Storage Temperature and Storage Duration Affect Fruit and Oil Quality of Coratina, Manzanillo and Picual Olives

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ABSTRACT

During 2008 and 2009 seasons, Coratina, Manzanillo and Picual olive fruits were stored at 5, 10 and 20˚C with 85 - 90 % relative humidity. All olive cvs were stored only for one week at 20˚C with the loss of fruit appearance. Coratina fruits were the most tolerant to chilling injury and no internal browning was observed in fruit flesh of all cvs during the storage period. Storage temperature had significant effect on fruit weight loss where the stored fruits at 10˚C lost more than 3 folds of those stored at 5˚C. By the progress of the storage period, fruit weight loss increased while the moisture values declined and the stored fruits at 5˚C had significantly higher moisture content. Coratina olives significantly contained the highest oil content (26.81 and 28.10 %) followed by Picual (25.21 and 26.44 %) then Manzanillo fruits (24.25 and 25.55 %). Oil content decreased significantly with increasing the storage temperature and time. Palmitic, arachidic, oleic, palmitoleic and linoleic fatty acids were not affected by the storage temperature. Myristic fatty acid increased in Coratina fruits stored at 10˚C. Stearic acid values of Coratina and Manzanillo declined by the end of the storage period while that of Picual increased. Myristic, palmitoleic and linoleic fatty acids increased with the progress of the storage period while arachidic and oleic fatty acids decreased. Linolenic acid content of Coratina fruits increased in the third week at 5 and 10˚C then decreased with the progress of the storage period. Coratina had the highest linolenic content at the third week while Manzanillo had the highest content after 4 weeks at 5˚C. There was no effect of the storage temperature or period on fruit lipids content but generally, the fruits that were stored at 20˚C contained lower values.

INTRODUCTION

Olive (*Olea europea* L.) is one of the most important and popular fruit crops in Egypt and its total area exceeded rapidly during the last years in new lands. Olive fruits are used for oil extraction or pickling. The beneficial health effects of olive oil are due to both its high content of monounsaturated fatty acids and its high content of antioxidative substances. Studies have shown that olive oil offers protection against heart disease by controlling LDL (bad) cholesterol levels while raising HDL (good) cholesterol levels. Due to the limited oil extraction capacities of the industrial facilities, processing of olives is not well synchronized with harvest. Therefore after harvest, olives might be piled in heaps and stored at ambient temperatures for up to several weeks before processing for oil extraction and during this period the greatest deterioration takes place. Pressure within the olive pile during storage can cause fluid secretion from the fruit that can provide an optimum medium for growth of fungi and bacteria. Furthermore, heat production from respiration activity may accelerate the deterioration of the fruits and eventually cause the breakdown of cell structure. Oil extracted from these damaged olives can be high in acidity and low in stability and can develop a high content of volatile acids (acetic or butyric) that causes a characteristic musty smell and the resultant oil requires refining resulting in higher costs and loss of market value (Ager *et al.,* 1998 & 1999; Garcia and Streif, 1991; Garcia *et al.,* 1996; Gutierrez *et al.,* 1992 and Olias and Garcia, 1997). Therefore, storage of fresh olives is more desirable and could allow a more orderly flow to the processing plant (Kader *et al.,* 1989). The possibility of extending the length of storage of olives before oil extraction could increase the yield of good quality oil (Petruccioli and Parlati, 1987). The storage below 5?C causes chilling injury (CI) and thus the minimum safe storage temperature is 5?C and the CI depends on time, temperature, cultivar, maturity and atmospheric composition (Maxie, 1998 and Kader *et al.,* 1990). The objective of this study was to evaluate inter-cultivar differences and to identify the optimum preprocessing storage temperature to maintain fruit and oil quality of Coratina, Manzanillo and Picual olive fruits.

MATERIALS AND METHODS

The present study was carried out during 2008 and 2009 seasons on Coratina, Manzanillo and Picual olive fruits harvested from El-Shrouq private orchard at Cairo-Alexandria desert road (74 km from Cairo, 6 October governorate). Sound selected fruits were packed in plastic open boxes (5kg of each) and transported to the Postharvest Center of Horticulture Crops, Faculty of Agriculture, Alexandria University.

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The initial fruit quality (average of 30 fruits of each cultivar) was determined (table 1) then the fruits were

Table 1. The initial quality of Coratina, Manzanillo and Picual olive fruits during 2008 and 2009 seasons

Parameter	Coratina		Manzanillo		Picual	
	2008	2009	2008	2009	2008	2009
Fruit wt. (gm)	4.03	4.16	5.06	4.56	3.57	3.37
Fruit size:						
Length(cm)	2.17	2.23	2.40	2.30	2.25	2.27
Diameter(cm)	1.63	1.83	1.97	1.97	1.57	1.73
Seed wt. (gm)	0.85	0.90	0.82	0.76	0.79	0.80
Flesh wt. (gm)	3.18	3.26	4.24	3.80	2.78	2.57
Flesh/fruit (%)	78.91	78.37	83.79	83.33	77.87	76.26

stored at 5, 10 and 20˚C with 85 - 90 % relative humidity. The physio-chemical properties of the stored fruits were followed up in 7 days intervals (oil properties were followed up after 0, 1, 3, 4, 6, 7 weeks) throughout the storage period as follow.

