc	3.85abc	4.52ab	5.15ab	6.14ab	6.77ab	7.34ab	7.98a	8.71a	0.978**
		Water	0.00a	1.72a	3.31a	4.60a	5.20a	5.81a	6.92a	7.45a	8.17a	8.90a	9.78a	0.970**
		Cont.	0.00a	1.68a	3.02ab	4.19ab	4.92ab	5.51ab	6.50ab	6.64ab	8.17a			0.967**
	YG	Steam	0.00a	1.24c	2.16de	3.05cd	3.57c	3.99cd	4.66de	5.21cde	5.48cd	6.16b	6.54b	0.971**
		Water	0.00a	1.64ab	3.13ab	4.34a	5.03a	5.51ab	6.56ab	7.28a	7.79ab	8.53a	9.27a	0.970**
		Cont.	0.00a	1.43abc	2.78abc	3.89ab	4.57ab	5.09ab	5.91abc	6.94ab	7.43ab			0.977**
	Y	Steam	0.00a	1.23c	2.40cde	3.56bcd	4.21bc	4.77bc	5.71bcd	6.44abc	6.99abc	7.60a	8.31ab	0.984**
		Water	0.00a	1.71a	3.13ab	4.30ab	4.96ab	5.50ab	6.47ab	7.18a	7.80ab	8.28a	9.02a	0.967**
		Cont.	0.00a	1.33bc	2.69bcd	3.80abc	4.49ab	4.98abc	6.10ab	6.82ab	7.35ab			0.979**
	LSD			0.32	0.58	0.81	0.90	1.04	1.15	1.38	1.64	1.78	1.96	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 2. Effect of heat treatments and the following storage temperature on weight loss (%) of cactus pear fruits in 2008 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	0.00a	0.74h	1.21i	1.90ij	2.27i	2.57ij	3.28hi	3.73hi	4.20g			0.993**
		Water	0.00a	1.11efg	1.99efg	2.88efgh	3.41efg	3.87defg	4.81defg	5.45defg	5.84def			0.986**
		Cont.	0.00a	0.89fgh	1.58fghi	2.37ghij	2.85fghi	3.34fghi	4.20efgh	4.86efgh				0.994**
5°C	YG	Steam	0.00a	0.70h	1.29hi	1.90ij	2.41hi	2.70hij	3.63fghi	4.16fghi	4.60efg			0.995**
		Water	0.00a	0.87fgh	1.48ghi	2.05hij	2.55ghi	2.70hij	3.53ghi	4.06ghi	4.41fg			0.987**
		Cont.	0.00a	1.12defg	1.94efgh	2.69fghi	3.34efgh	3.66efgh	4.88def	5.55cdef				0.988**
	Y	Steam	0.00a	0.81gh	1.40ghi	1.90ij	2.37hi	2.73hij	3.34hi	3.67hi	4.03g			0.987**
		Water	0.00a	0.96fgh	1.49ghi	2.04hij	2.43ghi	2.79ghij	3.34hi	3.75hi	4.02g			0.980**
		Cont.	0.00a	0.65h	1.11i	1.56j	1.93i	2.18j	2.78i	3.13i				0.991**
	G	Steam	0.00a	1.54abc	2.69cd	3.69bcde	4.30bcde	4.85bcd	5.82bcd	6.50bcd	7.04bcd	8.61ab	9.40ab	0.987**
		Water	0.00a	1.73ab	3.39ab	4.66a	5.42a	6.16a	7.32a	8.04a	8.75a	9.44a	10.35a	0.976**
		Cont.	0.00a	1.69ab	3.26abc	4.43ab	5.06ab	5.71ab	6.75ab	7.33ab	8.02ab			0.966**
10°C	YG	Steam	0.00a	1.20cdef	2.23def	3.14defg	3.59def	4.03def	4.67defg	5.27defg	5.57defg	6.13d	6.61d	0.969**
		Water	0.00a	1.47bcd	2.75bcd	3.86abcd	4.43bcd	4.85bcd	5.72bcd	6.36bcd	6.74bcd	7.42bcd	7.91bcd	0.964**
		Cont.	0.00a	1.87a	3.49a	4.67a	5.45a	6.02a	7.13a	7.97a	8.63a			0.969**
	Y	Steam	0.00a	1.18def	2.25de	3.15defg	3.75def	4.14def	5.04cde	5.67cde	6.09cde	6.76cd	7.30cd	0.982**
		Water	0.00a	1.40bcde	2.78bcd	4.04abc	4.73abc	5.30abc	6.25abc	6.94abc	7.45abc	8.05abc	8.68abc	0.970**
		Cont.	0.00a	1.32cde	2.55de	3.48cdef	4.02cde	4.43cde	5.23cde	5.76cde	6.20cd			0.962**
		LSD		0.35	0.67	0.85	0.98	1.09	1.29	1.42	1.55	1.79	1.90	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 3. Effect of heat treatments and the following storage temperature on color index of cactus pear fruits in 2007 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	Change %
	G	Steam	3.71a	2.87abcde	5.07a	3.32a	2.05a	2.71abc	1.78abc	2.20a	2.21ab			40.70
		Water	3.71a	3.45abc	4.84ab	2.67abcd	1.57a	2.45abcd	1.31abc	1.96ab	2.57a			47.17
		Cont.	3.71a	4.68a	3.21abc	1.63abcde	1.88a	1.70abcdefg	1.84abc	1.47abcd				60.38
5°C	YG	Steam	1.47a	3.44abc	2.01cdef	1.25bcde	1.22a	1.67abcdefg	2.41ab	1.07bcd	1.85abc			27.21
		Water	1.47a	2.99abcd	2.83abcd	2.99ab	1.92a	2.52abcd	0.63bc	1.44abcd	1.24abcd			2.04
		Cont.	1.47a	3.62abc	1.90cdef	2.37abcde	1.62a	1.31cdefg	1.10bc	1.59abc				8.16
	Y	Steam	1.19a	0.65f	0.62def	0.76de	0.81a	1.41cdefg	1.39abc	0.54cd	0.92bcd			54.62
		Water	1.19a	0.94def	0.27f	0.71e	0.86a	1.16defg	1.88abc	0.40d	0.57cd			66.39
		Cont.	1.19a	0.72ef	0.63def	1.27bcde	1.11a	0.72efg	1.84abc	0.57cd				52.10
	G	Steam	3.71a	2.13bcdef	1.87cdef	2.74abc	1.22a	1.46bcdefg	1.67abc	1.40abcd	1.84abc	2.69a	0.69ab	62.26
		Water	3.71a	3.41abc	1.92cdef	2.19abcde	2.31a	2.98ab	1.89abc	1.29abcd	0.79cd	1.08ab	0.68ab	65.23
		Cont.	3.71a	4.02ab	2.64bcde	3.33a	0.64a	2.22abcde	2.24abc	1.46abcd	1.28abcd			60.65
10°C	YG	Steam	1.47a	1.94bcdef	2.21cdef	2.09abcde	1.21a	2.22abcde	2.17abc	0.98bcd	1.11bcd	1.77ab	1.59a	33.33
		Water	1.47a	1.48cdef	1.41cdef	0.85cde	0.94a	2.01abcdef	2.08abc	1.23abcd	0.94bcd	1.78ab	1.16ab	16.33
		Cont.	1.47a	2.24bcdef	1.64cdef	1.51abcde	1.18a	3.11a	3.04a	0.66cd	1.44abcd			55.10
	Y	Steam	1.19a	1.69cdef	0.84def	0.50e	1.28a	1.16defg	1.60abc	0.61cd	1.84abc	0.29b	0.20b	48.74
		Water	1.19a	0.72ef	0.42ef	0.72de	0.99a	0.44g	0.61bc	0.67cd	0.35d	0.62ab	0.58ab	43.70
		Cont.	1.19a	1.17def	0.60def	0.90cde	1.52a	0.56fg	0.43c	0.38d	0.41d			68.06
		LSD	3.10	2.18	2.33	1.95	1.82	1.54	1.89	1.09	1.39	2.13	1.22	

