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Effect of Maturity Stages on Postharvest Quality of Jujube Fruits (*Ziziphus jujube* Mill.) During Cold Storage

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Abstract: A fundamental factor for successful storage and final quality of post-harvest is fruit maturity stage at harvest. The current study was carried out during two successive seasons 2019, 2020 to investigate the changes in postharvest quality in four cultivars of jujube fruits (Lee, Lang, Balahy and Seedy) at two maturity stages namely white maturity (WM) and red maturity (RM) under cold storage. Fruits were held in perforated polyethylene bags at 10°C and 85%RH. Weight loss, texture, total soluble solids, PH, fruit color, ascorbic acid, decay% and chilling injury were studied during storage period. The results showed that there was a significant effect among the maturity stages at harvest on storage quality parameters in jujube fruits during cold storage. Texture, PH%, L* and b* values were significantly higher at white maturity stage than red maturity stage and decreased with extension of cold storage period meanwhile, weight loss, TSS, a*value increased. Picked fruit at white mature stage (WM) with high texture had greater potential for long-term cold storage than red maturity stage (RM). Among the cultivars, the lowest percentage of weight loss, highest texture, highest content of ascorbic acid, highest a value color and highest score of visual quality were found in Lee cultivar. Meanwhile, the highest weight loss and lowest texture were detected in Seedy cultivar. Storage life for all tested cultivars at white maturity stage were 80 days at 10 C, while, at red maturity stage were only 40 days without any chilling injury symptoms.

Key words: Jujube fruits · White maturity · Red maturity · Polyethylene · Postharvest quality · Cold storage

INTRODUCTION

Jujube (*Ziziphus jujube* Mill.) belongs to the Rhamnaceae family and has more than 700 cultivars in China [1]. Nowadays, jujube has flourished and is widely cultivated in the warmer parts of Asia, Africa, Europe and America [2]. It is commonly used in China as a traditional medicine for its analeptic, palliative and antibacchii properties. The extract of jujube leaves is effective to improve the quality of sleep, the proper functioning of the heart and to stop bleeding and diarrhea [3].

Jujube, a fruit typically eaten fresh, due to its thin peel, juiciness, special flavor and abundant nutrients, fruit is also highly desired for its content in vitamin C, as an antioxidant, one of the most important nutritional quality factors and has many biological activities in the human body [4]. jujube is subject to rapid senescence after harvest, which lead to postharvest decay, dehydration, tissue softening, or flesh browning, resulting in a poor sensory quality and economic loss [5].

Maturity stage at harvest is an essential pre-harvest factor that determines the storage potential and final fruit quality [6]. Fruit maturity in winter jujube is mainly judged by peel color [7]. Fruit maturity at harvest time is one of the main factors that determine compositional quality of fruits and vegetables, as well as storage life and final quality [4]. Depending on the purpose, jujube fruit can be picked from the white mature stage, to the crisp mature stage, or the fully mature stage [8, 9]. Late harvesting of jujube fruit usually results in a dramatic decline in quality.

Jujube is a non-climacteric fruit and it is highly perishable and has a short post-harvest life. During storage and marketing, encounters several problems such as weight loss, decrease in firmness, reduction of vitamin C and pulp browning due to senescence, which reduce the quality of fresh jujube fruit [10].

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To prolong the shelf life, jujube is harvested at the white maturity WM stage and kept in low temperature storage for some time and then moved to market [11]. Many works have suggested that the physicochemical properties of winter jujube during fruit development were influenced by harvest maturity stage [12, 13]. Nevertheless, there is scare information regarding storage quality of jujube in relation to maturity at harvest stage.

Modified atmosphere packaging (MAP) and controlled atmosphere (CA) are some of the important techniques for maintaining quality for prolonging the shelf-life period during storage and marketing [14-16].

Generally, jujube fruits are packed in HDPE (High density polyethylene) or in PP (Polypropylene) which reduces moisture loss from fruits during storage [17]. Another method consists of harvest earlier the fruit, at the white ripening stage and to store it [18].