Five nets of 100 fruits of each cv. were labeled then weighed to calculate fruit weight loss percent during the storage period in relation to its original weights. Another same 5 nets were labeled to observe the change in fruit quality such as shrinkage, visual color changes, rot incidence and the chilling injury symptoms.

Moisture content (%) was determined by drying three recorded weights of fruit flesh from each treatment. Subsequent periodical weight determinations were carried out to obtain a constant dry weight then the percentage moisture content was calculated in relation to the initial recorded weight.

External color of the fruits was estimated visually and measured with Menolta colorimeter. L, a and b values were used to calculate the hue angle of each fruit in the sample of each treatment according to Mclellan *et al.,* (2007) as follows: Hue˚ = 180 + Arc tan (b/a).

Total lipids content of olive fruits was determined according the method of Folch *et al.,* (1957).

Preparation of fatty acid methyl esters from lipids (olive oil) was performed according to the procedure of Radwan (1978) and the oil percent was recorded. Analysis of fatty acids was carried out by gas liquid chromatography (GLC) according to AOAC (1984).

The termination of the experiment was done by the incidence of chilling injury symptoms and by the loss of good fruit appearance. All data obtained were statistically analyzed according to the methods described by Snedecor and Cochran (1980). The individual comparisons were carried out by using the Least Significant Difference (LSD) according to SAS Institute (1985). Simple regression coefficient (r^2) between storage period and studied properties was calculated using SAS program (1985).

RESULTS AND DISCUSSION

Visual fruit quality and storagability:

Manzanillo had the highest fruit weight and size with the highest flesh/fruit percent. The importance of olive fruit dimensions is determining the aperture size of separating machines. The variation of fruit mass, length and width of olive fruits could be due to different cultivars, environmental conditions and nutritional status of orchards. The higher flesh/pit ratio is a desired fruit property in olive (Ozturk *et al.,* 2009).

All the studied olive cvs were stored only for one week at 20˚C with the loss of fruit good appearance due to shrinkage and purple pigment accumulation (ripening) in Coratina and Manzanillo fruits while Picual fruits remained green. After that period at 20˚C, 2.70, 5.41, 8.11 and 16.22 % of Coratina fruits (average of two seasons) turned to 100, 75, 50 and 25 % skin purple color, respectively. The corresponding percentages of purple colored fruits for Manzanillo cv were 19.75, 9.26, 14.82 and 19.26 %, respectively.

The initial appearance of purple color was at 10˚C on Coratina fruits after one week. On the other hand, after the same period at 5˚C chilling injury symptoms started to be observed on Manzanillo fruit skin as small brown spots. Those symptoms increased with the progress of cold storage at 5˚C to reach the percent of 50 % of fruit number at the end of the storage period (4 weeks). Picual fruits showed more tolerance to chilling injury where the initial symptoms appeared after 3 weeks at 5˚C on few fruits and increased slowly to reach 50 % at the end of the storage period (6 weeks). Coratina fruits were the most tolerant to chilling injury where the symptoms appeared on 50 % of the fruits after a longest period of 7 weeks at 5˚C. No internal browning was observed in fruit flesh of all cvs during the storage period.

Fruits stored at 10˚C were safe from chilling injury but it suffered from water loss and shrinkage appearance on the fruits which reached the percent of

50 % after 3 weeks for Manzanillo and Picual and after 4 weeks for Coratina.

A high level of respiration determines two undesirable effects, a shorter commercial life for the stored product and a loss in weight and nutritional value, because this process consumes energy metabolites such as sugars, lipids or organic acids. Furthermore, refrigeration delays the deterioration activity of the pathogens (Garcia and Yousif, 2006). Storage of olives at room temperature led to their deterioration after 15 days of storage (Clodoveo *et al.*, 2007). In olives, decreasing the temperature from 18 to 5˚C led to chilling injury appearance (Garcia and Streif, 1991). The cause of chilling injury has been attributed to a non programmed accumulation of succinic acid in the Krebs cycle. Succinic-dehydrogenase should be more affected by a low temperature than the other enzymes of this metabolic system and its toxic substrate would destroy the fruit cell (Kader, 1985). At the same time, low temperature could affect the permeability of the plasmatic membrane, altering the physical properties of its main constituent, the phospholipids (Garcia and Yousif, 2006).

Chilling injury which can be a major cause of deterioration in fresh olives stored before processing, is described as internal browning around the pit or skin at advanced stages (Kader *et al.*, 1996; Kiritsakis *et al.*, 1998 and Agar *et al.*, 1999). Chilling injury symptoms were observed in mature-green Manzanillo olives when stored at 0 and 2.5˚C after 2 and 5 weeks respectively, whereas those stored at 5-7 ˚C had no visible symptoms of chilling injury (Kader *et al.*, 1990 and Agar *et al.*, 1999).

Skin color changes (hue angle):

Storage temperature in general, had a significant effect on skin color presented as hue˚ (table 2) of Coratina and Manzanillo fruits where the stored fruits at 20˚C for one week had the highest hue˚ values in the two seasons which reflect the skin color changes from green to bluish-purple.

