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Fruit Quality of Some New Lemon Cultivars under Cold Storage Conditions

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Abstract: This experiment was conducted during 2016 and 2017 seasons under Southern Tahrir district, Behera Governorate in order to study the changes in fruit properties of some new lemon cultivars (Prior, Corona, Monroe, Frost) at maturity and during cold storage at 10°C and 85-90% RH for four months. Morphological characteristics of fruits, total soluble solids, titratable acidity and ascorbic acid of juice were tested at maturity. Data showed that the fruits harvested after 260 days from full bloom (at140 days after fruit set) exhibited acceptable physic-chemical qualities with optimum fruit weight, texture%, fruit shape index, juice %, TSS: acidity, ascorbic acid. Lemons stored in perforated polyethylene bags for 4 months at 10°C, 85-90%RH simulated a long cold storage and transportation period, followed by 7 days at (18-20°C) of retail sale period simulating then a prolonged shelf life. Respiration rates of all cultivars stored at 10°C up to 4 months were 2 times highest, small differences among cultivars were observed in the changes of color parameters and chemical composition. The four cultivars remained marketable for up to 7days with a good retention of ascorbic acid. However, Corona lemon fruits had the highest keeping quality because of the greatest weight fruits, lowest number of seeds, the highest percentage of juice, vitamin C and its storage tolerance.

Key words: *Citrus lemon* L. · Prior · Corona · Monroe · Frost · Fruit maturity · Cold storage

INTRODUCTION

Lemon (*Citrus limon* L. Burm. F.; Rutaceae is one of the important citrus fruits appreciably not only for its beautiful appearance and pleasing flavor but also for excellent food qualities. Lemon fruit is rich in nutrients and bioactive compounds like citric acid, vitamin C, minerals, therefore widely used in the preparation of refreshing drinks, cordials and to flavor as well as garnish the foods [1]. Citrus fruits are commercially cultivated in different regions of Egypt. It identified the first rank as to harvested area and production [2]. Locally, 335, 814 tons of lemon fruit harvested from 14, 890 ha [3].

The harvest maturity stage of citrus fruit is one of the critical factors which affect its quality parameters such as fruit size and color [4]. Five characteristics are commonly utilized worldwide as indicators of maturity TSS, TA, TSS:TA ratio, juice content and color break, these may be considered as the most reliable maturity indices for taking harvest decision in lemon fruit according to California food and agricultural code [5, 6]. The quality and storage life of lemon fruit depends upon various physiological and biochemical changes which occur during fruit growth, development and maturity [7].

Published studies cleared that cold storage and high-density polyethylene reduced losses of fruit weight and decay %, decreased titratable acidity, continually increased TSS as well as TSS/acid ratio and slowed down enzyme activities which resulted in delaying declining of vitamin C contents [8, 9]. The main target of this research is evaluate the change of quality compounds of four lemon cultivars at 10°C, 85-90%RH for four months during 2016 and 2017 seasons.

MATERIALS AND METHODS

This investigation was carried out through (2016 & 2017) seasons on mature lemon fruits to study the fruit quality at maturity stage and during different cold storage periods. Uniform fruits were obtained from privet orchard at tahrir area, Behera Governorate. Sampling started after 240 days from full bloom; three samples

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(three trees for each cultivar and five fruits for each sample) were picked at 10 days intervals to determine fruit maturity for each cultivar. Also, fruit weight (g), texture (gm/cm^2), shape index, fruit nipple length (cm), peel thickness (cm), seeds number, peel color, clove number, juice % TSS%, acidity%, TSS: acidity ratio and ascorbic acid (mg/100g juice) were studied.

Concerning cold storage fruits with Greenwich color surface, juice 50, 58% and TSS 8.2 , 8.8%, were transported to the laboratory, graded, washed, air dried and packed in polyethylene bags each contained 4 fruits in carton boxes each contained 5 bags (20 fruits), five carton boxes for each cultivar stored for 4 months at 10°C with R.H. (85-90 %).

Three representative replicates for each sampling date, were taken for physical and chemical analysis, as follows.

Physical Properties

Fruit Weight Percentage: The value of WL of five fruits was expressed as the percentage loss of the initial weight using the following formula:

WL= [(W0 – W1)/W0] x100.

Where W_0 is the initial weight (g) of the lemons and W_t is the final weight (g) of the lemons on the sampling date.

Texture: Was determined by measuring the resistance of fruit flesh to a penetrating needle in the texture (Lera texture analyzer) for a fixed distance of 2 millimeters inside fruit flesh and texture is expressed in gram / cm^2.

Fruit peel color parameters (L*, a*, b*): were quantified at tristimulus colorimeter date using Hunter colorimeter model DP9000 (L. value: lightness). (a.value: green- red), (b. value: blue -yellow) [10].

Fruit decay percentage: were calculated according to the equation: Total number of decayed fruits x Initial number of stored fruits/ 100.

Juice percentage: Was calculated by weight using the formula

Juice weight (%) =Average juice weight /Average fruit weight ×100.

Respiration Rate: Sample of 5 fruits were taken from each cultivar (every month of cold storage period) for determining Co_2 according to Cross [11]. The respiration rate as ml Co_2/kg /hr. = (?%*10) (free space volume of container in liters /(product fwt in kg) (Time container inclosed in hours).

Chemical Properties

Total Soluble Solids (TSS%): Was determined in fruit juice by a hand refractometer.

Titratable Acidity %: Was determined using 10ml of the extracted juice, diluted to 100 ml and titrated against 0.1 N NaOH to pH 8.1. then it was expressed as citric acid (mg).

TSS /Acid Ratio: Was calculated by dividing TSS/Acid values as maturity index.

Ascorbic Acid (mg/100g Juice): Was determined using phenol indophenol dye method, 10g of the fresh samples were blended with 3% metaphosphoric acetic acid extracting solution to homogenous slurry and 5ml of the filtrate extract were titrated with standard Indophenol to pink end point [12].

