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RESPONSE OF BANZAHIR LIMES TO RIPENESS STAGE, POSTHARVEST HOT WATER DIP AND CHILLING STORAGE TEMPERATURE

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ABSTRACT

Avoiding fungicide use on lime fruits, an experiment was performed in 1998 and 1999, to investigate the influence of hot water dip, (50 ^{0}C, 5 min), stage of ripeness (colour - break and uniform yellow) and chilling storage temperature (5 or 10 ^{0}C and 85 - 90 % RH) on the storability of Banzahir limes. Fruits at both stages either treated with hot water or control, stored at 5°C, remained only 8 weeks of storage, whereas those stored at 10°C lasted 12 weeks. With the progress of storage period, rind colour developed, percentages of weight loss and unmarketable fruits significantly increased, TSS almost remained constant in the first season and slightly increased at the end of storage period in the second, while V.C and citric acid contents significantly decreased.

Hot water treatment, generally, had no significant effect on storage period or fruit quality (rind colour, weight loss, unmarketable fruits, TSS, V.C and acidity). Yellow fruits had significantly lower weight loss and citric acid percentages, and higher V.C content, compared with colour-break ones. Storing fruits at 10°C resulted to extend storage period and hastened colour change. Furthermore, weight loss and unmarketable fruits percentages were lower, while citric acid (except of fruits at yellow stage in the second season) and V.C contents were higher than those stored at 5°C, TSS percentages didn't significantly influence by hot water treatment, stage of ripeness or storage temperature, except for colour-break heated fruits stored at 10°C in the second season.

It could be concluded that long storability with good quality was found in colour-break fruits stored at 10°C.

Keywords: Banzahir lime, ripeness stage, chilling injury, storage temperature, storability and postharvest.

INTRODUCTION

The total citrus area in Egypt reached 342,674 feddans produced 2,401,054 tons of fruits in 2000. From this planted area, 36,383 feddans were planted with lime trees produced 274,484 tons of fresh fruits (according to statistics of Ministry of Agriculture, 2001). Because most of the Banzahir lime yield appears in August and September, the Banzahir lime growers don't get the most out of their orchards because the price during that period drops sharply, while during the rest of the year the price is extremely high. Spreading the crops of the Banzahir lime over a longer period is highly desirable from the grower as well as the consumer.

Cold storage of limes is best practiced using a relative high temperature (10-13°C), but that is not sufficient to suppress diseases or keep fruits intact in good conditions, so fruits should be exposed to anti-decay treatments. Pesticide residues constitute a problem for public health (Wagner

amd Molserg, 1989). Hot water dip treatment as a safe method, proved its usefulness in reducing decay and the sensitivity of citrus fruit to chilling injury (Rodov *et al.*, 1995). Chilling injury drasticaly limits the storage and marketing of limes. (Pantastico et al., 1968).

Therefore the objective of this study was to determine the effect of high temperature through hot water dip treatment on Banzahir limes at two ripeness stages during storage at 5 and 10°C. Thereby, supplying the local market with acceptable eatable fruits with suitable price for both producers and consumers for long time after the critical period of late September.

MATERIALS AND METHODS

This investigation was carried out in two successive seasons, during 1998 and 1999, on Banzahir limes (Citrus aurantifolia). Fruits from 22 years old trees, budded on sour orange rootstocks, and grown in a private orchard in Delengat, Behira Governorate were used. On the first weeks of January for both seasons, fruits were picked at two ripeness stages (colour-break and uniform yellow). 750 uniform, free of bruises fruits, of each stage were picked. For each stage, thirty fruits were used as an initial sample for physical parameters and chemical analysis every season. Half of the rest fruits of each stage (360 ones) were dipped for 5 minutes, in hot water (50°C) and the second half were dipped in tap water (control) for the same period. Fruits were air dried, divided into small groups, 30 fruits each (10 fruits for each replicate), and packed in mesh bags, i.e. there were 24 bags for each stage. All bags (48 ones) were put in 12 plastic open boxes (60 x 40 x 18 cm). Each box contained 4 bags which represented 4 different treatments (colour-break heated, colour-break control fruits, yellow heated, yellow control ones). Six boxes were stored at 5°C with relative humidity of 85-90%. The other 6 remained boxes were stored at 10°C with the same percentage of humidity.

There were 8 treatments as follows:

1. Colour-break fruits dipped for 5 min in hot water (50°C), stored at 5°C.
2. Colour-break fruits dipped for 5 min in tap water (control) stored at 5°C.
3. Yellow fruits dipped for 5 min in hot water (50°C), stored at 5°C.
4. Yellow fruits dipped for 5 min in tap water (control), stored at 5°C.
5. Colour-break fruits dipped for 5 min in hot water (50°C), stored at 10°C.
6. Colour-break fruits dipped for 5 min in tap water (control), stored at 10°C.
7. Yellow fruits dipped for 5 min in hot water (50°C), stored at 10°C.
8. Yellow fruits dipped for 5 min in tap water (control), stored at 10°C.

