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The Effect of Maturity Stages on the Characteristics of New Lemon Cultivar During Cold Storage

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Abstract: Quality and storage ability of fruits would depend on various physiological changes which occur during fruit growth, development and maturity. Such information is useful to assess the stage of maturity for harvesting the fruit. Fruits picked at the wrong maturity stage may develop physiological disorders in storage and may exhibit poor quality. Therefore, the objective of the experiment is to investigate the effects of two maturity stages (Greenish and yellowish) and two temperature cold storage (5°C and 10°C) 85-90%RH on Corona lemon characters under Southern Tahrir region of Behera Governorate during two successive seasons 2017 and 2018. The quality parameters such as fruit weight loss%, texture, respiration rate, fruit color parameters, L*, a*, b*, total soluble solids content (TSS%), titratable acidity (TA%), vitamin C in the fruit juice were estimated. Considering different fruit quality parameters, results demonstrated that, fruit weight loss%, TSS% and TA% decreased signi?cantly from greenish stage to yellowish stage and increased significantly with the extension of cold storage periods at 5°C and 10°C. L*, a*, b* values in the cold stored fruit increased significantly from green stage to yellow stage and also with the extension of cold storage periods at both 5°C and 10°C. Regarding to temperature, Corona cultivar fruit harvested at green stage can be stored 4 months at 5°C and more than 4 months at10°C. The green stage revealed to be a good stage of Corona lemon to store at low temperature due to it is tolerant to chilled temperature for long term, while Corona lemon fruit harvested at yellow stage are suitable to store for 3 months at 5°C and4 months at 10°C, which must be marketed more rapidly due their shorter shelf-life.

Key words: Citrus lemon · Corona cultivar · Quality parameters · Cold storage

INTRODUCTION

Lemon (*Citrus limon* (L.) Burm. f.) is the third crop for economic importance among citrus species. Together with lime, their global harvested area amounts to1.2 million hectares with a corresponding production of 20.1 million tons [1]. The 48% of the global lemon production comes from the Mediterranean Basin.

The bulk of the lemon crop matures in early winter, while the consumer demand for fresh lemons exists year-round. The harvest maturity stage of citrus fruit is one of the critical factors which affect its quality parameters such as fruit color [2].

Two physical characteristics that are of particular importance for lemon fruits are the volume of extractable juice (40%by weight being typical minimum level) and number of seeds, nevertheless, cultivars of mediocre quality are increasingly grown for fresh use because of consumer preference for citrus fruit with few or no seeds [3].

Lemon fruit is usually strip or selectively harvested depending upon the fruit size at the yellow, green-yellow or green stage, according to the market requirements. Color break is defined as “a break in color caused solely by nature” shall mean that the change produced by nature converting the dark green color to yellow color has progressed to the extent that a tinge of yellow is apparent. It has been reported that the fruit harvested at yellow stage could be stored for few weeks, whilst green-yellow stage for 6 weeks and green stage for 2-6 months before marketing at commercially acceptable state [3]. Al-Rousan *et al*. [4] reported that with the extension of the harvest period slightly increase the juice percentage, SSC, SSC: TA. Storage conditions and duration

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significantly influence the postharvest fruit quality parameters of lemon. High-density polyethylene (HDPE) wraps delayed loss of firmness and peel coloration of lemons for up to 6 months with the fruit kept at 17 to 20°C [5]. Lemon fruit, as other citrus species, is non-climacteric fruit, with persistently low respiration and ethylene production rates during ripening [6, 7]. The most important factor affecting postharvest life is temperature, because temperature has a profound effect on the rates of biological reactions; metabolism and respiration, increased temperatures cause an exponential rise in respiration. Lemon fruit is sensitive to cold temperature and when stored below 5°C it can develop chilling injury symptoms including discoloration, weight loss and development of brown spot and pitting on the fruit surface [8, 9]. Low storage temperature below 10°C promoted chilling injury incidences (CI) on lemons [10].

Lemons should be stored between 7-12°C for up to 6 months under the right conditions. Optimum RH is 85 to 95%. Because lemons are chilling sensitive, they should not be stored for prolonged periods below 10°C, though 3 to 4 weeks storage at 3 to 5°C [11].

Chilling injury is physiological disorders of lemons, which may lead to important economic losses due to low visual quality. Lemon fruit is very sensitive to storage temperature below 10°C appearing chilling injury symptoms, to reduced, or even avoided, physiological disorders (chilling injury and red blotch), minimizing weight losses, in lemon fruit during long storage and transportation and retail sale periods extending its shelf life.

The green stage (G-stage) revealed to be a good stage of lemon to store at low temperature due to it is tolerant to chilled temperature for long term [12]. Lemon fruit harvested at yellow stage are suitable to store for 30 days and the fruit harvested at green stage can be stored up to 90 days at 10°C [13].

