

STORAGE POTENTIAL OF 'LE CONTE' PEAR FRUITS HARVESTED AT DIFFERENT STAGES

El-Shiekh, A. F.; S. E. Habib; M. A. Bassal and A. M. Gomaa

Horticulture Department, College of Agriculture, Suez Canal University, Ismailia, Egypt

ABSTRACT

This study was carried out in 1999 and 2000 seasons on 'Le Conte' pear (*Pyrus communis*, L.) fruits. Fruits were harvested during August in each season at three different stages. The three harvest stages included one stage at the optimal commercial fresh market flavour development (second stage), one stage earlier than optimal (first stage), and one stage later than optimal (third stage). Fruits were stored at 2, 4, or 8 °C and 80–85 % RH and sampled at harvest (zero time) and at 10-day intervals up to 90 days for fruits stored at 2 or 4 °C and to 30 days for fruits stored at 8 °C. The objective of the study was to identify the effect of harvest stages, storage temperatures, and storage durations on storability and quality of 'Le Conte' pear fruits.

Colour tests indicated that fruits of the second and third harvest stages were more advanced in maturity than those of the first harvest stage.

No differences were noticed in fruit firmness between the first and second harvest stages while fruit firmness of third harvest stage was significantly lower than the other stages.

The highest weight loss was obtained from fruits of the second harvest stage in the first season while the lowest weight loss was obtained from the third harvest stage fruits in the two seasons.

Dry weight, soluble solids content (SSC), total phenolic acids and reducing sugars of the third harvest stage fruits were higher than the other harvest stages fruit. However, acidity of the first harvest stage fruits was higher than the fruits of the other stages.

Firmness was the highest in fruits stored at 2 °C while fruits stored at 8 °C showed the lowest values during the two seasons. Weight loss, SSC, and total phenolic acids corresponded with the increase in storage temperature while reducing sugars were higher in fruit stored at 2°C than those stored at 8°C. Acidity and dry weight seemed to be the highest in fruits stored at 8 °C in the first season and fruits stored at 2 °C in the second one.

In both seasons firmness decreased during storage while weight loss, soluble solids content, total phenols and reducing sugars increased significantly for fruits stored for 30 or 90 days. Dry weight of fruits did not change significantly during storage up to 70 days then increased significantly up to 90 days in the first season. In the second season dry weight increased significantly after 40 days of storage up to 90 days. Acidity decreased significantly in the first season after 70 days of storage. In the second season, acidity increased significantly after 30 days of storage up to 80 days of storage then decreased thereafter. The second harvest stage (SSC = 11.72 to 12.24%, firmness = 36.0 to 39.0 N, and starch index = 4 to 5) could be recommended as the best harvest stage for 'Le Conte' pear fruits. 'Le Conte' pear fruits could be stored at 2 °C for 70 days with good quality.

INTRODUCTION

Pear fruits (*Pyrus communis*, L.) are considered the third in importance among other deciduous fruits and the fourth among all fruits in the world (Scheer and Juergenon, 1976). The total area (according to the Ministry of Agriculture, 1999) of the pears grown in Egypt is 10898 feddan with total production of 38336 ton.

Abd El-Migid (1986) stored 'Le Conte' pear fruits for 13, 12, 4 and 2 weeks, while 'Kiefer' pears were stored for 13, 12, 6 and 4 weeks at 0, 5, 10, and 20 °C, respectively. He found that total soluble solids (TSS) of both cultivars showed a significant increase which was affected by the storage period and temperature. Titratable acidity percent decreased with the progress of storage time at 0, 5, 10 and 20 °C in both cultivars. Fruit firmness decreased with the progress of storage time at all temperatures used. Reducing and total sugar percentages increased significantly with the progress of storage time in both cultivars at all temperatures used but the non-reducing sugars showed a significant decrease with the progress of storage time. He found that fruit weight loss in both cultivars increased with the progress of storage at 0, 5, 10 and 20 °C. Paul, *et al.* (1993) found that titratable acidity of Columbia and Gebhard strains of 'Red d'Anjou' pear fruits was decreased significantly during storage.

Crisosto, *et al.* (1994) reported that 'Yali' pear fruits were harvested at intervals between 10 days before and 10 days after commercial harvest and stored at 0, 10, or 20 °C. Browning occurred only in fruits harvested when skin colour had changed from green to light green-yellow. El-Seidy (1994) stored 'Le Conte' pear fruits for 8 - 11, 4 - 5 and 1 week at 0, 10 °C and room temperature, respectively. The author stated that fruit weight loss, SSC, and reducing sugars increased, however, firmness and acidity decreased during storage. The higher the storage temperature, the higher the content of phenols. Chen, *et al.* (1995) found that 'Beurre Bosc' pear fruits harvested at commercial maturity with flesh firmness of 75 N and stored at -1°C were capable of ripening normally with good quality after 1, 2 and 3 months of storage. These fruits softened to 9.7 and 15 N during storage. Hussein, *et al.* (1997) stored 'Le Conte' fruits at 0, 10 and 20 °C, and found that fruit weight loss increased and flesh firmness decreased with increasing storage temperature. Changes in TSS and malic acid percentage were temperature and time dependent. Changes in peel colouration from green to yellow were related to storage temperature. XiaoMei, *et al.* (1998) reported that flesh firmness of 'Nanguoli' pear fruits decreased and SSC increased initially before decreasing during storage at 0°C. As a result of increasing the supply of pear fruits, there is a desperate need to identify the right stage of harvest (maturity) that will satisfy the consumer and to extend the marketing period with high quality fruits. The objective of this work was to study the effect of harvest stage, storage temperature, and storage period on storability and physical and chemical parameters of 'Le Conte' pear fruits.

MATERIALS AND METHODS

'Le Conte' pear fruits were obtained from College of Agriculture Experimental Farm, Suez Canal University, Ismailia. Fruits were hand harvested during August, 1999 and 2000 seasons, at three different stages of development and transported to the lab within 1hr of harvest. As starch indices have not yet been developed for 'Le Conte' pears, the optimal commercial fresh market flavour development was determined by using the starch index for 'Granny Smith' apple (Ministry of Agriculture and Foods, Horticultural Research Institute of Ontario, Vineland Station, 1988). The index was 1 = minimum starch and 6 = maximum starch. Starch index for pear fruits at harvest ranged between 5 - 6, 4 - 5 and 1 - 2 for first, second and third harvest stages, respectively. The three harvest stages included one stage at the optimal commercial fresh market flavour development (second harvest stage, starch index 4 - 5), one stage earlier than optimal (first stage of harvest: starch index 5 - 6) and one stage later than optimal (third harvest stage: starch index 1 - 2), Crisosto, et al., (1994). Soluble solids content (SSC) at harvest were 11.04, 11.72, and 12.38 for the first, second and third stages, respectively, for the first season. In the second season, SSC were 11.52, 12.24, and 12.94 for the first, second, and third, respectively. Firmness at harvest was 32.3, 36.0, and 30.6 for the first, second, and third harvest stages, respectively, for the first season. In the second season, firmness was 43.2, 39.0, and 39.9 for the first, second, and third stages, respectively. Fruits were sorted to eliminate defects. Sound fruits were washed by chlorine solution, 100 ppm and air dried. Five individual fruit replicates from each stage were used (one fruit per replicate) and were put into perforated colourless plastic 36.5 x 24.5 cm bags (1 mm in diameter hole per 16 cm² bag area). Three hundred fruits were used for each harvest stage. All bags from each maturity stage were divided into three groups. Each group (one hundred fruits from each harvest stage) was stored at 2, 4 or 8 °C and 75 - 80 % RH. Fruits were sampled at harvest (zero time) and at 10-day intervals. Fruits were analyzed upon removal from the cooler up to 90 days. Parameters measured were, fresh weight loss, firmness, soluble solids content (SSC), titratable acidity (TA), pH, phenolic acids, reducing sugars, colour intensity at harvest, and dry weight.