Fruits of each treatment were evaluated at a 14 days-interval throughout the storage period. A sample of 30 fruits (10 fruits for each replicate) was taken for each treatment, to study some physical and chemical characteristics as follows:

1. Physical characteristics:

a. Rind colour

Fruit rind colour was matched with the citrus colour chart of Harding *et al.* (1940). (Fig. 1).

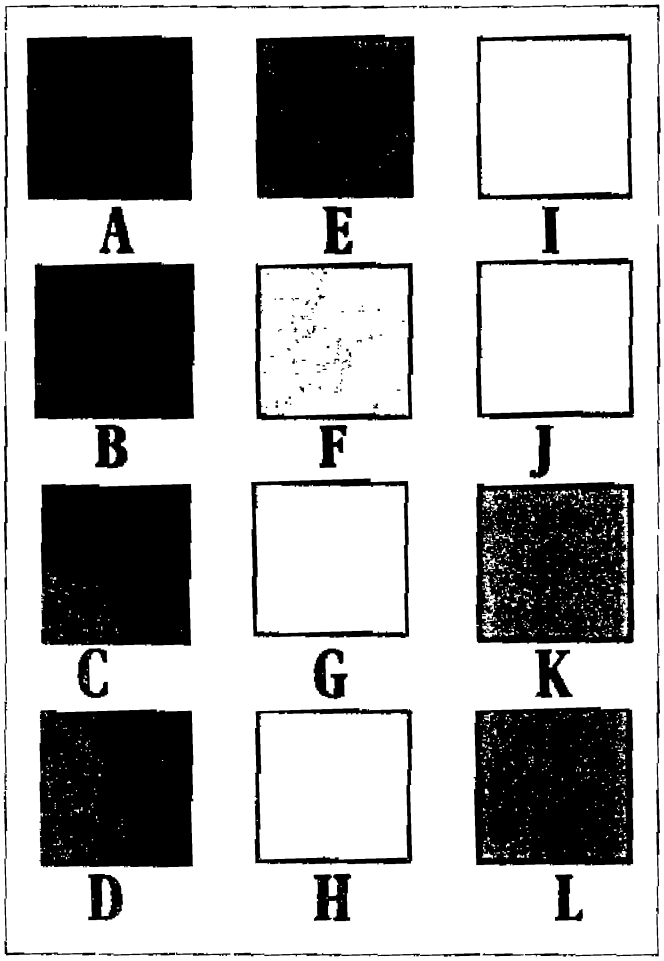

Fig.1 Colour chart used for determining the rind colour of citrus fruits, similar to that used by Harding et al.(1940).

b. Weight loss

Fruits were weighed at 14 day-interavals in each sample during storage and the loss in fruit weight was recorded and calculated as a percentage from the initial weight.

c. Unmarketable fruits.

The number of unmarketable fruits due to chilling injury and decay was calculated as percentage from the total number of each sample.

2. Chemical characteristics

a. Total soluble solids (TSS)

Total soluble solids in the juice were determined by a hand refractometer.

b.Ascorbic acid (V.C)

It was calculated as mg/100ml juice according to A.O.A.C. (1985).

c. Titratable acidity

Titratable acidity of the fruit juice was expressed as percentage of citric acid according to A.O.A.C. (1985)

Statistical analysis:

Data were statistically analyzed according to Snedecor and Cochran (1971). As the colour-break and uniform yellow fruits were included in the same experiment, one error was calculated for the whole experiment. As the error variance is independent from treatment means, LSD values were calculated from this pooled error.

RESULTS AND DISCUSSION

Storage period

Data recorded in Tables (5,6) indicated that fruits at both ripeness stages either treated with hot water or control, stored at 5°C remained only 8 weeks of storage with unmarketable fruits ranged from 70 to 90% in first season and 60 to 90% in the second, compared with 0.00% in both seasons for ones stored at 10°C, after 8 weeks of storage. Whereas, those stored at 10°C lasted 12 weeks with unmarketable fruits 20-30% in both seasons. It could be concluded that, storage temperature is the most effective factor of storage Banzahir limes at both stages of ripeness. Hardenburg *et al.* (1986) recommended a temperature of 9 to 10°C and 85 to 90% relative humidity for storage lime fruits. Optimum storage temperature is important for minimizing fruit injury and decay (Kawada and Kitagawa, 1994).

1. Physical characteristics

a. Rind colour

According to the colour chart (Fig. I), the data illustrated in Tables (1 and 2) showed that fruits of each ripeness stage had the same initial colour (letter E) for colour-break and (letter H) for uniform yellow, in both years of study. As the storage period advanced, there was a considerable colour development of fruit at both ripeness stages.

Table (1): Effect of various treatments on rind colour of Banzahir lime fruits during cold storage in 1998.