The aim of this study to determinate the effect of two maturity stages (Greenish and yellowish) on quality and storability of Corona lemon fruit at two temperature degrees 5°C, 10°C.

MATERIALS AND METHODS

The lemon fruit (*Citrus limon* (L.) Burm. F. cv. Corona) were picked from trees of 12-years old grafted on Volkamariana Lemon rootstock from a privet orchard located at Tahrir regent, Behera Governorate, Egypt. The fruit were picked at two different harvest maturity stages, selected and transported to Horticulture Research Institute within two hours, were thoroughly graded based on the color (green and yellow fruit) free from blemishes, diseases and pests. The fruit of two different maturity stages were packed in polyethylene bags (20 micron thick) each bag contained 20 fruits kept inside carton boxes (5 bags / box) and stored at 5°C and 10°C, 85-90%RH for 4 months. Each treatment was replicated three times and included ten fruits per replicate. Fruit samples were taken every month to study the following physical and chemical properties:

The Physical Properties

Weight Loss%: The fruit weight loss was calculated as a percentage of weight loss against the initial weight prior to the cold storage, by using the following equation:

Weight loss (%) (Initial weight–Final weight) 100 Initial weight.

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.

Juice Percentage: Juice percentage was calculated by weight. The juice contents were measured on digital balance and fruit juice contents (%) was calculated by using the formula:
Juice weight (%) =Average juice weight /Average fruit weight ×100

Respiration Rate: Sample of five lemon fruits cultivars were taken and CO_2 was determined according to Cross [14] method. The respiration rate as ml CO_2 /kg /hr. = (Δ%*10) (free space volume of container in liters /(product fwt in kg) (Time container inclosed in hours).

Fruit Color: Determination of fruit color coordinates using Hunter scale, fruit color coordinates were recorded using Hunter colorimeter DP9000 as a*, b* and L* at two positions on fruit surface around the equatorial plane of the fruit following the method earlier described by Rehman *et al*. [15]. The data were expressed as redness/greenness (a*) ('+' = redder; '-' = greener), yellowness/ blueness (b*) ('+' = yellower ; '-' = bluer). lightness/darkness (L*) ('+' = lighter; '-' = darker),

The Chemical Properties:

TSS%: Total soluble solids (TSS) were determined using an Abbe digital refractometer expressed as a per cent.

Acidity%: (TA) was determined by titrating 5mL of diluted juice (3 x) against 0.1N NaOH using phenolphthalein as an indicator, to the pink color endpoint. Acidity (TA) in the juice was expressed as per cent citric acid.

Vitamin C: The concentration of vitamin C was calculated using the standard curve drawn using 98% L-ascorbic acid standard and expressed as mg L/ of fresh juice [16].

Calcium and Potassium %: Mineral's content, Calcium and Potassium were determined in fruit pulp using atomic absorption Spectro-photometer according to AOAC [16] at the beginning and the end of cold storage period.

Pectin %: Fruit pectin were estimated according to Rouse [17]. The concentration was determined from a standard curve of galacturonic acid as mg. per 100 gm, dry weight.

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*. [18].

Determination of Poly Phenol Oxidation Activity: The activity of the crude enzyme extract was assayed according to the procedure of Wang *et al*. [19] this was done before and at the end of cold storage.

Chilling Injury: The symptoms of chilling injury (CI) include surface pitting and browning was determined according to the method described by Obenland *et al*. [20]. Grade levels were classified as: grade 0, the unaffected orange fruits; grade 1, CI symptoms on the fruit with decay of less than 25%; grade 2, CI symptoms on fruit with decay of 25-50%; and grade 3, more than 50% decay and CI symptoms on fruits.

The decay and CI index is calculated using the formula:

Decay and CI index (%) = (decay and CI Grade ×number of fruit at this level) / (highest level × total fruit number) ×100.

Also, total losses were determinate at the end of cold storage period and transport the fruits to ambient temperature 18°C-20°C.

Statistical Analysis: Data were subjected to analysis of variance according to Snedecor and Cochran [21]. Means of treatments were compared by L.S.D. at the 5% level.

RESULTS AND DISCUSSION

The Physical Properties:

Fruit Weight Loss%: Fruit weight loss was significantly affected by harvest maturity stages and cold storage periods at 5°C and 10°C (Table 1). Data obtained that, weight loss percentage was gradually increased by increasing the cold storage period and significantly highest in the fruit harvested at green stage compared to those harvested at yellow stage.

Variation in weight loss% at different harvest stages and different cold storage periods may be attributed to the differences in respiration rates. Respiration and transpiration are the main factors, which contribute to the weight loss in citrus fruit. Similar findings of the increased weight loss with the extension of storage periods were observed in the lemon fruit by Sun *et al.* [10].

Regarding to temperature, the results indicates that lemon stored at 10°C presented highest weight loss%, while exposure to 5°C presented the lowest after 4 months of storage. The superiority of low temperature and polyethylene packing on reducing weight loss could be due to water loss and carbon dioxide loss in respiration.