The aim of this study is to evaluate the changes in storage quality parameters, weight loss, texture, fruit color (L, a, b values), total soluble solid (TSS), PH%, ascorbic acid, decay% and the overall sensory quality of four jujube fruit with two harvest maturity stages (white maturity WM and red maturity RM) during cold storage.

MATERIALS AND METHODS

This experiment was carried out during 2019 and 2020 seasons on four jujube cultivars namely Lee, Lang, Balahy and Seedy grown in a private orchard located at South Tahrir, Behera governorate. Jujube fruit were collected at two maturity stages: (1) white maturity (WM) with light green color (80 days after full bloom) and (2) red maturity (RM) with fully red peel (120 days after full bloom). After harvesting, jujube fruit were immediately transported to the laboratory and were selected based on the absence of visual mechanical damage and diseases. After sorting, fruits were stored in polyethylene bags 20 micron in thickness (500 g fruits for each bag) in carton boxes (8 bags for each carton) three replicates for each cultivar at 10 C with 85 % relative humidity. Fruit samples were taken from each replicate at 20 days intervals up to 80 days for white mature stage (WM) and at 10 days up to 40 days for red mature stage (RM) of cold storage period to determine the following measurements:

Weight Loss (%): Was determined as follows:

Weight loss (%) = [(W0 – W1)/W0] x100

Where w0 is the initial weight and w1 is the weight measured at start of each storage period.

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.

TSS%: Total soluble solids% by Abbe digital refractometer.

PH%: Was measured by a pH meter instrument (Schott Gerate).

Fruit Peel Color Parameters (L*, a*, b*): Fruit color parameters were quantified at tristimulus colorimeter date using Hunter colorimeter model DP9000 the hunter (*L. lightness*) (a. value green red) (b. value blue yellow) [19].

L-Ascorbic Acid: Ascorbic acid (AA) content was determined using 2, 6- dichlorophenol indophenols by visual titration Results of AA content were expressed as milligrams ascorbic acid per 100 g of fresh weigh (mg. 100 g^{-1} fresh weight) determined according to AOAC [20].

Chilling injury and Decay (%): Decay % was determined by calculating the number of decayed fruits at harvesting date expressed as percentage of initial fruit number.

Determination of Sensory Analysis: Sensory quality attributes such as visual appearance, taste and overall acceptability were assessed according to the method of Galindo *et al.* [21]. Sensory attributes were scored based on the scale listed as bellows: 9 =excellent; 7=good; 5=fair, 3=poor and 1unusable fruit evaluated at less than 3 and considered unmarketable.

Statistical Analysis: Data were subjected to analysis of variance according to Snedecor and Cochran [22]. Means of treatments were compared by L.S.D. at the 5% level.

RESULTS AND DISCUSSION

Weight Loss (%): Data in Table (1) show a significant difference in fruit weight loss% under cold storage conditions for both maturity stages. Weight loss was significantly affected by cultivars, where Lee cultivar recorded the lowest weight loss after 80 days for the white maturity stage and after 40 days for the red maturity stage under cold storage followed by Balahy and Lang cultivars. Meanwhile the highest values of weight loss

were found with seedy cultivar in both seasons. The increase in fruit weight loss under cold storage may be due to respiration and transpiration of water through peel tissue and perishable fruit is a serious concern in its storage because loss of moisture decreases visual quality; salable weight and may result in physiological disfunction

Weight loss in jujube fruits at different maturity stages exhibited with the extension of cold storage time, which was constant with the finding obtained by Kou *et al*. [23]. This change may be due to the water loss caused by the absorption and respiration processes [5].