Weeks in storage	Treatments							
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C
0	E	E	H	H	E	E	H	H
2	E-F	E-F	H	H	E-F	E-F	H	H
4	E-F	E-F	H	H	E-F	F	H	H
6	E-F	F	H-I	I	F-G	G-H	H-I	I
8	E-F	F	I	I	G-H	G-H	H-I	I
10					G-H	H	H-I	I
12					G-H	H	I	I

Table (2): Effect of various treatments on rind colour of Banzahir lime fruits during cold storage in 1999.

Weeks in storage	Treatments							
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C
0	E	E	H	H	E	E	H	H
2	E-F	E-F	H	H	E-F	F	H	H
4	E-F	E-F	H-I	H	F	F-G	H-I	H-I
6	F-G	E-F	H-I	H-I	F-G	G-H	I	H-I
8	F-G	F	H-I	H-I	F-G	G-H	I	I
10	-	-	-	-	G	G-H	I	I
12	-	-	-	-	H	H	I-J	I

In general, hot water treatment did not affect fruits rind colour at both stages of ripeness, stored either at 5 or 10°C. These results weren't in line with those found by Williams *et al.* (1994) on Valencia oranges. They noticed that fruits received a hot water immersion treatment showed enhanced colour development. On the other side, El-Shiekh (1996) reported that hot water immersion of Marsh grapefruits resulted in lower colour intensity after 90 days of storage.

The rate of progress in colour, generally, was higher in the fruits at both stages, stored at 10°C compared with those stored at 5°C. These findings were in accordance with those obtained by Nam and Kweon (1989) on Satsuma mandarins and Predebon and Edwards (1992) on Eureka and Lisbon lemons.

b. Weight loss

The data existed in Tables (3 and 4) indicated that, the percentages of weight loss, as an average for all applied treatments, were increased gradually, in both experimental seasons, as the storage period advanced. The differences among all storage period were significant. These results were confirmed by those found by Fioravanco *et al.* (1995) on Tahiti limes; Schirra *et al.* (1997) on Tarocco oranges and El-Mughrabi (1999) on Balady oranges.

Weight loss was influenced by stage of ripeness. Yellow fruits either treated with hot water or control, stored at 5 or 10°C had significantly lower percentages of weight loss than those of colour-break ones, as an average for 8 or 12 weeks of storage, except in the second season, as the differences between weight loss percentages of yellow and colour-break treated fruits stored at 10°C, were not significant, as an average for 12 weeks of storage.

Hot water treatment had no effect on the fruits weight loss percentages at both stages of ripeness, either stored at 5 or 10°C, with one exception, as colour-break treated fruits stored at 5°C had significantly lower percentages of weight loss than those of control ones, as an average for 8 weeks of storage. These findings were in harmony with those obtained by Gonzalez-Aguilar *et al.* (1997) on Fortune mandarins. However, the results were not in line with those found by McLauchlan *et al.* (1997) on Eureka lemons. They noticed that, the rate of fruit weight loss was lower in heat treated fruits (47-53C° for 1-3 min) than controls.

Weight loss percentages of fruits stored at 10°C were significantly lower than those stored at 5°C, in both seasons, as an average for 8 weeks of storage. These findings were in agreement with those obtained by Manolopoulou-Lambrinou and Papadopoulou (1995) on Encore mandarins. They reported that at optimum storage temperature the rate of weight loss was minimal.

The least significant weight loss percentages were found in yellow fruits stored at 10°C (7.06-7.29 and 6.96-7.59 in 1998 and 1999, respectively) and the highest ones in colour-break fruits stored at 5°C (18.09-19.48 and 18.45-20.35, respectively), as an average for 8 weeks of storage. Concerning the last period of storage, still the former fruits had the least percentages of weight loss (9.92-10.06 and 9.62-10.64, respectively) as an average for 12 weeks.

Table (3): Effect of various treatments on percent weight loss of Banzahir lime fruits during cold storage in 1998.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C		
0	-	-	-	-	-	-	-	-	-	-
2	7.60	7.34	5.21	5.48	4.64	4.21	2.86	2.85	5.02 d	3.64 f
4	14.92	13.90	9.64	9.85	8.35	7.52	5.09	5.59	9.36 c	6.64 e
6	24.43	22.51	16.84	17.93	13.13	11.72	8.87	9.11	15.57 b	10.71 d
8	30.96	28.61	21.96	22.57	16.77	15.04	11.44	11.60	19.87 a	13.71 c
Average	19.48 a	18.09 a	13.41 b	13.96 b	10.72 c	9.62 c	7.06 d	7.29 d		
L.S.D	Treatments				Storage period			Interaction		
0.05	1.544				0.341			1.731		
0.01	2.127				0.456			2.349		
10	-	-	-	-	20.36	18.40	14.05	14.40		16.80 b
12	-	-	-	-	23.80	21.93	17.20	16.83		19.94 a
Average	-	-	-	-	14.51 a	13.13 a	9.92 b	10.06 b		
L.S.D	Treatments				Storage period			Interaction		
0.05	2.258				0.514			2.344		
0.01	3.285				0.687			3.282		

Averages followed by the same letters are not significant different at 0.05 level.