The loss of weight involves mainly the peel, not the pulp of the fruit, the peel changes its water status much more rapidly than the pulp, The volume of the cells of the G-stage is less than the Y-stage at to water loss. Also, the thickness of the lemon skin may determine the amount of water loss from the fruit. It became thinner with fruit developing during the season. So, with thin-flavedo layer fruit at Y-stage, lost water higher than thick fruit (G-stage) [12].

Texture: There was significantly affected by the harvest maturity stages and temperature during cold storage period. Data in Table (1) indicated that texture of Corona lemon fruit at two maturity stages decreased continuously with the increasing in storage duration, might be attributed to loss of cellular turgor pressure and cell wall disassembly increased with fruit ripening and senescence. However, fruit harvested at green stage maintained higher texture throughout the storage period, the lower fruit texture values in yellow fruit were obtained. Regarding the effect of temperature, it was found that 5°C retains the firmness of the fruits compared to 10°C. Lemon fruit firmness is related to cell turgidity and thickness of skin and it is one of the pivotal factors determining the commercial acceptance of citrus fruit [23].

Table 1: Fruit weight loss%, fruit texture (gm/cm)^2 and Juice % of lemon Corona cultivar during cold storage period

		Storage period (Month) (P)						Storage period (Month) (P)					
Maturity stage	Temperature	0	1	2	3	4	Mean	0	1	2	3	4	Mean
		Fruit weight loss% (First season)						Fruit weight loss% (Second season)					
Green	5°C	0.00	2.00	6.00	8.00	10.00	5.20	0.00	2.40	6.20	8.40	9.20	5.24
	10°C	0.00	2.70	6.80	8.60	11.20	5.86	0.00	2.80	6.50	9.00	10.00	5.66
	Mean	0.00	2.35	6.40	8.30	10.60		0.00	2.60	6.35	8.70	9.60	
L.S.D.5%		(P): 0.35 (T): 0.26 (PxT): 0.58						(P): 0.29 (T):0.22 (PxT):0.49					
Yellow	5°C	0.00	1.80	5.00	7.00	8.50	4.46	0.00	2.20	5.20	8.00	9.30	4.94
	10°C	0.00	2.40	5.30	7.70	9.30	4.94	0.00	2.70	5.80	8.70	9.70	5.38
	Mean	0.00	2.10	5.15	7.35	8.90		0.00	2.45	5.50	8.35	9.50	
L.S.D.5%		(P): 0.32 (T): 0.24 (PxT): 0.53						(P): 0.33 (T): 0.24 (PxT): 0.54					
		Fruit texture (gm/cm)^2 (First season)						Fruit texture (gm/cm)^2 (Second season)					
Green	5°C	128.0	122.0	109.0	93.0	88.0	108.0	130.0	122.0	104.0	91.0	78.0	105.0
	10°C	133.0	121.0	102.0	89.0	78.0	104.6	131.0	114.0	98.0	80.0	76.0	99.8
	Mean	130.5	121.5	105.5	91.0	83.0		130.5	118.0	101.0	85.5	77.0	
L.S.D.5%		(P): 3.19 (T):2.26 (PxT):5.04						(P): 3.11 (T): 1.96 (PxT): .38					
Yellow	5°C	126.0	120.0	100.0	90.0	76.0	102.4	127.0	123.0	112.0	88.0	73.0	104.6
	10°C	126.0	114.0	99.0	90.0	73.0	100.4	132.0	120.0	103.0	81.0	70.0	101.2
	Mean	126.0	117.0	99.5	90.0	74.5		129.5	121.5	107.5	84.5	71.5	
L.S.D.5%		(P): 3.30 (T): 2.01 (PxT): 4.50						(P): 3.33 (T): 1.88 (PxT): 4.21					
		Juice% (First season)					Mean	Juice% (Second season)					Mean
Green	5°C	56.00	58.00	58.50	59.00	59.00	58.10	54.00	55.00	55.40	56.00	57.00	55.48
	10°C	56.00	58.90	59.30	59.50	60.30	58.80	54.00	55.20	55.80	57.00	58.00	56.00
	Mean	56.00	58.45	58.90	59.25	59.65		54.00	55.10	55.60	56.50	57.50	
L.S.D.5%		(P): 1.16 (T):0.68 (PxT): 1.52						(P): 1.23 (T): 0.52 (PxT):1.62					
Yellow	5°C	60.00	60.30	62.00	62.70	63.00	61.60	58.00	58.40	58.80	59.30	59.70	58.84
	10°C	60.00	62.10	62.80	63.30	63.10	62.26	58.00	58.50	59.00	60.00	60.00	59.10
	Mean	60.00	61.20	62.40	63.00	63.05		58.00	58.45	58.90	59.65	59.85	
L.S.D.5%		(P): 0.49 (T): 0.45 (PxT): 1.14						(P): 0.51 (T): 0.12 (PxT): 0.70					