Texture: The fruit texture of jujube was significantly affected by the harvest maturity stages during the cold storage period. Table (2) showed that the texture of jujube fruit at two maturity stages decreased continuously with the increase in cold storage period in both seasons. An early mature stage (white mature) maintained higher texture throughout the storage period, while the lower fruit texture values were obtained in fruits harvested at the red mature stage (RM). Regarding cultivars, Lee cultivar fruits which picked at the white mature or red mature stage had the highest texture values after 80 days or 40 days of cold storage, Respectively, no significant difference was noticed at Lang and Balahy cultivars while the lowest texture values were noticed at Seedy cultivar. The decrease in texture fruit might be attributed to the loss of cellular turgor pressure and cell wall disassembly increased with fruit ripening and senescence. This is in agreement with those found by Yating *et al*. [24], jujube fruit at RM stage was lower than that of the WM stage during the entire storage period.

TSS (%): Table (3) indicated that there was a rapid TSS% increase in cultivars of jujube at the two maturity stages during the cold storage period. Significant differences were observed between maturity stages where red maturity stage recorded the higher TSS % than white maturity stage. Concerning cultivars, the highest TSS% was recorded with Balahy jujube fruits at white maturity (WM) stage and the lowest TSS% was found in Seedy jujube fruits for both seasons. Concerning to red maturity (RM) stage, Seedy jujube fruit recorded the highest total soluble solids after 40 days of cold storage, no significant differences was noticed at Lee, Lang and Balahy cultivars.

The same finding, TSS content in winter jujube fruit showed an upward trend from the WM stage to RM stage. The rapid increase in TSS content during jujube fruit development was due to the accumulation of sugars and a decline in moisture content [25, 26]. Moreover, the increase in TSS during storage is due to the increase in invertase enzyme that causes a change in sucrose. The reduction in fruit water content and conversion of cell wall components such as starch, protein, pectin and hemicelluloses into simple soluble sugars during storage are responsible for the increase in TSS content.

TSS content in four cultivars of jujube at two maturity stages increased with the extension of cold storage period, which was probably due to an accumulation of soluble sugars. These results were in line with findings observed in winter jujube during cold storage by Gao *et al.* [27] Burhan *et al*. [28] and Cheng *et al.* [29].

PH%: A significant difference was found in the PH% in jujube fruits at two maturity stages data in Table (4) showed that the declined in PH% was observed from the white maturity (WM) stage and red maturity (RM) stage with the increasing of the cold storage period. Concerning the maturity stages, white maturity (WM) stage had the lower PH% than red maturity (RM) stage in both seasons. The pH value varied from 4.9 to 4.7 during two seasons at WM stage and from 5.2 to 4.9 at RM stage in the different cultivars. Among the cultivars, the acid content was maximum in Lee and Lang which was determined as citric acid followed by Balahy and Seedy. Such results, which might be due to the conversion from acid into sugars
[9, 24].

Fruit Peel Color Parameters (L*, a*, b*): Color changes from green to whitish-green, then to reddish-brown, the fruit color indices L*, a* and b* values are important fruit color determination parameters the L* value represents lightness, a* value reflects the color change from green to red and b* value shows the change from blue to yellow.

L* Values: Table (5) show that the change in the color of the fruits is closely related to the stage of maturity and the characteristics of the color of the fruits (L*) were significantly affected by the stages of harvest maturity and cold storage period.

L* value was almost halved from (40.8, 55.4) to (18.7, 22.5) in the two seasons at white maturity (WM) during 80 days cold storage. It also decreased at red maturity stage (RM) from (23.2, 31.9) to (17.5, 18.2) in the two seasons for 40 days cold storage as a result of surface wilting and gloss reduction caused by drought.