Fresh weight loss evaluation:

Fruit were weighed individually after harvest, labeled, and stored. At each sampling time (10-day intervals up to 90 days) the same fruit were reweighed. Weight loss was expressed as a percentage of the original fresh weight of the fruit.

Firmness:

It was measured on two sides of the fruit using Effegi penetrometer (McCormick, Yakima, Washington) with 0.7 cm plunger.

For chemical analysis, peel and core of the fruits were removed and the remaining tissues were pulped into purees (using a blender).

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Soluble solids content (SSC).

They were determined in the puree using Milton Roy (Japan) refractometer.

Acidity.

It was determined by titrating 10 g of puree using 0.1N NaOH until pH 8.0 and expressed as % malic acid

Total phenolic acids.

They were quantitatively determined by the methods of Weurman and Swain (1955) at 640 nm with chlorogenic acid as the standard (Coseteng and Lee, 1987).

Reducing sugars.

They were determined according to the methods of the Association of Official Analytical Chemists (1984).

Colour intensity.

Colour evaluation was done at harvest time for each treatment at four sides around the equator of each fruit replicate (10 replicates were used for each treatment) using a Minolta CR 10 Chromameter (Minolta Corp, Japan) measuring CIE L, a, b coordinates (Francis, 1980) Average values were determined for individual fruit exocarp for subsequent statistical analyses.

Dry weight.

Ten grams grated pear mesocarp were weighed in aluminum pan, dried at 70 °C to constant weight. The weight of aluminum pan was subtracted and % dry weight (dry weight / FW x 100) was calculated.

Statistical Analysis

The statistical analysis was done between all the effects, stages of harvest, storage temperatures (2, 4 and 8 °C), and storage duration up to 30. Then another statistical analysis was run for stages of harvest, storage temperatures (2 and 4 °C) and storage duration from harvest up to 90 days of storage. This was done for all the variables being studied. LSD (5 %) values were calculated for each variable in each year. The experiment design was completely randomized with a factorial arrangement of harvest date, storage temperature, and sampling time (Steel and Torrie, 1980). Analysis of variance and means comparison (LSD) were performed using Statistix 4.1 (Analytical Software, Inc., Tallahassee, FL). The model used for analysis contained harvest date, storage temperature, and sampling time effects and their interactions.

RESULTS AND DISCUSSION

Effect of harvest stages on pear fruit parameters.

Fruit peel colour values.

Colour values of fruits of different harvest stages in both seasons (1999 and 2000) are shown in Table 1. At harvest, the 'L' colour values, which measure relative white (100) to black (0) colour, were higher in fruits of stages two and three with no significant differences between the two harvest stages. However, 'L' colour values for stage one of harvest was significantly lower than the other two stages of harvest, which means that the first harvest stage had fruits with darker peel colour than the other two stages.

The 'a' colour values, which indicate the relative green (-) or red (+) colour, were lower for stage one of harvest than the other stages in both seasons. This indicates that the fruits at the first harvest stage was greener and darker than stages two and three. The differences in 'a' colour values between the first stage and the other two stages of harvest were significant. However, the differences in 'a' colour values between stages two and three were not significant.

The 'b' colour values, which measure relative yellow (+) to blue (-) colour, were also significantly lower for the fruits at the first harvest stage than the other two stages in both seasons. This indicates that the second and third harvest stages were more advanced in maturity than the first stage of harvest.

Firmness, weight loss (%), dry weight (%), soluble solids content (SSC), acidity and pH, total phenolic acids (%), and reducing sugars (%).

In the first season, no significant differences in fruit firmness were noticed between harvest stages one and two (Tables 2 & 3). However, firmness of the third harvest stage was significantly lower than stages one and two. The highest weight loss was obtained from fruits of the second harvest stage, in the first season. However, in the second season, the first harvest stage fruits had the highest weight loss.

In the first season, the third harvest stage fruits had the highest dry weight followed by the second harvest stages while the first harvest stage fruits had the lowest dry weight content (Tables 2 & 3). In the second season, the second harvest stage fruits had the lowest dry weight. It worth to mention that stage three of harvest, more advanced in ripening, lost more water during storage and that could explain the increases in dry weight. The different data obtained in the second season may be due to the availability of water to the tissue at the time of harvest.

In both seasons, fruits of the third harvest stage (Tables 2 & 3) had significantly higher SSC and lower acidity than fruits of the other harvest stages. The second harvest stage fruits had higher SSC (in the first season) and lower acidity in both seasons than the first harvest stage (Table 2). The second harvest stage fruits (Table 3) had significantly higher SSC (in both seasons) and lower acidity (in the second season) than the first harvest stage fruits.

Table 1. Colour values ('L', 'a' and 'b') at harvest of 'Le Conte' pear fruit harvested at 3 different stages in 1999 & 2000 seasons.

Stages of harvest	'L'		'a'		'b'	
	99	2000	99	2000	99	2000
1	63.66	64.05	-8.45	-6.39	38.01	37.39
2	67.71	68.36	-5.50	-5.13	41.75	41.28
3	68.26	68.31	-5.12	-5.11	41.96	39.32
LSD 5%	1.44	1.47	1.18	2.90	3.87	1.00

L' = colour value; indicates the relative white (100) to black (0) colour.

a = colour value; indicates the relative green (-) to red (+) colour.

b = colour value; indicates the relative yellow (+) to blue (-) colour.

Table 2. Effect of harvest stages on some physical and chemical parameters of 'Le Conte' pear fruits. Composite effect of storage duration (0 – 90 days) and storage temperatures (2 or 4 °C) in 1999 and 2000 seasons.

Parameters	Year	Stages of harvest			LSD 5%
		1	2	3	
Firmness (N)	99	27.6	27.4	25.1	0.7
	2000	32.8	31.4	27.8	1.0
Weight loss (%)	99	6.74	7.09	6.01	0.46
	2000	7.95	7.19	6.77	0.35
Dry weight (%)	99	13.78	14.12	15.35	0.22
	2000	16.66	15.82	16.79	0.22
SSC (%)	99	12.00	12.40	13.70	0.19
	2000	14.06	13.87	14.92	0.19
Malic acid (%)	99	0.246	0.230	0.200	0.007
	2000	0.406	0.336	0.335	0.013
pH	99	4.00	4.04	4.09	0.04
	2000	4.58	4.76	4.84	0.03
Phenolics (%)	99	0.060	0.061	0.065	0.003
	2000	0.053	0.054	0.052	0.003
Red sugars (%)	99	8.39	8.50	9.24	0.22
	2000	7.96	8.36	8.96	0.21

Table 3. Effect of stages of harvest on some physical and chemical parameters of 'Le Conte' pear fruits. Composite effect of storage duration (0 – 30 days) and storage temperatures (2, 4 or 8 °C) in 1999 and 2000 seasons.