On the other hand, no significant changes were obtained with Picual fruits which remained green. The stored fruits at 10˚C had higher hue˚ degrees which changed significantly with the storage duration. Fruit skin color is considered to be the most important index of olive external quality and an important consideration to determine maturity of fruits (Ozturk *et al.*, 2009). A 90˚ hue angle represents yellow, 180˚ represents bluish-green, 270˚ represents blue and 0˚ represents reddish-purple (McGuire, 1992). Agar *et al.*, (1999) reported that Manzanillo olives stored at 20˚C had significant poorer color than fruit from the other treatments.

Fruit weight loss and moisture content (%):

Storage temperature had significant effect on weight loss of Coratina, Manzanillo and Picual fruits where the stored fruits at 20˚C loss of its initial weight more than 16 % in Coratina, more than 12 % in Manzanillo and more than 11 % in Picual (table 3). The stored fruits at 10˚C lost more than 3 folds of those stored at 5˚C. By the progress of storage period fruit weight loss of all cvs increased significantly (r^2 values were highly significant).

Ager *et al.*, (1998) showed that weight loss increased with storage time and ranged between 0.6 (Sevillano) and 1.5 % (Manzanillo) in black-ripe olives which were stored at 5˚C, while it ranged between 2.3 and 3 % in those stored at 20˚C for 2 weeks. Castellano *et al.*, (1993) reported that higher weight loss at 20˚C might be partially due to fungal decomposition of olives resulting in the leakage of cell fluids as well as transpiration.

The initial moisture content of olive fruits in this work ranged from 74.48 to 76.05 %. Those values declined significantly after 1 week when the fruits were stored at 20˚C and there was no significant difference between fruits that were stored at 5 and 10˚C (table 4). In the second week and during the storage period the stored fruits at 5˚C had significantly higher moisture content than those stored at 10˚C. Fruit moisture content of all cvs decreased (r^2 values were not significant) with the progress of the storage time.

Ager *et al.*, (1998) reported that water content at harvest was 67.9, 60.5, 52.5 and 61.2 % in Ascolano, Manzanillo, Mission and Sevillano olives, respectively. There were no significant differences in water content of black-ripe olives over storage time. Kiritsakis, (1998) recorded that water in olive fruit served as solvent for organic acids, tannins, oleuropein and other water soluble components of the fruits and its content was based on stage of maturity, variety, climate condition, irrigation and soil moisture.

Fruit oil content:

Significantly in 2008 and 2009 seasons, Coratina olives contained the highest oil content (26.81 and 28.10 %) followed by Picual (25.21 and 26.44 %) then Manzanillo (24.25 and 25.55 %) fruits (table 5). Oil content decreased significantly with the increasing of the storage temperature especially at 20˚C where the above initial values decreased to 18.33 and 18.52 % in Coratina, 16.44 and 16.77 % in Picual and to 15.66 and 16.93 % in Manzanillo fruits respectively in 2008 and 2009 seasons. With the progress of the storage period, oil content of the three cvs decreased and r^2 values were highly significant.

Table 2. Effect of Storage Temperature and Storage Duration on Skin Color (hue angle) of Coratina, Manzanillo and Picual Olives in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)								r^2
		0	1	2	3	4	5	6	7	
1st Season	Coratina									
	5°C	185.17b	193.23bc	190.20b	188.47c	201.02b	204.07a	213.93a	214.53	
	10°C	185.17b	200.40bc	195.82b	215.66a	235.64a				
	20°C	185.17b	224.53a							
	Manzanillo									
	5°C	186.37ab	199.83bc	192.75b	200.04bc	216.20ab				
	10°C	186.37ab	207.71ab	215.94a	203.26ab					
	20°C	186.37ab	224.46a							
	Picual									
	5°C	190.05a	188.31c	194.61b	208.84ab	214.91b	197.36b	194.93a		
	10°C	190.05a	194.28bc	221.21a	207.98ab					
	20°C	190.05a	190.31bc							
2nd Season	Coratina									
	5°C	189.15ab	194.58bc	196.20b	196.79cd	195.70a	205.14a	202.40a	228.46	0.672*
	10°C	189.15ab	191.19c	198.20b	201.76bc	201.73a				0.939**
	20°C	189.15ab	206.97ab							
	Manzanillo									
	5°C	184.13b	195.58abc	195.92b	189.63d	191.05a				0.466
	10°C	184.13b	197.44abc	225.70a	207.30ab					0.540
	20°C	184.13b	207.84a							
	Picual									
	5°C	194.67a	194.28c	196.40b	210.77a	206.43a	197.91b	190.82a		0.004
	10°C	194.67a	189.44c	200.95b	208.38ab					0.069
	20°C	194.67a	197.11abc							

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 3. Effect of Storage Temperature and Storage Duration on Weight Loss (%) of Coratina, Manzanillo and Picual Olive Fruitsin 2008 and 2009 Seasons