Means within columns having a common letter(s) are not significantly different.

Table 4. Effect of heat treatments and the following storage temperature on color index of cactus pear fruits in 2008 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	Change %
	G	Steam	2.74a	3.64ab	4.39ab	3.95a	1.38abcde	2.67ab	2.03abc	1.04abcde	1.75ab			62.04
		Water	2.74a	3.26bcd	5.21a	3.15ab	1.34abcde	3.12a	2.90a	1.25abcd	1.44abc			54.38
		Cont.	2.74a	4.83a	4.52a	2.20abcd	2.21ab	3.06a	1.13bcd	1.09abcde				60.22
5°C	YG	Steam	1.96ab	3.28bcd	2.66cd	1.08cde	1.58abcde	1.22cde	1.78abcd	1.91a	1.25abc			2.55
		Water	1.96ab	2.83bcde	2.40cdef	2.16abcd	1.24abcde	2.36abc	1.32bcd	1.44abc	1.15abc			26.53
		Cont.	1.96ab	3.10bcd	1.48defg	2.14bcd	1.65abcd	1.86abcd	0.78cd	1.13abcde				42.35
	Y	Steam	0.98b	0.50gh	0.45g	1.94bcde	0.47e	1.29cde	1.09bcd	0.24de	1.90a			75.51
		Water	0.98b	0.87fgh	0.62g	0.42de	0.61e	0.67de	1.35bcd	0.44cde	1.02abc			55.00
		Cont.	0.98b	1.10fgh	0.38g	1.69bcde	0.60de	1.56bcde	0.96bcd	0.69bcde				29.59
	G	Steam	2.74a	3.47abc	3.00bc	2.48abc	1.64abcd	2.42abc	2.26ab	1.14abcde	0.94abc	2.01a	0.97ab	58.39
		Water	2.74a	3.26bcd	2.50cde	2.05bcde	2.30a	1.77abcd	2.07abc	1.82a	0.77bc	0.34a	0.53ab	33.58
		Cont.	2.74a	4.22ab	1.22defg	2.43abc	1.92abc	1.59bcde	1.18bcd	1.48ab	1.45abc			45.99
10°C	YG	Steam	1.96ab	1.44efgh	1.23defg	1.43bcde	1.46abcde	1.48bcde	2.90a	0.59bcde	1.43abc	1.68a	1.35a	69.90
		Water	1.96ab	2.05cdef	0.97fg	0.75cde	1.47abcde	1.26cde	2.78a	0.98abcde	1.19abc	0.89a	0.30b	50.00
		Cont.	1.96ab	1.99def	1.71cdefg	1.29cde	0.88cde	1.53bcde	1.89abcd	0.53bcde	1.36abc			72.96
	Y	Steam	0.98b	1.17fgh	1.08efg	0.95cde	1.23abcde	1.15cde	0.63d	0.22e	1.79ab	0.87a	0.55ab	77.55
		Water	0.98b	0.42h	0.69g	1.10cde	0.86cde	0.28e	1.66abcd	0.61bcde	0.50c	0.36a	0.84ab	37.76
		Cont.	0.98b	1.91defg	0.95fg	0.31e	1.05bcde	0.64de	1.36bcd	0.70bcde	1.36abc			28.57
		LSD	1.59	1.44	1.50	1.80	1.18	1.37	1.39	1.15	1.11	1.79	0.91	

Means within columns having a common letter(s) are not significantly different.

progress of the storage period and that was faster at 10?C. The green fruits changed to the yellowish green and the yellowish green fruits changed to the yellow color while the yellow ones changed to the orange color. Lopez *et al*., (2003) reported that Naranjona cactus pear fruits developed yellow-orange skin coloration at store whereas, Charola fruits skin color essentially remained as it was at harvest.

The color is one of the main attributes of cactus pear fruits, which can determine the consumer acceptability and serving as an indicative of the harvest point of some fruits (Silva *et al.,* 2009). Pérez *et al.,* (2005) reported that the changes in carotenes and xanthophylls contents are somewhat related to the ripening period of cactus pear fruits. Silva *et al*., (2009) accessed cactus pear fruits color each 3 days storage by a Minolta colorimeter through the parameter L*, C* and H* and found that lightness (L*) declined during storage but Lopez *et al*., (2003) reported that lightness (L*) did not change significantly.

Pulp Juice Weight %:

The pulp juice weight as percentages of the pulp weight are tabulated in tables 5 and 6. At harvest in the two experimental seasons, yellow fruits had the highest contents (89.94 and 88.56 %) of juice compared with the yellowish green (84.01 and 80.27 %) and the green fruits (76.64 and 73.91%). In the two seasons, heat treatments had no significant effect on pulp juice weight at 5 and 10 ?C but generally the WS treated fruits had highest juice weight which may be due to the water loss reduction. Except the green fruits cactus pear lost its juiciness with the progress of the storage time at 5 and 10 ?C due to the water loss but the changes (r^2 values) were not significant.