Calcium and Potassium Content: Mineral's content of Calcium and Potassium (mg/100g juice) were determined in fruit pulp using atomic absorption spectro-photometer according to AOAC [12] at the beginning and the end of cold storage period.

Poly Phenol Oxidation Activity (PPO)

Extraction of PPO: Crude enzyme was extracted from the peel (5gm) according to the method described by Galeazzi *et al.* [13].

Determination of Poly Phenol Oxidation Activity: The activity of the crude enzyme extract was assayed according to the procedure of Wang *et al*. [14] this was done before storage and at the end of cold storage.

Shelf -Life Studies: At the end of cold storage, fruits were transferred from cold storage (10°C) to room temperature (18-20 °C) for 7 days as a marketing period, changes in fruit characters and physiological disordered were recorded.

Statistical Analysis: Data were subjected to analysis of variance according to Snedecor and Cochran [15]. Means of treatments were compared by L.S.D. at the 5% level.

RESULTS AND DISCUSSION

Maturity Indices

Morphological Characteristics of Fruit Maturity: There were significant differences in fruit morphological characteristics among the four studied cultivars. The fruit weight, which is one of the most important characteristics influencing consumer preferences, increased gradually till the age of 260 days from full bloom. Among cultivars, the fruit weight was the highest for Corona cultivar (average 123.9 g and 149.3 g) in both seasons, respectively. Prior cultivar reached the lowest fruit fresh weight average (104.7 g., 118.2 g) in both seasons respectively.

Concerning fruit texture, data in Table (1) show a significant difference in fruit texture during maturity stages. Fruit texture was significantly affected by cultivars, where Prior cultivar recorded the lowest texture (101.7, 107) after 260 days from full bloom during the two study seasons. Corona cultivar had the highest texture (119, 122 gm/cm^2) respectively in the both seasons at 260 days from full bloom.

In addition, fruit shape index, it was decreased during maturity stage and differed among the four lemon cultivars.

Concerning fruit nipple length increased until it reaches to the maturity and there are slight differences between the four tested cultivars.

For peel thickness, Data in Table (2) showed that peel thickness decreased significantly at maturity and there are no significant differences between the cultivars.This is in agreement with those obtained by Mukhim *et al.* [7], they found that, the fruit showed rapid increase in rind thickness in the first stage of growth and then declined with maturity.

Seeds number is very important because the marketable value of lemons for fresh consumption is greatly affected by the seed number per fruit. Data in Table (2) among the cultivars showed that, Corona was characterized by a low number of seeds compared to the other cultivars.

Fruit peel color as measured by a*, b*, L* value revealed that during maturation, the color changed from dark green after 240 days from full bloom to light green after 260 days bloom (Table 3).

The mean values a* of four cultivars varied from (-16.8, 15.4) at 240 days from full bloom to (-9.3, -10.0) at 260 days from full bloom during the two seasons, highlighting a reduction in the green color of peel, highest values are found for Corona cultivar.

Regarding the parameter b*, which indicates the variation of the yellow color of peel, it increased significantly during maturation with means values of four cultivars, ranging from a minimum of (32.3, 30.3) to a maximum of (47.8, 45.5) at 260 days from full bloom for two seasons. The highest values are found for Corona cultivar.

L* value means of four cultivars increased from (39, 36.5) at the first date to (49.3, 50.5) at the last date of maturation for two seasons, from showing an increase in lightness of peel during maturity stage. The highest value of L* was registered by Corona cultivar.

Slight statistical difference was observed regarding fruit clove number during maturity. Monroe lemon cultivar had the highest clove number.

Juice percentage showed a significant and gradual increase during maturation period for all cultivars. The increase might be accounted mainly for the accumulation of water and solutes to the juice vesicles. Corona cultivar reached the highest percentage 46.7, 47 % of total weight in juice in both seasons (Table 4).

These finding are in accordance with Landaniya and Singh [6] on lime cultivar; Hassan [16] on lemonera lemon and Gihan [17] on Fremont tangerine, most lemon varieties have highly similar morphological and biochemical characters, fruit of varying ages, sizes and appearance are always present on the tree. Fruit is generally oval to elliptical with characteristic necks and nipples, [18].

Chemical Characteristics of Fruit Maturity: Total soluble solid showed statistically significant differences among cultivars under observation, during maturation, a significant increase in TSS occurred from 7.3, 7.1 to 8.5% during two seasons (Table 4). Similarly, Hassan [16] found that TSS significantly increased during the fruit maturity of lemonera lemon. Conversely, Mukhim *et al*. [7] found that TSS% significantly decreased during the fruit growth of a seedless lemon cultivar.

Titratable acidity of four cultivars increased gradually with advanced time but not significant. Corona cultivar recorded the highest values of juice acidity (9.1%) during the first season of the study.

TSS: Acid ratio increased from 240 days till 260 days from full bloom in both season in the four cultivars from (0.82, 0.81) to (0.92, 0.93) during the two seasons. Among cultivars, Corona and Monroe had the highest values. These results are in agreement with the finding of Gihan [17] on Fremont tangerine.