Juice Percentage: Data in Table (1) showed that, fruit juice content increased during cold storge period in the first and the second season starting with 56, 54% and attaining 59.6, 57.5% in green fruits at the end of cold storage. The highest values (63, 59%) were noticed in yellow fruit, while the lowest values were recorded with green fruits. Among temperature, fruit stored at 10°C recorded highest juice% increased, this increase is unreal increase due to the increase in weight loss during cold storage, as the weight of the fruit decreases and thus the percentage of juice increases. The percent of juice showed a steady increase (37%, 41%) in both nonsealed and sealed Eureka lemons during the first 3 months of storage plus shelf life. After the 3rd month of storage, the amount of juice remained relatively constant in sealed fruit, while that in nonsealed lemons increased significantly during the 4th month of storage (47.0%) [5].

Respiration Rate: The rate of the respiration of the fruits were taken at the beginning of the experiment and after the second and fourth month, it is clear from Table (2) that the respiration rate in green lemon fruit is higher and gradually increases with advancement in development and ripening according to determination the respiration rate of fruit at the initial and the end of storage. The respiration and transpiration in the cold stored fruit increase with the extension of storage [24]. Regarding to temperature, an increase occurred at first in fruits stored at10°C then increased significantly with extend the cold storage period, consistent with chilling injury. The date showed that respiration rate was higher at 10°C temperature, packing in polyethylene and low cold storage temperature were effective in retarding respiration rate.

Fruit Color (a*, b*, L*): The fruit color attributes were significantly affected by the harvest maturity stages and cold storage periods (Table 3).

a* value was significantly increased with the extension of cold storage periods. a* value of cold stored fruit harvested at the green stage was signigicantly the lowest compared to those harvested at yellow stage. The interaction between different harvest maturity stages and the cold storage periods was found to be significant for a* value.

Table 2: Respiration rate (mlCO_2 /kg /hr.) of Corona lemon fruits during cold storage period

Maturity stage	Temperature	Storage period (Month) (P) 0	2	4	Mean	Storage period (Month) (P) 0	2	4	Mean
		(First season)				(Second season)			
Green	5°C	1.37	1.64	2.40	1.80	1.25	2.10	2.49	1.95
	10°C	1.37	1.74	2.58	1.90	1.25	2.20	2.50	1.98
	Mean	1.37	1.69	2.49	1.85	1.25	2.15	2.50	1.97
L.S.D.5%		(P): 0.02 (T): 0.02 (PxT): 0.02				(P): 0.01 (T): 0.01 (PxT): 0.01			
Yellow	5°C	1.39	1.51	2.31	1.74	1.29	1.95	2.16	1.80
	10°C	1.39	1.66	2.55	1.87	1.29	1.99	2.47	1.92
	Mean	1.39	1.59	2.43	1.80	1.29	1.97	2.32	1.86
L.S.D.5%		(P): 0.06 (T): 0.003 (PxT): 0.01				(P): 0.05 (T): 0.004 (PxT): 0.01			

Table 3: Fruit color (a*, b* and L*value) of Corona lemon cultivar during cold storage

