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INTERMITTENT WARMING EFFECTS ON POST-HARVEST COLD STORAGE OF BALADI LIME FRUITS

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ABSTRACT : Several intermittent 13 ±1°C warming (IW) treatments were applied to Baladi lime fruits during 1998 and 1999 seasons. The treatments were as follows : (1) stored at constant temperature 13± 1°C, (2) stored at 7± 1°C for 4 days (d) + 3d at 13 ± 1°C , (3) stored at 7 ± 1°C for 5 d + 2d at 13 ± 1°C, and (4) stored at 7±1°C for 6 d + 1 d at 13 ± 1°C . All IW treatments decreased fresh weight losses (FWL) percent , fruit decay (FD) percent and total acidity, the most clear reductions were associated with IW treatment (6d at 7±1°C +1d at 13±1°C) in the two tested seasons. Meanwhile, IW treatments increased respiration rate , TSS , peel and pulp firmness , the highest values were due to the treatment No. 4 in the two seasons. Fruit juice (%), juice volume obtained from one kg fruits , pH values and ascorbic acid content were increased with all IW treatments in the second season only. Moreover, during the following shelf life at 20°C and 60 - 70 % RH , all IW treatments increased the FWL, peel and pulp firmness , TSS and juice volume obtained from one kg fruits compared with fruit stored at constant temperature (13±1°C) in both seasons, but fruit juice (%) and arcorbic acid content were increased with all IW treatments in the second season only. An increase in total acidity and pH value was detected during shelf life after all IW treatments.

INTRODUCTION

Baladi lime is one of the most important citrus cultivars. Egyptian consumers prefere it rather than lemon due to its high acidity and small fruit size. There is a constant demand for Baladi lime fruits throughout the year in Egypt and Arab countries. As such lime growers tried to use some agricultural treatments to prolong the lime marketing period and, hence , to obtain higher prices. The usually used fostening treatment proved to be harm full for trees. Prolonged refrigeration at 12-13°C may lead to hgih fresh weight lossess, peel shriveling and a high incidence of decay resulting in unmarketable fruit. Conversely, long -term storage at lower temperatures favours chilling injury (CI) development .

Investigation with various horticultural crops have shown periodic interruption of cold storage by fruit exposure to short periods of warming to prevent or reduce CI development and maintain fruit quality for longer period (Wang, 1993). The greatest difficulty in creating optimum conditions with intermittent warming (IW) during storage lies in the need to operate with temperature duration and IW frequency that may greatly change according to cultivar. The technique of lemon storage at 2°C with warming at 13°C has been adopted as a commercial method in Israel (Cohen , 1988).

Storage of lemon at 13 , 8 and 2°C (IW) was used to prevent CI at the lowest temperature (Cohen *et al.* , 1990). Also, the best storage of Murcatt mandarin fruit was at 6°C for six days + 14°C for one day ; longer or shorter temperature cycle caused greater CI (Arras and Usai 1991). In addition, Thompson Navel orange fruits indicated significantly lower CI and respiratory rates when stored under temperature cycles, rather than under constant temperature. Rot , ethanol, acidity and the penetrometirc index of Thompson Navel orange fruits were highly significantly intercorrelated as were CI, TSS , pH and ascorbic acid contents of the juice (Arras and Usai, 1992).

Weight loss in Fortune tangarin fruits was significantly higher under the cyclical regime compared with constant low temperature (Arras and Usai, 1993 ; Mulas and Ibba, 1994). Reduction in Primofiory lemon fruits decay was the best with two cycles of 2 weeks at 2°C and 2 weeks at 13°C; the ascorbic acid increased, but soluble solid concentration, pH and titratable acidity were not changed (Artes *et al.*, 1993).

IW delayed the onset of CI of Olinda orange fruits by 10 weeks when stored with cycles of 3 weeks at 3°C followed by 2 weeks at 15°C compared with continuous storage at 3°C (chilling temperature). TSS and titrable acidity were not significantly affected by temperature storage condition. Respiration rates of fruit under IW treatments were almost the same over the whole storage period, while decreased in fruit stored at constant temperature (Schirra and Cohen, 1999).

In Egypt, lime fruits, generally, reach their highest prices in April (the time of Eastermonday) and then lower price in August to December (time of recropping) .

This experiment aimed to store Baladi lime fruits from December to April . Fruit quality including fresh weight losses, fruit decay, pulp and peel firmness, peel carotenoids content, fruit juice percentage, total and activated acidity of juice, juice TSS and

respiration rate were evaluated during 7 months of storage.

MATERIALS AND METHODS

This study has been carried out during the 1998 and 1999 seasons on Baladi lime fruits. The fruits were harvested at late December from a private orchard at Abou-Kabeer district, Sharkia Governorate, Egypt. The trees were 20-year-old, grown in silty - loam soil at five meters apart and were irrigated with Nile water using the traditional basin irrigation system. The trees received the standard horticultural care during the two seasons.