Parameters	Year	Stages of harvest			LSD 5%
		1	2	3	
Firmness (N)	99	28.4	28.3	26.5	1.0
	2000	39.9	33.3	31.2	1.6
Weight loss (%)	99	2.90	3.22	3.06	0.30
	2000	3.76	2.78	3.00	0.35
Dry weight (%)	99	13.67	14.16	15.19	0.25
	2000	15.72	15.41	16.01	0.30
SSC (%)	99	11.48	12.27	13.36	0.24
	2000	12.65	13.13	14.16	0.25
Malic acid (%)	99	0.250	0.251	0.222	0.010
	2000	0.331	0.311	0.310	0.017
pH	99	3.81	3.86	3.97	0.05
	2000	4.53	4.69	4.81	0.05
Phenolics (%)	99	0.057	0.057	0.061	0.005
	2000	0.045	0.048	0.044	0.004
Red sugars (%)	99	7.62	6.15	8.43	0.24
	2000	7.09	7.59	7.98	0.27

In both seasons, pH was significantly higher in the second and third harvest stages fruit than the first harvest stage. Data revealed that pH values were higher for fruits of the second season than the first one within all harvest stages fruits (Table 2 & 3). Mellenthin and Chen (1981) reported that later harvested 'Anjou' pear fruits tended to have less titratable acidity after storage.

In the first season, the third harvest stage fruits had higher phenolic acids and reducing sugars than the first and second harvest stages fruit (Tables 2 and 3). No significant differences were noticed in total phenolic acids (Tables 2 and 3) and reducing sugars (Table 2) between the first and second stages fruit. In the second season, the three stages showed somewhat similar total phenolic compound values while the second and third harvest stages fruit had significantly higher reducing sugars than the first stage fruits (Table 2). For both seasons, fruits of different harvest stages (Table 3) had no differences in total phenolic acids. Ju (1991) found that late harvested pear fruits had four times lower phenolic acids and higher reducing sugars content than early harvested fruits. However, Herregods and Goffing, (1993) found that late harvested fruits were more sensitive to internal breakdown during storage and may be this is the reason for the tissue to start accumulating phenolic compounds.

Effect of storage temperatures.

Fruits stored at 2 °C (Table 4) had significantly higher firmness than fruits stored at 4 °C in both seasons. Fruits stored at 2 or 4 °C (Table 5) had significantly higher firmness than fruits stored at 8 °C.

As fruit mature and ripen they soften by dissolution of the middle lamella of cell walls. The higher the temperature during storage, the faster this process will happen.

Fluctuation in data in response to storage temperatures (Table 4) was obtained for fruit weight loss and dry weight in both seasons. However, fruits stored at 8 °C had significantly higher weight loss (in both seasons) and dry weight (in the first season) than fruits stored at 2 or 4 °C. No differences were noticed in weight loss or dry weight between fruits stored at 2 or 4 °C (Table 5). Shcherbatko, *et al.* (1986) reported that storage of pear fruits was associated with a reduction in dry matter content. The increases in % dry weight during storage at high temperature might related to the relatively higher water loss. Hussein *et al.* (1997) stored 'Le Conte' pear fruits at 0, 10 and 20 °C and found that fruit weight loss increased with increasing storage temperature.

Water loss from fruit tissue increases at higher storage temperatures, which results in increasing weight loss. Also, high storage temperature increases respiration rate during which organic materials (sugars and organic acids) are consumed and water is lost, accordingly, weight loss increases.

In both seasons, fruits stored at 2 °C had higher acidity than fruits stored at 4 °C (Table 4) while no significant differences were noticed in SSC between fruits stored at 2 and 4 °C (Tables 4 and 5). Fruits stored at 8 °C had higher SSC and acidity than fruits stored at 2 or 4 °C in the first season (Table 5). In the second season fruits stored at 8 °C had the lowest acidity. No definite trends were obtained for fruit pH as affected by the different storage temperatures in both seasons. El-Seidy (1994) reported that malic acid content of 'Le Conte' pear fruits decreased with increasing of storage temperature.

Table 4: Effect of storage temperatures (2 or 4 °C) on some physical and chemical parameters of 'Le Conte' pear fruits. Composite effect of stages of harvest and storage duration (0 – 90 days) in 1999 and 2000 seasons.

Parameters	Year	Storage temperatures (°C)		LSD 5 %
		2	4	
Firmness (N)	99	29.0	24.5	0.6
	2000	31.7	29.6	0.8
Weight loss (%)	99	6.88	6.35	0.38
	2000	7.05	7.56	0.29
Dry weight (%)	99	14.53	14.30	0.16
	2000	16.44	16.41	0.18
SSC (%)	99	12.77	12.64	0.15
	2000	14.31	14.26	0.16
Malic acid (%)	99	0.230	0.220	0.006
	2000	0.361	0.357	0.010
pH	99	4.01	4.07	0.03
	2000	4.75	4.71	0.03
Phenolics (%)	99	0.063	0.061	0.002
	2000	0.051	0.055	0.003
Red. sugars (%)	99	6.77	8.65	0.18
	2000	8.38	8.47	0.17

Table 5: Effect of storage temperatures (2, 4 or 8 °C) on some physical and chemical parameters of 'Le Conte' pear fruits. Composite effect of harvest stages and storage duration (0 – 30 days) in 1999 and 2000 seasons.

Parameters	Year	Storage temperatures (°C)			LSD5%
		2	4	8	
Firmness (N)	99	31.3	30.4	21.5	1.0
	2000	37.0	36.1	29.3	1.6
Weight loss (%)	99	2.70	2.49	3.99	0.30
	2000	2.47	2.56	4.51	0.35
Dry weight (%)	99	14.25	14.25	14.53	0.26
	2000	15.89	15.93	15.31	0.30
SSC (%)	99	12.26	12.18	12.68	0.24
	2000	13.41	13.37	13.17	0.25
Malic acid (%)	99	0.235	0.239	0.249	0.009
	2000	0.347	0.340	0.266	0.017
pH	99	3.88	3.94	3.82	0.05
	2000	4.65	4.64	4.74	0.05
Phenolics (%)	99	0.056	0.056	0.064	0.005
	2000	0.044	0.047	0.047	0.004
Red sugars (%)	99	7.81	7.91	8.47	0.24
	2000	7.59	7.68	7.39	0.27

Fruits stored at 4 °C had significantly higher pH in the first season and lower pH in the second season than fruits stored at 2 °C (Table 4). However, fruits stored at 4 °C had higher pH than fruits stored at 2 °C or 8 °C in the first season (Table 5). In the second season, fruits stored at 8 °C had higher pH than fruits stored at the other two temperatures (Table 5).

In the first season, fruits stored at 4 °C had significantly lower % total phenolic acids than fruits stored at 2 °C while the opposite was true in the

second season (Table 4). In the first season, fruits stored at 8 °C had significantly higher phenolic compounds and reducing sugars than fruits stored at 2 or 4 °C (Table 5). Also, fruits stored at 4 °C had higher reducing sugars than fruits stored at 2 °C.

Abd El-Migid (1986) found that reducing and total sugars percentages increased with the progress of storage time in 'Le Conte' and 'Kiefer' pear fruits at all temperatures used but the non-reducing sugars of both cultivars showed a significant reduction with the progress of storage time. Also, El-Seidy (1994) found that reducing sugars increased with the increase of storage temperature of 'Le Conte' pear fruit.

The increases in reducing sugars during storage may be due to the needs of the tissues for these sugars to respire (for ripening process) at low rate depending on the storage temperature. Such increase is partially due to the changes of complex carbohydrates like starch to simple sugars.

Effect of storage duration on pear fruit parameters.

In both years, firmness decreased during storage while weight loss, SSC, total phenolic acids, and reducing sugars increased significantly (Tables 6 & 7).

In the first season, dry weight (Table 6) of fruits did not change significantly during storage up to 60 days then increased. In the second season, dry weight increased after 40 days of storage in fruits stored for 90 days (Table 6).