SSC %:

At harvest, yellow fruits had the highest (12.47 and 12.67 5%) SSC percent (Table 7 and 8) then the yellowish green (12.27 and 12.33%) and the green ones (12.00 and 11.93%) with no significant differences in the two seasons. Generally, heat treatments had no significant effect on the SSC of cactus pear fruits except the higher significant content of yellowish green heated fruits at the intervals of 12 and 16 days at 5 ?C and 20 and 24 days at 10 ?C, in the first season. Also, at the intervals of 16 and 20 days for yellow fruits at 5 ?C and the green ones at 10 ?C and of 20 and 24 days for the yellowish green fruits stored at 10 ?C. The above results agree with the results of Schirra *et al.,* (1999).

SSC of all treatments decreased with the duration of cold storage at 5 and 10 ?C in the two seasons except the highest values obtained from yellow fruits at the end of storage at 10 ?C. These results of decreasing SSC with storage agree with Garcia *e*t al., (1997).On the other hand, Lopez *et al*., (2003) found an increase in SSC of cactus pear fruits by storage at 18 ?C. The changes in SSC, although generally are useful as an approximation of sugar content, do not necessarily correlate well with changes in sugar content (Cantwell, 1995). These changes are related to starch synthesis-degration, depending on starch and sugar content in the fruit at harvest (Lopez *et al*., 2003).

Titratable Acidity %:

In the two experimental seasons, yellowish green fruits had the highest significant citric acid content (Tables 9 and 10). Heat treatments had significant effect on fruit pulp acidity especially the WS treatment which had the highest values at the two storage temperatures and in two seasons. The higher content of citric acid in heated fruits may be due to the effect of heat treatment on regulating respiration and perhaps other metabolic processes during storage. The above results and associated discussion agree with the results on papaya (Lazan *et al.,* 1989 and El Naggar and El Saedy, 2004) and cherimoya fruits (Undurraga *et al.,* 1995 and El Saedy, 2005). On the other hand, Schirra *et al.,* (1999) and Berger *et al.,* (2002) reported that heat treatment had no significant effect on cactus pear acidity.

Fruit acidity increased by the end of the cold storage at 5 ?C and after the same period at 10 ?C (32 days) then decreased at the last two intervals at 10 ?C (r^2 values were not significant). Cantwell, (1995) and Pérez *et al.,* (2005) reported that citric acid decreased during ripening of cactus pear fruits. On the other hand, Piga *et al.,* (2003) reported a significant increase of cactus pear acidity after cold storage.

Water Soluble Pectin (WSP) %:

At harvest in the two seasons, green fruits had the lowest WSP content (0.21 and 0.22%) then yellowish green (0.22 and 0.24 %) and yellow (0.30 and 0.31%) fruits with no significant differences (Tables 11 and 12). In both seasons, heat treatments had significant effect on WSP of cactus pear fruits where the heated fruits contained lower values compared with control fruits. That finding may be due to the effect of heat treatment on regulating metabolic processes and the activity suppression of softening enzymes (Chein, 2000 and Zainon *et al.,* 2000). With the advancing of cold storage, WSP content increased with the loss of fruit firmness and the lowest changes were obtained with the yellow fruits and the fruits stored at 5 ?C.