Harvesting took place early in the morning in December, using a small clipper and packed in plastic boxes. Fruits were directly taken to Post-Harvest Laboratory in Horticulture Department, Faculty of Agriculture, Zagazig University.

All fruits were washed with water and soap and then rinsed with water to remove the residue of soap . All fruits then dipped in 1000 ppm Thiobendazole (TBZ) for 15 minutes.

Defect - free fruits were selected and divided into four groups comprised 630 fruits, bagged in perforated (0.5% of the area) polyethelene bags, each bag contained 30 fruits. The four main fruit groups csrresponded the following four treatments :

1. Stored under constant temperature (13 ±1°C) .
2. Stored under 7 ± .1°C for four days, than under 13 ± 1°C for three days.
3. Stored under 7 ± 1°C for five days and under 13 ±1°C for two days .
4. Stored under 7 ± 1°C for six days and under 13 ± 1°C for one day.

After each month of cold storage , samples from each treatment were randomly taken (three bags =90 fruits) to evaluate the effects of cold storage period .

Beginning with the fourth month, of cold storage fruit characters were investigated after 7 days under conditions of 20°C and 60-70% relative humidity (RH) in an incubator (the same as supermarket conditions) for detecting the effect of shelf life.

Evaluation of cold storage period and shelf life effects on Baladi lime fruits were carried out through the following parameters :

1. Fresh weight losses (FWL) %: The fruits were weighed before cold storage , after each month of cold storage and after one week of the shelf life; the fresh weight losses (%) at each period were calculated.
2. Fruit decay (%) : Decay incidence was assessed as total rots caused by *Penicillium italicum*

Wehmer, *P. digitatum* Sacc., *Botrytis cinerea* Pers, Exfr. or as miscellaneous rots of unidentified fungi and calculated as:

$$\frac{\text{Weight of decayed pat of fruit}}{\text{Total fruit weight}} \times 100$$

3. Respiration rate : five fruits from each replicate were randomly taken and placed in 0.9 L glass jars (respiratory chambers) mounted in groups of four, three out of four were used for the respiratory rate determination while the fourth one was used as the air blank. The air stream from each jar, was passed through two gas dispersion tubes connected in series (double trap) containing 0.1*N* barium hydroxide and 0.2% barium chloride solution. CO_2 output was recorded by titration and respiration rate was calculated as mg CO_2 $kg^{-1}h^{-1}$. Respiration rates of fruits were determined under 20°C.

4. Percentage of juice : juice was extracted from randomly taken lime fruits per replicate . Juice content was expressed as percent of fruit weight (w/w).

5. Volume of juice obtained from one kg fruits : juice content was expressed as volume of juice extracted from one kg fruits.

6. Juice total acidity : acidity was determined by titrating an aliquot of juice against 0.1*N* NaOH and the result were expressed as (9m) citric acid per 100 ml juice according to A.O.A.C. (1960).

7. Juice active acidity (pH) : it was determined using a digital pH meter (style Hanna 8514).

8. Juice total soluble solids content (TSS) : was determined 0.92 using a hand refractometer.

9. Ascorbic acid (Vitamin C) content : was determined by titration against 2,5 dichlorophenol - indophenol, using 2% oxalic acid solution as substrate . Ascorbic acid was calculated as milligrams per 100 ml of juice (Lucoss , 1944).

10. Peel and pulp firmness : Peel of fruit was removed , the firmness was determined for each of the peel and the pulp separately using pushpull dynamometer McCormick (Model FT 327) with plunger tip 5/16. The rind oil rupture pressure (RORP), i.e. the amount of pressure required to cause rupture of the oil cells on the surface of a rind was determined. Reedings were taken from four different locations, on each of five fruits per replicate. Their average was expressed as (Lb).

11. Rind total carotenoids : was numerically expressed through

determination of carotenoids pigments in the peel according to Wettestein (1957).

Statistical analysis :The complete randomized block design with 3 replicates and with factorial arrangement was followed through the whole work (Snedecor and Cochran, 1980). The means representing the effect of tested treatments were compared by Duncan's multiple range test at $P \leq 0.05$.

RESULTS AND DISCUSSION

1. Fresh Weight Loss (FWL)

1.1 During cold storage

As shown in Table 1 FWL in both seasons was lowermost after one month of cold storage, while it gradually increased with increasing storage period. It is also clear that IW treatment for six d. in 7°C and one d. in 13°C revealed the lowest FWL % in comparison with other treatments . This was true in the two seasons during four months of cold storage. However , the differences between treatments were significant in the second season only. No significant difference was detected between the two treatments (zero d. at 7°C and six d. at 13°C) and (five d. at 7 °C and two d. at 13°C) in the first season. However, in the fifth month, the only significant decrease in FWL was noticed with the treatment (six d. at 7°C and one d. at 13°C) ; this was true in both seasons.

The interaction between cold storage period and storage temperature was significant in the two seasons. The highest losses came from all treatments after four months of cold storage , while the least values were recorded by all tested treatments after one or two months specially with (six d. at 7°C and one d. at 13°C).

