

# Anthocyanin Content, Peroxidase and Polyphenol Oxidase Activities in Relation to Browning Potential of Celebration, Sapphire and Santa Rosa Plum Fruits During Cold Storage

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## ABSTRACT

The present study was carried out during 2007 and 2008 seasons on fruits of the newly introduced plum cvs. Celebration and Sapphire (from South Africa) in comparison with the local cv. Santa Rosa. The fruits were stored at 0°C and 85 - 90 % relative humidity. The physico-chemical properties of the stored fruits were followed up in 4 days intervals during the storage period and a sample was transferred to 20°C for observation after 2, 4 and 6 days (shelf life sample to simulate the marketability period). Fruits cooled at 0°C can be stored for 28 days with good firmness but they lost their firmness and became dull in shelf life store. Chilling injury (CI) symptoms as flesh browning, translucency and bleeding appeared in the last two cold storage intervals (24 and 28 days) when the fruits were transferred to 20°C. During cold storage period at 0°C, Celebration had the highest significant weight loss percentages. In all cvs., weight loss averages of shelf life fruits were less than 1 % after 2 days and Sapphire fruits had the lowest percentages of weight loss. After 8 days at 0°C then storage at 20°C, Sapphire cv. had the lowest firmness loss percent. After 16 days of cold storage, the three cvs. had good firmness values but when the fruits were transferred to 20°C, those values decreased significantly after 2 and 4 days. After cold storage, fruits of Santa Rosa cv. lost the highest percent of soluble solids content (SSC) compared with Celebration and Sapphire fruits. For shelf life fruits, there were no significant changes in SSC for the three cvs. in most intervals. Celebration fruits had the lowest initial acidity values and during the first cold storage periods (4 and 8 days) the acidity values of all cvs. decreased slightly but they increased when the fruits were transferred to 20°C. With the progress of cold storage, the fruits of the three cvs. had less acidity content compared with the initial values and those values declined during the subsequent shelf life period. Peel anthocyanin content of Santa Rosa fruits (red cv.) decreased with the advancing of cold storage while that content of Celebration fruits (red cv.) increased slightly. On the other hand, the yellow Sapphire cv. showed the greatest increase in peel anthocyanin content. Santa Rosa flesh had the highest initial content of anthocyanin compared with the other two cvs. The flesh anthocyanin contents increased during the first 12 days of cold storage then decreased with the advancing of cold storage. During cold storage, peroxidase (POD) activity of all cvs. decreased then increased again during the last intervals.

There was general trend of decreasing POD activity in shelf life fruits of all cvs. in the first 12 days of the experiment then it increased during the last 16 days. On the other hand, Sapphire fruits significantly had the highest initial values of polyphenol oxidase (PPO) activity and those values decreased sharply by the end of cold storage period. Celebration and Santa Rosa cvs. showed contrast trend where the PPO activities showed an increasing trend with the progress of cold storage.

## INTRODUCTION

Plum fruits have the potential to contribute greatly to human nutrition because of their richness in fibers and antioxidants (Kim *et al.*, 2003 and Crisosto *et al.*, 2004). Plums are highly perishable and have a commercial life of 2-6 weeks depending on cultivar even when stored at 0°C (Guerra and Casquero, 2008). The temperature and humidity are suboptimal during marketing with changing temperatures and rather dry air during handling. In addition, the consumers wish the plums to keep fresh for several days after the purchase (Vangdal *et al.*, 2007). Low temperature storage is recommended to extend plum fruits postharvest life and maintain its quality due to ethylene reduction and senescence delaying, however the benefits may be limited by the development of physiological disorders such as softening (overripe), incidence of chilling injury (flesh browning, gel breakdown, flesh translucency and red pigment accumulation known as bleeding), reduced flavour quality (too low acidity, no aroma), less favourable appearance (lack of freshness, shriveling or bruising) and fungal decay (Candan *et al.*, 2006; Manganaris *et al.*, 2007; Vangdal *et al.*, 2007; Cantin *et al.*, 2008 and Larrigaudière *et al.*, 2009). Market life potential, based on losses as a consequence of chilling injury symptoms, was subjectively defined as the number of weeks each cultivar could be stored at 0°C (maximum) or 5°C (minimum) before chilling injury became limiting (Crisosto *et al.*, 1999). The end of market life was determined to occur when more than 25 % of the fruits have symptoms of chilling injury (Mitchell and Kader, 1989). So, it is recommended that plums should be marketed and consumed within their potential market life (Crisosto *et al.*, 2004).

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The main objective of this work was to determine the ideal storage period for Celebration, Sapphire and Santa Rosa plums based on the fruit quality during cold storage and its market life potential (shelf life) after storage.

### MATERIALS AND METHODS

The present study was carried out during 2007 and 2008 seasons on fruits of the newly introduced plum cvs. Celebration and Sapphire (from South Africa) in comparison with the local cv. Santa Rosa harvested from a private orchard in El-Giza governorate. Sound selected fruits were packed in one layer (40-50 fruits depending on fruit size of each cv.) closed carton boxes (15 boxes of each cv.) and transported to the Postharvest Center of Horticulture Crops, Faculty of Agriculture, Alexandria University.

The initial fruit quality was determined (zero time cold storage period) as an average of 25 fruits of each cv. (table 1 and fig 1) then after 2, 4 and 6 days at 20°C (shelf life of zero time cold storage period). The fruits were stored at 0°C with 85 - 90 % relative humidity. The physio-chemical properties of the cold stored fruits were followed up in 4 days intervals and after 2, 4 and 6 days of subsequent storage at 20°C (shelf life fruits) to simulate marketability so the treatments were :

- 1- Storage at 0°C
- 2- Storage at 0°C+2 days at 20°C (0°C +Shelf life 2 d.)
- 3- Storage at 0°C+4 days at 20°C (0°C+Shelf life 4 d.)
- 4- Storage at 0°C+6 days at 20°C (0°C+Shelf life 6 d.)