Table 5. Effect of heat treatments and the following storage temperature on juice weight (%) of cactus pear fruits in 2007 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	76.64b	80.93abcd	74.57bcde	79.46a	76.84abcd	80.55abc	81.20abc	78.14abc	77.15abc			0.026
		Water	76.64b	76.10bcd	67.28de	79.23a	75.65bcd	77.97abc	81.03abc	76.60bc	75.02bc			0.064
		Cont.	76.64b	75.56bcd	63.38e	78.50a	76.03abcd	79.95abc	80.67abc	76.86abc				0.161
5°C	YG	Steam	84.01ab	80.94abcd	74.13bcde	82.13a	80.34abc	82.77ab	84.04ab	80.99abc	80.81ab			0.014
		Water	84.01ab	80.61abcd	80.24abc	81.24a	78.79abc	82.56ab	83.80ab	80.56abc	79.51abc			0.059
		Cont.	84.01ab	80.85abcd	81.69abc	78.97a	78.94abc	81.68abc	83.73ab	80.27abc				0.032
	Y	Steam	89.94a	85.29abc	86.57a	85.14a	85.22a	87.34a	89.08a	88.51a	84.02a			0.023
		Water	89.94a	81.09abcd	83.74ab	81.63a	82.19ab	84.86ab	87.22ab	85.39abc	83.09a			0.005
		Cont.	89.94a	83.24abcd	84.71ab	82.32a	81.56ab	84.54ab	85.95ab	83.86abc				0.116
	G	Steam	76.64b	78.40abcd	79.88abc	81.31a	75.04bcd	76.35abc	79.59abc	77.48abc	73.16c	79.84ab	77.65a	0.025
		Water	76.64b	71.26d	71.14cde	77.02a	68.95d	75.63bc	78.08bc	75.73c	72.41c	71.16b	74.85a	0.001
		Cont.	76.64b	73.94cd	76.78abcd	74.74a	71.19cd	70.69c	72.48c	74.99c	79.33abc			0.001
10°C	YG	Steam	84.01ab	83.60abc	83.70ab	82.94a	78.19abcd	81.48abc	83.46ab	79.73abc	82.27ab	83.74a	78.32a	0.206
		Water	84.01ab	80.10abcd	80.84abc	81.62a	77.31abcd	81.03abc	81.99abc	79.41abc	80.84ab	81.39ab	78.59a	0.133
		Cont.	84.01ab	80.62abcd	80.66abc	81.54a	78.11abcd	80.60abc	83.22ab	78.76abc	78.92abc			0.249
	Y	Steam	89.94a	88.86a	86.67a	84.04a	80.74ab	83.36ab	85.77ab	87.48ab	84.09a	86.84a	84.62a	0.006
		Water	89.94a	87.67ab	86.29a	84.90a	80.38abc	82.88ab	85.34ab	83.81abc	82.94a	84.41a	81.86a	0.274
		Cont.	89.94a	86.05abc	84.25ab	83.22a	80.64ab	82.86ab	84.75ab	81.35abc	82.66a			0.486*
		LSD	10.74	12.17	11.42	11.39	9.34	11.00	10.31	11.74	7.63	10.85	13.63	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 6. Effect of heat treatments and the following storage temperature on juice weight (%) of cactus pear fruits in 2008 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	73.91b	82.91abc	78.04bc	82.15ab	78.65abc	77.29abcd	79.43abcde	77.46bcde	78.10bc			0.001
		Water	73.91b	81.42abc	75.10c	83.10ab	77.24abc	77.12abcd	77.07bcde	76.63de	77.75cd			0.001
		Cont.	73.91b	82.63abc	75.65c	77.63bc	77.88abc	75.65bcd	76.40cde	76.49de				0.021
5°C	YG	Steam	80.27ab	83.24abc	82.05abc78	85.14ab	80.97abc	82.03abc	83.23abcd	82.60abcde	80.63abcd			0.001
		Water	80.27ab	82.89ab	.75abc	83.43ab	80.33abc	80.89abc	83.12abcd	79.45abcde	79.39abcd			0.039
		Cont.	80.27ab	83.11abc	78.06bc	83.26ab	79.67abc	79.76abcd	81.71abcde	80.30abcde				0.007
	Y	Steam	88.56a	85.61ab	87.28a	87.92a	83.73a	86.54a	86.13a	86.47a	84.06ab			0.291
		Water	88.56a	83.63ab	83.47abc	85.55ab	83.29a	84.91ab	84.86abc	85.93ab	83.06abc			0.115
		Cont.	88.56a	83.28abc	84.66ab	87.87a	81.88ab	85.03ab	83.96abc	84.54abcd				0.149
	G	Steam	73.91b	80.34bc	78.65abc	83.24ab	77.86abc	76.44abcd	79.32abcde	76.99cde	78.91bcd	80.47c	77.40ab	0.009
		Water	73.91b	76.87c	77.89bc	82.36ab	73.70c	74.08cd	74.89de	75.06e	76.35d	69.42d	76.22b	0.118
		Cont.	73.91b	80.10bc	75.64c	74.13c	74.85bc	70.05d	73.64e	75.87de	76.18d			0.040
10°	YG	Steam	80.27ab	83.99ab	85.00abc82	83.49ab	80.03abc	79.15abcd	81.08abcde	81.54abcde	78.89bcd	83.65abc	80.90ab	0.079
C		Water	80.27ab	80.99bc	.28abc	83.64ab	79.58abc	77.45abcd	80.60abcde	78.35abcde	80.99abcd	82.61bc	79.72ab	0.026
		Cont.	80.27ab	82.81abc	81.58abc	83.63ab	79.28abc	77.87abcd	80.99abcde	78.95abcde	80.96abcd			0.152
	Y	Steam	88.56a	87.93a	86.74ab	87.25a	82.82a	84.62ab	85.47ab	85.60abc	84.51a	88.36ab	84.99a	0.149
		Water	88.56a	83.35abc	86.72ab	85.51ab	81.53abc	83.17abc	83.95abc	85.52abcd	81.99abc	88.36a	83.72ab	0.041
		Cont.	88.56a	83.29abc	85.95ab	85.52ab	80.97abc	82.27abc	83.87abc	83.19abcde	81.80abc			0.446*
		LSD	10.96	6.54	8.99	7.93	7.94	10.17	8.58	8.75	5.42	5.18	7.66	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 7. Effect of heat treatments and the following storage temperature on soluble solids content (SSC %) of cactus pear fruits in 2007 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	12.00a	12.47abc	11.00fgh	11.73def	11.07de	11.53defgh	11.60cdef	11.40def	11.13cdef			0.297
		Water	12.00a	12.07cde	10.53gh	12.33bcdef	11.80bcd	11.53defgh	11.33efgh	12.07abcdef	11.07def			0.053
		Cont.	12.00a	12.40abcd	11.67cdef	12.73abcd	12.00bcd	10.73ghi	11.60cdef	12.20abcd				0.088
5°C	YG	Steam	12.27a	12.27abcde	11.33efg	13.33ab	12.60ab	11.67cdefg	10.67h	12.27abc	10.80ef			0.216
		Water	12.27a	11.53e	12.20bcde	12.53abcde	12.33abc	11.67cdefg	12.13abcde	11.93bcdef	11.40bcde			0.148
		Cont.	12.27a	12.60abc	12.47abc	12.27cdef	11.47cde	11.66cdefg	11.93bcde	11.73cdef				0.541*
	Y	Steam	12.47a	13.07a	12.40abcd	12.73abcd	13.20a	12.67abc	12.33abcd	12.13abcde	11.07def			0.400
		Water	12.47a	12.47abc	13.27a	13.13abc	12.33abc	12.53abcd	12.80a	11.93bcdef	11.93abcd			0.270
		Cont.	12.47a	12.73abc	12.73ab	13.20abc	12.33abc	11.87cdef	12.80a	11.53cdef				0.274
	G	Steam	12.00a	12.20bcde	12.33bcd	11.33f	11.40cde	11.27fghi	11.53defg	12.07abcdef	10.33f	9.00c	9.67c	0.642**
		Water	12.00a	12.07cde	12.33bcd	11.53ef	10.40e	11.73bcdefg	10.73gh	11.53cdef	10.87ef	10.47b	11.13b	0.447**
		Cont.	12.00a	12.33abcde	11.53def	11.33f	11.40cde	10.60hi	11.33efgh	11.47cdef	10.33f			0.593*
10°C	YG	Steam	12.27a	11.60de	10.33h	12.27cdef	12.60ab	11.47efgh	12.40abc	11.33ef	12.27ab	10.27bc	11.73b	0.026
		Water	12.27a	12.60abc	12.87ab	12.47abcde	12.73ab	12.40abcde	11.53defg	11.73cdef	11.40bcde	12.60a	11.74b	0.321
		Cont.	12.27a	13.07a	12.80ab	12.53abcde	12.67ab	10.27i	10.80fgh	11.27f	11.60bcde			0.448*
	Y	Steam	12.47a	12.80abc	12.60ab	12.53abcde	12.73ab	12.73ab	12.47ab	12.60ab	12.33ab	12.20a	13.27a	0.005
		Water	12.47a	12.80abc	12.27bcd	13.40a	12.87ab	12.93a	12.13abcde	12.67ab	12.07abc	12.60a	13.07a	0.002
		Cont.	12.47a	13.00a	12.87ab	12.53abcde	12.87ab	12.73ab	11.80bcde	12.87a	12.80a			0.016
		LSD	2.10	0.82	0.88	1.06	1.07	1.01	0.86	0.86	0.97	1.37	1.10	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 8. Effect of heat treatments and the following storage temperature on soluble solids content (SSC %) of cactus pear fruits in 2008 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	11.93a	12.33bcde	10.67ghi	11.33c	10.73gh	11.27cde	11.13cdefg	11.20bcd	11.00bcde			0.282
		Water	11.93a	12.00efg	10.33hi	11.87bc	11.53defg	11.33bcd	10.67fgh	11.60bcd	10.73def			0.190
		Cont.	11.93a	12.27cdef	11.13efgh	12.53ab	11.80cdef	10.73def	11.27bcdef	12.00ab				0.094
5°C	YG	Steam	12.33a	12.13defg	11.00fghi	12.80a	12.40abcd	11.47bcd	10.07h	12.13ab	10.87cde			0.214
		Water	12.33a	12.27cdef	11.93bcde	12.27ab	12.20abcdef	11.60bcd	11.67abcde	11.67abcd	10.73def			0.702**
		Cont.	12.33a	12.53abcde	12.00bcde	12.40ab	11.27fgh	11.53bcd	11.80abcd	11.47abcd				0.566*
	Y	Steam	12.67a	12.80abc	12.00bcde	12.33ab	13.13a	12.07abc	12.00ab	11.80abc	10.67def			0.480*
		Water	12.67a	12.40bcde	12.93a	12.67ab	12.13bcdef	12.73a	12.27a	10.73d	11.53bcd			0.500*
		Cont.	12.67a	12.47abcde	12.20abcd	13.07a	12.07bcdef	11.47bcd	12.40a	11.27bcd				0.422
	G	Steam	11.93a	11.67g	11.60cdef	10.47d	11.33fg	11.13cde	10.93efg	11.93abc	9.87f	9.47b	9.27d	0.594**
		Water	11.93a	12.40bcde	11.87bcdef	11.33c	10.33h	11.80abc	10.40gh	11.33bcd	10.67def	10.07b	11.07c	0.462*
		Cont.	11.93a	12.27cdef	11.33defg	11.13cd	10.73gh	10.33ef	11.07defg	11.00cd	10.07ef			0.673**
10°C	YG	Steam	12.33a	11.73fg	10.20i	11.93bc	12.27abcdefe	11.40bcd	11.80abcd	11.00cd	11.80abc	10.53b	11.53c	0.079
		Water	12.33a	13.00a	12.53ab	12.34ab	12.40abcd	11.53bcd	11.33bcdef	11.67abcd	11.07bcd	12.07a	12.27b	0.316
		Cont.	12.33a	12.67abcd	12.73ab	12.33ab	12.60abc	10.07f	10.53fgh	11.00cd	11.27bcd			0.508*
	Y	Steam	12.67a	12.73abc	12.33abc	12.33ab	12.13cdef	12.27ab	12.27a	12.33a	11.93ab	12.20a	13.13a	0.006
		Water	12.67a	12.40bcde	12.13abcd	13.07a	12.87ab	12.67a	11.93abc	12.32a	11.80abc	12.27a	12.93a	0.037
		Cont.	12.67a	12.87ab	12.67ab	12.27ab	12.80ab	12.27ab	11.93abc	12.32a	12.67a			0.210
		LSD	1.03	0.58	0.91	0.81	0.96	0.97	0.82	0.99	0.98	1.52	0.54	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 9. Effect of heat treatments and the following storage temperature on acidity (%) of cactus pear fruits in 2007 season