1.2 After one week of shelf life

Data in Table 1 indicated in significant differences between all treatments after shelf life in the second season. However, a significant increase in FWL after shelf life can be observed after five months of cold storage in the first season only.

The reduction in FWL during cold storage with the treatment (six d. at 7°C and one d. at 13°C) may be due to the long exposure to low temperature (7°C) . Analogical results were obtained by Arras and Usai (1991, 1993) and Mulas and Ibba (1994) on Murcott mandarins and Fortune tangarins.

2. Fruit Decay (%) (FD)

2.1 During cold storage

From Table 1 , it is clear that FD (%) was increased with prolonging the cold storage period, the same trend was shown above for weight loss . The FD was 15.69% after four months and reached 68.64% after seven months in the

first season . The same trend was detected in the second season.

Fruits stored at 13°C for seven months consistantly showed the highest decay (%) in both seasons. While the two treatments (five d. at 7°C and two at d.13°C) and (six d. at 7°C and one at d. 13°C) greatly depressed decay percent . It could be suggested that increasing period of 7°C led to decrease FD percentage in both seasons .

The interaction was significant in the two tested seasons. The highest value came from (seven d. at 13°C) after seven months . The lowest values came from all IW treatments during the first four months as well as from the two treatments (five d. at 7°C and two d at 13°C) and (six d. at 7°C and one d. at 13°C) after five months in both seasons.

2.2 After one week of shelf life

An increase in FD (%) was observed after shelf life with the treatment of constant 13°C after 5 months of cold storage in the first season only compared with the all IW treatments .

These results are in good line with those obtained by Arras and Usai (1992) and Shirra and Cohen (1999).

3. Pulp and Peel Firmness

3.1 During cold storage

As shown in Table 2, pulp and peel firmness were decreased gradually as cold storage period increased. However, the rate of this reduction was more pronounced in pulp than in peel. Pulp firmness decreased from 4.36 and 4.01 Lb. after one month to 3.79 and 3.39Lb. after four months of cold storage in the first and second seasons, respectively. Meanwhile, peel firmness decreased from 7.35 and 7.76 Lb. after one month to 6.97 and 7.20Lb. after four months of cold storage in the first and second seasons, respectively.

The effect of IW on pulp and peel firmness was clear. All IW treatments significantly increased pulp and peel firmness during the early four months of cold storage compared with the treatment of constant 13°C. The two treatments (five d at 7°C and two d at 13°C) and (6d at 7°C and 1 d. at 13°C) significantly increased pulp firmness in both seasons compared with the treatment of (seven day at 13°C).

The interaction (treat. X period) was significant in the two seasons. The highest values of pulp and peel firmness were obtained from all treatments after one and two months of cold storage, but the lowest one came from treatment without IW after four months of cold storage in both seasons.

3.2 After one week of shelf life

The IW treatment of (six d at

7°C + one d. at 13°C) gave the highest values of pulp and peel firmness in the two tested seasons after one week shelf life following four and five months of cold storage , but such increments were insignificant in all cases.

These result are in line with those obtained by El-Zeftawi *et al.* (1989) who reported that Valencia orange fruits subjected to IW treatment (13 weeks at 15°C + 15 weeks at 3°C) produced softer fruits than IW treatment (15 weeks at 5°C + three week at 15°C). The latter treatments gave fruits as firm as those subjected to treatments (5°C for nine weeks + 15°C for nine weeks) or (5°C for 18 weeks). The increase in pulp and peel firmness after IW treatment may be due to the exposure to the lower temperature for longer time during cold storage which delays the ripening process and ethylene production and consequently increase firmness.

4. Fruit Juice Percent

4.1 During cold storage

It is clear from Table 4 that fruit juice percentages were increased with increasing cold storage period in the two tested season.This came true after three and four months of cold storage compared with one and two months of storage.

All IW storage treatments increased fruit juice percentage significantly in the second season . The IW treatments (7°C for six d + 13°C for one d) increased significantly the fruit juice % during the two seasons. The differences between all treatments were insignificant after 5 months of cold storage.

The interaction (treat x period) was significant in the two seasons. The highest values came from all treatments during the early two months of cold storage. While the lowest values came from the treatment (constant 13°C) after three and four months of cold storage in both seasons.

4.2 After one week of shelf life after cold storage period

The data also indicate significant increment in fruit juice (%) after shelf life following four months of cold storage under IW treatment (7°C for six d + 13°C for one d); this was true in both seasons. On the other hand, no significant differences could be detected between all IW treatments after shelf life following five months of cold storage.

The obtained results are in line with those obtained by Cohen *et al.* (1990) who reported that worming lemons during storage at low temperature increased juice content.

The increment in fruit juice

% with the IW treatments may be due to the low fresh weight loss which related to high water content of fruit that in turn led to higher fruit juice percentage.

5.Juice Volume From one kg Fruits (JV)

5.1 During cold storage

Table 4 shows clear decrease in JV with the advance in cold storage period during the two tested seasons. This might be due to the increment in fresh weight losses during cold storage period.