Maturity stage	Temperature	Storage period (Month) (P) 0	1	2	3	4	Mean	Storage period (Month) (P) 0	1	2	3	4	Mean
		a* value (First season)						a* value (Second season)					
Green	5°C	-8.80	-6.70	-4.60	-2.40	-1.60	-4.82	-5.90	-3.30	-2.00	-1.40	-0.80	-2.68
	10°C	-8.80	-5.90	-4.00	-1.80	0.10	-4.08	-5.90	-3.10	-1.40	0.60	1.90	-1.58
	Mean	-8.80	-6.30	-4.30	-2.10	-0.75		-5.90	-3.20	-1.70	-0.40	0.55	
		(P): 0.31 (T): 0.04 (PxT): 0.32						(P): 0.16 (T): 0.07 (PxT): 0.20					
Yellow	5°C	-1.50	-1.20	0.90	1.70	2.80	0.54	-0.70	-0.40	1.20	3.70	4.20	1.60
	10°C	-1.50	-0.40	2.10	2.80	3.20	1.24	-1.40	2.30	3.70	4.50	5.10	2.84
	Mean	-1.50	-0.80	1.50	2.25	3.00		-1.05	0.95	2.45	4.10	4.65	
L.S.D.5%		(P): 0.22 (T): 0.03 (PxT): 0.06						(P): 0.18 (T): 0.12 (PxT): 0.26					
		b* value (First season)						b* value (Second season)					
green	5°C	48.00	48.40	50.70	55.60	60.00	52.54	44.10	46.50	48.80	51.20	55.00	49.12
	10°C	48.40	53.00	55.80	58.90	64.70	56.16	43.50	48.00	54.20	56.00	60.10	52.36
	Mean	48.20	50.70	53.25	57.25	62.35		43.80	47.25	51.50	53.60	57.55	
L.S.D.5%		(P): 1.10 (T):1.55 (PxT): 2.68						(P): 1.23 (T): 1.72 (PxT): 2.98					
Yellow	5°C	57.20	59.00	62.60	64.50	66.70	62.00	52.30	56.00	59.60	60.10	63.30	58.26
	10°C	59.00	62.00	64.40	66.20	68.00	63.92	52.00	57.70	60.30	63.10	66.40	59.90
	Mean	58.10	60.50	63.50	65.35	67.35		52.15	56.85	59.95	61.60	64.85	
L.S.D.5%		(P): 0.96 (T): 1.42 (PxT): 3.16						(P): 1.44 (T): 1.63 (PxT): 3.64					
		L* value (First season)						L* value (Second season)					
Green	5°C	55.00	55.90	57.40	58.70	60.70	57.54	50.20	52.40	54.70	55.10	57.00	53.88
	10°C	55.00	58.10	59.70	60.40	63.80	59.40	50.30	54.20	55.40	57.30	59.00	55.24
	Mean	55.00	57.00	58.55	59.55	62.25		50.25	53.30	55.05	56.20	58.00	
L.S.D.5%		(P): 1.16 (T):1.56 (PxT): 3.49						(P): 1.25 (T):0.76 (PxT): 2.96					
Yellow	5°C	62.00	62.60	64.10	64.80	66.00	63.90	59.00	59.10	59.30	59.50	60.00	59.38
	10°C	60.00	64.00	65.60	68.10	70.00	65.54	59.00	59.30	59.60	59.90	60.30	59.62
	Mean	61.00	63.30	64.85	66.45	68.00		59.00	59.20	59.45	59.70	60.15	
L.S.D.5%		(P): 1.06 (T):1.47 (PxT): 3.24						(P): 0.02 (T): 0.2 (PxT): 0.04					

b* value showed a significant rise during cold storage period, lowest b* values were noticed in the fruit harvested at green stage, fruit harvested at yellow stage showed significantly highest. The interaction between different harvest maturity stages and cold storage periods was noted to be significant for b* value., significantly highest b* were found in the fruit harvested at yellow stage at 10°C.

L*value was significantly lowest in the cold stored fruit harvested at green stage than those harvested at yellow stage. The interaction between different harvest maturity stages and cold storage periods was significant.

These changes in values are due to the conversion of fruit color from green to yellow during cold storage. A slow change in color occurs to the fruits at 5°C, while the color more developed at 10°C. The carotenoids

get accumulated in the fruit flavedo with extension of cold storage period leading to development of yellow color. Similar changes were also reported in Ponkan mandarins and in sweet orange [25, 15].

TSS%: Harvest maturity stages and temperature cold storage periods at 5°C and 10°C have significantly affected TSS. Data from Table (4) illustrated that significantly lowest TSS% was recorded in cold stored fruit harvested at green stage compared to those harvested at yellow stage. The interaction between different harvest maturity stages and cold storage periods was significant for TSS. Fruit harvested at yellow stage following 4 months cold storage period showed significantly highest TSS% as compared to fruit harvested at green maturity stages and stored for different storage periods, among temperature, the highest TSS% noticed at 10°C.

TSS % of cold stored lemon fruit exhibited a declining trend from the green stage to yellow stage and increased with the extension of cold storage periods. Increase in TSS with the extension of storage periods may be attributed to numerous catabolic processes during fruit storage periods. Kaur [26] suggested that water loss causes the increase in TSS during storage periods in Baramasi lemon fruit. The increase in SSC and sugars is directly related with water loss from the fruit also correlated with fruit senescence and respiration rate [27]. Decrease in ascorbic acid contents also increases the SSC and glucose in juice [28].

TSS could be due to an increase of the net photosynthetic rate of tree, which would lead to increase sugar accumulation at harvest and after 4 months of storage.

Acidity%: It is clear from data presented in Table (4) that acidity% in the juice significantly decreased during storage period, fruit which were harvested at green stage was significantly highest compared to those harvested at yellow stage. There was a significant interaction between different harvest maturity stages and cold storage periods. Fruit harvested at green stage following 4 months cold storage exhibited significantly highest acidity as compared to yellow maturity stage and storage period. These findings were in accordance with Sun *et al.* [10] who observed that the decreasing in TA% from G-Stage up to Y-Stage suggests the possibility of decreasing inorganic acid content with increasing fruit maturity stage. A rapid decline in titratable acidity of control fruits is also caused by the conversion of acids into sugars within the fruit.

Among different temperature, Corona lemon exposed to 10°C presented the most substantial decrease in acidity whereas the fruit in the 5°C.This reduction may be explained as the citric acid is a respiratory substrate and its consumption in respiration increased with progress of storage period. TA was slightly declined during different experimental periods up to 4 months of storage. These results are in line with those reported by Hassan [29] on lemonera lemon.