Table 1: The changes of weight loss% in jujube fruits harvested at two maturity stages, during cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	0.0	1.3	2.9	4.1	7.1	3.1	0.0	1.7	2.9	4.8	7.4	3.4
Lang	0.0	2.1	3.8	6.5	8.5	4.2	0.0	1.9	2.9	6.1	8.2	3.8
Balahy	0.0	1.8	2.9	4.5	9.0	3.7	0.0	2.1	3.2	5.6	7.8	3.7
Seedy	0.0	2.5	4.9	6.6	9.7	4.7	0.0	2.2	3.2	6.1	8.8	4.1
Mean	0.0	1.9	3.6	5.4	8.6		0.0	2.0	3.1	5.7	8.0	
L.S.D. 0.05:	(P):0.34		(C): 0.29		(PxC): 0.64		(P):5.45		(C):5.10		(PxC): 0.63	
	Second season (2020)											
Lee	0.0	1.3	2.3	3.9	7.4	3.0	0.0	1.2	2.3	3.9	7.5	3.0
Lang	0.0	1.5	3.1	4.3	8.5	3.5	0.0	1.5	3.0	5.8	7.7	3.5
Balahy	0.0	1.5	2.8	4.8	9.0	3.6	0.0	1.6	3.5	5.7	8.7	3.9
Seedy	0.0	1.6	3.6	4.9	9.3	3.9	0.0	1.7	3.6	7.4	10.0	4.5
Mean	0.0	1.5	3.o	4.5	8.6		0.0	1.5	3.1	5.7	8.5	
L.S.D. 0.05 :	(P):0.37		(C): 0.30		(PxC): 0.67		(P):0.34		(C):0.25		(PxC):0.57	

Table 2: The changes of texture (gram / cm) in jujube fruits harvested at two maturity stages during cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar(C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	157.7	131.7	120.3	98.3	88.7	119.3	125.0	111.3	90.0	75.7	68.7	94.1
Lang	144.7	117.7	100.0	78.3	72.0	102.5	117.3	104.0	88.3	74.3	64.0	89.6
Balahy	138.0	124.7	103.0	80.7	71.7	103.6	95.0	81.0	68.7	63.3	60.0	73.6
Seedy	109.7	93.7	82.0	74.7	60.7	84.1	86.0	96.3	59.7	57.3	55.0	65.5
Mean	137.5	116.9	101.3	83.0	73.3		105.8	91.4	76.7	67.7	61.9	
L.S.D. 0.05:	(P):0.77		(C): 0.49		(PxC): 13.98		(P):5.45		(C):5.10		(PxC): 11.41	
	Second season (2020)											
Lee	179.0	148.0	115.3	98.7	85.0	125.2	170.7	154.3	98.0	88.3	75.0	117.3
Lang	157.3	113.3	90.3	83.7	73.7	103.7	121, 7	102.0	90.0	81.3	69.7	92.9
Balahy	159.3	114.3	97.3	78.0	70.3	103.9	123.7	94.3	91.7	76.7	68.7	91.0
Seedy	146.0	119.3	96.3	75.0	63.7	100.1	131.3	111.3	90.0	68.0	61.7	92.5
Mean	160.4	123.8	99.8	83.8	73.2		136.8	115.5	92.4	78.6	68.8	
L.S.D. 0.05:	(P):5.89		(C): 7.95		(PxC): 17.78		(P):6.26		(C):0.69		(PxC):16.76	

Table 3: The changes of T.S.S% in jujube fruits harvested at two maturity stages during cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	14.6	15.2	16.4	17.9	23.5	17.5	25.7	26.0	26.4	26.2	26.8	26.2
Lang	16.5	17.2	18.2	18.3	22.7	18.6	25.7	26.2	26.5	25.8	25.7	26.0
Balahy	19.3	21.7	21.3	22.3	24.7	21.9	25.4	26.4	26.3	25.5	25.7	25.9
Seedy	13.2	12.8	12.9	12.8	20.3	14.4	31.7	32.5	33.8	35.3	34.7	33.6
Mean	15.9	16.7	17.2	17.8	22.8		27.1	27.8	5.1	28.2	28.2	
L.S.D. 0.05:	(P):0.77		(C): 0.49		(PxC): 1.09		(P): 0.38		(C):0.39		(PxC): 0.13	
	Second season (2020)											
Lee	15.5	16.1	17.5	19.0	23.0	18.2	23.8	24.7	24.9	25.0	25.3	24.8
Lang	16.2	16.5	17.3	18.5	22.3	18.2	24.7	25.0	25.8	25.3	25.0	25.2
Balahy	19.2	19.7	19.8	21.3	22.7	20.5	23.3	25.1	25.8	25.8	25.7	25.1
Seedy	15.2	15.3	15.3	16.2	21.0	16.6	28.1	30.3	32.3	32.3	33.3	31.3
Mean	16.5	16.9	17.5	18.8	22.3		25.0	26.3	27.2	27.1	27.3	
L.S.D. 0.05:	(P):0.40		(C): 0.49		(PxC): 1.10		(P): 0.82		(C):0.69		(PxC): 1.54	