All IW treatments increased significantly JV compared with treatment stored in constant 13°C, but in the second season only. However, IW treatment (7°C for six d + 13°C for one d) increased JV significantly in both season.

The interaction (treatment x period) was significant in the two tested seasons . The highest values came from all treatments during the early two months of cold storage, while the lowest values came from constant temperature treatment after three and four months of cold storage.

5.2 After one week shelf life

No significant differences could be treated after the shelf life following five months of cold storage between IW treatments during the two tested seasons. However, a significant increment in JV was observed with the IW treatment (7°C for six d + 13°C for one d) after shelf life following 4 months of cold storage in both seasons.

This increment in JV with the IW treatment may be due to the effect of long term storage in low temperature on fruit water content .

6.Juice Total Soluble Solids Content (TSS)

6.1. During cold storage

Table 5 shows significant increase in TSS with the advance in cold storage periods during the two tested seasons.

The tested treatments obviously affected TSS % in the two seasons. The two treatments (7°C for five d and 13°C for two d) and (7°C for six d and 13°C for one d) significantly increased TSS % during the four months compared to other treatments in the first season only. Meanwhile, the treatments (7°C for four d and 13°C for three d) and (7°C for five d and 13°C for two d) significantly increased TSS % in the second seasons only .

The interaction (PxT) was significant in the two seasons. The uppermost values came from the treatment (7°C for six d and 13°C for one d) after four months of cold storage. The lower most values were obtained by all treatments after one month of cold

storage and with the constant 13°C all after one, two and three months.

6.2 After one week of shelf life

The data showed no clean effect of IW on the TSS% after shelf life in the two seasons; no actual trend can be detected.

7.Juice Ascorbic Acid (V.C) Content

7.1 During cold storage

Data in Table 5 showed significant reduction in juice VC content with the advance in cold storage period during the five months in both seasons.

The three IW treatments indicated significant increases in the second season compared with the constant 13°C. Meanwhile, reductions in juice VC content were shown in the first season with all the IW treatments compared with the constant 13°C.

The interaction (period x treatment) was significant in the two tested seasons. The uppermost values came from all treatments during the early two months of cold storage. The lowermost values were obtained in the third and fourth months of cold storage with all treatments.

7.2 After one week shelf life

The data revealed that juice VC content was increased after shalf life by all IW treatments after five weeks of cold storage.

The obtained results are in line with those reported by Arras and Usai (1992) and Artes *et al.* (1993).

8. Juice Total Acidity and Activated Acidity (pH)

8.1 During cold storage

Data in Table 6 revealed a significant decrease in juice total acidity and a significant increase in pH values with the advances in cold storage periods .

As for the IW treatments , the results showed a significant decrease in juice total acidity compared with the constant temperature in the first season. On the other hand, a significant increase in juice acidity was observed with the two IW treatments (7°C for four d + 13°C for three d, 7°C for five d + 13°C for two d) in the second season . The IW treatment (7°C for six d + 13 °C for one d) indicated a significant decrease in both seasons.

Regarding the juice activated acidity , a significant increment in pH value was observed with the two IW treatments ; i.e. 7°C for five d + 13 °C for two d and 7°C for six d +13°C for one d compared with the two other treatments in the first season. However,

Table 1. Effect of intermittent warming treatments on fresh weight losses (%) and fruit decay (%) in Baladi lime fruits during cold storage period and shelf life (1998 and 1999 seasons).

Treatments regim within each week in days (d)		*Fresh weight loss (%)								**Fruit decay (%)											
		Cold storage period (months)						Shelf life for one week		Cold storage period (months)								Shelf life for one week			
7± 1°C	13± 1°C	1	2	3	4	Treat av.	5	4+ 1w	5+ 1w	1	2	3	4	5	6	7	Treat av.	4+ 1w	5+ 1w	6+ 1w	7+ 1w
										First season (1998)											
		h	g	f	ab	B		A					e	d	b	a	A	5.82	-*	-	-
Od	7d	4.01	6.13	7.27	11.31	7.18	-	6.45	-	0	0	0	31.49	58.92	69.63	76.66	33.81				
		h	g	d	a	A	A	A	B				h	f	d	b	B	0	0	-	-
4d	3d	4.13	5.98	8.21	11.45	7.44	14.58	6.50	9.48	0	0	0	11.34	22.42	59.61	68.48	23.12				
		h	g	de	b	B	A	A	B				h	fg	d	c	C	0	0	-	-
5d	2d	4.05	5.87	7.82	10.94	7.17	14.53	6.67	9.66	0	0	0	10.12	19.77	58.08	65.29	21.89				
		h	g	e	c	C	B	A	A				h	g	d	c	C	0	0	-	-
6d	1d	4.06	5.82	7.68	10.25	6.95	13.48	6.78	9.80	0	0	0	9.81	18.33	56.84	64.13	21.30				
		D	C	B	A								D	C	B	A					
Period av.		4.06	5.95	7.74	10.99								15.69	29.86	61.04	68.64					
										Second season (1999)											
		i	f	d	a	A		A					c	c	a	a	A				
Od	7d	4.03	6.59	7.82	12.02	7.63	-	7.29	-	0	0	0	44.16	62.71	72.32	75.46	36.37	0	-	-	-
		j	g	d	b	B	A	A	A				h	f	c	b	B				
4d	3d	3.50	6.13	8.08	11.24	7.24	14.0	7.30	10.28	0	0	0	18.16	31.78	60.79	65.83	25.22	0	0	-	-
		k	h	d	b	C	A	A	A				h	f	c	b					
5d	2d	2.90	5.01	7.88	11.00	6.70	13.87	7.39	10.44	0	0	0	17.95	30.04	58.65	64.80	24.49	0	0	-	-
		k	i	e	c	D	B	A	A				i	g	d	b	C				
	1d	2.73	4.01	6.93	9.57	5.81	11.80	7.51	10.51	0	0	0	14.87	28.51	55.49	63.62	23.18	0	0	-	-
		D	C	B	A								D	C	B	A					
Period av.		3.30	5.43	7.68	10.96								23.73	38.26	61.81	67.42					