Table (4): Effect of various treatments on percent weight loss of Banzahir lime fruits during cold storage in 1999.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow Hot water 10°C	Uniform yellow control 10°C		
0	-	-	-	-	-	-	-	-	-	-
2	7.20	8.28	5.88	5.28	3.95	3.95	3.20	2.89	5.08 d	3.50 f
4	13.65	16.21	11.05	9.96	7.13	8.00	5.44	5.29	9.59 c	6.46 e
6	23.36	25.29	18.55	18.32	11.41	12.73	9.45	8.54	15.96 b	10.53 d
8	29.57	31.63	23.76	23.54	14.54	16.06	12.28	11.10	20.31 a	13.50 c
Average	18.45 b	20.35 a	14.81 c	14.28 c	9.26 d	10.18 d	7.59 e	6.96 e		
L.S.D	Treatments				Storage period			Interaction		
0.05	1.650				0.330			1.809		
0.01	2.273				0.441			2.453		
10	-	-	-	-	17.45	20.13	15.06	13.72		16.59 b
12	-	-	-	-	20.69	23.05	18.38	16.14		19.57 a
Average	-	-		-	12.53 ab	13.99 a	10.64 bc	9.62 c		
L.S.D	Treatments				Storage period			Interaction		
0.05	1.934				0.464			2.029		
0.01	2.814				0.621			2.841		

Averages followed by the same letters are not significant different at 0.05 level.

c. Unmarketable fruits

Data nominated in Tables (5 and 6) disclosed that the percentages of unmarketable fruits, as an average for all treatments, were significantly increased, in both seasons, as the storage period advanced. Hot water treatment had no obvious effect on reducing the percentages of unmarketable fruits at both stages of ripeness either stored at 5 or 10°C, except in the second season, as yellow treated fruits stored at 5°C and colour break ones stored at 10°C had significantly lower percentages of unmarketable fruits than those of control ones, as an average for 8 and 12 weeks, respectively. These findings confirmed by those found by McLauchlan *et al.* (1997). They noticed that heat treatment (47-53°C for 1-3 min) had no significant effect on the incidence of disease at all durations of storage Eureka lemons. However, the results were not in line with those obtained by Rodov *et al.* (1995) and Schirra and Mulas (1995b) on lemons.

The effectiveness of ripeness stage on the percentages of unmarketable fruits, was noticed when yellow fruits were stored at 5°C, they had significant lower percentages of unmarketable fruits than those of colour-break ones, as an average for 8 weeks in both seasons, except in the first one, for treated yellow fruits. Similarly, Obenland *et al.* (1996) found that green lemons were injured more severely than yellow ones. On the other side, at 10°C yellow control fruits had significant higher percentages of unmarketable fruits than colour - break ones in the first season, as an average for 12 weeks. These findings were in harmony with those found by Naim *et al.* (1995) on Clementines and Lafuente *et al.* (1997) on Fortune mandarins.

The percentages of unmarketable fruits were greatly influenced by storage temperature. Fruits at both stages treated with hot water or control, stored at 10°C had 0.00 and 0.00-2.00% unmarketable ones in 1998 and 1999, respectively, as an average of 8 weeks of storage, while those stored at 5°C had 36.00-41.33% and 25.33-39.33% respectively. As an average of 12 weeks of storage, the former fruits had only 4.29-7.14% and 2.86-7.14%, respectively. The highest percentage of unmarketable fruits of those stored at 5°C could be attributed to fruit chilling injury, as the limes were susceptible to cold storage breakdown, membranos stain, albedo browning and pitting. The pits may coalesce and form leathery, brown, sunken areas on the rind, thereafter, the tissues weakened as they are unable to carry on normal metabolic processes and consequently various physiological and biochemical alterations occur in chilling-sensitive tissues in response to chilling stress. These were in accordance with those found by Pantastico *et al.* (1968) on limes. The Refrigeration Research Foundation (1983) reported that Tahiti limes can be stored satisfactory at 9-10°C for 6-8 weeks.

2. Chemical characteristics

a. Total soluble solids (TSS)

The data presented in Tables (7 and 8) indicated that the percentages of TSS, as an average of all treatments, almost remained constant during the storage period, in the first season.

Table (5): Effect of various treatments on the percentage of unmarketable Banzahir lime fruits during cold storage in 1998.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C		
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00 e	0.00 c
2	10.00	10.00	20.00	10.00	0.00	0.00	0.00	0.00	6.25 d	0.00 c
4	30.00	30.00	30.00	30.00	0.00	0.00	0.00	0.00	15.00 c	0.00 c
6	66.67	56.67	66.67	70.00	0.00	0.00	0.00	0.00	32.50 b	0.00 c
8	80.00	90.00	90.00	70.00	0.00	0.00	0.00	0.00	41.25 a	0.00 c
Average	37.33 b	37.33 b	41.33 a	36.00 c	0.00 d	0.00 d	0.00 d	0.00 d		
L.S.D 0.05	Treatments 1.224				Storage period 1.987			Interaction 5.319		
0.01	1.686				2.643			7.206		
10	-	-	-	-	10.00	10.00	10.00	20.00		12.50 b
12	-	-	-	-	20.00	20.00	30.00	30.00		25.00 a
Average	-	-	-	-	4.29 b	4.29 b	5.71 ab	7.14 a		
L.S.D 0.05	Treatments 1.902				Storage period 2.760			Interaction 5.768		
0.01	2.768				3.683			8.067		

Averages followed by the same letters are not significant different at 0.05 level.