Acidity of the fruits decreased significantly in the first season after 70 days of storage. However, in the second season, acidity increased after 30 up to 80 days of storage then decreased again at 90 days of storage (Table 6). Fruits stored for 30 days (Table 7) had higher dry weight and lower acidity during storage than at harvest but data failed to show any significant differences in both seasons. Abd El-Migid (1986) reported that Firmness decreased with the progress of storage time of 'Le Conte' and 'Kiefer' pear fruits. Such changes were temperature – time dependent. Fruits weight loss, SSC, and reducing sugars in both cultivars increased while acidity decreased with the progress of storage at 0, 5, 10 and 20 °C. Shcherbatko, *et al* (1986) of pears fruits, respectively, decreased during storage. Paul, *et al.* (1993) found that titratable acidity of Columbia and Gebhard strains of 'Red d'Anjou' pear fruits was decreased significantly during storage

Table 6. Effect of storage duration on some physical and chemical parameters of 'Le Conte' pear fruit. Composite effect of harvest stages and storage temperatures (2 or 4 °C) in 1999 and 2000 seasons.

Parameters	Year	0 ¹	Storage duration (days)												LSD 5%		
			10	20	30	40	50	60	70	80	90						
Firmness (N)	99	33.0	30.8	28.9	28.1	28.6	27.2	23.0	19.9	17.0	1.3						
	2000	40.7	39.4	36.0	34.1	30.2	30.4	26.8	24.9	23.0	21.0	1.8					
Weight loss (%)	99	0.00	2.10	3.14	5.14	6.39	6.68	8.02	10.10	11.65	12.91	0.85					
	2000	0.00	1.94	2.97	5.15	7.15	8.34	9.74	11.06	12.82	13.87	0.64					
Dry weight (%)	99	14.27	14.24	14.17	14.33	14.08	14.46	14.50	14.69	14.66	14.77	0.41					
	2000	15.64	15.91	16.09	16.00	16.43	16.44	16.76	16.98	16.86	17.14	0.41					
SSC (%)	99	11.71	12.24	12.36	12.56	12.55	12.76	12.74	13.04	13.35	13.68	0.35					
	2000	12.23	13.24	13.93	14.14	14.67	14.44	14.74	14.86	15.23	15.36	0.35					
Malic acid (%)	99	0.241	0.235	0.235	0.236	0.231	0.231	0.234	0.215	0.212	0.179	0.013					
	2000	0.326	0.344	0.343	0.359	0.368	0.381	0.391	0.386	0.354	0.337	0.023					
pH	99	3.85	3.87	3.95	3.97	4.03	4.10	4.12	4.11	4.16	4.28	0.07					
	2000	4.42	4.63	4.80	4.74	4.69	4.69	4.75	4.72	4.85	4.98	0.06					
Pterololics (%)	99	0.054	0.054	0.055	0.060	0.063	0.067	0.068	0.063	0.064	0.070	0.005					
	2000	0.040	0.045	0.046	0.050	0.050	0.052	0.060	0.063	0.060	0.064	0.006					
Red. sugars (%)	99	7.53	7.82	7.80	8.29	8.54	8.87	9.24	9.49	9.75	9.79	0.40					
	2000	6.57	7.66	8.26	8.06	8.32	8.20	8.94	9.24	9.43	9.56	0.39					

¹ initial value at harvest, prior to storage.

Table 7. Effect of storage duration on some physical and chemical parameters of 'Le Conte' pear fruits. Composite effect of harvest stages and storage temperature (2, 4, or 8 °C) in 1999 and 2000 seasons.

Parameters	Year	Storage duration (days)				LSD 5%
		0 ²	10	20	30	
Firmness (N)	99	33.0	30.1	24.8	23.1	1.1
	2000	40.7	36.5	32.8	29.2	1.8
Weight loss (%)	99	0.00	2.48	4.07	5.69	0.35
	2000	0.00	2.58	3.91	6.23	0.40
Dry weight (%)	99	14.27	14.35	14.32	14.43	0.30
	2000	15.64	15.67	15.76	15.71	0.46
SSC (%)	99	11.71	12.51	12.60	12.66	0.27
	2000	12.23	13.17	13.76	14.08	0.29
Malic acid (%)	99	0.241	0.246	0.239	0.238	0.011
	2000	0.326	0.310	0.310	0.324	0.020
pH	99	3.85	3.85	3.89	3.93	0.05
	2000	4.42	4.65	4.82	4.81	0.06
Total phenolics (%)	99	0.054	0.055	0.060	0.066	0.005
	2000	0.040	0.046	0.047	0.051	0.005
Reducing sugars (%)	99	7.53	7.93	8.28	8.51	0.27
	2000	6.57	7.48	8.03	8.14	0.31

² initial value at harvest, prior to storage.

Interaction effects of harvest stages, storage temperatures and storage duration.

1. Firmness

In 1999 and 2000 seasons, firmness decreased significantly during storage for 90 days (Table 8) in all fruits from the different stages of harvest after 70 days of storage. The reduction in firmness during storage was obvious and greater in the fruits from the third harvest stage, which were more advanced in maturity. In the first season, the reduction of storage temperature (2 °C) maintained fruit firmness without significant differences up to 50 days for the first and third harvest stages and up to 20 days at 4 °C for all stages of harvest. However, under 8 °C, the firmness of the fruits reduced to almost half (from 32.3, 36.0 and 30.6 for first, second and third harvest stages, respectively, to 15.4, 15.9 and 15.9) after 20 days of storage. After 90 days of storage at 2 °C, firmness reached to 26.8, 24.7 and 22.8 N for the first, second and third stages of harvest, respectively. On the other hand, at 4 °C and after 90 days of storage, firmness of the first, second and third harvest stages were 5.1, 10.8 and 11.7, respectively. The maximum reduction in firmness was obtained from fruits stored at 8 °C up to 30 days followed by fruits stored at 4 °C. Storage at 2 °C maintained good fruit firmness.

In the second season, firmness also decreased significantly during storage of fruits at either 2, 4 or 8 °C from all stages of harvest. Storage at 2 and 4 °C maintained fruits firmness for longer time during storage while 8 °C helped in maintaining the firmness for almost 10 days in both seasons.

Table 8. Effect of harvest stages, storage temperatures and storage duration, on 'Le Conte' pear fruit firmness in 1999 & 2000 seasons.

Parameters	Stages of harvest (SH)	Storage temp. (°C, ST)	0 ^z	Storage duration (SD) - Days								
				10	20	30	40	50	60	70	80	90
Firmness (N)	(1999)	1	32.30	32.30	33.50	32.30	32.40	28.80	26.20	27.40	26.80	
		2	36.00	31.20	29.50	29.20	30.30	27.80	26.80	25.80	24.70	
		3	30.60	29.80	27.80	29.00	28.10	27.00	24.60	23.80	22.80	
		1	32.30	31.20	29.10	26.10	28.30	26.50	19.60	17.60	5.10	
		2	36.00	31.70	28.20	27.00	29.00	27.90	26.30	10.20	10.80	
		3	30.60	28.80	25.40	25.10	23.70	24.90	14.40	14.60	11.70	
	(2000)		1	32.30	15.40	05.90						
			2	36.00	28.00	07.30						
			3	30.60	26.60	12.30						
LSD 5%		ST x SD / SH x SD / ST x SH	2.00 ^y / 2.00 / 1.70									
		SH x ST x SD	3.40									
				1.90 ^x / 2.30 / 1.00								
		1	43.20	43.20	37.20	34.20	35.70	28.90	25.10	21.50	23.40	
		2	39.00	38.50	32.00	30.60	28.00	31.80	28.50	29.50	23.60	
		3	39.90	35.80	30.30	31.20	30.80	27.80	27.60	26.20	23.40	
	1	43.20	47.00	44.60	41.80	31.00	25.30	21.80	18.60	17.90		
	2	39.00	36.80	34.70	33.70	32.90	31.10	27.40	24.60	23.90		
	3	39.90	35.20	31.50	29.29	24.00	15.90	18.80	17.80	14.20		
LSD 5%	ST x SD / SH x SD / ST x SH	3.70 / 3.20 / 2.70										
	SH x ST x SD	5.50										
							2.60 / 3.20 / 1.40					
										4.50		

^z initial value at harvest, prior to storage.