Table 1: Fruit weight, texture and shape index of some lemon cultivars at maturity stage

	Fruit Weight (g)				Fruit texture (gm/cm^2)				Fruit shape index			
	Days from full bloom (D)				Days from full bloom (D)				Days from full bloom (D)			
Cultivars (C)	240	250	260	Mean	240	250	260	Mean	240	250	260	Mean
					First season							
Prior	86.2	98.0	130	104.7	113	99	93	101.6	1.33	1.32	1.25	1.30
Corona	98.8	120.0	153.0	123.9	124.0	122.0	119.0	121.6	1.39	1.40	1.24	1.34
Monroe	91.0	103.0	141.0	111.6	130.0	112.0	110.0	117.3	1.40	1.36	1.32	1.36
Frost	90.0	111.0	151.0	117.3	131.0	120.0	104.0	118.3	1.40	1.48	1.33	1.40
Mean	91.5	108	143.7		124.5	113.2	106.5		1.38	1.39	1.28	
L.S.D 0.05	(D): 2.96 (C): 2.67 (DxC): 4.62				(D):6.54 (C): 3.48 (DxC): 6.04				(D): 0.07 (C): 0.04 (DxC): NS			
					Second season							
Prior	96.7	118.0	140.0	118.2	120.0	103	98	107	1.25	1.22	1.26	1.24
Corona	128.8	146.0	173.0	149.2	129.0	126	122	125.6	1.32	1.30	1.25	1.29
Monroe	110.0	140.0	151.0	133.6	141.0	130	112	127.6	1.25	1.25	1.27	1.25
Frost	117.0	149.0	162.0	142.6	129.0	125	114	122.6	1.30	1.33	1.30	1.31
Mean	113.1	138.2	156.5		129.7	121	111.5		1.28	1.28	1.27	
L.S.D 0.05	D): 4.22 (C): 3.32 (DxC): 5.76				D): 7.41 (C): 3.77 (DxC): 6.54				(D): NS (C): 0.04 (DxC): NS			

Table 2: Fruit nipple length, peel thickness and seeds number of some lemon cultivars at maturity stage

	Fruit nipple length (cm)				Peel thickness (cm)				Seeds number			
	Days from full bloom (D)				Days from full bloom (D)				Days from full bloom (D)			
Cultivars (C)	240	250	260	Mean	240	250	260	Mean	240	250	260	Mean
					First season							
Prior	0.8	0.9	2.0	1.23	0.5	0.5	0.4	0.46	12	12	14	12.6
Corona	0.8	0.9	2.1	1.26	0.5	0.4	0.4	0.43	4	6	6	5.3
Monroe	0.9	1.1	3.0	1.66	0.5	0.4	0.4	0.43	20	22	22	21.3
Frost	1.2	1.4	3.0	1.86	0.6	0.6	0.5	0.68	18	18	18	18
Mean	0.92	1.07	2.52		0.52	0.47	0.42		13.5	14.5	15	
L.S.D 0.05	(D): 0.06 (C): 0.04 (DxC): 0.08				(D): NS (C): NS (DxC): NS				(D): 0.51 (C): 0.56 (DxC): 0.97			
					Second season							
Prior	0.9	1.0	2.0	1.30	0.5	0.5	0.5	0.5	12	16	14	14
Corona	0.8	1.0	2.0	1.26	0.4	0.4	0.4	0.4	4	4	6	4.6
Monroe	1.1	1.3	2.4	1.60	0.5	0.4	0.4	0.43	20	20	22	20.6
Frost	1.1	1.1	3.0	1.73	0.5	0.5	0.5	0.5	18	20	18	18.6
Mean	0.97	0.85	2.35		0.47	0.45	0.45		13.5	15	15	
L.S.D 0.05	(D): 0.04 (C): 0.03(DxC): 0.06				(D): NS (C): NS (DxC): NS				(D): 0.52 (C): 0.56 DxC): 0.99			

Table 3: Fruit color (a*, b* and L* value) of some lemon cultivars at maturity stage

	a* value				b* value				L* value			
	Days from full bloom (D)				Days from full bloom (D)				Days from full bloom (D)			
Cultivars (C)	240	250	260	Mean	240	250	260	Mean	240	250	260	Mean
					First season							
Prior	-17.5	-14.1	-9.6	-13.7	32	39	42	37.7	38	40	50	42.7
Corona	-15.0	-11.8	-8.5	-11.8	35	44	52	43.7	45	48	53	48.7
Monroe	-18.9	-14.7	-9.9	-14.5	32	40	50	40.7	37	40	43	40.0
Frost	-15.7	-12.0	-9.0	-12.2	30	38	47	38.3	36	41	51	42.7
Mean	-16.8	-13.2	-9.3		32.3	40.3	47.8		39.0	42.3	49.3	
L.S.D 0.05	D): 1.14 (C): 0.50 (DxC): 1.35				(D): 1.15 (C): 0.96 (DxC): 1.83				(D):1.77 (C):1.24 (DxC):2.54			
					Second season							
Prior	-15.0	-12.2	-10.2	-12.5	29	38	44	37.0	35	42	52	43.0
Corona	-13.0	-11.3	-9.0	-11.1	32	42	50	41.3	44	48	55	49.0
Monroe	-17.0	-15.2	-10.7	-14.3	30	38	46	38.0	35	40	45	40.0
Frost	-16.6	-13.2	-9.9	-13.2	30	40	42	37.3	36	40	48	41.3
Mean	-15.4	-13.0	-10.0		30.3	39.5	45.5		37.5	42.5	50.0	
L.S.D 0.05	(D): 0.94 (C):0.44 (DxC): 1.14				(D):1.34 (C):0.87 (DxC):1.86				(D):1.44 (C): 1.11 (DxC):2.18			

Table 4: Clove number, Juice% and TSS% of some lemon cultivars at maturity stage

	Clove number				Juice%				TSS%			
	Days from full bloom (D)				Days from full bloom (D)				Days from full bloom (D)			
Cultivars (C)	240	250	260	Mean	240	250	260	Mean	240	250	260	Mean
					First season							
Prior	8	8	9	8.3	30	35	50	38.3	7.0	7.5	8.2	7.6
Corona	8	8	8	8.0	40	45	55	46.7	7.7	8.6	8.8	8.4
Monroe	10	9	9	9.3	34	43	48	41.7	7.4	8.0	8.6	8.0
Frost	8	8	9	8.3	35	44	50	43.0	7.0	7.5	8.2	7.6
Mean	8.5	8.3	8.8		34.8	41.8	50.8		7.3	7.9	8.5	
L.S.D 0.05	(D): NS (C):0.29 (DxC):0.50				(D):1.15 (C):1.02 (DxC):1.90				(D): 0.34 (C): 0.21 (DxC):NS			
					Second season							
Prior	9	8	8	8.3	33	38	53	41.3	7.1	7.7	8.5	7.8
Corona	8	9	9	8.7	38	47	56	47.0	7.4	8.5	8.9	8.3
Monroe	9	9	9	9.0	33	42	48	41.0	7.2	8.2	8.6	8.0
Frost	8	8	9	8.3	35	45	48	42.7	6.6	7.0	8.0	7.2
Mean	8.5	8.5	8.8		34.8	43.0	51.3		7.1	7.9	8.5	
L.S.D 0.05	(D):NS (C):0.29 (DxC):1.06				(D): 1.13 (C): 1.04 (DxC):1.92				(D): 0.28 (C):0.20 (DxC):NS			