*The treatment was terminated after the decay of 50% of fruits

** The treatments were continued for 7 months to follow up fruit decay over 50%

Table 2. Effect of intermittent warming treatments on pulp and peel firmness in Baladi lime fruits during cold storage period and shelf life (1998 and 1999 seasons).

Treatments regim within each week in days (d)		* Pulp firmness (Lb)								* Peel firmness (Lb)							
		Cold storage period (months)						Shelf life for one week		Cold storage period (months)						Shelf life for one week	
7± 1°C	13± 1°C	1	2	3	4	Treat av.	5	4+ 1w	5+ 1w	1	2	3	4	Treat av.	5	4+ 1W	5+ 1W
First season (1998)																	
Od	7d	a	cde	fgh	j	C		B	-	ab	be	dg	g	B		A	-
		4.35	4.07	3.93	3.73	4.02	-	3.55	C	7.31	7.16	7.06	6.91	7.11	-	6.72	A
4d	3d	a	bcd	efg	ij	BC	B	AB	3.43	ab	be	efg	fg	AB	A	A	6.66
		4.34	4.15	3.96	3.77	4.05	3.58	3.62	B	7.33	7.18	7.05	6.94	7.12	6.81	6.79	A
5d	2d	a	bc	ef	hij	AB	AB	A	3.49	a	ad	cf	efg	AB	A	A	6.74
		4.36	4.18	4.00	3.82	4.09	3.64	3.67	A	7.37	7.23	7.12	7.01	7.18	6.88	6.86	A
6d	1d	a	b	aef	ghi	A	A	A	3.54	a	abc	cde	efg	A	A	A	6.77
		4.39	4.20	4.03	3.86	4.12	3.69	3.7		7.40	7.27	7.13	7.03	7.20	6.90	6.90	
Period av.		A	B	C	D					A	B	C	D				
		4.36	4.15	3.98	3.79					7.35	7.21	7.09	6.97				
Second season (1999)																	
Od	7d	ab	d	ef	g	B		C		b	ef	g	h	B		B	
		3.95	3.73	3.53	3.33	3.63	-	3.21	-	7.63	7.30	7.10	6.94	7.24	-	6.74	-
4d	3d	a	cd	e	g	A	A	BC	A	a	bc	de	f	A	A	A	B
		4.01	3.81	3.60	3.37	3.69	3.22	3.25	3.14	7.77	7.60	7.43	7.25	7.51	7.12	7.09	6.95
5d	2d	a	cd	e	g	A	A	AB	A	a	b	d	ef	A	A	A	AB
		4.03	3.83	3.61	3.41	3.72	3.26	3.29	3.18	7.82	7.62	7.46	7.29	7.54	7.17	7.14	7.01
6d	1d	a	bc	e	fg	A	A	A	A	a	b	cd	ef	A	A	A	A
		4.05	3.85	3.62	3.44	3.74	3.29	3.32	3.21	7.83	7.63	7.48	7.32	7.56	7.21	7.17	7.06
Period av.		A	B	C	D					A	B	C	D				
		4.01	3.80	3.59	3.39					7.76	7.54	7.36	7.20				

*The treatment was terminated after the decay of 50% of fruits

Table 3. Effect of intermittent warming treatments on fruit respiration rate and peel carotenoids content in Baladi lime fruit during cold storage period and shelf life (1998 and 1999 seasons).