Treatment			Storage Period (days)											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	0.15ab	0.21ab	0.17cde	0.12cfghi	0.12efg	0.24a	0.20bcde	0.20bc	0.20cdefg			0.147
		Water	0.15ab	0.15hg	0.14efgh	0.11hi	0.13bcdef	0.17d	0.22abc	0.20bc	0.23bc			0.575*
		Cont.	0.15ab	0.18cdefgh	0.14efgh	0.10i	0.11fg	0.16d	0.17efg	0.17def				0.026
5°C	YG	Steam	0.19a	0.19bcde	0.21ab	0.13defgh	0.16a	0.17d	0.18def	0.22b	0.22cd			0.086
		Water	0.19a	0.20abc	0.23a	0.14cdefg	0.13cdefg	0.16d	0.18def	0.20bcd	0.21cdef			0.001
		Cont.	0.19a	0.20abcd	0.16cdef	0.12ghi	0.14abcde	0.17d	0.14g	0.17ef				0.178
	Y	Steam	0.13b	0.20abcd	0.20abc	0.13defgh	0.12defg	0.18cd	0.25a	0.21bc	0.28a			0.414
		Water	0.13b	0.23a	0.18bcd	0.13efgh	0.11fg	0.17d	0.22abcd	0.17ef	0.22cde			0.097
		Cont.	0.13b	0.19bcd	0.19abc	0.12fghi	0.11g	0.17d	0.17fg	0.19cde				0.047
	G	Steam	0.15ab	0.16efgh	0.22ab	0.19ab	0.14abcd	0.16d	0.20bcde	0.25a	0.23bc	0.11ab	0.11d	0.015
		Water	0.15ab	0.15h	0.15defg	0.15cdef	0.12efg	0.16d	0.19cdef	0.21bc	0.20cdefg	0.10b	0.19a	0.091
		Cont.	0.15ab	0.16fgh	0.19abc	0.16cd	0.11g	0.15d	0.18def	0.25a	0.17fg			0.149
10°C	YG	Steam	0.19a	0.17cdefgh	0.13fgh	0.19a	0.15ab	0.23a	0.20bcdef	0.22b	0.16g	0.13ab	0.14bc	0.033
		Water	0.19a	0.16efgh	0.11h	0.17abc	0.13bcdef	0.16d	0.21bcde	0.16ef	0.22cde	0.14ab	0.16b	0.022
		Cont.	0.19a	0.20abc	0.11gh	0.15cdc	0.15abc	0.21abc	0.18def	0.17def	0.19defg			0.026
	Y	Steam	0.13b	0.17defgh	0.21ab	0.16bc	0.13defg	0.22ab	0.23ab	0.27a	0.26ab	0.15a	0.19a	0.179
		Water	0.13b	0.19bcdef	0.16cdef	0.16bc	0.13bcdef	0.17d	0.19def	0.18cdef	0.20cdef	0.13ab	0.13cd	0.001
		Cont.	0.13b	0.18cdefg	0.12gh	0.14cdefg	0.16a	0.18bcd	0.21abcd	0.16f	0.18efg			0.329
		LSD	0.05	0.03	0.04	0.03	0.02	0.04	0.04	0.03	0.04	0.05	0.03	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 10. Effect of heat treatments and the following storage temperature on acidity (%) of cactus pear fruits in 2008 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	0.15b	0.21ab	0.14ef	0.11ef	0.12cdef	0.21a	0.23a	0.18def	0.18efg			0.111
		Water	0.15b	0.14de	0.14fg	0.11ef	0.11cdef	0.14d	0.19cdc	0.16gh	0.23b			0.375
		Cont.	0.15b	0.17cde	0.15def	0.10f	0.12cde	0.15d	0.17e	0.17fgh				0.033
5°C	YG	Steam	0.18a	0.18bcd	0.21a	0.10f	0.12cde	0.16d	0.18de	0.20cd	0.19de			0.016
		Water	0.18a	0.15cde	0.20a	0.11ef	0.13cd	0.15d	0.19cde	0.15h	0.19def			0.008
		Cont.	0.18a	0.16cde	0.14fg	0.10f	0.11ef	0.16d	0.22ab	0.17efg				0.052
	Y	Steam	0.13b	0.23a	0.19abc	0.12ef	0.12cdef	0.17bcd	0.21abc	0.18de	0.25a			0.162
		Water	0.13b	0.21ab	0.19ab	0.11ef	0.10f	0.17cd	0.17e	0.15h	0.19de			0.009
		Cont.	0.13b	0.17cde	0.16cde	0.12def	0.11ef	0.15d	0.13f	0.16gh				0.002
	G	Steam	0.15b	0.15cde	0.18bc	0.18ab	0.13bc	0.17cd	0.19cde	0.25ab	0.23b	0.10cd	0.11c	0.001
		Water	0.15b	0.14e	0.17bcd	0.14cde	0.11def	0.14d	0.16e	0.21c	0.17efg	0.09d	0.18a	0.016
		Cont.	0.15b	0.15cde	0.13fg	0.15bc	0.11def	0.15d	0.18cde	0.24b	0.17fg			0.316
10°	YG	Steam	0.18a	0.18bc	0.13fgh	0.19a	0.15a	0.22a	0.16e	0.21c	0.20cd	0.12abc	0.13bc	0.041
C		Water	0.18a	0.16cde	0.10i	0.12cdef	0.12cdef	0.14d	0.19cd	0.15h	0.16g	0.13ab	0.16ab	0.010
		Cont.	0.18a	0.15de	0.11hi	0.18ab	0.11cdef	0.20abc	0.18cde	0.16gh	0.18efg			0.073
	Y	Steam	0.13b	0.16cde	0.19ab	0.14cde	0.15ab	0.21ab	0.19cd	0.26a	0.22bc	0.13a	0.19a	0.161
		Water	0.13b	0.16cde	0.11ghi	0.15bcd	0.13cd	0.17cd	0.19cd	0.16gh	0.17efg	0.11bc	0.12bc	0.001
		Cont.	0.13b	0.16cdc	0.15ef	0.14cde	0.13bc	0.17cd	0.20bcd	0.15h	0.18defg			0.341
		LSD	0.03	0.04	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.04	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 11. Effect of heat treatments and the following storage temperature on water soluble pectin (%) of cactus pear fruits in 2007 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	0.21a	0.17c	0.23bcd	0.24f	0.37de	0.39def	0.25a	0.28g	0.31d			0.331
		Water	0.21a	0.17e	0.24bcd	0.31cdef	0.36de	0.41cdef	0.23a	0.29fg	0.32cd			0.275
		Cont.	0.21a	0.18de	0.26bc	0.34cdef	0.57a	0.57a	0.28a	0.34efg				0.249
5°C	YG	Steam	0.22a	0.18de	0.23bcd	0.27ef	0.34de	0.39def	0.22a	0.38defg	0.37cd			0.533*
		Water	0.22a	0.18de	0.27bc	0.28ef	0.35de	0.38def	0.24a	0.29fg	0.39bcd			0.441
		Cont.	0.22a	0.17de	0.39a	0.32cdef	0.38cde	0.43bcdef	0.28a	0.40cdef				0.387
	Y	Steam	0.30a	0.18cde	0.29b	0.29def	0.37de	0.43 bcdef	0.23a	0.38defg	0.33cd			0.192
		Water	0.30a	0.31b	0.29b	0.26ef	0.39bcde	0.41 bcdef	0.26a	0.37efg	0.38bcd			0.216
		Cont.	0.30a	0.53a	0.38a	0.38bcde	0.49abc	0.51abcd	0.26a	0.52ab				0.036
	G	Steam	0.21a	0.19cde	0.17d	0.36cdef	0.34de	0.38ef	0.25a	0.45bcde	0.48ab	0.62ab	0.59b	0.806**
		Water	0.21a	0.18de	0.20cd	0.51ab	0.45bcd	0.44bcde	0.25a	0.48abcd	0.55a	0.72a	0.70a	0.703**
		Cont.	0.21a	0.26bc	0.20cd	0.56a	0.58a	0.54ab	0.26a	0.58a	0.58a			0.422
10°C	YG	Steam	0.22a	0.21cde	0.18d	0.35cdef	0.31e	0.37ef	0.27a	0.50abc	0.53a	0.71a	0.71a	0.828**
		Water	0.22a	0.16c	0.21cd	0.30cdef	0.28e	0.30f	0.26a	0.31fg	0.33cd	0.53bc	0.50c	0.739**
		Cont.	0.22a	0.25bcd	0.29b	0.43abc	0.50ab	0.53abc	0.30a	0.54ab	0.57a			0.621*
	Y	Steam	0.30a	0.17de	0.21cd	0.26ef	0.38cde	0.45abcdc	0.23a	0.27g	0.31d	0.47c	0.47c	0.390
		Water	0.30a	0.19cde	0.29b	0.29ef	0.43bcd	0.43bcdef	0.24a	0.29fg	0.32d	0.46c	0.44c	0.312
		Cont.	0.30a	0.20cde	0.30b	0.43abcd	0.49abc	0.52abc	0.27a	0.35efg	0.41bc			0.155
		LSD	0.15	0.07	0.08	0.14	0.12	0.13	0.08	0.11	0.10	0.13	0.09	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 12. Effect of heat treatments and the following storage temperature on water soluble pectin (%) of cactus pear fruits in 2008 season