^y LSD values for all temperatures and all stages of harvest up to 30 days of storage.

^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

Abd El-Migid (1986) reported that firmness decreased with the progress of storage time in 'Le Conte' and 'Kiefer' pear fruits at all temperatures used. Such changes were temperature – time dependent. The decrease of firmness could be a result of changes of insoluble carbohydrates (protopectine, cellulose and hemicellulose) to simple carbohydrates like pectin.

2. Weight loss (%)

Weight loss of the third harvest stage was higher than that of the first and second harvest stages at all temperature used in both seasons. In addition, no major differences were noticed in fruits weight loss for the fruits stored at 2 or 4 °C (Table 9). Minimum weight loss was obtained during 10 and 20 days of storage and the highest weight loss was obtained from the fruits stored up to 90 days. Fruits weight loss was maximum at 90 days of storage at both 2 and 4 °C in both seasons. Weight loss increased during storage under all the temperatures used. Fruits weight loss (%) was doubled at 30 days of storage at 8 °C. Abd El-Migid (1986) reported that pear fruit weight loss increased with the progress of storage at 0, 5, 10 and 20 °C. El-Seidy (1994) reported a significant increase in pear fruit weight loss with the increasing of storage temperature and with the progress of storage time. The higher the storage temperature, the higher the respiration rate and the higher the weight loss is. Weight loss is mainly a result of water loss from fruit tissues and partially of the respiration process during storage.

3. Dry weight (%)

At harvest, percent dry weight was significantly higher in fruits from the third harvest stage than the fruits from the first and second harvest stages.

During storage at all temperatures used, dry weight was higher in third harvest stage fruits than the other fruits and this was true for both seasons (Table 10). Significant increments were noticed in dry weight in the second season for fruits stored at 2 or 4 °C.

Fruits dry weight was higher for fruits stored at 8 °C for 10, 20 and 30 days in comparison with fruits stored at 2 or 4 °C.

The increase in dry weight during storage is partially due to the water loss from fruit tissue. The higher the storage temperatures the higher the water loss and the higher the tissue dry weight content.

4. Soluble solids content (SSC)

Soluble solids content increased significantly during storage of all fruits from different stages of harvest and stored at different temperatures in both seasons (Table 11).

At harvest, SSC (%) was higher in fruits from the third harvest stage than fruits of the first and second harvest stages in both seasons. No differences were noticed in SSC between the fruits of second and third harvest stages at harvest. No differences were noticed in SSC during storage at 2 or 4 °C of first and second harvest stages fruit while the third harvest stage fruits had significantly higher SSC than fruits from both stages.

Table 9. Effect of harvest stages, storage temperatures and storage duration, on 'Le Conte' pear fruit % weight loss in 1999 & 2000 seasons.

Parameters	Stages of harvest (SH)	Storage temp. (°C, ST)	0 ^z	Storage duration (SD) - Days									
				10	20	30	40	50	60	70	80	90	
Weight loss (%) (1999)	1	2	0.00	02.22	03.26	05.92	05.68	07.71	08.69	11.12	12.52	13.81	
	2		0.00	02.34	03.56	04.46	06.39	08.25	11.90	10.47	11.68	14.10	
	3		0.00	02.35	03.22	05.09	06.97	05.59	06.38	09.14	12.23	11.30	
	1	4	0.00	01.33	02.59	04.01	07.08	06.47	07.78	10.14	11.26	13.14	
	2		0.00	02.39	03.38	06.42	06.67	06.96	06.52	09.29	12.41	14.64	
	3		0.00	01.98	02.82	04.90	05.54	05.08	06.84	10.43	09.84	10.50	
	1	8	0.00	03.44	04.77	07.24							
	2		0.00	02.68	06.65	06.75							
	3		0.00	03.60	06.41	06.37							
LSD 5%													
ST x SD / SH x SD / ST x SH				0.60 ^y / 0.60 / 0.52									
SH x ST x SD				1.05									
				1.20 ^x / 1.47 / 0.66									
				2.07									
(2000)	1	2	0.00	02.26	03.53	05.42	08.09	08.62	11.01	12.01	13.35	12.87	
	2		0.00	01.84	03.36	05.33	06.73	08.71	07.40	10.27	11.67	13.62	
	3		0.00	01.25	02.95	03.66	06.42	06.54	09.77	10.95	11.85	12.11	
	1	4	0.00	02.69	02.47	06.34	06.93	09.28	12.43	11.34	13.46	16.62	
	2		0.00	01.31	03.38	04.03	08.12	08.47	08.83	11.33	14.90	14.68	
	3		0.00	02.29	02.13	06.11	06.64	08.44	08.99	10.43	11.61	13.34	
	1	8	0.00	04.39	07.02	10.00							
	2		0.00	02.27	04.59	07.23							
	3		0.00	04.93	05.74	06.98							
LSD 5%													
ST x SD / SH x SD / ST x SH				0.70 / 0.70 / 0.61									
SH x ST x SD				1.21									
				0.91 / 1.12 / 0.50									
				1.58									

^z initial value at harvest, prior to storage.

^y LSD values for all temperatures and all stages of harvest up to 30 days of storage.

^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

Table 10. Effect of harvest stages, storage temperatures and storage duration on 'Le Conte' pear fruit % dry weight in 1999 & 2000 seasons

Parameters	Stages of harvest (SI)	Storage temp. (°C, ST)	0 ²	Storage duration (SD) - Days									
				10	20	30	40	50	60	70	80	90	
Dry weight (%) (1999)	1	2	13.42	13.43	13.79	13.84	14.69	14.45	14.18	14.29	14.30	14.13	
	2	2	13.79	14.64	14.26	14.74	14.14	14.39	14.23	14.63	14.37	14.71	
	3	2	15.59	15.46	14.03	13.98	13.97	15.30	15.32	16.14	15.64	16.03	
	1	4	13.42	13.16	13.19	13.62	13.15	13.32	13.60	14.06	13.85	13.67	
	2	4	13.79	13.74	13.81	14.13	13.47	13.71	13.61	13.61	14.18	14.36	
	3	4	15.59	14.99	15.91	15.64	15.07	15.59	16.04	15.38	15.64	15.74	
	1	8	13.42	13.90	14.41	14.42							
	2	8	13.79	14.81	13.94	14.50							
	3	8	15.59	15.01	15.54	14.99							
LSD 5%													
ST x SD / SI x SD / ST x SI			0.52 ^y / 0.52 / 0.45										
SI x ST x SD			0.91										
								0.57 ^x / 0.70 / 0.31					
								0.99					
(2000)	1	2	15.84	16.25	16.28	16.40	16.71	16.34	17.17	17.51	17.47	17.40	
	2	2	15.19	15.59	15.35	15.69	15.18	15.65	15.97	16.91	15.97	16.86	
	3	2	15.89	16.18	16.05	15.97	17.19	16.90	17.13	17.91	17.13	17.80	
	1	4	15.84	16.27	16.27	16.26	16.21	16.36	17.51	16.95	16.95	17.20	
	2	4	15.19	15.23	16.01	14.93	16.09	16.60	16.11	16.16	16.00	15.84	
	3	4	15.89	15.98	16.55	16.76	17.19	16.78	16.66	16.47	17.61	18.35	
	1	8	15.84	14.64	14.76	14.97							
	2	8	15.19	15.86	15.15	15.52							
	3	8	15.89	15.20	15.42	16.31							
LSD 5%													
ST x SD / SI x SD / ST x SI			0.60 / 0.60 / 0.52										
SI x ST x SD			1.04										
								0.57 / 0.70 / 0.32					
								1.00					

² initial value at harvest, prior to storage.
^y LSD values for all temperatures and all stages of harvest up to 30 days of storage.
^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

Table 11. Effect of harvest stages, storage temperatures and storage duration on 'Le Conte' pear fruit SSC (%) in 1999 & 2000 seasons.