TA decreases during the maturation with the utilization of individual organic acids in pyruvate decarboxylation reaction. The rise in TA values can be related to increase in weight loss of fruits due to loss of water. Similar relation between TA and weight loss was also explained by Tsantili *et al*. [30] during storage of Maglino lemon.

TSS: Acid ratio: It is evidenced from Table (4) that harvest maturity stages and cold storage periods have significantly affected TSS/TA ratio, which was gradually increased by increasing the cold storage period and significantly lowest in the fruit harvested at green stage compared to those harvested at yellow stage. Regarding to temperature, the results indicates that lemon stored at 10°C presented highest TSS: Acidity. The level of SSC/ acidity increased by increasing the storage period that might be due to the decline of acidity and increase of sugars during the storage [31].

Vitamin C: Date presented in Table (4) showed that, vitamin C content in the juice generally decreased as cold stored period advanced, significantly affected by the harvest maturity stages, cold storage periods and the interaction between them. The fruit harvested at green stage showed highest vitamin C content when stored 4 months during cold storage periods.

Similarly, founded by Hassan [29] on lemonera lemon, on contrary, no significant effects of harvest maturity and storage conditions on vitamin C had been reported in Eureka lemon fruit [10]. Lemon at G-stage presented the highest amount of AA, decreasing in AA content independently found on the different HFCS of lemon fruits [12]. The effect of storage temperature was clearly that fruits stored at 5°C had significantly higher than fruits stored at 10°C. Although the VC level decreased throughout storage at each respective temperature, the use of a low temperature significantly reduced the loss of VC in the lemon samples. Vitamin C retention is also improved when citrus fruits are stored in modified

Table 4: Fruit TSS%, acidity % and TSS: acid ratio of Corona lemon cultivar during cold storage period

		Storage period (Month) (P)						Storage period (Month) (P)					
Maturity stage	Temperature	0	1	2	3	4	Mean	0	1	2	3	4	Mean
		TSS% (First season)						TSS% (Second season)					
Green	5°C	8.30	8.40	8.70	9.00	9.30	8.74	8.00	8.30	8.60	9.10	9.20	8.64
	10°C	8.40	8.50	8.80	9.30	9.60	8.92	8.00	8.60	9.00	9.50	9.60	8.94
	Mean	8.35	8.45	8.75	9.15	9.45		8.00	8.45	8.80	9.30	9.40	
L.S.D.5%		(P): 0.08 (T): 0.11 (PxT): 0.24						(P): 0.07 (T): 0.10 (PxT): 0.23					
Yellow	5°C	8.80	8.80	8.90	9.00	9.00	8.90	9.00	9.00	9.20	9.30	9.50	9.20
	10°C	8.80	9.00	9.00	9.20	9.40	9.08	9.00	9.20	9.30	9.40	9.40	9.26
	Mean	8.80	8.90	8.95	9.10	9.20		9.00	9.10	9.25	9.35	9.45	
L.S.D.5%		(P): 0.17 (T): 0.23 (PxT): 0.52						(P): 0.08 (T): 0.03 (PxT): 0.10					
		Acidity% (First season)						Acidity% (Second season)					
Green	5°C	9.00	8.80	8.50	8.40	8.00	8.54	8.50	8.30	8.10	8.00	8.00	8.18
	10°C	9.00	8.50	8.40	8.00	7.50	8.28	8.50	8.20	8.00	7.70	7.40	7.96
	Mean	9.00	8.65	8.45	8.20	7.75		8.50	8.25	8.05	7.85	7.70	
L.S.D.5%		(P): 0.18 (T): 0.20 (PxT): 0.34						(P): 0.16 (T): 0.18 (PxT): 0.33					
Yellow	5°C	8.00	7.70	7.50	7.50	7.00	7.54	7.50	7.30	7.00	7.00	6.70	7.10
	10°C	8.00	7.50	7.20	7.00	6.50	7.24	7.50	7.20	7.00	6.80	6.50	7.00
	Mean	8.00	7.60	7.35	7.25	6.75		7.50	7.25	7.00	6.90	6.60	
L.S.D.5%		(P): 0.18 (T):0.21 (PxT): 0.34						(P): 0.07 (T): 0.08 (PxT): 0.14					
		TSS: acid ratio (First season)						TSS: acid ratio (Second season)					
Green	5°C	0.92	0.95	1.02	1.07	1.16	1.02	0.94	1.00	1.06	1.13	1.15	1.06
	10°C	0.93	1.00	1.04	1.16	1.28	1.08	0.94	1.04	1.12	1.23	1.29	1.12
	Mean	0.93	0.98	1.03	1.12	1.22		0.94	1.02	1.09	1.18	1.22	
L.S.D.5%		(P): 0.03 (T): 0.03 (PxT): 0.07						(P): 0.02 (T): 0.04 (PxT): 0.08					
Yellow	5°C	1.10	1.00	1.18	1.20	1.38	1.17	1.20	1.23	1.31	1.32	1.25	1.26
	10°C	1.10	1.20	1.25	1.31	1.44	1.26	1.20	1.27	1.32	1.38	1.44	1.32
	Mean	1.10	1.10	1.22	1.26	1.41		1.20	1.25	1.32	1.35	1.35	
L.S.D.5%		(P): 0.02 (T): 0.03 (PxT): 0.04						(P): 0.02 (T): 0.03 (PxT): 0.08					
		Ascorbic acid mg/100mg (First season)						Ascorbic acid mg/100mg (Second season)					
Green	5°C	58.00	58.00	57.60	56.70	54.90	57.04	60.00	58.70	58.00	56.40	56.00	57.82
	10°C	58.00	56.00	55.60	55.10	53.10	55.56	60.00	57.00	56.40	53.80	53.00	56.04
	Mean	58.00	57.00	56.60	55.90	54.00		60.00	57.85	57.20	55.10	54.50	
L.S.D.5%		(P): 0.18 (T): 1.41 (PxT): 2.52						(P): 1.14 (T):1.35 (PxT):2.43					
Yellow	5°C	55.00	54.00	53.30	53.00	52.70	53.60	54.00	53.00	53.00	50.00	50.00	52.00
	10°C	54.00	52.00	51.40	50.30	50.00	51.54	54.00	52.00	51.00	48.00	47.00	50.40
	Mean	54.50	53.00	52.35	51.65	51.35		54.00	52.50	52.00	49.00	48.50	
L.S.D.5%		(P): 1.26 (T): 1.44 (PxT): 2.60						(P): 1.13 (T): 1.28 (PxT): 2.33					