Table 4: The changes of PH% in jujube fruits harvested at two maturity stages during cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	5.1	5.1	5.1	5.1	4.9	5.1	5.2	5.1	5.1	5.1	5.0	5.1
Lang	4.9	4.9	4.9	4.9	4.7	4.8	5.8	5.7	5.6	5.6	5.1	5.6
Balahy	4.8	4, 7	4.6	4.6	4.5	4.6	5.3	5.2	5.2	5.2	5.0	5.2
Seedy	4.9	4.7	4.7	5.7	4.7	4.9	4.7	4.6	4.5	4.6	4.4	4.6
Mean	4.9	4.8	4.8	5.1	4.7		5.2	5.2	5.1	5.1	4.9	
L.S.D. 0.05:	(P):0.15		(C): 0.14		(PxC): 0.31		(P): 3.21		(C): 1.63		(PxC): 0.13	
	Second season (2020)											
Lee	5.0	5.0	4.9	4.8	4.7	4.9	5.1	5.0	5.0	4.9	4.8	5.0
Lang	5.0	4.9	4.8	4.8	4.7	4.8	5.4	5.3	5.1	5.1	5.0	5.2
Balahy	4.9	4.7	4.7	4.6	4.6	4.7	5.3	5.1	5.1	5.2	5.1	5.2
Seedy	4.9	4.8	4.8	4.6	4.6	4.7	4.7	4.7	4.7	4.6	4.5	4.6
Mean	4.9	4.9	4.8	4.7	4.7		5.1	5.1	5.0	4.9	4.8	
L.S.D. 0.05:	(P):0.04		(C): 0.04		(PxC): 0.07		(P): 0.07		(C):0.06		(PxC): 0.13	

Table 5: The changes of color L values in jujube fruits harvested at two maturity stages during cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	43.2	35.8	20.1	18.2	18.4	27.2	30.2	24.8	23.7	19.6	18.8	23.4
Lang	37.4	24.8	24.4	20.0	19.4	25.2	20.0	20.4	19.4	18.4	17.7	19.2
Balahy	42.3	22.4	26.3	22.0	21.1	26.8	27.1	22.1	21.3	21.2	19.3	22.2
Seedy	40.4	30.2	24.7	14.9	16.0	25.2	15.4	16.6	15.8	15.3	14.3	15.5
Mean	40.8	28.3	23.9	18.8	18.7		23.2	21.0	20.0	18.6	17.5	
L.S.D. 0.05:	(P): 2.65		(C): 1.46		(PxC): 3.27		(P): 3.21		(C): 1.63		(PxC): 3.65	
	Second season (2020)											
Lee	55.4	30.8	24.7	23.2	21.3	31.1	28.4	24.4	22.7	18.5	17.7	22.3
Lang	55.7	41.0	26.5	21.9	21.6	33.3	35.4	30.2	25.6	20.2	19.0	26.1
Balahy	61.0	48.5	32.0	25.9	24.7	38.4	34.3	29.6	27.6	19.7	18.2	25.9
Seedy	49.6	52.6	30.8	22.6	22.3	35.6	29.5	27.6	24.4	19.0	18.0	23.7
Mean	55.4	43.2	28.5	23.4	22.5		31.9	27.9	25.1	19.3	18.2	
L.S.D. 0.05:	(P): 1.51		(C): 1.01		(PxC): 2.27		(P): 0.76		(C): 1.86		(PxC): 4.16	