	Treat.	Storage period (weeks)								r^2
		0	1	2	3	4	5	6	7	
1st Season	Coratina									
	5°C	0.00	1.21d	3.35b	3.68b	4.19b	5.24a	6.28a	7.37	0.970**
	10°C	0.00	3.77c	8.29a	10.84a	14.07a				0.991**
	20°C	0.00	16.77a							
	Manzanillo									
	5°C	0.00	1.05d	2.87b	3.32b	3.79b				0.933**
	10°C	0.00	4.11c	8.20a	10.90a					0.991**
	20°C	0.00	12.10b							
	Picual									
	5°C	0.00	1.04d	2.92b	3.34b	4.67b	4.65b	5.75b		0.959**
	10°C	0.00	3.76c	7.84a	10.77a					0.995**
	20°C	0.00	10.92b							
2nd Season	Coratina									
	5°C	0.00	1.31d	3.50b	3.70b	4.12b	5.14a	6.30a	7.49	0.962**
	10°C	0.00	4.21c	8.25a	12.20a	16.33a				0.999**
	20°C	0.00	16.17a							
	Manzanillo									
	5°C	0.00	1.05d	3.04b	3.50b	3.66b				0.894**
	10°C	0.00	4.96c	9.74a	12.53a					0.985**
	20°C	0.00	12.03b							
	Picual									
	5°C	0.00	0.98d	2.19b	2.85b	3.77b	4.60b	5.63b		0.996**
	10°C	0.00	4.26c	8.08a	11.11a					0.994**
	20°C	0.00	11.70b							

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 4. Effect of Storage Temperature and Storage Duration on Moisture Content (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)								r^2
		0	1	2	3	4	5	6	7	
1st Season	Coratina									
	5°C	75.70a	74.46bc	77.65a	75.93a	76.53a	74.63a	74.65a	73.59	0.246
	10°C	75.70a	74.17bc	74.77b	73.97b	70.89c				0.734
	20°C	75.70a	68.75d							
	Manzanillo									
	5°C	74.66a	75.20b	77.17a	73.92b	74.00b				0.103
	10°C	74.66a	73.71bc	72.94c	73.44b					0.626
	20°C	74.66a	73.19c							
	Picual									
	5°C	75.00a	78.23a	74.91b	77.02a	76.31a	75.65a	74.24a		0.120
	10°C	75.00a	78.64a	72.79c	76.73a					0.270
	20°C	75.00a	73.95bc							
2nd Season	Coratina									
	5°C	74.48a	75.18b	77.79a	75.41bc	75.28a	74.16b	75.63a	73.86	0.099
	10°C	74.48a	74.17bc	75.42b	74.53c	69.49b				0.417
	20°C	74.48a	67.95b							
	Manzanillo									
	5°C	74.70a	74.79bc	77.04a	74.61c	74.05a				0.041
	10°C	74.70a	73.69bc	73.61c	72.03d					0.897*
	20°C	74.70a	72.89c							
	Picual									
	5°C	76.05a	80.19a	75.39b	77.00a	76.35a	77.05a	75.23a		0.129
	10°C	76.05a	79.26a	74.30bc	76.09ab					0.091
	20°C	76.05a	74.75bc							

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 5. Effect of Storage Temperature and Storage Duration on Oil Content (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5°C	26.81a	25.07a	21.63a	20.73a	17.67a	16.00	0.955**
	10°C	26.81a	24.67a	18.70bc	17.22c			0.967**
	20°C	26.81a	18.33c					
	Manzanillo							
	5°C	24.25b	22.65bc	19.14bc	18.18bc			0.960**
	10°C	24.25b	20.74d	17.32d				0.979**
	20°C	24.25b	15.66f					
	Picual							
	5°C	25.21ab	23.49b	19.93b	18.87b	16.03b		0.950**
	10°C	25.21ab	21.88cd	18.12cd				0.969**
	20°C	25.21ab	16.44f					
2nd Season	Coratina							
	5°C	28.10a	26.21a	22.22a	21.32a	18.33a	16.65	0.970**
	10°C	28.10a	25.05ab	20.13b	18.11b			0.997**
	20°C	28.10a	18.52e					
	Manzanillo							
	5°C	25.55b	22.74cd	18.51c	17.85b			0.967**
	10°C	25.55b	21.40d	17.18d				0.982**
	20°C	25.55b	16.93ef					
	Picual							
	5°C	26.44ab	23.62bc	20.66b	18.44b	16.40b		0.978**
	10°C	26.44ab	21.41d	18.11cd				0.873**
	20°C	26.44ab	16.77f					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Ager *et al.,* (1998) found that the oil content of olive fruits remained unchanged during storage at 5˚C. Black ripe Ascolano and Sevillano olives contained 28.5 and 28.8 % oil, respectively, whereas Manzanillo and Mission olives contained 33.3 and 37.7 %, respectively. Oil content of black ripe Manzanillo and Ascolano olives stored at 20 ˚C for 2 weeks was 29.9 and 26.5 %, respectively, which was lower than the initial values and those of olives stored at 5 ˚C, whereas oil content of other cvs remained unchanged.

The above results are associated also with those of Raie and Latif (1982); Gutierrez *et al.,* (1992) and Ager *et al.,* (1999).

Fatty acid composition:

a- Saturated fatty acids:

The initial total percent of saturated fatty acids in Coratina, Manzanillo and Picual olive fruits respectively were 23.94, 25.23 and 23.53 % in the first season and 26.54, 25.78 and 25.56 % in the second one. Those percentages mainly included the values of palmitic, stearic and arachidic acids.