atmosphere packaging and controlled atmosphere (CA) [28]. The reduction may be to the fact that ascorbic acid in its phosphorylated form acts as an oxidation reduction catalyst in the change of organic acids to sugar, thus the amount of ascorbic acid decreased during cold storage period. A gradual reduction in ascorbic acid levels, titratable acidity and a rise in soluble solids content have been noted with advancement of the maturation process in sweet orange fruit [32].

Calcium and Potassium Content: Regarding to calcium and Potassium content, it is clear from Table (5) that there was significant decreased with prolong cold storage period. This decrease was determined to be at different storage temperature at 5°C and 10C, where the fruits stored at 5°C retained the proportion of calcium and potassium than those stored at 10°C. The green fruits also retained the ratio of calcium and potassium over the yellow fruits. Therefore, the green fruits retain a higher texture than the yellow ones.

Pectin %: It is evident from Table (5) that Corona cultivar fruits increased in total soluble pectin% during cold storage period, green fruit were highest in pectin content. Generally, fruit stored at the low temperature were highest in pectin. During storage, softening and subsequent deformation of the peel are accompanied by a concomitant increased in soluble pectin and pectinates at the expense of insoluble protopectin decreased in uronic acid (the main component of pectin).

Table 5: Calcium%, potassium%, pectin % and polyphenol oxidase (PPO) (U) activity of Corona lemon fruit at the initial and end of cold storage

		Season 2017											
		Calcium %			Potassium %			Pectin %			PPO (U)		
Maturity stage	Storage Temp.	Initial	End (4 months)	Mean	Initial	End (4 months)	Mean	Initial	End (4 months)	Mean	Initial	End (4 months)	Mean
						First season							
Green	5°C	3.80	3.40	3.60	4.0	3.8	3.9	1.26	2.62	1.94	7.5	110	58.7
	10°C	3.80	3.10	3.45	4.0	3.6	3.8	1.23	3.45	2.34	7.5	57	32.2
	Mean	3.80	3.25		4.0	3.7		1.25	3.04		7.5	83.5	
L.S.D.5%		(P) 0.06 (T) 0.01 (PXT) 0.07			(P) 0.03 (T) 0.01(PXT) 0.04			(P) 0.22 (T) 0.03 (PXT) 0.05			(P) 9.4 (T) 2.1 (PXT) 9.6		
Yellow	5°C	3.2	2.90	3.05	3.6	3.2	3.4	2.32	4.16	3.24	16.0	130	
	10°C	3.2	2.80	3.0	3.6	3.0	3.3	2.34	4.78	3.56	14.6	77	
	Mean	3.2	2.85		3.6	3.10		2.33	4.47		15.3	103.5	
L.S.D.5%		(P) 0.04 (T) 0.04 (PXT) 0.06			(P) 0.06 (T) 0.06 (PXT) 0.8			(P) 0.26 (T) 0.03 (PXT) 0.27			(P) 10.9 (T2) 0.1 (PXT) 11.1		
						Second season							
Green	5°C	3.88	3.44	3.6	4.6	4.3	4.45	1.12	2.66	1.89	7.7	90	48.8
	10°C	3.88	3.18	3.5	4.6	4.2	4.40	1.10	3.07	2.09	7.7	54	30.8
	Mean	3.88	3.31		4.6	4.2		1.11	2.87		7.9	72	
L.S.D.5%		P.06 T.01 P*T.01			P.04 T.01 P*T.05			P.21 T.02 P*T.22			P7.99 T1.44 P*T8.08		
Yellow	5°C	3.6	2.70	3.15	4.0	3.5	3.75	2.20	4.30	3.25	14.0	120	67
	10°C	3.6	2.63	3.12	4.0	3.3	3.65	2.20	4.70	3.45	18.6	80	49.3
	Mean	3.6	2.67		4.0	3.4		2.20	4.50		16.3	100	
L.S.D.5%		(P) 0.12 (T) 0.01 (PXT) 0.12			(P) 0.07 (T) 0.01 (PXT) 0.08			(P) 0.28 (T) 0.03 (PXT) 0.29			(P) 10.3 (T) 1.6 (PXT) 10.4		