Table 6: The changes of color a value in jujube fruits harvested at two maturity stages during cold storage at 10?C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30day	40days	Mean
	First season (2019)											
Lee	-4.2	2.5	11.7	13.0	14.5	7.5	12.1	12.9	15.9	17.3	16.1	14.9
Lang	-5.9	9.3	11.8	14.2	16.0	9.1	13.9	15.8	14.7	14.8	14.8	14.8
Balahy	-7.4	12.2	16.3	19.0	19.7	12.0	8.5	17.2	16.7	16.0	16.0	14.9
Seedy	-4.8	-4.0	7.0	14.1	15.7	5.6	22.2	13.6	10.6	9.8	8.8	13.0
Mean	-5.6	5.0	11.7	15.1	16.5		14.2	14.9	14.5	14.5	13.9	
L.S.D. 0.05:	(P): 2.28		(C): 1.83		(PxC): 4.08		(P): 0.56		(C): 0.43		(PxC): 0.98	
	Second season (2020)											
Lee	-8.5	6.1	13.8	14.6	15.2	8.2	13.8	13.9	13.8	15.7	16.6	14.8
Lang	-4.8	2.9	7.9	11.1	12.5	5.9	12.9	13.7	17.0	17.6	17.7	15.8
Balahy	-6.2	3.9	9.4	11.7	13.4	6.4	18.6	17.7	18.9	18.7	18.7	18.5
Seedy	-0.6	1.4	1.2	7.3	11.5	4.1	14.6	14.8	15.8	18.7	15.8	15.9
Mean	-5.0	3.6	8.1	11.2	13.1		15.0	15.0	16.4	17.7	17.2	
L.S.D. 0.05:	(P): 0.76		(C): 0.67		(PxC): 1.51		(P): 0.89		(C): 1.08		(PxC): 2.42	

Lee and Balahy cultivars recorded the highest L value and the fruits retained their luster whether they were picked at the white or red maturity stage. Similarly, long-term storage has been reported to reduce the attractiveness of peel color and brightness [30].

a* Values: Table (6) show that a* values increase with extended cold storage period, there are significant differences between color and ripening stages. Where a* values rapid increase in white ripening stage (WM) from (-5.6, - 5.0) to (16.5, 13.2) during 80 days of cold storage. While there is a slight increase in red maturity (RM) stage from (14.2, 15.0) to (13.9, 17.2) during 40 days of cold storage.

As for the cultivars, the lowest a* value was recorded by Seedy cultivar in the white maturity (WM) stage of the two seasons. As for the stage of red maturity for the first season, no significant differences appeared between the three cultivars, the least of which was Seedy cultivar, while Balahy cultivar recorded the highest a* value at the second season.

b* Values: Table (7) show that the b* values decrease by the cold storage period and there are significant differences between the color and maturity stages, as the b*color fruits decreased significantly in the white maturity stage from (33.1, 33.9) to (13.1, 12.9) during both seasons within 80 days of cold storage. While there is a slight decrease in red maturity (RM) stage (29.2, 14.2) to (13.9, 11.4) within 40 days of cold storage.

As for the cultivars, Lee and Lang cultivars scored the lowest b* value. These variations in color values were attributed to the conversion of the fruit color from white to red during cold storage and were associated with fruit ripening, senescence and chlorophyll degradation in winter jujube fruit [23]. A similar upward trend in a* and a decrease trend in L*, b* was also observed in winter jujube fruit during storage by Chen *et al*. [26].