The highest percent was for palmitic acid which initially was (an average of two seasons) 20.27 % in Coratina, 20.93 % in Manzanillo and 21.21 % in Picual fruits (table 6). Those initial values were not affected by the storage temperatures (fruits were stored at 20˚C slightly had highest values) or by the storage period (r^2 values were not significant). Agar *et al.,* (1998) reported that palmitic acid is the primary saturated fatty acid in olives. Manzanillo (14.3 %) and Ascolano (13.9 %) olives had a significantly higher content of palmitic acid than Mission (11.2 %). Also, palmitic acid changed significantly over storage time. Agar *et al.,* (1999) recorded that palmitic acid content in black-ripe Manzanillo olives was 15.2 % at harvest and ranged between 13.7 and 14.9 % during 6 weeks storage.

Stearic acid contents (table 7) as an average of the two seasons were 3.61, 3.89 and 2.83 % for Coratina, Manzanillo and Picual olives, respectively. Those values of Coratina and Manzanillo declined by the end of the storage period while that of Picual increased Agar *et al.,* (1999) showed that the stearic acid content of black-ripe Manzanillo ranged between 3.8 and 5.3 % in air stored olives during 6 weeks storage.

Table 6. Effect of Storage Temperature and Storage Duration on Palmitic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5˚C	19.54a	20.43ab	17.62d	19.12a	19.76a	19.41	0.004
	10˚C	19.54a	20.54ab	21.58abc	20.21a			0.214
	20˚C	19.54a	21.19ab					
	Manzanillo							
	5˚C	20.44a	18.36b	19.92c	19.31a			0.070
	10˚C	20.44a	22.04a	20.64bc				0.013
	20˚C	20.44a	19.24ab					
	Picual							
	5˚C	19.95a	19.39ab	23.21a	20.05a	20.94a		0.077
	10˚C	19.95a	21.75a	21.97ab				0.083
	20˚C	19.95a	21.22a					
2nd Season	Coratina							
	5˚C	20.99a	20.47ab	20.62a	19.58a	19.78a	19.72	0.468
	10˚C	20.99a	18.82b	21.14a	19.70a			0.033
	20˚C	20.99a	20.80ab					
	Manzanillo							
	5˚C	21.41a	22.47ab	21.43a	20.93a			0.243
	10˚C	21.41a	21.31ab	21.63a				0.451
	20˚C	21.41a	22.92ab					
	Picual							
	5˚C	22.46a	20.53ab	22.12a	19.73a	20.77a		0.336
	10˚C	22.46a	19.51b	21.44a				0.116
	20˚C	22.46a	24.05a					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficie

Table 7. Effect of Storage Temperature and Storage Duration on Stearic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5˚C	3.18ab	2.61ab	3.08bc	2.80a	2.68a	2.33	0.542
	10˚C	3.18ab	3.07ab	3.97a	2.53a			0.052
	20˚C	3.18ab	2.54b					
	Manzanillo							
	5˚C	4.20a	2.90ab	2.72c	2.81a			0.646
	10˚C	4.20a	3.35a	3.75ab				0.280
	20˚C	4.20a	2.76ab					
	Picual							
	5˚C	2.99b	2.32b	3.02bc	2.53s	3.12a		0.045
	10˚C	2.99b	2.52b	3.58ab				0.308
	20˚C	2.99b	2.46b					
2nd Season	Coratina							
	5˚C	4.03a	2.19c	2.93a	2.84b	2.95b	3.11	0.047
	10˚C	4.03a	2.47bc	3.28a	2.25c			0.518
	20˚C	4.03a	2.66bc					
	Manzanillo							
	5˚C	3.57ab	3.32b	2.99a	3.18b			0.629
	10˚C	3.57ab	4.62a	3.17a				0.071
	20˚C	3.57ab	4.52a					
	Picual							
	5˚C	2.66b	2.06c	2.74a	3.98a	4.11a		0.726
	10˚C	2.66b	2.28bc	3.64a				0.488
	20˚C	2.66b	3.02bc					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Arachidic acid percent was less than 1 % in all cvs where as an average of two seasons Coratina contained 0.512 %, Manzanillo contained 0.583 % and Picual contained 0.610 % (table 8). Those initial contents declined by the end of the storage period and there was no significant effect of storage temperature on arachidic content of all olive cvs in this work. Agar *et al.,* (1999) reported that arachidic acid content of black-ripe Manzanillo declined from 0.9 % at harvest to between 0.2 and 0.7 % irrespective of storage temperature and atmosphere.

Olive fruits of Carotina, Manzanillo and Picual contained as an average of the two seasons 0.195, 0.197 and 0.169 % of myristic acid (table 9) which increased in Coratina fruits which were stored at 10 ˚C in the two seasons. Also, myristic acid increased by the progress of the storage time.

b- Unsaturated fatty acids:

The total unsaturated fatty acids of Coratina, Manzanillo and Picual olives were 76.06, 74.77 and 76.37 %, respectively in the first season and were 73.46, 74.23 and 74.44 % in the second one.