Table 6: Total losses % of Corona lemon fruits after 4 months of cold storage

		First season				Second season			
Maturity stage	Storage Temp.	Weight loss%	Decay %	Chilling injury %	Total losses %	Weight loss %	Decay %	Chilling injury %	Total losses %
Green	5°C	10.0	0	0	10.0	9.2	0	0	9.2
	10°C	11.2	3	0	14.0	10.0	0	0	10.0
Yellow	5°C	8.5	9	11 (grade1)	28.5	9.3	5	9 (grade1)	23.3
	10°C	9.3	12	6 (grade1)	27.3	9.7	10	5 (grade1)	24.7

PPO Activity: Table (5) illustrates that PPO activity in lemon increased in conjunction with an extension of storage time, Furthermore, the PPO activity in the fruits exposed to both temperatures increased to varying degrees of increase, as well as increased after 4 months of cold storage period. Low temperatures can effectively inhibit PPO enzyme activity, but fruits stored at 5°C displayed greater activity than fruits stored at 10°C.

Liu *et al*. [33] reported that PPO activity was an essential factor affecting enzymatic browning, except for phenolics and VC. Browning resulted from polyphenol oxidation by PPO, as well as the accumulation of phenolic compounds after cold storage based on antioxidant capacity. Therefore, a balance may be evident between the antioxidation and enzymatic browning of phenolics when the fruits are stored at low temperatures [34]. Polyphenol oxidase (PPO) is closely related to the senescence and browning of fruit tissues, so its activity has become an important indicator of fruit senescence [35].

Chilling Injury: The incipient of visible symptoms of chilling injury was indicated by development of pitting on peel fruits and discoloration areas, browning of albedo and of the carpellary membranes. the fruits at the G-color stage had not presented the symptoms during the storage period while yellow lemon remarked chilling injury symptoms, which it stared at the third month and reached to index-2 (moderate symptoms). Apparently, fruit at Y-color stage presented the distinguished symptoms than fruit at the G and the YG color stage [12].

Concerning Corona lemon fruits stored at 5°C, slight symptoms of chilling injury were noticed after 3 months of cold storage period, it presented the percentage of (10%, 12%) in both seasons and were more severe when transferred at ambient temperature 18-20°C those noticed in both seasons. 5°C was not a safe holding temperature, due to the severe degradation of the yellow lemon samples after 3 months.

Total Loss: Total loss included the weight loss, decay and chilling injury, Table (6) shows that total loss due to weight loss during cold storage plus marketing, decay and chilling injury. Generally, loss at first and second months of cold storage due to weight loss fruits. The storage period was extended to three months, it could be concluded that a positive correlation was detected between the loss in weight and decay. After 4 months, some signs of chilling injury start to appear at 5°C. These results are in line with Gihan and El-Orabi, [36] on Mandarin.

Shelf-Life: It is evident that during shelf life at ambient temperature 18-20°C at the end of cold storage period, the weight loss%, juice%, TSS%, peel color were increased while, acidity and ascorbic acid content were decreased with prolonged storage. Shelf-life period was affected and prolonged by different maturity stage and temperature, such increased may be due to flesh texture increasing by maintaining the total pectin and Ca contents at a higher concentration and increasing the number of flesh cell layers.

In conclusion, the harvest maturity of Corona lemon affects the cold storage life and fruit quality. The green stage revealed to be a good stage of Corona lemon to store at low temperature due to it is tolerant to chilled temperature for long term up to 4 months at 10°C plus 7 days marketing.

The yellow fruits were stored safely and considered marketable for a period of 3 months at 5°C plus 7 days at 18-20°C and the loss in weight was in the acceptable range with beginning of symptoms of CI.

In order to extend its commercial life, it is usually harvested at mature stage and stored at low temperatures. Storage of Corona lemon as an originally subtropical fruits at low temperature is limited by the risk of chilling injury (CI). Slight CI symptoms appeared after 3 months on yellow fruits at 5°C.

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