Table (6): Effect of various treatments on percentage of unmarketable Banzahir lime fruits during cold storage in 1999.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow Hot water 10°C	Uniform yellow control 10°C		
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00 e	0.00 c
2	20.00	20.00	0.00	10.00	0.00	0.00	0.00	0.00	6.25 d	0.00 c
4	30.00	30.00	10.00	30.00	0.00	0.00	0.00	0.00	12.50 c	0.00 c
6	56.67	66.67	56.67	40.00	0.00	0.00	0.00	10.00	28.75 b	2.50 c
8	90.00	80.00	60.00	80.00	0.00	0.00	0.00	0.00	38.75 a	0.00 c
Average	39.33 a	39.33 a	25.33 c	32.00 b	0.00 d	0.00 d	0.00 d	2.00 d		
L.S.D	Treatments				Storage period			Interaction		
0.05	3.238				2.187			6.514		
0.01	4.462				2.908			8.826		
10	-	-	-	-	0.00	20.00	10.00	10.00		10.00 b
12	-	-	-	-	20.00	30.00	20.00	20.00		22.50 a
Average	-	-	-	-	2.86 c	7.14 a	4.29 bc	5.71 ab		
L.S.D	Treatments				Storage period			Interaction		
0.05	2.329				3.582			7.447		
0.01	3.389				4.793			10.415		

Averages followed by the same letters are not significant different at 0.05 level.

Table (7): Effect of various treatments on percentage total soluble solids (TSS) of Banzahir lime fruits during cold storage in 1998.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C		
0	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20 a	9.20
2	9.33	9.00	9.00	9.33	9.00	9.47	9.20	9.00	9.17 a	9.17
4	9.53	9.00	9.33	9.00	9.00	9.47	9.47	9.00	9.23 a	9.23
6	9.00	8.27	8.33	9.00	9.00	9.00	8.67	9.00	8.78 b	8.92
8	9.53	10.00	9.47	9.00	9.47	9.00	9.00	9.00	9.31 a	9.12
Average	9.32	9.09	9.07	9.11	9.13	9.23	9.11	9.04		
L.S.D	Treatments				Storage period			Interaction		
0.05					0.241					
0.01	NS				0.321			NS		
10	-	-	-	-	9.20	9.33	9.00	9.00		9.13
12	-	-	-	-	9.00	9.53	8.80	9.00		9.08
Average	-	-	-	-	9.12	9.29	9.05	9.03		
L.S.D	Treatments				Storage period			Interaction		
0.05										
0.01	NS				NS			NS		

Averages followed by the same letters are not significant different at 0.05 level. NS: Not significant.

Table (8): Effect of various treatments on the percentage total soluble solids of Banzahir lime fruits during cold storage in 1999.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C		
0	9.00	9.00	9.33	9.33	9.00	9.00	9.33	9.33	9.17 b	9.17
2	9.00	9.00	9.20	9.00	9.33	9.00	9.00	9.00	9.07 cb	9.08
4	9.00	9.00	9.00	9.00	9.47	9.00	9.00	9.00	9.06 cb	9.12
6	8.67	8.53	9.00	9.00	9.33	8.00	10.00	9.00	8.94 c	9.08
8	9.33	9.67	9.67	9.33	9.87	9.00	9.20	9.00	9.38 a	9.27
Average	9.00 cd	9.04 bcd	9.24 abc	9.13 abc	9.40 a	8.80 d	9.31 ab	9.07 bcd		
L.S.D	Treatments				Storage period			Interaction		
0.05	0.276				0.184			0.549		
0.01	0.380				0.244			0.744		
10	-	-	-	-	9.67	9.33	9.00	9.20		9.30
12	-	-	-	-	9.47	9.67	9.00	9.67		9.45
Average	-	-	-	-	9.45 a	9.00 c	9.22 b	9.17 cb		
L.S.D	Treatments				Storage period			Interaction		
0.05	0.206							0.602		
0.01	0.300				NS			0.842		

Averages followed by the same letters are not significant different at 0.05 level. NS: Not significant.

The same trend was found in the second one, as an average for fruits stored at 10°C, while they increased at the end of the first storage period (8 weeks), as an average for all treatments. These findings were in harmony with those obtained by Subedi (1998) on mandarin oranges at 5 maturity stages. He reported that total soluble solids content of fruits remained unchanged during storage.