Table 5: Acidity %, TSS: Acid ratio and Vitamin C of some lemon cultivars at maturity stage

	Acidity %				TSS: Acid ratio				Vitamin C			
	Days from full bloom (D)				Days from full bloom (D)				Days from full bloom (D)			
Cultivars (C)	240	250	260	Mean	240	250	260	Mean	240	250	260	Mean
					First season							
Prior	8.9	9.0	9.2	9.0	0.78	.83	.89	0.83	55.9	55	54.4	55.1
Corona	8.8	9.1	9.3	9.1	0.87	.94	.94	0.92	57	58	57	57.3
Monroe	8.7	8.8	9.2	8.9	0.85	.90	.93	0.89	53	52	52	52.3
Frost	8.9	9.0	9.0	9.0	0.78	.83	.91	0.84	54	54	52	53.3
Mean	8.8	9.0	9.2		0.82	0.88	0.92		55.0	54.8	53.9	
L.S.D 0.05	(D): NS (C): NS (DxC): NS				(D):0.04 (C):0.02 (DxC): NS				(D): NS (C):1.59 (DxC): NS			
					Second season							
Prior	8.9	9.0	9.2	9.0	0.79	o.85	o.92	0.85	58	56	56	56.7
Corona	8.8	9.0	9.0	8.9	0.84	0.94	o.96	0.91	63	60	60	61.0
Monroe	8.5	9.0	9.0	8.8	0.84	0.91	0.95	0.90	52	54	54	53.3
Frost	8.8	9.0	9.0	8.9	0.75	0.77	0.88	0.80	56	54	55	55.0
Mean	8.8	9.0	9.1		0.81	0.87	0.93		57.3	56.0	56.3	
L.S.D 0.05	(D): NS (C): NS (DxC): NS				(D): 0.03 (C):0.02 (DxC): NS				(D): NS (C):1.67 (DxC): NS			

Ascorbic acid showed significant differences among cultivars and maturity stages (Table 5). In particular, the average of Ascorbic acid concentration showed a steadily decrease along maturity stages with 55.0 and 57.3 mg 100 g^{-1} at 240 days from full bloom to 53.9 and 56.3 mg 100 g^{-1} at 260 days from full bloom in both seasons, the greatest average was recorded at 260 days from full bloom in Corona cultivar (57.3 and 60.0 mg 100 g^{1-}).

The decline in ascorbic acid during maturation could be due to its utilization in certain metabolic process. The present results were in conformity with the findings of Sema and Sanyal [19] and Mukhim *et al.* [7]. Ascorbic acid correlated with the colorimetric parameters a*, b*, L* reflecting the dramatic metabolic and morpho-physiological changes. However, variations of the ascorbic acid, along maturity stages evidenced cultivar-specific trends. Overall, given the observed variations in fruit weight, juice content and ascorbic acid across maturity, these results suggest that harvesting lemon fruits at maturity after 260 days from full bloom where juice % was of 48% with 9% acidity allowed, this stage yielding the maximum amount of TSS and ascorbic acid per fruit in all four cultivars and among all, Corona cultivar gave the best performance.

Cold Storage and Transit

Physical Properties

Fruit Weight Loss: Weight loss is usually associated with the loss of water. The results in Table (6) indicates that weight loss% increased significantly at10°C till the end of the storage period for all cultivars after 4 months, there are significantly differences between cultivars it is evident that physiological weight loss was the lowest value at Corona cultivar (5.3 and 5.1) in both seasons, the superiority of low storage temperature and polyethylene packaging on weight loss could be due to loss of water and carbon dioxide in respiration processes. Packing in polyethylene and low temperature were effective in reducing water loss. This is in agreement with Roongruangsri *et al*. [8] on Tangarins and Obenland *et al*. [9] on Mandarins.

Fruit Texture: The fruit texture of lemon was significantly affected by the cold storage period. Table (6) showed that the texture of lemon fruit decreased continuously with the increase in cold storage period in both seasons. A significant difference regarding cultivars, Corona cultivar fruits had the highest texture values after 4 months of cold storage respectively, no significant difference was noticed at Monroe and Frost cultivars. While the lowest texture values were noticed at Prior cultivar.

Fruit Decay Percentage: Fruit decay is the main cause of post-harvest losses, it is clear that fruit did not have any decay symptoms after 4 months of storage in both seasons except Monroe cultivar at the fourth month of storage with the percentage of 12% and 10% in both seasons (Table 6). The great effect of polyethylene bags on minimizing fruit decay could be explained by diminishing respiration rate and reducing fruit rind shrinkage as a result of degrading water loss. This mention was supported by Roongruangsri *et al*. [8] on Tangarins and Obenland *et al*. [9] on Mandarins.

Fruit Color: The mean values of, a*, b*, L* increased from green to yellow stage with the extension of cold storage periods (Table 7). These changes in values are due to the conversion of the fruit color from green to yellow during cold storage, significant difference among cultivars, Corona cultivar had the highest a*, b*, L* values.