At harvest, Coratina, Manzanillo and Picual olives contained (an average of two seasons) 65.02, 63.12 and 65.90 % of oleic (monounsaturated) acid (table 10). Those percentages were not affected by the storage temperature but generally the fruits that were stored at 5˚C contained higher percents. Oleic acid contents declined with the progress of the storage period (r^2 values were not significant). Agar *et al.,* (1998) recorded that the average oleic acid content of Mission olives was 73 %, that of Sevillano and Manzanillo olives was 69 % and Ascolano olives contained 63.5 % oleic acid after 6 and 8 weeks at 5˚C. A high concentration of oleic acid enhances the stability of the oil, and a diet rich in this fatty acid reduces cholesterol levels. On the other hand, Ager *et al.,* (1999) reported that oleic acid (66.1-70.4 %) is the main monounsaturated fatty acid in olives which also contain low amounts of palmitoleic acid (1.3-1.9 %).

Table 8. Effect of Storage Temperature and Storage Duration on Arachidic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5°C	0.600a	0.640ab	0.600a	0.600a	0.587a	0.307	0.497
	10°C	0.600a	0.653ab	0.653a	0.500a			0.288
	20°C	0.600a	0.370b					
	Manzanillo							
	5°C	0.593a	0.643ab	0.540a	0.233b			0.686
	10°C	0.593a	0.557ab	0.607a				0.074
	20°C	0.593a	0.770a					
	Picual							
	5°C	0.547a	0.823a	0.633a	0.213b	0.503b		0.247
	10°C	0.547a	0.703a	0.643a				0.372
	20°C	0.547a	0.577ab					
2nd Season	Coratina							
	5°C	0.423b	0.400c	0.607abc	0.413a	0.493a	0.400	0.004
	10°C	0.423b	0.610abc	0.523bc	0.330a			0.152
	20°C	0.423b	0.517bc					
	Manzanillo							
	5°C	0.573ab	0.550abc	0.557abc	0.453a			0.703
	10°C	0.573ab	0.803a	0.407c				0.174
	20°C	0.573ab	0.767ab					
	Picual							
	5°C	0.673a	0.747ab	0.787a	0.327a	0.467a		0.449
	10°C	0.673a	0.630abc	0.710ab				0.214
	20°C	0.673a	0.530bc					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 9. Effect of Storage Temperature and Storage Duration on Myristic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5°C	0.205a	0.183bc	0.230a	0.447a	0.987a	0.375	0.315
	10°C	0.205a	0.537a	0.440a	0.660a			0.722
	20°C	0.205a	0.140c					
	Manzanillo							
	5°C	0.122b	0.190bc	0.317a	0.433a			0.986**
	10°C	0.122b	0.190bc	0.390a				0.725
	20°C	0.122b	0.253bc					
	Picual							
	5°C	0.178a	0.300b	0.280a	0.600a	0.530a		0.787*
	10°C	0.178a	0.243bc	0.350a				0.981**
	20°C	0.178a	0.193bc					
2nd Season	Coratina							
	5°C	0.179a	0.130d	0.437ab	0.273b	0.260b	0.353	0.429
	10°C	0.179a	0.377a	0.490a	0.830a			0.955*
	20°C	0.179a	0.170cd					
	Manzanillo							
	5°C	0.272a	0.137cd	0.240bc	0.287b			0.080
	10°C	0.272a	0.200bcd	0.243bc				0.160
	20°C	0.272a	0.200bcd					
	Picual							
	5°C	0.160a	0.303ab	0.377ab	0.350b	0.660a		0.823*
	10°C	0.160a	0.300ab	0.163c				0.003
	20°C	0.160a	0.250bc					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 10. Effect of Storage Temperature and Storage Duration on Oleic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5˚C	66.51a	64.47a	64.34a	65.81a	62.32a	64.70	0.272
	10˚C	66.51a	62.01a	60.38a	63.73a			0.241
	20˚C	66.51a	65.19a					
	Manzanillo							
	5˚C	62.89a	64.29a	63.41a	64.04a			0.276
	10˚C	62.89a	64.31a	62.07a				0.131
	20˚C	62.89a	62.03a					
	Picual							
	5˚C	66.55a	68.29a	63.66a	63.82a	62.60a		0.690
	10˚C	66.55a	65.33a	60.82a				0.790
	20˚C	66.55a	63.47a					
2nd Season	Coratina							
	5˚C	63.52a	67.58a	62.91abc	60.57a	62.03a	59.52	0.548
	10˚C	63.52a	65.61a	60.19bc	62.74a			0.200
	20˚C	63.52a	66.10a					
	Manzanillo							
	5˚C	63.35a	59.01bc	63.38abc	63.29a			0.062
	10˚C	63.35a	59.22bc	66.03a				0.153
	20˚C	63.35a	57.85c					
	Picual							
	5˚C	65.24a	64.35ab	64.55ab	63.61a	59.10b		0.702
	10˚C	65.24a	63.96abc	58.39c				0.684
	20˚C	65.24a	58.98bc					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Olives contained low percentage of palmitoleic (monounsaturated) acid (table 11) which were at harvest (as an average of two seasons) 1.81, 2.31 and 1.83 % in Coratina, Manzanillo and Picual fruits, respectively. Those initial values were not affected by the storage temperature and increased with the end of the storage time (r^2 values were not significant).

Manzanillo olives contained the highest initial percents (an average of two seasons) of linoleic (polyunsaturated) acid (7.09 %) compared with Coratina (5.65 %) and Picual (5.02 %) fruits (table 12). The above percentages increased with the progress of the storage period (r^2 values were significant only in Coratina fruits in the second season) and were not affected by storage temperature.