TSS percentages were not significantly influenced by hot water treatment, stage of ripeness or storage temperature, except in the second season, as colour-break heated fruits stored at 10°C had sigificant highest percentages of TSS compared with those of control ones (as an average for 8 or 12 weeks), those stored at 5°C (as an average for 8 weeks) and yellow ones stored at 10°C (as an average for 12 weeks).

The insignificant effect of hot water treatment on TSS percentages, was previously reported by many investigators such as Schirra and Mulas (1993) and Schirra *et al.* (1998) on grapefruits; Schirra and Mulas (1995a) and Schirra *et al.* (1997) on Tarocco oranges and Borthakur and Ranjit (1998) on Baramasi lemons. Regarding ripeness stage, the results were not in line with those obtained by Abd El-Baki and Hassan (1963). They found that TSS of Banzahir lime yellow fruit was more than that of yellow green. Concerning storage temperature, the results were confirmed by those found by Kanlayanarat *et al.* (1988). They found that TSS of (Citrus hassaku) fruits was not affected by temperature (2-20°C) after 30 days in storage.

b. Ascorbic acid (V.C)

The data introduced in Tables (9 and 10) declared that there was a significant reduction of V.C content during storage, as an average for all used treatments, in both years of study. These results were confirmed by those obtained by Sharafat *et al.* (1990) on Blood red oranges and El-Zayat *et al.* (1998) on lemons, limes and sweet lemons. Isshak *et al.* (1976) reported that the general trend of ascorbic acid in lemon fruits was slightly decreased during storage at different colour stages and temperatures.

Hot water treatment had no significant effect on V.C content, as an average for 8 or 12 weeks of storage, in both seasons, except in the second one as V.C contents of yellow heated fruits stored at 10°C were significantly higher than those of the control ones, as an average for 8 weeks. These findings were not in line with those obtained by Kawada and Kitagawa (1986) as they noticed that warming citrus fruits reduced the V C content. On the other side, Artes *et al.* (1993) mentioned that V.C. values of Primofori lemons increased after warming treatment during storage.

It was clearly noticed that V.C contents of fruits stored at 10°C were significant higher than those of ones stored at 5°C, as an average for 8 or 12 weeks of storage in both experimental seasons. These results were not in harmony with those found by El-Zorkani (1968). He reported that no significant differences between the two storage temperatures (5 and 17°C), were observed in respect to their influence on V.C of Eureka lemons, stored for 60 days.

Table (9): Effect of various treatments on V.C (mg/100ml juice) of Banzahir lime fruits during cold storage in 1998.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow Hot water 10°C	Uniform yellow control 10°C		
0	57.64	57.64	62.50	62.50	57.64	57.64	62.50	62.50	60.07 a	60.07 b
2	54.08	54.54	64.17	60.89	57.57	54.08	63.70	63.33	59.05 a	59.67 b
4	53.33	53.33	61.63	57.78	65.00	61.67	68.33	71.67	61.59 a	66.67 a
6	20.49	21.44	28.58	27.63	35.73	32.39	37.63	35.25	28.89 b	35.25 e
8	14.43	14.93	30.01	34.77	41.26	36.20	42.87	42.87	32.17 b	40.80 d
Average	39.99 c	40.38 c	49.38 b	48.71 b	51.44 ab	48.40 b	55.01 a	55.13 a		
L.S.D	Treatments				Storage period			Interaction		
0.05	4.162				2.725			8.178		
0.01	5.735				3.624			11.080		
10	-	-	-	-	39.06	38.11	46.66	47.41		42.81 d
12	-	-	-	-	41.81	44.24	51.51	53.93		47.87 c
Average	-	-	-	-	48.30 b	46.33 b	53.32 a	53.85 a		
L.S.D	Treatments				Storage period			Interaction		
0.05	3.901				3.960					
0.01	5.676				5.283			NS		

Averages followed by the same letters are not significant different at 0.05 level. NS: Not significant.

Table (10): Effect of various treatments on V.C (mg/100m/juice) of Banzahir lime fruits during cold storage in 1999.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C		
0	57.77	57.77	60.89	60.89	57.77	57.77	60.89	60.89	59.33 a	59.33 c
2	51.51	53.33	62.96	57.57	60.89	62.50	68.33	61.67	59.85 a	63.35 b
4	46.66	47.41	63.70	54.08	63.33	64.17	76.67	72.50	61.07 a	69.17 a
6	20.49	21.91	29.53	30.49	33.82	30.49	40.96	37.63	30.67 b	35.73 f
8	16.92	11.44	32.39	31.92	41.79	38.11	40.96	39.06	31.57 b	39.98 e
Average	38.67 e	38.37 e	49.90 cd	46.99 d	51.52 cb	50.61 c	57.56 a	54.35 b		
L.S.D	Treatments				Storage period			Interaction		
0.05	3.076				2.570			7.340		
0.01	4.238				3.418			9.945		
10	-	-	-	-	42.87	39.05	41.26	46.66		42.46 e
12	-	-	-	-	45.45	45.45	54.54	57.57		50.75 d
Average	-	-	-	-	49.42 b	48.22 b	54.80 a	53.71 a		
L.S.D	Treatments				Storage period			Interaction		
0.05	3.082				4.010					
0.01	4.484				5.365			NS		

Averages followed by the same letters are not significant different at 0.05 level. **NS: Not significant.**

However, Izumi *et al.* (1990) noticed that V.C content of Hayashi mandarins remained constant at 5°C but decreased gradually at 15°C, during storage for 3 months.