Color changes in the citrus fruit are attributed to degradation of chlorophyll pigments with maturation process and accumulation of carotenoids in the avedo [4]. Carotenoids impart characteristic yellow color in the lemon fruit but co-exist with green color pigment chlorophyll. The expression of carotenoid pigments is masked by chlorophylls in the green lemon fruit. With advancement of fruit maturity, the chlorophyll pigments are degraded allowing accumulation and expression of carotenoids in the fruit avedo and as a result fruit color changes from green to yellow.

Juice Percentage: It is evident from Table (8) that a gradual increase in juice percentage of the fruits occurred as the storage duration advanced. It can be noticed that there were no significant differences between cultivars except Corona cultivar had the highest value. The increase in the percentage of juice is an unreal increase due to the increase in weight loss, as the weight of the fruit decreases and thus the percentage of juice increases.

Respiration Rate: According to determination the respiration rate of fruit during cold storage period, it is clear that an increase occurred at first in fruits stored then increased significantly with extend the cold storage period, these results are in agreement with Hassan [16], Aspaia and Kader [20]. The date presented in Table (9) showed that respiration rate was higher at Prior and Forest cultivars in the first season, while Monroe cultivar was the highest rate in the second one, generally Corona cultivar had the lowest respiration rate in both seasons.

Chemical Properties:

Tss %: As for TSS content, data in general showed gradual increase during storage periods (Table 10). Sight significant variance was observed among cultivars, Corona cultivar recorded the highest percentage of total soluble solids in the two seasons. The increased values in soluble solids could be due to fruit weight loss and subsequently fruit juice concentration [21].

Acidity: The effect of prolong cold storage period on the acidity content of the lemon cultivars is shown in Table (10). The results revealed that the acidity decreased in conjunction with prolonged storage time, the acidity content in the lemon samples was significantly lower than the initial value. Prior cultivar showed the highest value of acidity. Acidity was slightly declined during different periods up to 4 months of storage this is due to its consumption in the respiratory process. These results are in line with those reported by Hassan [16] on lemonera lemon and Gihan [17] on Fremont Tangerine.

Table 6: Fruit weight loss (%), fruit texture (gm/cm^2) and fruit decay (%) of some lemon cultivars during cold storage

	Storage period (Month) (P)						Storage period (Month) (P)					
Cultivars (C)	0	1	2	3	4	Mean	0	1	2	3	4	Mean
	Fruit weight loss% (First season)						Fruit weight loss% (Second season)					
Prior	0.0	3.0	7.0	9.0	12.1	6.2	0.0	2.8	6.7	9.1	11.2	5.6
Corona	0.0	2.7	5.8	8.0	10.2	5.3	0.0	2.4	5.5	7.8	10.0	5.1
Monroe	0.0	3.8	6.6	9.2	12.0	6.3	0.0	3.2	6.2	8.8	11.3	5.9
Frost	0.0	3.4	6.3	9.0	10.9	5.9	0.0	3.0	6.8	8.9	10.7	5.8
Mean	0.0	3.2	6.4	8.8	11.3		0.0	2.8	6.3	8.6	10.8	
L.S.D 0.05	(P) 0.42 (C) 0.21 (P*C)0.58						(P) 0.41 (C) 0.19 (P*C)0.58					
	Fruit texture (gm/cm^2) (First season)						Fruit texture (gm/cm^2) (Second season)					
Prior	101	96	88	74	63.1	84.4	117	111	99	87.7	70.2	73.5
Corona	120	113	96.0	88.0	77.5	98.9	134	129	119	99.2	80.0	112.2
Monroe	110	103	89.6	79.4	73.0	91.0	128	121	111	95.9	77.8	106.7
Frost	118	111	90.3	80.7	70.9	94.1	130	124	110	90.0	73.0	108.0
Mean	112.2	105.7	90.9	81.5	71.1		127.2	121.2	112.2	93.9	75.2	
L.S.D 0.05	(P) 4.52 (C) 3.55 (PXC) 7.94						(P) 5.04 (C) 4.01 (PXC) 8.98					
	Fruit decay % (First season)						Fruit decay % (Second season)					
Prior	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monroe	0.0	0.0	0.0	0.0	12.0	2.4	0.0	0.0	0.0	0.0	10.0	2.0
Frost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.0	0.0	0.0	0.0	3.0		0.0	0.0	0.0	0.0	2.5	

Table 7: Fruit color (a*, b* and L* value) of some lemon cultivars during cold storage

	Storage period (Month) (P)						Storage period (Month) (P)					
Cultivars (C)	0	1	2	3	4	Mean	0	1	2	3	4	Mean
	a* value (First season)						a* value (Second season)					
Prior	-8.6	-5.0	0.20	1.3	2.8	-1.89	-7.4	-2.7	1.6	3.1	4.6	-0.16
Corona	-8.5	-6.4	-1.4	0.5	2.6	-2.64	-7.7	-4.4	-2.2	0.4	2.11	-2.35
Monroe	-7.9	-2.6	0.4	1.6	3.1	-1.08	-7.4	-1.2	0.6	2.7	4.2	-0.22
Frost	-7.0	-5.8	-1.8	1.7	3.0	-1.98	-7.1	-4.9	-1.8	1.6	3.2	-1.80
Mean	-8.0	-4.95	-0.65	1.27	2.87		-7.4	-3.3	-0.45	1.95	3.52	
L.S.D 0.05	(P) 0.30 (C) 0.09 (PXC) 0.34						(P) 0.24 (C) 0.10 (PXC) 0.31					
	b* value (First season)						b* value (Second season)					
Prior	43.0	54	56	60	65.0	55.6	47	53	58	58	60	55.2
Corona	51.0	53	62	63	65.7	58.9	50	55	57	60	64	57.2
Monroe	50.1	52	56	60	64.0	56.4	48	53	55	55	56	53.4
Frost	47.0	55	60	63	64.6	57.9	48	57	57	58	60	56.0
Mean	47.7	56	64.2	64.5	65.0		48.2	54.5	56.7	57.7	60	
L.S.D 0.05	(P) 1.85 (C) 1.34 (PXC) 3.19						(P) 1.69 (C) 1.29 (PXC) 3.01					
	L* value (First season)						L* value (Second season)					
Prior	47	61.4	66	67	69.1	62.1 c	48	58	61	64	66	59.4 b
Corona	56	66.4	68.1	70	71.5	66.4 a	55	61	63	66	67.5	62.5 a
Monroe	53.8	66	68	66	68.2	64.4 b	50	54	58	60.7	64	57.3 c
Frost	55	61	65	56.8	67.9	61.1 d	52	55	59	63	66	59.0 b
Mean	55.2	63.7	66.7	64.9	69.1		51.2	57.0	60.2	63.4	65.8	
L.S.D 0.05	(P) 1.95 (C) 1.47 (PXC) 3.46						(P) 1.89 (C) 1.40 (PXC) 3.13					