Parameters	Stages of harvest (SH)	Storage temp. (°C, ST)	t ²	Storage duration (SD) - Days									
				20	30	40	50	60	70	80	90		
SSC (%)	(1999)	1	11.04	11.36	11.16	11.76	12.08	12.46	12.56	12.11	12.46	12.92	
		2	11.72	12.68	12.08	12.80	12.24	12.24	12.52	12.91	13.38	13.62	
		3	12.38	13.24	13.44	13.44	13.62	13.68	13.88	14.20	14.16	14.82	
		1	11.04	11.36	11.40	11.82	11.78	12.10	12.16	12.60	12.61	13.28	
		2	11.72	11.68	11.96	12.16	11.84	12.00	11.88	12.51	13.18	12.91	
		3	12.38	13.12	14.12	13.38	13.74	14.08	13.45	13.93	14.31	14.55	
	(2000)		1	11.04	11.60	12.30	11.92						
			2	11.72	12.64	12.80	13.30						
			3	12.38	14.88	14.18	13.34						
LSD 5%		ST x SD / SH x SD / ST x SH	0.47 ¹ / 0.47 / 0.41										
		SH x ST x SD	0.82										
									0.49 ² / 0.60 / 0.27				
		1	11.52	13.06	13.40	13.72	14.84	14.24	14.64	14.56	15.36	15.51	
		2	12.24	12.80	13.64	14.24	14.14	14.12	14.20	14.64	14.80	14.96	
		3	12.94	14.08	14.78	14.44	15.36	15.06	15.20	15.88	15.40	15.72	
LSD 5%	1	11.52	13.08	13.48	13.50	14.02	13.86	15.12	15.18	15.39	15.19		
	2	12.24	12.50	13.58	13.44	14.26	14.36	14.00	14.16	14.73	14.44		
	3	12.94	13.92	14.77	15.48	15.32	14.46	15.02	15.28	15.70	16.36		
LSD 5%	ST x SD / SH x SD / ST x SH	0.50 / 0.50 / 0.43											
	SH x ST x SD	0.87											
								0.50 / 0.61 / 0.27					

¹ initial value at harvest, prior to storage
² LSD values for all temperatures and all stages of harvest up to 30 days of storage.
³ LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

During storage at 8 °C, fruits of the second and third harvest stages had higher SSC than fruits of the first harvest stage.

In the first season, it was noticed that fruits of the first harvest stage and stored at 8 °C had significantly higher SSC up to 20 days of storage, then the SSC decreased thereafter.

In the second season, fruits of the first, second and third harvest stages and stored at different temperatures (2 or 4 °C) had no differences in SSC during storage. During storage at 8 °C, first harvest stage fruits had lower SSC than the same fruits stored at 2 °C or 4 °C. Chen and Mellenthin (1981) stored 'Anjou' pear at -1.1 °C for 5 months. Soluble solids increased from 12.1 to about 13.1% then stabilized at about 13.2% and remained at that level with little change throughout 5 months of storage. Hussein, *et al.* (1997) stated that changes in TSS of 'Le Conte' pear fruits stored at 10 and 20 °C were temperature and time dependent.

The increase in SSC could be due to the degradation of complex insoluble compounds (starch) to simple soluble sugars.

5-Acidity (%) and pH

In 1999, fruits acidity of the first and third harvest stages increased during storage at 2 or 4 °C then decreased after 80 days and 60 days for the first and third harvest stages, respectively. At 8 °C, fruits of the first and third harvest stages behaved similarly in the first week of storage. The acidity of the second harvest stage fruits decreased significantly during storage at all temperatures used (Table 12).

Data in the second season showed significant acidity increases during storage for fruits of all harvest stages and stored at 2 °C or 4 °C up to 70 days then decreased thereafter. Fruits stored at 8 °C for 30 days had significantly lower acidity during storage.

The pH of the first harvest stage fruits was lower than the other two stages of harvest in both seasons (Table 13). During storage at 2 °C or 4 °C of all harvest stages fruit, pH increased significantly. However, fruits of the first and third harvest stages stored at 8 °C up to 30 days had no significant changes in pH during storage in the first season. In addition, pH of the second harvest stage fruits decreased significantly during storage at 8 °C. In the second season, pH increased in all fruits from different stages of harvest and stored at different temperatures (2, 4 and 8 °C). The differences were great in the pH of the fruits at harvest and after 30 and 90 days of storage. Abd El-Migid (1986) found that titratable acidity decreased with the progress of storage time at 0, 5, 10 and 20 °C in 'Le Conte' and 'Kiefer' pear fruits. Paul, *et al.* (1993) stated that titratable acidity of Columbia and Gebhard strains of 'Red d'Anjou' pear fruits was decreased significantly during storage.

Malic acid is a respiratory substrate and its consumption in respiration increases with the progress of storage period and this may be responsible for the observed decreases in acidity during the last days of storage.

Table 12. Effect of harvest stages, storage temperatures and storage duration on 'Le Conte' pear fruit % malic acid in 1999 & 2000 seasons.

Parameters	Stages of harvest (SH)	Storage temp. (°C, ST)	0 ^z	Storage duration (SD) - Days									
				10	20	30	40	50	60	70	80	90	
Malic acid (%) (1999)	1	2	0.229	0.268	0.256	0.260	0.254	0.255	0.278	0.261	0.263	0.238	
			0.290	0.236	0.227	0.217	0.220	0.233	0.227	0.230	0.221	0.220	
			0.205	0.252	0.201	0.199	0.189	0.201	0.211	0.180	0.192	0.200	
	1	4	0.229	0.229	0.256	0.261	0.272	0.280	0.272	0.235	0.206	0.117	
			0.290	0.245	0.241	0.256	0.245	0.204	0.219	0.219	0.220	0.131	
			0.205	0.260	0.228	0.225	0.208	0.215	0.199	0.165	0.171	0.165	
	1	8	0.229	0.284	0.251	0.246							
			0.290	0.247	0.239	0.235							
			0.205	0.274	0.249	0.244							
LSD 5%													
ST x SD / SH x SD / ST x SH			0.018 ^y / 0.018 / 0.015										
SH x ST x SD			0.031										
									0.019 ^x / 0.023 / 0.010				
(2000)	1	2	0.335	0.389	0.362	0.416	0.443	0.449	0.516	0.443	0.422	0.459	
			0.322	0.329	0.315	0.322	0.315	0.322	0.329	0.352	0.325	0.288	
			0.322	0.362	0.355	0.332	0.376	0.355	0.379	0.342	0.288	0.292	
	1	4	0.335	0.342	0.362	0.389	0.349	0.422	0.476	0.439	0.382	0.393	
			0.322	0.322	0.335	0.342	0.382	0.359	0.308	0.406	0.402	0.302	
			0.322	0.322	0.329	0.355	0.345	0.396	0.335	0.332	0.305	0.286	
	1	8	0.335	0.232	0.231	0.248							
			0.322	0.270	0.255	0.278							
			0.322	0.223	0.242	0.239							
LSD 5%													
ST x SD / SH x SD / ST x SH			0.035 / 0.035 / 0.030										
SH x ST x SD			0.060										
									0.033 / 0.040 / 0.018				
									0.056				

^z initial value at harvest, prior to storage

^y LSD values for all temperatures and all stages of harvest up to 30 days of storage

^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

Table 13. Effect of harvest stages, storage temperatures and storage duration on 'Le Conte' pear fruit pH in 1999 & 2000 seasons.