Treatment			Storage Period											
Sto. Temp.	Fruit Color	Heat. Treat.	0	4	8	12	16	20	24	28	32	36	40	r^2
	G	Steam	0.22a	0.19cd	0.26abcd	0.20h	0.35ef	0.40ef	0.24b	0.30de	0.33d			0.341
		Water	0.22a	0.16d	0.21cde	0.28defg	0.34ef	0.39ef	0.24b	0.33cde	0.35d			0.504*
		Cont.	0.22a	0.19cd	0.26abc	0.30defg	0.53a	0.56ab	0.27b	0.39bc				0.322
5°C	YG	Steam	0.24a	0.20cd	0.25abcd	0.23fgh	0.32efg	0.37f	0.25b	0.34cde	0.43bc			0.621*
		Water	0.24a	0.19cd	0.26abcd	0.25efgh	0.33efg	0.37f	0.29b	0.39cde	0.38cd			0.744**
		Cont.	0.24a	0.19cd	0.25abcd	0.29defg	0.35ef	0.39ef	0.25b	0.47ab				0.564*
	Y	Steam	0.31a	0.19cd	0.26abc	0.29defg	0.37cdef	0.41ef	0.21b	0.29e	0.33d			0.067
		Water	0.31a	0.29b	0.28a	0.23fgh	0.36def	0.40ef	0.25b	0.35cde	0.33d			0.096
		Cont.	0.31a	0.47a	0.29a	0.35bc	0.50ab	0.53bc	0.40a	0.53a				0.375
	G	Steam	0.22a	0.20cd	0.18e	0.34bcd	0.30fg	0.37fg	0.23b	0.44ab	0.47ab	0.56ab	0.52bc	0.779**
		Water	0.22a	0.17cd	0.18e	0.47a	0.38cdef	0.40ef	0.24b	0.50a	0.55a	0.64a	0.61ab	0.719**
		Cont.	0.22a	0.23bc	0.20de	0.50a	0.53a	0.59a	0.23b	0.51a	0.54a			0.382
10°C	YG	Steam	0.24a	0.20cd	0.19e	0.37b	0.26g	0.31gh	0.29b	0.29e	0.35d	0.64a	0.65a	0.626**
		Water	0.24a	0.19cd	0.20de	0.32bcd	0.25g	0.28h	0.26b	0.44ab	0.49ab	0.42bc	0.43cd	0.718**
		Cont.	0.24a	0.23bcd	0.27ab	0.49a	0.45bc	0.49cd	0.29b	0.49a	0.51a			0.500*
	Y	Steam	0.31a	0.18cd	0.25abcd	0.23gh	0.40cde	0.44de	0.25b	0.29e	0.33d	0.37c	0.42cd	0.293
		Water	0.31a	0.17cd	0.22bcde	0.30cde	0.38cde	0.41ef	0.25b	0.28e	0.31d	0.39bc	0.37d	0.261
		Cont.	0.31a	0.19cd	0.27abc	0.34bcd	0.44bcd	0.47d	0.27b	0.34cde	0.37cd			0.184
		LSD	0.17	0.07	0.06	0.07	0.08	0.05	0.08	0.09	0.08	0.16	0.10	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 13. Effect of heat treatments and the following storage temperature on PPO activity of cactus pear fruits in 2007 season