Table 8: Juice% of lemon fruit during cold storage

	Storage period (Month) (P)						Storage period (Month) (P)					
Cultivars (C)	0	1	2	3	4	Mean	0	1	2	3	4	Mean
	First season						Second season					
Prior	50	52.0	55.0	56.7	55.1	53.7	45	47	51	54	57	50.8
Corona	58	59.0	60.0	59.0	60.5	59.3	55	56	58	58	59	57.2
Monroe	48	50.8	52.6	54.4	55.0	52.1	47	51	54	55	55	52.4
Frost	50	53.4	56.3	56.7	57.9	54.8	51	55	57	57	58	55.6
Mean	51.5	53.8	58.2	58.9	57.1		49.5	52.2	55	56	57.2	
L.S.D 0.05	(P) 1.57 (C) 1.24 (PXC) 2.87						(P) 1.47 (C) 1.22 (PXC) 2.79					

Table 9: Respiration rate of lemon fruit during cold storage

	Storage period (Month) (P)						Storage period (Month) (P)					
Cultivars (C)	0	1	2	3	4	Mean	0	1	2	3	4	Mean
	First season						Second season					
Prior	1.39	1.70	1.9	2.7	3.1	2.15	1.28	1.6	2.0	2.5	2.9	2.05
Corona	1.37	1.61	1.7	2.0	2.5	1.83	1.25	1.6	2.1	2.3	2.4	1.93
Monroe	1.40	1.77	1.9	2.4	3.0	2.09	1.30	1.8	2.6	2.7	2.9	2.26
Frost	1.40	1.75	1.8	2.7	2.9	2.11	1.32	1.7	2.5	2.5	2.7	2.14
Mean	1.39	1.70	1.82	2.45	2.87		1.28	1.6	2.3	2.5	2.7	
L.S.D 0.05	(P) 0.19 (C) 0.11 (PXC) 0.29						(P) 0.33 (C) 0.15 (PXC) 0.44					

Table 10: Fruit TSS, Acidity (%), TSS/acid ratio and Ascorbic acid (mg 100 g^{-1}) of some lemon cultivars during cold storage

	Storage period (Month) (P)						Storage period (Month) (P)					
Cultivars (C)	0	1	2	3	4	Mean	0	1	2	3	4	Mean
	TSS% (First season)						TSS% (Second season)					
Prior	8.6	8.6	8.8	8.8	8.8	8.72	7.8	8.0	8.2	8.5	8.5	8.20
Corona	8.8	8.8	9.0	9.0	9.2	8.96	8.5	8.5	8.7	8.8	8.8	8.66
Monroe	8.5	8.5	8.6	8.8	9.0	8.68	8.1	8.4	8.5	8.5	8.5	8.40
Frost	8.2	8.1	8.3	8, 7	9.0	8.46	8.0	8.5	8.6	8.7	8.7	8.40
Mean	8.52	8.5	8.67	8.82	9.0		8.1	8.35	8.5	8.62	8.62	
L.S.D 0.05	(P) 0.19 (C) 0.11 (PXC) 0.29						(P) 0.23 (C) 0.18 (PXC) 0.42					
	Acidity % (First season)						Acidity % (Second season)					
Prior	9.2	9.0	8.4	7.8	7.1	8.3	9.2	9.0	8.8	8.6	8.5	8.8
Corona	9.0	8.5	8.2	8.0	7.0	8.1	9.0	8.5	8.0	7.5	7.0	8.0
Monroe	9.2	8.8	8.6	8.0	7.0	8.3	9.0	8.8	8.4	8.0	7.8	8.4
Frost	9.0	8.7	8.3	8, 0	7.3	8.2	9.0	8.8	8.2	7.7	7.5	8.2
Mean	9.1	8.7	8.3	7.95	7.1		9.05	8.7	8.35	7.95	7.7	
L.S.D 0.05	(P) 0.19 (C) 0.18 (PXC) 0.40						(P) 0.21 (C) 0.18 (PXC) 0.41					
	TSS/acid ratio (First season)						TSS/acid ratio (Second season)					
Prior	0.93	0.95	1.04	1.12	1.23	1.05	0.84	0.88	0.93	0.98	1.00	0.92
Corona	0.97	1.03	1.09	1.12	1.31	1.10	0.94	1.00	1.08	1.17	1.25	1.08
Monroe	0.92	0.96	1.00	1.10	1.28	1.05	0.90	0.95	1.01	1.01	1.08	0.99
Frost	0.91	0.93	1.00	1.08	1.23	1.03	0.88	0.96	1.04	1.12	1.16	1.03
Mean	0.93	0.96	1.03	1.10	1.26		0.89	0.94	1.01	1.07	1.12	
L.S.D 0.05	(P) 0.04 (C) 0.02 (PXC) 0.05						(P) 0.03 (C) 0.02 (PXC) 0.05					
	Ascorbic acid (First season)						Ascorbic acid (Second season)					
Prior	56	55	53	54	51	53.8 b	54.5	52.4	50.8	50.0	48.2	51.1 b
Corona	60	57	57	55	53.8	56.5 a	57	55.1	52.8	51.2	50.0	53.2 a
Monroe	54	54	52	50	47.0	51.4 d	52	50.1	46.5	45.8	45.0	47.8 d
Frost	55	54	52	52	50.9	52.7 c	52	50.4	50.1	48.2	45.8	49.3 c
Mean	56.2	55	53.5	52.7	50.6	53.6	53.8	52	50.0	48.8	47.2	
L.S.D 0.05	(P) 1.41 (C) 1.18 (P*C)2.65						(P) 1.31 (C) 1.11 (P*C)2.48					

TSS: Acid ratio Data in Table (10) revealed that there was a gradual increase in TSS/ acid ratio with significant variance between cultivars and storage periods. Frost cultivar showed the lowest value of TSS/ acid ratio. The decline in total acid contents led to increases in TSS/acid ratio over the same time period [22].