Parameters	Stages of harvest (SH)	Storage temp. (°C; ST)	0 ^z	Storage duration (SD) - Days									
				10	20	30	40	50	60	70	80	90	
pH	(1999)	1	03.72	03.80	03.77	03.72	03.99	03.97	04.07	04.14	04.10	04.09	
		2	03.90	03.75	03.84	04.00	04.10	04.17	04.18	04.07	04.05	04.12	
		3	03.94	03.83	04.13	04.17	04.07	04.18	04.14	04.09	04.22	04.10	
		1	03.72	04.01	04.09	03.92	03.93	04.01	04.05	04.15	04.17	04.62	
		2	03.90	03.99	03.83	04.02	03.99	04.16	04.10	04.00	04.07	04.50	
		3	03.94	03.81	04.01	04.00	04.13	04.11	04.15	04.22	04.33	04.23	
		1	8	03.72	03.77	03.73	03.70						
			2	03.90	03.83	03.63	03.76						
			3	03.94	03.87	03.93	04.07						
LSD 5%			0.09 ^x / 0.11 / 0.05										
ST x SD / SH x SD / ST x SH			0.09 ^y / 0.09 / 0.08										
SH x ST x SD			0.16										
(2000)		1	2	04.08	04.40	04.76	04.70	04.70	04.54	04.44	04.49	04.81	04.74
			2	04.38	04.72	04.80	04.90	04.70	04.78	04.74	04.78	05.01	05.08
			3	04.81	04.70	04.82	04.76	04.64	04.72	05.01	05.03	05.10	05.27
	1	4	04.08	04.48	04.84	04.72	04.82	04.60	04.44	04.47	04.71	04.71	
		2	04.38	04.78	04.80	04.74	04.58	04.80	04.80	04.76	04.67	04.99	
		3	04.81	04.68	04.78	04.60	04.68	04.72	05.04	04.81	04.82	05.08	
	LSD 5%			0.09 / 0.11 / 0.055									
	ST x SD / SH x SD / ST x SH			0.10 / 0.10 / 0.09									
	SH x ST x SD			0.18									

^z initial value at harvest, prior to storage.

^y LSD values for all temperatures and all stages of harvest up to 30 days of storage.

^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

6-Total phenolic acids (%)

In the first season (Table 14), the third harvest stage fruits had higher phenolic acids than the first and second stages at harvest. At 90 days of storage, no significant differences were noticed in the total phenolic contents of the different harvest stages fruit under 2 or 4 °C. However, after 30 days of storage at 8 °C first harvest stage fruits had significantly higher phenolics than the other fruits stored at 2, 4, or 8 °C. Fruit total phenolic acids increased significantly during storage in both seasons.

In the second season (Table 14) no differences were noticed between different harvest stages fruits at harvest. Fruits of the first harvest stage stored at 8 °C had significantly higher phenolics after 10 days of storage. The second harvest stage fruits had higher phenolics at 30 days of storage at 8 °C. However, phenolic contents of the third harvest stage fruits did not change significantly during storage at 8 °C.

Mellenthin and Wang (1974) indicated that phenolic substances, which are associated with discoloration and which serve as the substrate for polyphenoloxidase, also declined with maturity and accumulated during storage of 'd'Anjou' pear. Late harvested fruits were more sensitive to internal breakdown during storage and accumulate phenolic compounds. (Herregods and Goffing, 1993). El-Seidy (1994) found that the higher the storage temperature, the higher content of pear fruit phenols. The accumulation of phenolic compounds may be a result of low polyphenoloxidase activity during storage of the fruits.

7-Reducing sugars

In both seasons (Table 15), at harvest, fruits of the third and second harvest stages had higher reducing sugars than the other stages. During storage at 2 or 4 °C reducing sugars (%) increased significantly after 30 days of storage for all stages of harvest relative to the harvest time. However, fruits stored at 8 °C had significantly higher reducing sugars after 20 days for the first and third harvest stages fruit and after 10 days for the second harvest stage fruits. At 2 or 4 °C no major differences were noticed in fruit reducing sugars content between the different harvest stages. Fruits stored at 8 °C had higher reducing sugars content after 20 days than fruits stored at 2 or 4 °C.

In the second season and after 10 days of storage at 2 or 4 °C, fruits of the first and third harvest stages had significantly higher reducing sugars than fruits at harvest. The second harvest stage fruits content of the reducing sugars increased after 10 days of storage at 2 or 4 °C. The first and third harvest stage fruits content of reducing sugars increased during storage at 8 °C. The increases were significant after 10 of storage for the first and third harvest stages and after 20 days for the second harvest stage. El-Seidy (1994) found that the reducing sugars content of 'Le Conte' pear fruits increased with increasing storage temperature and with the progress of storage period.

Table 14. Effect of harvest stages, storage temperatures and storage duration on 'Le Conte' pear fruit total phenolic acids (%) in 1999 & 2000 seasons.

Parameters	Stages of harvest (SH)	Storage temp. (°C; ST)	0 ^z	Storage duration (SD) - Days								
				10	20	30	40	50	60	70	80	90
Total phenolics (%)												
(1999)	1	2	0.049	0.050	0.058	0.064	0.070	0.069	0.074	0.060	0.064	0.072
	2		0.052	0.049	0.050	0.059	0.065	0.058	0.066	0.069	0.068	0.072
	3		0.060	0.058	0.053	0.069	0.058	0.079	0.064	0.067	0.067	0.081
	1	4	0.049	0.047	0.047	0.050	0.058	0.066	0.067	0.057	0.068	0.065
	2		0.052	0.058	0.059	0.058	0.065	0.058	0.073	0.067	0.058	0.060
	3		0.060	0.061	0.063	0.063	0.062	0.072	0.065	0.060	0.062	0.072
LSD 5%												
	1	8	0.049	0.058	0.073	0.094						
	2		0.052	0.059	0.071	0.068						
	3		0.060	0.055	0.060	0.067						
LSD 5%												
	ST x SD / SH x SD / ST x SH		0.009 ^y / 0.009 / 0.008									
	SH x ST x SD		0.016									
										0.008 ^x / 0.009 / 0.004		
										0.013		
(2000)	1	2	0.038	0.040	0.039	0.052	0.059	0.059	0.066	0.058	0.056	0.061
	2		0.046	0.044	0.047	0.048	0.047	0.046	0.051	0.067	0.058	0.062
	3		0.038	0.050	0.045	0.042	0.044	0.044	0.056	0.056	0.061	0.062
	1	4	0.038	0.046	0.045	0.049	0.037	0.046	0.074	0.075	0.066	0.067
	2		0.046	0.047	0.051	0.051	0.057	0.052	0.054	0.075	0.062	0.067
	3		0.038	0.047	0.050	0.058	0.057	0.066	0.062	0.050	0.059	0.066
LSD 5%												
	1	8	0.038	0.059	0.052	0.052						
	2		0.046	0.048	0.048	0.059						
	3		0.038	0.036	0.041	0.046						
LSD 5%												
	ST x SD / SH x SD / ST x SH		0.008 / 0.008 / 0.007									
	SH x ST x SD		0.014									
										0.008 / 0.010 / 0.005		
										0.014		

^z initial value at harvest, prior to storage.