Ascorbic Acid: Data in Table (8) show a real significant difference between the effects of two maturity stages on fruit ascorbic acid content under cold storage conditions. Fruits at red maturity (RM) stage recorded a higher content than those harvested at the white maturity (WM) stage in both seasons, Ascorbic acid content decreased throughout the cold storage period. Among the cultivars, the highest content of ascorbic acid (565.9 and 591.3 mg. 100 g^{-1} fresh weight) was detected in the Lee cultivar fruit at white maturity (WM) stage in both seasons. While the lowest values of ascorbic acid were found in the Seedy cultivar fruits after 80 days of cold storage. The content of ascorbic acid at red maturity (RM) stage belongs to Lee cultivar (773.47mg/100g FW) in the first season and (868.27mg/100g FW) in the second season. This result is in agreement with those found, by Moradinezhad *et al*. [10], the highest value in ascorbic acid of jujube fruits was recorded in harvested fruit at fully mature stage (637 mg/100g FW). Ascorbic acid content was in the range of 463.3-591.7mg/100g FW, with the lowest and highest value in seedy and Lee, respectively [9].

Chilling Injury: No chilling injury symptoms were noticed during cold storage period, this result due to suitable storage temperature 10 C and packing in perforated polyethylene bags, this result is in agreement with those of Kader [31] who stated that, fresh jujube fruits appear to be susceptible to chilling injury (sheet pitting or large sunken areas on the skin) if held at 0 C., to avoid this symptom, fruits should not expose to temperatures below 2.2C.

Decay Incidence: Decay is the main cause of post-harvest losses, fruits harvested at white maturity stage (WM) of four cultivars can be held 80 days at 10C without significant quality deterioration or decay due to fruit packing in polyethylene bags. It can be noticed that Seedy fruits at red maturity showed slight decay % at the end of storage period (40 days).

Jujube fruit rapidly spoils due to the increase in browning and decay rate and dehydration at postharvest and such as many fruit species, spoilage increases with a longer storage period in jujube as well [32]. It is possible to reduce the losses caused by the decay by controlling the atmosphere of gas and moisture around the fruit with postharvest MAP applications [33].

The Visual Quality: The sensory scores of jujube fruits at different stages of maturity at the end of the storage period at 10°C are shown in Table (9) statistically significant differences for all attributes between the stage of white maturity (WM) and the stage of red maturity (RM) fruits. The scores of visual appearance, taste, texture and general acceptability of the jujube fruits gradually decreased during the storage period. Among the cultivars, Lee cultivar scored the highest average visual quality scores for fruits picked in the white maturity (WM) stage at the first season, while it was equal to Lang cultivar in the second season. As for the fruit picked in the red maturity (RM) stage Lee cultivar retained the highest average sensory quality scores during the two seasons.

Table 7: The changes of color b values in jujube fruits harvested at two maturity stages during cold storage at 10?C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	35.8	25.6	15.7	11.8	11.5	20.1	32.0	17.9	13.6	11.8	11.0	17.3
Lang	34.0	24.3	17.1	12.5	11.8	19.9	25.8	18.1	17.8	14.9	14.0	18.1
Balahy	32.2	21.7	20.4	16.6	14.9	21.2	32.3	25.5	22.9	21.9	16.0	23.7
Seedy	30.5	26.9	15.7	15.6	14.3	20.6	26.5	22.8	20.6	16.4	14.7	20.2
Mean	33.1	24.6	17.2	14.1	13.1		29.2	21.1	18.7	16.2	13.9	
L.S.D. 0.05:	(P): 1.19		(C): 0.85		(PxC): 1.91		(P): 1.77		(C): 1.47		(PxC): 3.27	
	Second season (2020)											
Lee	33.0	22.7	10.3	9.2	9.9	17.0	9.2	11.6	11.3	9.6	10.5	10.5
Lang	34.8	28.1	12.1	10.5	10.4	19.2	16.5	17.4	13.3	12.3	12.1	14.3
Balahy	36.9	24.6	19.6	15.6	14.4	22.2	16.6	16.1	14.6	12.6	12.7	14.5
Seedy	30.8	27.8	31.9	18.9	17.0	25.3	14.3	13.5	12.6	11.3	10.3	12.4
Mean	33.9	25.8	18.5	13.5	12.9		14.2	14.7	13.0	11.4	11.4	
L.S.D. 0.05:	(P): 1.39		(C):0.93		(PxC): 2.09		(P): 1.21		(C): 0.95		(PxC): 2.13	