Ascorbic Acid: It is clear that ascorbic acid decreased with the increased of cold storage period. There were significantly differences between cultivars, Corona cultivar recorded the highest value (56.5 and 53.2 mg 100 g^{-1}) in both seasons, followed by Prior, Monroe and Frost cultivar.

Although the ascorbic acid level decreased throughout storage, the use of a low temperature significantly reduced the loss of ascorbic acid in the lemon samples. The same results founded by Asanda *et al*. [23] that, ascorbic acid retention is also improved when citrus fruits are stored in modified atmosphere packaging and controlled atmosphere (CA).

Table 11: Calcium, Potassium (mg/100g) and Polyphenol oxidase activity (U)of lemon fruit at the initial and end of cold storage

	Storage period (Month) (P)								
Cultivars (C)	Initial	End (4 months)	Mean	Initial (0)	End (4 months)	Mean	Initial (0)	End (4 months)	Mean
	Calcium			Potassium			Polyphenol oxidase (U)		
					First season				
Prior	2.56	1.60	2.08	3.85	2.88	3.36	7.5	70	38.75
Corona	3.60	2.40	3.00	4.24	3.96	4.10	7.5	65	36.25
Monroe	2.80	1.40	2.10	4.31	3.95	4.13	7.8	78	42.90
Frost	3.20	2.30	2.75	4.90	3.95	4.42	7.7	77	42.35
Mean	3.04	1.92		4.32	3.68		7.62	72.5	
L.S.D 0.05	(P) 0.05 (C) 0.02 (PXC) 0.05			(P) 0.03 (C) 0.01 (PXC) 0.01			(P) 8.79 (C) 0.27 (PXC) 8.80		
					Second season				
Prior	2.50	2.48	2.49	4.50	4.20	4.35	8.1	75	41.55
Corona	3.36	3.12	3.24	4.70	4.50	4.60	7.7	60	33.85
Monroe	3.12	2.88	3.00	4.90	4.60	4.75	8.2	66	37.10
Frost	3.04	2.85	2.94	4.40	4.20	4.30	8.5	74	41.25
Mean	3.00	2.83		4.62	4.37		8.12	68.7	
L.S.D 0.05	(P) 0.72 (C) 0.01 (PXC) 0.73			(P) 0.04 (C) 0.02 (PXC) 0.05			(P) 4.58 (C) 0.18 (PXC) 4.60		

Table 12: Fruit characters after cold storage at 10°C plus7 days as a marketing period (Shelf life at 18-20°C)

Cultivars (C)	Weight loss%	Juice%	Acidity%	Ascorbicacid (mg/100g juice)	Physiological disorder %
			First season		
Prior	13.1	58	7.1	46	---
Corona	10.5	62	6.5	49	---
Monroe	13.0	57	7.0	42	12.0
Frost	10.9	55	6.9	44	---
			Second season		
Prior	11.4	58	7.0	48	----
Corona	9.4	60	6.8	51	---
Monroe	10.5	55	6.9	45	10.0
Frost	10.8	52	6.8	44	----

Calcium and Potassium Content: It is evident from Table (11) that according to determination Calcium and Potassium content of fruit at the initial and the end of cold storage, it is clear that Calcium and Potassium content decreased with prolong of cold storage period. The differences between cultivars were insignificant.

PPO Activity: Table (11) illustrates that, PPO activity in lemon peel increased in conjunction with an extension of storage time, a higher activity at the end of storage period than those at the initial of storage. Furthermore, the PPO activity in the cultivars increased to varying degrees of increase, this is in agreement with Cruz *et al*. [24]; Hassan [16] and Liu *et al.* [25]. Polyphenol oxidase is related to senescence and browning of fruit tissues, so its activity has become an important indicator of fruit senescence [26].

Shelf Life: Shelf life was improved by storage at ideal low temperatures, which due to attributed to the lowest level of water loss and retention of a better balance between the sugars and acids in the fruit, decrease the weight loss, delay decay incidence and changes in compounds influencing the quality fruits. From the point of view of the consumer, the most important characteristics at the end of the storage period are percentage of weight loss, percentage of juice, decay and the percentage of ascorbic acid.

Table (12) illustrated characters of fruits at the end of cold storage period plus 7 days at room temperature (18-20°C) as a market period or transit to export. Data showed increasing in weight loss and juice % for the cultivars. In contrast significant decrease in acidity and ascorbic acid were detected. This result is in agreement with those found by El-Oraby and Gihan [27] on grapefruit and Hassan [16] on lemonera lemon.

Physiological Disorder: These included chilling injury, fruits without button, ring break down and aging. There was no incidence of physiological disorder during cold storage period and marketing except few Monroe fruit cultivar suffered from capsule fall (without button) and decay after 4 months of storage.

CONCLUSION

Across maturity, lemon fruits undergo dramatic changes in their attitude to harvesting and post-harvesting management largely depending on the final product destination and on the cultivar. Among the four lemon cultivars, Corona cultivar had larger and relatively juicier fruit than other cultivars. The rind of Prior and Monroe were significantly thicker than those of Corona and Frost cultivars. Generally, Corona cultivar had a higher TSS, TA and ascorbic acid content. The cultivars lemon harvested at maturity stage and stored in polyethylene bags at10?C retained marketable quality for up 4 months and 7 days as a shelf-life to market or transit period to export, also, Corona fruits had the highest keeping quality.