Treatment			Storage Period						
Sto. Temp.	Fruit Color	Heat. Treat.	0	8	16	24	32	40	r^2
5°C	G	Steam	0.005a	0.009def	0.018hi	0.021hi	0.008c		0.170
		Water	0.005a	0.008ef	0.017i	0.016i	0.009bc		0.233
		Cont.	0.005a	0.012bcdef	0.022fghi	0.024fgh	0.009bc		0.146
	YG	Steam	0.007a	0.008f	0.026efgh	0.020hi	0.014abc		0.260
		Water	0.007a	0.009def	0.021ghi	0.024gh	0.014abc		0.386
		Cont.	0.007a	0.012bcdef	0.026efg	0.029cdefg	0.014abc		0.269
	Y	Steam	0.009a	0.012bcdef	0.028defg	0.025efgh	0.013abc		0.152
		Water	0.009a	0.013bcdef	0.029defg	0.027defg	0.011bc		0.091
		Cont.	0.009a	0.012bcdef	0.035bcd	0.033cd	0.013abc		0.134
10°C	G	Steam	0.005a	0.011cdef	0.029def	0.032cde	0.010bc	0.008b	0.005
		Water	0.005a	0.008f	0.033cde	0.034cd	0.009bc	0.008b	0.006
		Cont.	0.005a	0.015abcd	0.038abc	0.032cdef	0.011bc		0.105
	YG	Steam	0.007a	0.013abcdef	0.030def	0.036bc	0.011bc	0.009b	0.002
		Water	0.007a	0.012bcdef	0.026efg	0.029cdefg	0.011bc	0.011ab	0.010
		Cont.	0.007a	0.018ab	0.043ab	0.043ab	0.012bc		0.103
	Y	Steam	0.009a	0.016abc	0.041abc	0.043ab	0.013abc	0.012ab	0.001
		Water	0.009a	0.014abcde	0.039abc	0.045a	0.016ab	0.015a	0.022
		Cont.	0.009a	0.019a	0.044a	0.049a	0.019a		0.205
		LSD	0.005	0.006	0.008	0.008	0.007	0.006	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

Table 14. Effect of heat treatments and the following storage temperature on PPO activity of cactus pear fruits in 2008 season

Treatment			Storage Period						
Sto. Temp.	Fruit Color	Heat. Treat.	0	8	16	24	32	40	r^2
	G	Steam	0.006b	0.007fg	0.017h	0.015h	0.006g		0.056
		Water	0.006b	0.008fg	0.018h	0.018gh	0.006g		0.064
		Cont.	0.006b	0.011bcdefg	0.022gh	0.024f	0.010f		0.176
5°C	YG	Steam	0.008ab	0.009efg	0.024fg	0.020g	0.012def		0.181
		Water	0.008ab	0.011cdefg	0.024fg	0.025f	0.013def		0.237
		Cont.	0.008ab	0.011cdefg	0.027efg	0.031d	0.015cde		0.284
	Y	Steam	0.010a	0.010defg	0.028def	0.026ef	0.012ef		0.123
		Water	0.010a	0.013bcde	0.027efg	0.029de	0.013def		0.154
		Cont.	0.010a	0.014bcd	0.035bc	0.036c	0.016cde		0.190
	G	Steam	0.006b	0.008fg	0.031cde	0.033cd	0.010f	0.010cd	0.015
		Water	0.006b	0.008fg	0.031cde	0.036c	0.012ef	0.008d	0.012
		Cont.	0.006b	0.015bc	0.033cd	0.037c	0.020ab		0.382
10°	YG	Steam	0.008ab	0.012bcdefg	0.029def	0.036c	0.017bc	0.012bcd	0.041
C		Water	0.008ab	0.012bcdef	0.030cde	0.036c	0.021a	0.014abc	0.094
		Cont.	0.008ab	0.014bcd	0.044a	0.042c	0.014cde		0.272
	Y	Steam	0.010a	0.015bc	0.042a	0.044b	0.011f	0.016ab	0.005
		Water	0.010a	0.016b	0.039ab	0.046ab	0.018abc	0.017a	0.009
		Cont.	0.010a	0.022a	0.045a	0.049a	0.011f		0.156
		LSD	0.003	0.005	0.006	0.004	0.004	0.005	

Means within columns having a common letter(s) are not significantly different. r^2 =Determination coefficient.