In both years of study, V.C values of yellow fruits were significantly higher than those of colour-break ones, as an average for 8 or 12 weeks, with one exception in the first season, as the differences were so slight to be significant between yellow heated fruits stored at 10°C and colour - break ones, as an average for 8 weeks. These findings partly agreed with those found by Abdi and Mojdeh (1994). They noticed that V.C content of Satsuma mandarins was higher at the orange-yellow and orange stages than that at yellow green and yellow stages.

C. Titratable acidity:

The data obtained from Tables (11 and 12) declared that the percentage of citric acid, as an average for all applied treatments, were significantly decreased as the storage period advanced. The reduction in citrus acidity was mainly due to a decrease in citric acid, malic acid content being little affected. Both citric and malic acid contents were reduced by cold storage, (Kawada and Kitagawa, 1986). The results were confirmed by those obtained by El-Gazzawy (1973) on limes; El-Nawam (1991) on oranges; Cohen *et al.* (1991) and Subedi (1998) on mandarin oranges. They all recorded a decrease in fruit acidity as the storage period advanced.

The data also revealed that, in both seasons, hot water treatment had no significant effect on citric acid content, except for colour-break fruits stored at 10°C, as citric acid percentages in heated fruits were significantly higher than those in control ones, as an average for 8 or 12 weeks in first season and for 8 weeks in the second one. Similary, Schirra and Mulas (1993) on Orblanco grapefruit; Schirra *et al.* (1995) on Ovale Kumquat; Schirra *et al.* (1997) on Tarocco orange and Borthakur and Ranjit (1998) on Baramasi lemon fruits. They all stated that acidity was not sigificantly affected by hot dip treatment. However, the results were not in line with those found by El-Shiekh (1996) on Marsh grapefruit. He noticed that water immersion of fruits at 48°C for 2 or 3h resulted in lower titratable acidity.

Citric acid percentages at 10°C were significantly higher than those at 5°C, for fruits at both stages in first season and colour break ones in the second, as an average for 8 weeks of storage. These findings were in agreement with those obtained by Murata and Yamawaki (1992) on several varieties of citrus fruits. However, the results were not in harmony with those obtained by Kanlayanarat *et al.* (1988). They found that titratable acidity of (Citrus hassaku) fruits was not affected by temperature (2-20°C) until after 30 days in storage. Citric acid content was greatly affected by ripeness stage. Colour-break fruits had significantly higher percentages of citric acid than yellow ones, in both seasons, as an average for 8 or 12 weeks of storage. The results agreed with those obtained by Naim *et al.* (1995) on Cadoux and Nour clementines. Likewise, Abdi and Mojdeh (1994) on Satsuma, Clementine mandarin and Thomson navel sweet orange, noticed that the highest acidity was found at the yellow-green stage and the lowest at the orange stage

Table (11): Effect of various treatments on percent citric acid of Banzahir lime fruits during cold storage in 1998.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow hot water 10°C	Uniform yellow control 10°C		
0	11.73	11.73	8.92	8.92	11.73	11.73	8.92	8.92	10.33 a	10.33 a
2	9.86	9.68	8.20	8.14	11.60	11.51	9.00	8.68	9.58 b	10.20 a
4	9.73	9.56	8.24	8.68	11.51	9.39	8.72	9.05	9.36 c	9.67 b
6	8.28	8.24	7.99	7.63	9.86	9.47	7.99	8.72	8.52 d	9.01 c
8	8.43	7.94	7.97	7.71	9.56	9.13	8.70	8.28	8.47 d	8.92 c
Average	9.61 c	9.43 c	8.27 e	8.22 e	10.85 a	10.25 b	8.67 d	8.73 d		
L.S.D	Treatments				Storage period			Interaction		
0.05	0.227				0.153			0.455		
0.01	0.312				0.203			0.617		
10	-	-	-	-	8.92	8.48	8.60	8.48		8.62 d
12	-	-	-	-	8.60	8.72	8.45	7.63		8.35 e
Average	-	-	-	-	10.25 a	9.78 b	8.63 c	8.54 c		
L.S.D	Treatments				Storage period			Interaction		
0.05	0.138				0.191			0.402		
0.01	0.201				0.255			0.562		

Averages followed by the same letters are not significant different at 0.05 level.

Table (12): Effect of various treatments on percent citric acid of Banzahir lime fruits during cold storage in 1999.