Treatments regim within each week in days (d)		* Respiration rate mg CO_2/kg/ hours						* Peel carotenoids content							
		Cold storage period (months)						Cold storage period (months)						Shelf life for one week	
7±1 °C	13± 1°C	1	2	3	4	Treat av.	5	1	2	3	4	Treat av.	5	4+ 1W	5+ 1W
							First season (1998)								
		k	j	i	h	D		fg	cf	abc	a	A		A	
Od	7d	14.58	16.73	17.83	18.96	17.03	-	0.58	0.62	0.67	0.71	0.64	-	0.74	-
		i	p	d	b	C	B	g	efg	bf	abc	B	A	A	B
4d	3d	18.19	20.89	23.15	24.88	21.78	25.20	0.56	0.60	0.63	0.67	0.61	0.71	0.69	0.74
		i	p	d	ab	B	B	fg	dg	ae	ab	AB	A	A	AB
5d	2d	18.34	21.12	23.38	25.33	22.04	25.93	0.57	0.61	0.65	0.68	0.63	0.72	0.70	0.75
		g	e	c	a	A	A	efg	bf	ae	a	A	A	A	A
6d	1d	20.13	22.33	24.07	25.77	23.08	26.83	0.60	0.63	0.66	0.69	0.64	0.73	0.72	0.77
		D	C	B	A			D	C	B	A				
Period av.		17.81	20.27	22.11	23.74			0.58	0.61	0.65	0.69				
							Second season (1999)								
		j	i	f	a	D		j	ghi	bed	a	A		A	
Od	7d	15.07	17.14	19.99	22.32	18.63	-	0.50	0.58	0.67	0.75	0.62	-	0.79	-
		i	gh	e	c	C	C	if	fi	cf	abc	A	A	A	A
4d	3d	17.66	19.20	21.51	23.33	20.42	24.01	0.53	0.59	0.64	0.70	0.61	0.75	0.73	0.77
		h	f	d	b	B	A	ig	eh	cbe	ab	A	A	A	A
5d	2d	18.86	20.30	22.19	24.18	21.34	24.99	0.54	0.60	0.65	0.71	0.63	0.77	0.74	0.79
		g	e	c	a	A	A	hij	dg	be	a	A	A	A	A
6d	1d	19.35	21.02	23.05	25.54	22.24	26.63	0.55	0.61	0.66	0.73	0.64	0.78	0.76	0.80
		D	C	B	A			D	C	B	A				
Period av.		17.69	19.42	21.68	23.84			0.53	0.60	0.65	0.72				

*The treatment was terminated after the decay of 50% of fruits

Table 4. Effect of intermittent warming treatments on fruit juice (%) and juice volume obtained from one kilogram fruits in Baladi lime fruits during cold storage periods and shelf life (1998 and 1999 seasons).

Treatments regim within each week in days (d)		* Fruit juice (%)								* Juice volume (cm^3) obtained from 1kg fruit							
		Cold storage period (months)						Shelf life for one week		Cold storage period (months)						Shelf life for one week	
7± 1°C	13± 1°C	1	2	3	4	Treat av.	5	4+ 1w	5+ 1w	1	2	3	4	Treat av.	5	4+1W	5+1W
First season (1998)																	
		abe	ad	de	e	AB		B		ab	be	fig	j	B	-	B	
Od	7d	49.69	49.30	48.65	48.36	49.00	-	48.16	-	487.8	484.0	477.5	474.5	481.0	A	472.7	-
		ad	ae	de	e	B	A	B	A	bcd	cf	gj	ij	B	472.1	B	A
4d	3d	49.44	49.16	48.70	48.36	48.92	48.11	48.14	47.90	485.4	482.7	478.0	474.7	480.2	A	472.7	470.2
		ab	ad	cde	de	AB	A	AB	A	ab	be	fi	rig	B	474.9	AB	A
5d	2d	49.72	40.31	48.83	48.57	49.11	48.39	48.38	48.10	488.3	484.1	479.2	476.7	682.1	A	474.9	471.2
		a	abc	ae	bc	A	A	A	A	a	abc	ag	eg	A	476.1	A	A
6d	1d	49.95	49.60	49.11	48.89	49.39	48.51	48.69	48.27	490.6	487.0	482.2	480.0	484.9		478.0	473.9
		A	A	B	B					a	B	C	D				
Period av.		49.70	49.34	48.82	48.55					488.0	484.5	479.2	476.5				
Second season (1999)																	
		ab	ab	c	c	B	-	B	-	ad	def	h	i	C		D	
Od	7d	50.19	49.74	48.18	47.70	48.95		A	47.48	A	491.9	487.4	471.8	467.0	479.5	-	464.8	-
		a	ab	ab	c	A	48.27	A	48.05	abc	be	ef	g	B	B	C	A
4d	3d	50.31	50.01	49.57	48.90	49.70	A	48.57	A	493.0	490.1	485.6	479.0	486.9	472.5	476.6	470.5
		a5	a	ab	ab	A	48.61	A	48.42	ab	abc	cf	f	A	AB	B	A
5d	2d	0.52	50.31	49.85	49.39	50.02	A	49.01	A	495.2	493.1	488.6	483.9	490.2	476.0	480.0	474.2
		a	a	ab	ab	A	49.01	A	48.80	a	ab	be	ef	A	A	A	A
6d	1d	50.70	50.53	50.03	49.59	50.02		49.41		497.0	495.3	490.3	485.9	492.1	479.0	483.3	475.9
		A	A	B	B					A	B	C	D				
Period av.		50.43	50.15	49.41	48.90					494.3	491.5	484.1	479.0				

*The treatment was terminated after the decay of 50% of fruits

Table 5. Effect of intermittent warming treatments on total soluble solids (TSS) and ascorbic acid (VC) content in juice of Baladi lime fruit during cold storage period and shelf life (1998 and 1999 seasons).