REFERENCES

1. González-Molina, E., R. Domínguez-Perles, D.A. Moreno and C. García-Viguera, 2010. Natural bioactive compounds of citrus limon for food and health. J. Pharm. Biomed. Anal., 51: 327-345.
2. Ministry of Agriculture Statistics, 2015. Agriculture Directorates of Governorates Publisher: Economic Affairs Sector, pp: 1-450.
3. F A O STAT, 2017. http://www.fao.org/ faostat/en/#data/QC Google Scholar.
4. Alós, E., M. Cercós, M.J. Rodrigo, L. Zacarías and M. Talón, 2006. Regulation of color break in citrus fruits. Changes in pigment profiling and gene expression induced by gibberellins and two ripening retardants. J. Agric. Food Chem., 54(13): 4888-4895.
5. Kader, A.A., 2000. Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing. J. Agric. Food Chem., 48: 4581-4589.
6. Ladaniya, M.S. and S. Singh, 2000. Maturity indices for acid lime Indian. J. Agric. Sci., 70(5): 292-295.
7. Mukhim, C., A. Nath, B.C. Deka and T.L. Swer, 2015. Changes in physico-chemical properties of Assam lemon (*Citrus limon* Burm.) at different stages of fruit growth and development Bioscan, 10 pp: 535-537 View Record in ScopusGoogle Scholar.
8. Roongruangsri, W., N. Rattanapanone, N. Leksawasdi and D. Boonyakiat, 2013. Influence of Storage Conditions on Physico-Chemical and Biochemical. Journal of Agricultural Science, 5(2): 70-84.
9. Obenland, D., C. Sue, M. Bruce, S. James and L.A. Mary, 2011. Storage temperature and time influences sensory quality of mandarins by altering soluble solids, acidity and aroma volatile composition. Postharvest Biol. Technol., 59: 187-193.
10. McGure, R.Q., 1992. Reporting of objective color measurements. Hortscience, 27(12): 1254.
11. Cross, R.A., 1966. Analysis of the major constituents of pel gas by gas chromatography. Nature, 211.409.
12. A.O.A.C., 2005. Official Methods of Analysis, (18th ed.). Association of Official Analytical Chemistry.
13. Galeazzi, M.A.M., V. Sgarbieri and S.M. Constantantinides, 1981. Isolation purification and physiochemical characterization of polyphenoloxidase from dwarf variety of banana. J. Food Sci., 46: 150.
14. Wang, T.A., G.C. Walker and D.O. Pearson, 1971. A direct titrimetric method for the rapid estimation of sulfur dioxide in fresh pork sausage. Food Technol., 6: 179.
15. Snedecor, G.W. and W.C. Cochran, 1990. Statistical methods, 6th, Ed. Iowa state Univ, Press, Ames, Iowa, pp: 543.
16. Hassan, A.M., 2004. Maturity indices and influence of some treatments on storage of lemon fruits. Egypt. J. Appl.Sci., 19(6B): 651-666.
17. Gihan M. Ail, 2002. Effect of four citrus rootstocks on fruit quality and storability of Fremont Tangerine. 2ed Inter. Conf. Hort. Sci., 10-12 Sept. pp: 312-326 Kafr El-Sheikh, Tanta Univ., Egypt.
18. Gulsen, O., A. Uzun and H. Pala, 2007. Development of seedless and mal secco tolerant mutant lemon through budwood irradiation. Sci. Hortic., 112(2): 184-190.
19. Sema, A. and D. Sanyal, 2003. Developmental physiology of lemon fruits. I. Physical characteristics. Crop Res., 26(3): 446-451.
20. Arpaia, M.L. and A.A. Kader, 2001. Lemon. Recommendation for maintaing postharvest quality. Science in Horticulture, pp: 202-224.
21. Khademi, Z. and A. Ershadi, 2013. Postharvest application of salicylic acid improves storability of peach (*Prunus persica* cv. Elberta) fruits. Intern. J. Agric. and Crop Sci., 5(6): 651-655.

22. Salwa, A. Orabi, Elham Z. Abd El-Motty, M.S. El-Shamma, S.D. Abou-Hussein and Faida A. Sharara, 2018. The effect of salicylic acid and aspirin treatments on enzymes activity and fruit quality of clementine mandarin fruits during different cold storage periods. Middle East Journal of Agriculture Research, 7: 583-593.
23. Asanda, M., Lembe S. Magwaza, S. Zeray, T. Umezuruike and L. Opara, 2017. Postharvest factors affecting vitamin C content of citrus fruits: A review. Scientia Horticulturae, 218: 95-104.
24. Cruz, J.D., G. Vela, D.M. Leon and H.S. Garcia, 2003. Polyphenoloxidase activity during ripening and chilling stress in Manila mangoes. The Journal of Horticulture Science and Biotechnology, 78(1): 104-107.
25. Liu, H., W.B. Jiang, J.K. Cao and Y. Li, 2019. Effect of chilling temperatures on physiological properties, phenolic metabolism and antioxidant level accompanying pulp browning of peach during cold storage. Sci. Hortic-Amsterdam, 255: 175-182.
26. Zhao, H., B. Liu, W. Zhang, J. Cao and W. Jiang, 2019. Enhancement of quality and antioxidant metabolism of sweet cherry fruit by near-freezing temperature storage. Postharvest Biol. Technol., 147: 113-122.
27. El-Oraby, S.O. and Gihan M. Ali, 2002. Maturity and cold storage of three new cultivars of grapefruits. 2nd Inter Conf. Hort. Sci.10-12 Sept. pp: 327-343 Kafr El-Sheikh, Tanta Univ. Egypt.