Weeks in storage	Treatments								Average	Average of the last 4 treatments
	Colour-break Hot water 5°C	Colour-break Control 5°C	Uniform yellow hot water 5°C	Uniform yellow control 5°C	Colour-break Hot water 10°C	Colour-break Control 10°C	Uniform yellow Hot water 10°C	Uniform yellow control 10°C		
0	11.51	11.51	8.72	8.72	11.51	11.51	8.72	8.72	10.12 a	10.12 a
2	9.56	9.05	9.26	9.13	11.41	9.68	9.00	8.66	9.46 b	9.67 ab
4	9.39	9.47	8.13	8.13	11.33	9.26	9.05	8.28	9.13 c	9.48 b
6	7.63	8.20	7.97	8.14	9.86	9.40	7.82	8.34	8.43 d	8.88 c
8	8.28	7.71	7.82	8.13	8.24	9.21	8.68	7.97	8.26 d	8.53 c
Average	9.27 c	9.19 c	8.38 d	8.45 d	10.47 a	9.81 b	8.66 d	8.40 d		
L.S.D	Treatments				Storage period			Interaction		
0.05	0.446				0.317			0.934		
0.01	0.614				0.422			1.265		
10	-	-	-	-	9.05	8.91	8.14	8.24		8.59 c
12	-	-	-	-	8.91	9.13	8.20	8.14		8.60 c
Average	-	-	-	-	10.04 a	9.59 a	8.52 b	8.34 b		
L.S.D	Treatments				Storage period			Interaction		
0.05	0.466				0.533			1.146		
0.01	0.678				0.711			1.603		

Averages followed by the same letters are not significant different at 0.05 level.

CONCLUSIONS

Storage temperature is the most effective factor of storage Banzahir limes, as fruits stored at 10°C remained 12 weeks while those stored at 5°C lasted only 8 weeks. Long storability with good quality was found in colour-break ones stored at 10°C.

Inspite of high temperature through hot water dip treatment (50°C, 5 min) was recommended for reducing decay and sensitivity of several varieties of citrus fruits to chilling injury such as March and Red blush grapefruits, Fortune mandarins and Eureka lemons, it is clearly noticed that it is not sufficiently suitable for Banzahir lime fruits. Therefore the authors confirm on the importance of trying another high temperatures and durations of water dips.

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إستجابة الليمون البنزهير إلى مرحلة النضج والغمس فى المـــاء الســـاخن ودرجة برودة التخزين

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أجرى البحث عامى ١٩٩٨، ١٩٩٩ على ثمار ليمون بنزهير لدراسة تأثير مرحلة النضج والغمس فى الماء الساخن بالإضافة لدرجة برودة التخزين على طول فترة التخزين ومواصفات الجودة. غمست الثمـــار المقطوفـــة عنـــد مرحلتى نضج (إنكسار اللون ، الأصفر المعتاد) فى ماء ساخن درجة حرارته ٥٥°م لمدة ٥ دقائق وخزنـــت علـــى درجتى حرارة ١٠،٥°م وقد ظهرت النتائج الآتى:

١- لم يكن هناك تأثير يذكر للمعاملة بالماء الساخن على طول فترة التخزين أو مواصفات جودة الثمـــار (الطبيعيـــة والكيميائية).

٢- استمرت الثمار المخزنة على درجة حرارة ٥°م لمدة ٨ أسابيع فقط بينما أستمرت الثمار المخزنة على ١٠°م لمدة ١٢ أسبوع.

٣- بتقدم فترة التخزين تطور اللون، وكان معدل التغير أسرع عند التخزين على درجة ١٠°م.

٤- زادت النسبة المئوية للفقد فى الوزن بتقدم فترة التخزين وكانت أقل نسب معنوية فى الثمار الصفـــراء المخزنـــة على درجة ١٠°م.

٥- زادت النسبة المئوية للثمار الغير قابلة التسويق بتقدم فترة التخزين وكانت شبه منعدمة بعد ٨ أسابيع من التخزين فى الثمار فى مرحلتى النضج المخزنة على ١٠°م.

٦- لم يكن هناك تغير معنوى فى النسبة المئوية للمواد الصلبة الذائبة طوال فترة التخزين فى الموسم الأول وأرتفعت قليلا عند نهاية فترة التخزين فى الموسم الثانى. لم تتأثر هذه النسب معنويا بالمعاملة بالمـــاء الســـاخن، مرحلـــة النضج أو درجة حرارة التخزين باستثناء الثمار عند مرحلة انكسار اللون المخزنة على ١٠°م فى الموسم الثانى.

٧- انخفض محتوى الثمار معنويا من V.C بتقدم فترة التخزين وكانت أعلى القيم معنويا فى الثمار الصفراء المخزنة على ١٠°م.

٨- انخفضت الحموضة معنويا بتقدم فترة التخزين وكانت أعلى القيم معنويا فى الثمار الخضـــراء المخزنـــة علـــى ١٠°م.