Table 8: The changes of ascorbic acid (mg. 100 g^{-1} fresh weight) in jujube fruits harvested at two maturity stages during cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM)						Red Mature (RM)					
	Storage period (P)											
Cultivar (C)	0days	20days	40days	60days	80days	Mean	0days	10days	20days	30days	40days	Mean
	First season (2019)											
Lee	591.7	588.0	572.0	556.0	522.0	565.9	788.0	795.0	760.0	766.0	758.0	773.4
Lang	549.7	550.0	533.0	523.0	504.0	531.9	743.0	728.0	744.0	738.0	720.0	734.6
Balahy	543.3	533.0	512.0	517.0	476.0	516.3	733.0	742.0	720.0	732.0	726.0	730.6
Seedy	463.3	455.0	455.0	450.0	430.0	450.7	688.0	680.0	676.0	700.0	675.0	683.8
Mean	537.0	531.5	518.0	511.5	483.0		738.0	736.3	725.0	734.0	719.8	
L.S.D. 005:	(P): 3.49		(C): 3.22		(PxC): 7.22		(P): 4.44		(C): 3.93		(PxC): 8.79	
	Second season (2020)											
Lee	588.3	590.0	588.0	605.0	587.0	591.7	897.0	878.0	886.0	846.0	834.0	868.2
Lang	545.0	565.0	544.0	562.0	545.0	552.2	788.0	761.7	776.0	746.0	754.0	765.1
Balahy	546.7	554.0	540.3	553.0	540.0	546.8	756.0	788.0	768.0	780.0	762.0	770.8
Seedy	502.4	487.0	513.0	498.0	484.0	496.9	822.0	796.0	785.0	813.0	788.0	800.8
Mean	545.6	549.0	546.3	554.5	539.0		815.8	805.9	803.8	796.3	784.5	
L.S.D. 0.05:	(P): 4.84		(C): 3.75		(PxC): 8.39		(P): 5.51		(C): 3.73		(PxC): 8.34	

Table 9: Visual quality of jujube fruits harvested at two maturity stages after cold storage at 10°C (2019 and 2020 seasons)

	White Mature (WM) after 80 days				Red Mature (RM) after 40 days			
	Visual quality							
Cultivar (C)	Visual app.,	Texture	Taste	Average visual quality	Visual app.,	Texture	Taste	Average visual quality
	First season (2019)							
Lee	9.00	9.00	7.00	8.33	9.00	7.00	7.00	7.67
Lang	9.00	7.00	7.00	7.67	7.00	7.00	7.00	7.00
Balahy	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Seedy	7.00	7.00	7.00	7.00	5.00	5.00	7.00	5.67
L.S.D. 0.05:	0.61	0.50	0.35		0.50	0.35	0.35	
	Second season (2020)							
Lee	9.00	9.00	7.00	8.33	9.00	9.00	7.00	8.33
Lang	9.00	9.00	7.00	8.33	7.00	7.00	7.00	7.00
Balahy	7.00	7.00	7.00	7.00	7.00	5.00	5.00	5.67
Seedy	7.00	7.00	9.00	7.67	5.00	5.00	7.00	5.67
L.S.D. 0.05:	0.65	0.65	0.54		0.54	0.50	0.35	

CONCLUSIONS

The ideal harvest stage for jujube fruits is picking in the white mature stage (WM)and packing in polyethylene bags, where cold storage period extends to 80 days at 10 C. Lee cultivar considered one of the best cultivars of jujuba fruits in terms of its high storability, the lowest value for weight loss, the highest percentage of texture, the best coloring, the highest content in ascorbic acid and the highest values of sensory quality

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