Treatments* regim within each week in days (d)		Total soluble solids (TSS)								Ascorbic acid (VC)							
		Cold storage period (months)						Shelf life for one week		Cold storage period (months)						Shelf life for one week	
7± 1°C	13± 1°C	1	2	3	4	Treat av.	5	4+ 1w	5+ 1w	1	2	3	4	Treat av.	5	4+1W	5+1W
First season (1998)																	
Od	7d	h 9.00	gh 9.23	eh 9.50	cf 9.83	C 9.39	-	A 9.66	-	a 59.81	bcd 57.71	efg 55.48	ghi 53.54	A 56.63	-	A 52.78	-
4d	3d	h 9.00	eh 9.50	dg 9.66	cf 9.83	C 9.50	B 10.07	B 9.00	A 9.83	abc 58.99	de 56.57	fi 54.05	i 52.14	B 55.44	B 50.33	B 51.38	C 49.70
5d	2d	h 9.00	cf 9.83	ab 10.17	abc 10.33	B 9.83	AB 10.60	A 9.66	A 9.83	ad 58.04	def 56.09	fgh 54.39	hi 52.93	B 55.36	AB 51.12	AB 52.18	B 50.42
6d	1d	fgh 9.33	bc 10.00	ab 10.50	a 10.67	A 10.13	A 10.83	A 9.80	A 10.00	ab 59.14	cde 57.00	efg 55.25	ghi 53.67	AB 56.26	A 51.87	A 52.91	A 57.17
Period av.		C 9.08	B 9.64	A 9.95	A 10.17					A 59.00	B 56.84	C 54.79	D 53.07				
Second season (1999)																	
Od	7d	hi 9.16	fgh 9.36	dg 9.50	cdc 9.76	B 9.45	-	AB 9.73	-	d-g 56.38	fgh 54.58	hi 53.87	i 52.43	B 54.31	-	C 52.13	-
4d	3d	fgh 9.33	dg 9.50	cd 9.76	a 10.67	A 9.81	A 10.73	A 10.13	A 10.67	abc 59.14	de 56.99	ef 54.97	hi 53.82	A 56.23	B 52.03	B 53.43	C 51.57
5d	2d	fgh 9.36	cde 9.70	bc 9.93	b 10.10	A 9.77	B 10.17	AB 10.10	AB 10.17	ab 59.34	cd 57.19	dg 56.17	ghi 54.26	A 56.74	A 52.47	AB 53.91	B 52.03
6d	1d	i 9.00	ghi 9.26	eh 9.40	cd 9.63	B 9.32	B 10.00	B 9.63	B 10.00	a 59.52	bcd 57.34	def 56.44	fi 54.54	A 56.96	A 52.64	A 54.09	A 52.22
Period av.		D 9.21	C 9.45	B 9.65	A 10.04					A 58.39	B 56.53	C 55.36	D 53.76				

*The treatment was terminated after the decay of 50% of fruits

Table 6. Effect of intermittent warming treatments on total acidity as citric acid and activated acidity (pH) in juice of Baladi lime fruits during cold storage period and shelf life (1998 and 1999 seasons).

Treatments days in cold storage temperature		Total acidity as citric acid								Activated acidity (pH)							
		Cold storage period (months)						Shelf life for one week		Cold storage period (months)						Shelf life for one week	
7±1 °C	13± 1°C	1	2	3	4	Treat av.	5	4+ 1w	5+ 1w	1	2	3	4	Treat av.	5	4+ 1W	5+ 1W
First season (1998)																	
		a	b	def	ij	A		B		d	c	a	a	A		A	
Od	7d	8.97	8.69	8.11	7.15	8.23	-	7.05	-	2.35	2.64	2.79	2.80	2.64	-	2.85	-
		bc	efg	h	j	C	C	C	C	d	c	ab	a	AB	A	AB	A
4d	3d	8.48	8.01	7.47	6.90	7.72	6.42	6.76	6.32	2.32	2.62	2.77	2.80	2.63	2.80	2.81	2.80
		cde	g	h	hi	C	B	B	B	d	c	ab	ab	B	A	B	A
5d	2d	8.27	7.87	7.49	7.24	7.71	7.03	7.08	6.90	2.33	2.63	2.75	2.76	2.61	2.80	2.77	2.80
		cd	cf	fg	g	B	A	A	A	d	c	b	ab	B	A	AB	A
6d	1d	8.34	8.20	7.98	7.81	8.08	7.45	7.66	7.16	2.33	2.61	2.72	2.75	2.60	2.80	2.79	2.80
		A	B	C	D					C	B	A	A				
Period av.		8.52	8.18	7.76	7.27					2.33	2.62	2.76	2.78				
Second season (1999)																	
		c	ef	f	f	C		B		f	de	c	b	C		B	
Od	7d	7.67	7.31	7.23	7.19	7.35	-	7.09	-	2.66	2.73	2.92	3.05	2.84	-	3.05	-
		a	b	cd	def	A	A	A	A	de	d	c	a	A	A	A	A
4d	3d	8.44	7.93	7.57	7.37	7.82	7.29	7.25	7.22	2.75	2.78	2.91	3.13	2.89	3.18	3.16	3.23
		b	cd	cde	f	B	B	B	B	ef	de	c	a	BC	A	A	A
5d	2d	8.05	7.56	7.50	7.23	7.58	6.87	7.13	6.78	2.70	2.75	2.89	3.10	2.86	3.19	3.12	3.24
		cd	de	g	g	D	C	C	C.	de	d	c	a	AB	A	A	A
6d	1d	7.56	7.47	7.00	6.86	7.22	6.55	6.74	6.43	2.74	2.47	2.87	3.10	2.87	3.18	3.12	3.25
		A	B	C	D					D	C	B	A				
Period av.		7.93	7.56	7.32	7.16					2.71	2.75	2.90	3.09				