On the other hand, the initial contents (an average of two seasons) of linolenic (polyunsaturated) acid were 1.71 % in Coratina, 2.09 % in Manzanillo and 2.09 % in Picual (table 13). Linolenic acid was affected slightly by storage time (r^2 values were not significant) and was not affected by storage temperature. Linolenic acid content of Coratina fruits increased in the third week at 5 and 10˚C then decreased with the progress of the storage period. Coratina had the highest linolenic content at the third week while Manzanillo had the highest content after 4 weeks at 5˚C. Agar *et al.*, (1999) recorded that polyunsaturated fatty acids are very important for human nutrition as they are considered essential. Linoleic acid was the dominant polyunsaturated fatty acid in Manzanillo olives ranging

from 9.1 to 11.5 %, while linolenic acid ranged from 0.9 to 1.4 % . Raina, (1995)

Table 11. Effect of Storage Temperature and Storage Duration on Palmitoleic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5°C	1.57b	2.81a	3.46a	1.61a	1.72a	2.66	0.003
	10°C	1.57b	2.77a	2.10b	1.70a			0.004
	20°C	1.57b	2.46ab					
	Manzanillo							
	5°C	2.39a	2.03bc	1.87b	2.46a			0.001
	10°C	2.39a	2.01bc	2.43ab				0.007
	20°C	2.39a	1.92bcd					
	Picual							
	5°C	1.89ab	1.38d	2.10b	2.13a	1.95a		0.207
	10°C	1.89ab	1.54cd	2.11b				0.138
	20°C	1.89ab	1.76cd					
2nd Season	Coratina							
	5°C	2.05a	2.26bcd	2.03a	3.40a	2.33a	2.44	0.139
	10°C	2.05a	2.04cde	2.30a	1.72b			0.157
	20°C	2.05a	1.86de					
	Manzanillo							
	5°C	2.22a	2.77abc	1.87a	2.14b			0.152
	10°C	2.22a	3.26a	1.89a				0.053
	20°C	2.22a	2.86ab					
	Picual							
	5°C	1.77a	1.28e	2.11a	2.06b	2.62a		0.637
	10°C	1.77a	1.85de	2.13a				0.707
	20°C	1.77a	1.65de					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 12. Effect of Storage Temperature and Storage Duration on Linoleic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5°C	6.19ab	7.14abc	9.22a	8.70a	9.87a	8.65	0.607
	10°C	6.19ab	7.89abc	7.05a	7.42a			0.262
	20°C	6.19ab	6.19abc					
	Manzanillo							
	5°C	7.17a	8.17ab	7.25a	7.35a			0.011
	10°C	7.17a	5.51abc	8.78a				0.242
	20°C	7.17a	8.49a					
	Picual							
	5°C	5.23b	4.90c	7.97a	8.47a	7.59a		0.633
	10°C	5.23b	5.35bc	5.35a				0.750
	20°C	5.23b	6.23abc					
2nd Season	Coratina							
	5°C	5.10ab	4.71c	9.54a	10.09a	9.64a	11.73	0.814**
	10°C	5.10ab	6.11c	7.55a	10.33a			0.948**
	20°C	5.10ab	5.61c					
	Manzanillo							
	5°C	7.00a	9.71ab	6.43a	8.22ab			0.001
	10°C	7.00a	7.42bc	6.23a				0.407
	20°C	7.00a	12.10a					
	Picual							
	5°C	4.80b	6.82c	9.03a	6.88b	9.23a		0.596
	10°C	4.80b	6.15c	5.90a				0.586
	20°C	4.80b	7.42bc					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 13. Effect of Storage Temperature and Storage Duration on Linolenic Acid (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Coratina							
	5°C	1.57a	1.30c	3.25ab	1.32b	1.97a	2.00	0.027
	10°C	1.57a	2.14bc	3.45a	1.87ab			0.119
	20°C	1.57a	1.63bc					
	Manzanillo							
	5°C	2.30a	1.80bc	2.57abc	2.25a			0.063
	10°C	2.30a	1.65bc	1.90bc				0.372
	20°C	2.30a	2.06bc					
	Picual							
	5°C	2.24a	2.28b	1.97bc	1.39b	2.30a		0.100
	10°C	2.24a	2.16bc	1.71c				0.860
	20°C	2.24a	3.97a					
2nd Season	Coratina							
	5°C	1.84a	1.99c	3.21a	1.57b	1.65b	2.62	0.011
	10°C	1.84a	1.93c	3.40a	1.96ab			0.100
	20°C	1.84a	1.46c					
	Manzanillo							
	5°C	1.88a	1.92c	2.46ab	2.45a			0.520
	10°C	1.88a	2.32bc	1.67b				0.100
	20°C	1.88a	2.11c					
	Picual							
	5°C	1.93a	3.34ab	2.18b	1.45b	2.92a		0.003
	10°C	1.93a	2.30bc	1.90b				0.767
	20°C	1.93a	3.71a					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

Table 14. Effect of Storage Temperature and Storage Duration on Lipids Content (%) of Coratina, Manzanillo and Picual Olive Fruits in 2008 and 2009 Seasons