The above finding associated with those of Bicalho and Camargo, (1982) and Cantwell, (1995). On the other hand, Martinez-Olea, (1986) reported that WSP remained relatively constant during ripening of cactus pear fruits.

Pulp PPO Activity:

Tables 13 and 14 showed the obtained data of pulp PPO activity of cactus pear fruits (OD) The green fruits were the lowest in PPO activity at harvest and during cold storage. Heat treatments had significant effect on reducing the activity of PPO pulp enzyme and the differences were clear on the second season compared with unheated fruits. There were no significant differences between the two heat treatments in most intervals of the two seasons. With the advancing of cold storage PPO activity increased then decreased (r^2 values were not significant) after 24 days at 5 and 10 ?C due to the oxidation of phenolic compounds by PPO to form quinones that are lightly unstable and polymerize quickly.

The above results and discussion agree with those of Ingham *et al.*, (1998) on apples, El-Saedy, (2000) on peaches and El-Saedy and El-Naggar, (2005) on guava.

Stintzing *et al.*, (2001) reported that the presence of polyphenols in the juice is at the level of 393 mg / kg and it is very important for antioxidative properties.

ACKNOWLEDGEMENT

The author wish to express her thanks to the Alexandria Post-harvest Center, Pomology Department, Faculty of Agriculture (El-Shatby), Alexandria University for providing the necessary facilities, help and encouragement during the course of this work.

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الملخص العربي

تأخير ظهور أعراض أضرار البرودة وتقليل تدهور ثمار التين الشوكى أثناء التخزين المبرد باستخدام المعاملات الحرارية

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ثمار التين الشوكى لثلاث مراحل نضج هى الأخضر الفاتح والأخضر المصفر والأصفر تم معاملتها ببخار الماء عند ٧٨ °م تقريبا لمدة دقيقة واحدة أو بالماء الساخن عند ٥٥ °م لمدة دقيقتين أو بالغسيل بماء الصنبور فقط (الكنترول). كل من هذه المجاميع التسع (٣ مراحل نضج × ٣ معاملات) تم تقسيمها الى قسمين الأولى تم تخزينها على ٥ °م والثانية على ١٠ °م. المعاملات الحرارية أطالت فترة التخزين لجميع مراحل نضج الثمار على ٥ و١٠°م على التوالي حيث تم تخزين الثمار المعاملة لمدة ٣٢ و٤٠ يوم بالمقارنة ب ٢٨ و٣٢ يوم للكنترول. ثمار الكنترول كانت أول من بدأ ظهور العفن عليها نتيجة حدوث أضرار البرودة خاصة الخضراء منها والمخزنة على ٥ °م وقد فقدت الثمار مظهرها نتيجة لفقد لمعانها بينما إحتفظت الثمار المعاملة حراريا بمظهرها الجيد الخالي من العفن والكرمشة لمدة أطول. وقد أخرت المعاملات الحرارية ظهور أعراض أضرار البرودة علي الثمار المخزنة على ٥ °م وقد كان أفضل مظهر للثمار بأقل أضرار تبريد هي الثمار الصفراء. والثمار المخزنة على ١٠ °م كانت خالية من أعراض البرودة فيا عدا بعض البقع الحمراء الصغيرة على ثمار الكنترول.و المعاملة ببخار الماء قللت من فقد الوزن لثمار التين الشوكى وكانت الفروق معنوية للثمار الخضراء المصفرة فيما عدا المخزنة على ٥ °م في الموسم الأول. ومن ناحية أخرى فإن معاملة الماء الساخن أدت إلي زيادة فقد الوزن لجميع المعاملات بفروق غير معنوية مقارنة بثمار الكنترول لكنها قللت من فقد الوزن للثمار الخضراء المصفرة في الموسم الثاني. والثمار الخضراء كان لها أعلى دليل لون و المعاملة الحرارية لم تؤثر على دليل اللون لجميع المعاملات و لم يكن هناك فروق معنوية بين المعاملات الحرارية. وفى كلا الموسمي فإن الثمار الصفراء أعطت أعلى نسبة من العصير عند الجمع. والمعاملة الحرارية لم يكن لها تأثير على نسبة وزن العصير إلي وزن اللب لكن بصفة عامة فإن الثمار المعاملة ببخار الماء أعطت أعلى وزن عصير وربما يرجع ذلك نتيجة لتقليل فقد الماء. وقد فقدت الثمار عصيريتها مع تقدم التخزين فيا عدا الثمار الخضراء . وعند الجمع فإن الثمار الصفراء كان لها أعلى قيم من المواد الصلبة الذائبة والبكتين الذائب في الماء ونشاط إنزيم البولي فينول أوكسيديز و أقل نسب من الحموضة. و لم يكن هناك تأثير معنوي للمعاملات الحرارية على المواد الصلبة الذائبة ما عدا المحتوى العالي معنويا للثمار المعاملة حراريا في بعض فترات التخزين. وقد كان للمعاملات الحرارية تأثير معنوي على الحموضة خاصة المعاملة ببخار الماء والتي كان لها أعلى قيم في درجتي حرارة التخزين وفي كلا الموسمين. والمعاملات الحرارية كان لها تأثير معنوي على تقليل البكتين الذائب في لب الثمار والحموضة ونشاط إنزيم البولي فينول أوكسيديز. وقد قلت المواد الصلبة الذائبة في جميع المعاملات في كلا الموسمين مع تقدم فترة التخزين وقد كانت أعلى قيم للثمار الصفراء. وقد زادت حموضة الثمار مع نهاية فترة التخزين المبرد على ٥ °م وبعد نفس الفترة على ١٠ °م (٣٢ يوم) ثم قلت بنهاية فترتي التخزين على ١٠ °م. وقد إزداد محتوى الثمار من البكتين الذائب مع فقد الصلابة وقد كانت أقل نسبة تغير للثمار الصفراء و المخزنة على ٥ °م. وقد إزداد نشاط إنزيم البولي فينول أوكسيديز ثم قل بعد ٢٤ يوم من التخزين على ٥ و ١٠ °م.