*The treatment was terminated after the decay of 50% of fruits

significant increments in pH values can be detected with all the three IW treatments in the second season.

The interaction between period and treatments was significant in the two seasons for the total and activated acidity and took the same trend as main factors.

8.2 After one week shelf life

The juice total and activated acidity failed to reveal any actual trend with all tested treatments .

In this regard Artes *et al.* (1993) who treating Primofiori lemons in cold storage with intermittent warming reported that pH and titratable acidity did not change relative to values at harvest. Similar results were also found by Schirra and Cohen, (1999).

Conclusively, the obtained results give basis to recommend IW storage of Balady lime , i.e. bee pries fruits under 7±1°C for six days each week and under 13 ± 1°C for the following one day. This treatment significantly reduced FWL after 4 weeks of storage to reach 10.25 & 9.57 % organisms 11.31 & 12.02% for constant 13 ± 1°C in the two seasons, respectively . The same IW treatment depressed FD to 9.87% against 31.49 & 44.16%, respectively. However the same IW treatment increase of respiration rate, juice percentage and juice volume in the two seasons compared with the constant 13± 1°C . In addition , such IW treatment also significantly increased TSS % and total acidity, but in the fruit season only.

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تأثير التدفئة المتقطعة تحت ظروف التخزين المبرد على ثمار الليمون البلدى

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أجريت عده معاملات تخزينية مع استعمال التدفئة المتقطعة على ثمار الليمون البلدى خلال موسمى ١٩٩٨ ، ١٩٩٩ كانت المعاملات كالتالى ١- ثمار خزنت فى حراره ثابته ١٣ ± ٥١° م ٢- ثمار خزنت على درجة ٧ ± ٥١° م لمدة ٤ أيام + ٣ أيام على درجة ١٣ ± ٥١° م ٣- ثمار خزنت على درجة ٧± ٥١° م لمدة ٥ أيام + ٢ يوم على درجة ١٣ ± ٥١° م ٤- ثمار خزنت على درجة ٧ ± ٥١° م لمدة ٦ أيام + ١ يوم على درجة ١٣ ± ٥١° م.

أظهرت النتائج أن جميع معاملات التدفئة (المعاملات ٢، ٣، ٤) قللت من نسبة الفقد فى الوزن الطازج ، ونسبة تلف الثمار ، والحموضة الكلية ، وأظهرت المعاملة رقم ٤ أكبر تأثير فى كلا الموسمين . كما أدت معاملات التدفئة المتقطعة (المعاملات ٢ ،٣، ٤) إلى زيادة كل من معدل التنفس ، والمواد الصلبة الذائبة الكلية ، ودرجة صلابة كل من اللب والقشرة ، وكانت أعلى زيادة أيضاً مع المعاملة رقم ٤ وأظهرت النتائج أيضاً أن معاملات التدفئة المتقطعة أدت إلى زيادة كل من نسبة العصير ، وحجم العصير المتحصل عليه من ١ كجم ثمار والحموضة الفعلية وفيتامين جـ فى الموسم الثانى فقط وقد أدت جميع معاملات التدفئة المتقطعة وخلال فترة العرض على درجة ٢٠° م و ٦٠ - ٧٠ ٪ رطوبة نسبية إلى زيادة الفقد فى الوزن الطازج ، وانخفاض وصلابة القشرة واللب ، ونسبة المواد الصلبة الذائبة ، وحجم العصير المتحصل عليه من ١ كجم ثمار مقارنه بالمعاملة رقم ١ فى كلا الموسمين . بينما أدت جميع معاملات التدفئة المتقطعه إلى زيادة محتوى الثمار من فيتامين جـ (فى الموسم الثانى فقط) وزيادة الحموضة الكلية والحموضة الفعلية (pH) خلال فترة العرض بعد كل معاملات التدفئة المتقطعه .