	Treat.	Storage period (weeks)						r^2
		0	1	3	4	6	7	
1st Season	Cortina							
	5˚C	26.03b	27.34a	26.18a	27.58a	25.43b	25.74	0.124
	10˚C	26.03b	25.99a	26.52a	26.18a			0.006
	20˚C	26.03b	27.30a					
	Manzanillo							
	5˚C	27.91a	27.00a	25.73a	27.82a			0.039
	10˚C	27.91a	26.62a	26.12a				0.096
	20˚C	27.91a	26.92a					
	Picual							
	5˚C	27.04b	26.93a	25.99a	26.37a	28.93a		0.201
	10˚C	27.04b	25.30a	26.21a				0.596
	20˚C	27.04b	26.38a					
2nd Season	Cortina							
	5˚C	25.95a	25.96ab	24.60a	27.99ab	25.58a	24.67	0.113
	10˚C	25.95a	27.02ab	25.79a	26.27b			0.004
	20˚C	25.95a	27.61ab					
	Manzanillo							
	5˚C	26.92a	28.70a	26.23a	29.71a			0.227
	10˚C	26.92a	27.52ab	25.78a				0.416
	20˚C	26.92a	26.78ab					
	Picual							
	5˚C	27.19a	26.33ab	26.35a	26.44b	25.08a		0.734
	10˚C	27.19a	25.13b	27.69a				0.034
	20˚C	27.19a	24.97b					

Means within columns (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient

said that the maximum limit allowed by IOOC (International Olive Oil Council) in extra olive oil is 0.9 % linolenic acid.

Lipids:

At harvest, total lipids content of Coratina were 26.03 and 25.95 %, of Manzanillo were 27.91 and 26.92 % and that of Picual were 27.04 and 27.19 %, respectively in 2008 and 2009 seasons (table 14). There was no effect of storage temperature on lipids content of the three cvs but generally, the fruits that were stored at 20˚C contained lower values than those at 5 and 10˚C. There was no significant change in total lipid percent during the cold storage period where r^2 values were not significant.

As a conclusion, in the present work it is recommended that Carotina, Manzanillo and Picual olive fruits should not be stored more than 4 weeks at 5˚C to avoid the chilling injury, the loss of oil content and the increasing of linolenic acid. Also**,** olive fruits should not be stored at 10˚C for more than 2 weeks where the fruits could loss more than 25 % of its oil content.

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الملخص العربي

تأثير درجة حرارة التخزين و مدته على جودة ثمار وزيت الزيتون أصناف كوراتينا ومانزانيللو وبيكوال

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أجريت هذه الدراسة خلال موسمى ٢٠٠٨ و ٢٠٠٩ على ثمار الزيتون أصناف كوراتينا، مانزانيللو و بيكوال. تم تخزين الثمار على درجة حرارة ٥، ١٠ و ٢٠°م ورطوبة نسبية ٨٥-٩٠ %. تم تخزين جميع الأصناف لمدة أسبوع واحد فقط على ٢٠ °م مع فقد جودة الثمار. كانت ثمار الصنف كوراتينا الأكثر تحملا لأضرار البرودة و لم يلاحظ تكون لون بني في لحم الثمارلجميع الأصناف خلال فترة التخزين. أثرت درجة حرارة التخزين معنويا على فقد وزن الثمار حيث فقدت الثمار المخزنة على١٠°م أكثر من ٣ أضعاف تلك المخزنة على ٥ °م. زاد فقد وزن الثمار مع تقدم فترة التخزين بينما قل محتواها الرطوبي وقد أحتوت الثمار المخزنة على ٥ °م على أعلى محتوى رطوبي معنويا. أحتوت ثمار الصنف كوراتينا على أعلى نسبة زيت معنويا (٢٦,٨١ و ٢٨,١٠ %) يليها ثمار الصنف بيكوال (٢٥,٢١ و ٢٦,٤٤ %) ثم الصنف مانزانيللو (٢٤,٢٥ و٢٥,٥٥ %) و قد قلت نسبة الزيت معنويا مع زيادة درجة حرارة و مدة التخزين. لم تتأثر الأحماض الدهنية بالمتيك، أراكيديك، أوليك، باليتوليك و لينوليك بدرجة حرارة التخزين. زاد الحامض الدهني مايريستيك في ثمار الكوراتينا المخزنة على ١٠°م. الحامض الدهني ستياريك لثمار الكوراتينا و المانزانيللو قل مع نهاية مدة التخزين بينما زاد في ثمار البيكوال. الأحماض الدهنية مايريستيك، باليتوليك و لينوليك زادت مع تقدم فترة التخزين بينما قلت الأحماض الدهنية أراكيديك و أوليك. زاد محتوى ثمار الكوراتينا من حامض اللينولينيك في الأسبوع الثالث على ٥ و ١٠ °م ثم قلت مع نهاية مدة التخزين. ثمار الكوراتينا أحتوت على أعلى نسبة من حامض اللينولينيك في الأسبوع الثالث بينما كان أعلى محتوى لثمار المانزانيللو بعد ٤ أسابيع على ٥ °م. لم يكن هناك تأثير لدرجة حرارة التخزين و مدته على محتوي الثمار من الدهون الكلية لكن بوجه عام أحتوت الثمار المخزنة على ٢٠°م على أقل محتوى.