^y LSD values for all temperatures and all stages of harvest up to 30 days of storage

^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

Table 15. Effect of harvest stages, storage temperatures and storage duration on 'La Conte' pear fruit reducing sugars (%) in 1999 & 2000 seasons

Parameters	Stages of harvest (SH)	Storage temp. (°C, ST)	0 ^z	Storage duration (SD) - Days									
				10	20	30	40	50	60	70	80	90	
Red. sugars (%)	(1999)	1	7.23	7.31	7.34	7.80	8.24	8.47	8.80	9.31	10.48	9.43	
		2	7.47	8.15	7.39	8.38	8.61	8.01	8.86	10.19	9.41	9.56	
		3	7.90	8.11	7.95	8.76	8.58	9.66	10.21	10.16	10.45	10.99	
		1	7.23	7.46	6.99	7.97	7.93	9.03	8.83	9.05	9.49	9.46	
		2	7.47	7.86	7.92	8.09	8.68	8.44	8.79	8.79	9.12	8.93	
		3	7.90	8.03	9.21	8.78	9.21	9.65	9.99	9.43	9.53	10.40	
	(2000)		1	7.23	7.59	8.75	8.52						
			2	7.47	8.45	9.89	9.23						
			3	7.90	8.45	9.09	9.08						
		1	6.11	7.26	7.67	8.09	7.77	7.42	7.99	8.92	9.47	8.65	
		2	6.90	7.54	7.88	8.20	7.72	8.06	8.67	10.17	9.24	9.25	
		3	6.70	8.03	8.67	8.08	8.90	9.27	9.52	9.47	9.31	10.55	
		1	6.11	7.12	7.75	7.51	8.22	7.45	8.19	8.45	9.62	9.35	
		2	6.90	7.27	8.61	7.91	8.03	8.33	8.81	9.28	9.61	8.81	
		3	6.70	8.77	9.01	8.35	9.27	8.65	10.45	9.18	9.35	10.74	
LSD 5%													
ST x SD / SH x SD / ST x SH			0.47 ^y / 0.47 / 0.41										
SH x ST x SD			0.81										
								0.57 ^x / 0.69 / 0.31					
								0.98					
LSD 5%													
ST x SD / SH x SD / ST x S.1			0.54 / 0.54 / 0.47							0.55 / 0.68 / 0.30			
SH x ST x SD			0.94							0.95			

^z initial value at harvest, prior to storage.
^y LSD values for all temperatures and all stages of harvest up to 30 days of storage
^x LSD values for 2 and 4 °C at all stages of harvest up to 90 days of storage.

The second harvest stage (SSC = 11.72 to 12.24%, firmness = 36.0 to 39.0 N, and starch index = 4 to 5) could be recommended as the best harvest stage for 'Le Conte' pear fruits. 'Le Conte' pear fruits could be stored at 2 °C for 70 days with good quality. Storage of 'Le Conte' pear fruits at temperature higher than 2 °C does not help the fruit in preserving good quality. Also, storage period longer than 70 days causes deterioration to the fruit quality especially after taking the fruit out the cooler.

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القدرة التخزينية لثمار الكمثرى صنف ليكونت عند مراحل قطف مختلفة
أحمد فتح الله الشيخ وسند السيد حبيب و مجدي على بصل و علاء محمد جمعة
قسم البساتين - كلية الزراعة - جامعة قناة السويس - الإسماعيلية - مصر

أجريت هذه الدراسة في موسمي ١٩٩٩، ٢٠٠٠ م علي ثمار الكمثرى ليكونت. تم جمع الثمار في شهر أغسطس وذلك علي ثلاث مراحل وهي: المرحلة الأولى قبل المرحلة الثانية (عند اكتمال النكهة التجارية التسميوية الطازجة) بعشرة أيام والمرحلة الثالثة بعد المرحلة الثانية بعشرة أيام. وقد تم تخزين الثمار علي ٢° م، ٤° م، ٨° م ونسبة رطوبة ٨٠ - ٨٥ % وقد تم أخذ العينات للتحليل الطبيعي والكيمائي عند الجمع وكذلك كل ١٠ أيام من التخزين حتى ٩٠ يوما وذلك بالنسبة للثمار التي تم تخزينها علي ٢° م، ٤° م وحتى ٣٠ يوما بالنسبة للثمار تم تخزينها علي ٨° م وكان الهدف من الدراسة هو التعرف علي تأثير مرحلة القطف ودرجة حرارة التخزين وكذلك فترة التخزين علي جودة ثمار الكمثرى ليكونت.

ولقد بينت قياسات اللون أن مرحلة القطف الثانية والثالثة كانت أكثر تقدما فسي اكتمال النمو عن المرحلة الأولى ولم تلاحظ أي اختلافات في صلابة الثمار بين المرحلة الأولى والثانية من القطف بينما كانت صلابة ثمار المرحلة الثالثة أقل من نظيرتها في المرحلتين الأخريين. ولقد كان أعلى فقد في الوزن الطازج للثمار ناتج عن المرحلة الثانية من القطف في الموسم الأول بينما كان أقل فقد في الوزن الطازج أثناء التخزين ناتج من ثمار المرحلة الثالثة من القطف فسي كلا الموسمين. كذلك فإن الوزن الجاف والمواد الصلبة الذائبة والأحماض الفينولية الكلية والسكريات المختزلة كانت أعلى في مرحلة القطف الثالثة عنة في مراحل القطف الأخرى بينما كانت حموضة ثمار المرحلة الأولى من القطف أعلى منها في ثمار مرحلتي القطف الأخريين.

ولقد نتج عن التخزين علي درجة حرارة ٢° م أعلى قيمة لصلابة الثمار بينما نتج عن التخزين علي درجة حرارة ٨° م أقل قيمة لصلابة الثمار في كلا الموسمين. وكلما زادت درجة حرارة التخزين كلما زاد الفقد في الرزوز الطازج للثمار وزادت نسبة الممواد الصلبة الذائبة والأحماض الفينولية بالثمار. ولقد كانت نسبة السكريات المختزلة مرتفعة في الثمار التي تم تخزينها علي ٢° م وذلك بالمقارنة بالثمار التي تم تخزينها علي ٨° م. كذلك فإن حموضة الثمار و السوزن الجاف لها كانت مرتفعة بالمقارنة بالثمار التي تم تخزينها علي ٨° م في الموسم الأول وفي الثمار التي تم تخزينها علي ٢° م في الموسم الثاني.

ولقد انخفضت صلابة الثمار أثناء التخزين في كلا الموسمين بينما زاد كل من القند فسي الوزن الطازج للثمار ونسبة الممواد الصلبة الذائبة والأحماض الفينولية ونسبة السكريات المختزلة بعد التخزين لمدة ٣٠ - ٩٠ يوما ولم يختلف الوزن الجاف بالثمار معنويا أثناء التخزين لمدة ٧٠ يوما والتي بعدها حدث زيادة في الوزن الجاف في الموسم الأول بينما في الموسم الثاني زاد الوزن الجاف للثمار معنويا بعد ٤٠ يوما من التخزين. وفي الموسم الأول انخفضت حموضة الثمار بعد ٧٠ يوما من التخزين بينما زادت الحموضة بعد ٣٠ يوما في الموسم الثاني وحتى ٨٠ يوما ثم انخفضت بعد ذلك.

وبذلك يتضح أن مرحلة قطف ثمار كمثرى ليكونت الثانية (مواد صلبة ذائبة ١١ و ٢٤ و ١٢ % ، صلابة ٣٦ - ٣٩ نيوتن ، دليل نشا ٤ - ٥) هي أفضل مرحلة قطف وأن التخزين علي درجة حرارة ٢° م لمدة ٧٠ يوما يساعد علي احتفاظ الثمار بجودتها.