Fifteen fruits of each cv. were labeled then weighed to calculate fruit weight loss percent during the storage period in relation to its original weight.

Patches of skin were peeled from two opposite sides of each given fruit in the sample (15 fruits) to measure the flesh firmness by using the Effegi pressure tester with an eight mm plunger (Effegi, 48011 Alfonsine, Italy).

Two opposite segments from the rose to the stem end of each fruit were taken and each of them was squeezed and the obtained juice was used to determine the percentage of the soluble solids content (SSC) by the use of a hand refractometer (Chen and Mellenthin, 1981).

Juice of another two segments was taken and the titratable acidity was determined in three samples as g malic acid /100 ml of fruit juice (Chen and Mellenthin, 1981).

Fruit peel and fruit flesh anthocyanin contents were determined according to the method of Fuleki and Francis (1968). Three samples of 50 g of each treatment were extracted in 100 ml mixture of ethanol and Hcl (85:15). Five ml of the above extraction were centrifuged for 10 min then the obtained supernatant was measured spectrophotometrically at 535 nm and the anthocyanin content was calculated as mg / 100 g sample.

Polyphenol oxidase (PPO) and peroxidase (POD) enzymes activities were determined in the crude extracts (Brenneman and Black, 1979) of three samples of fruit pulp in each treatment. The activity of PPO was measured using the method of Matta and Dimond (1963) and the activity of POD was determined by the method of Chance and Maehly (1955).

The termination of the experiment was done by the occurrence of peel shrinkage and when the flesh firmness reached the average of less than 3 lb/inch<sup>2</sup> and with the appearance of chilling injury (CI) symptoms in shelf life fruits.

All data obtained were statistically analyzed according to 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 Institute (1985).

**Table 1. The Initial Quality of Celebration, Sapphire and Santa Rosa Plum Fruits during 2007 and 2008 Seasons**

Parameter	Cultivar (cv.)					
	Celebration		Sapphire		Santa Rosa	
	2007	2008	2007	2008	2007	2008
Weight (gm)	104.0	109.2	49.81	48.47	64.42	59.50
Length(cm)	3.70	4.00	4.13	3.83	3.03	2.90
Diameter(cm)	4.08	3.93	3.83	3.53	3.00	3.00
Firmness (lb/in <sup>2</sup> )	5.40	5.67	7.60	9.07	5.53	5.54
SSC (%)	16.57	16.63	17.47	17.20	15.90	15.67
Acidity (%)	0.85	0.84	1.18	1.12	1.32	1.17

## RESULTS AND DISCUSSIONS

### Fruit Appearance, Storability and Chilling Injury Incidence:

Celebration plum fruit was weighed 106.60 g (average of two seasons) with dull dark purple skin, light yellow fleshy pulp with purple narrow area parallel the skin and semi attached seed. Santa Rosa fruit was weighed 49.14 g (average of two seasons) with shiny light purple skin, dark yellow juicy pulp and attached seed. On the other hand, the fruit of the yellow cv. Sapphire was weighed 61.96 g (average of two seasons) with yellow skin and yellow fleshy pulp and attached seed (table 1 and fig. 1).

If the fruits of Celebration and Santa Rosa were kept directly after harvest at 20°C (zero time cold storage period), it can be stored for 2 days with good quality and for 4 days with loss of its firmness (less than 3 lb/in<sup>2</sup>) and with the shrinkage appearance around the stem end of the fruit (fig. 2). The fruits of Sapphire can be stored with good quality at the same above conditions for 4 days and on the 6<sup>th</sup> day the fruit flesh became mealy with the shrinkage appearance and more than 50 % of the fruits became full red (only the peel turn to red).

When the fruits were cooled at 0°C it can be stored for 28 days for all cvs. with good firmness but the fruits lost its firmness and became dull when they were transferred to 20°C for 2 days. The above findings were noticed for the fruits after 16 days at 0°C when were transferred to 20°C for 4 days. Sapphire was the only cv. which had 6 days shelf life period at 20°C after cold storage of 12 days (compared with the 6<sup>th</sup> day of the other cvs. after 4 days cold storage only) but with the increasing of cold storage period the fruits became mealy.

Mealiness is characterized by the loss of juiciness and pectin gel formation due to the abnormal modifications in the activities of cell wall-degrading enzymes (Brummell *et al.*, 2004 and Manganaris *et al.*, 2008).

Another chilling injury (CI) symptoms appeared in the last two intervals (24 and 28 days) of cold storage when the fruits of Celebration (fig. 3) and Santa Rosa (fig. 4) were transferred to 20°C as flesh browning (around the seed), translucency or overripe (watery appearance from the skin toward the seed) and bleeding or the flesh turn to red color (start from the skin toward the seed). On the other hand, those symptoms were not noticed on Sapphire fruits except the overripe of some fruits with the change of skin color to red (fig. 5).

Crisosto *et al.*, (2004) evaluated browning as a brown coloration originating near the pit and extending out into the flesh, and reported that translucency occurred as water soaked areas in the outer mesocarp immediately under the epidermis as a consequence of the fruit being overripe. Flesh bleeding was evaluated as an accumulation of red pigment either around the stone or immediately beneath the epidermis.

It is known that the symptoms of CI develop faster at 5°C than at 0°C and mainly during the shelf life period (Crisosto *et al.*, 1999). CI in plum is related to the climacteric behavior of the cv. and more precisely to its capacity to produce ethylene and to respond to cold stress which promote ethylene production after removal from storage due to the promotion of accumulation of ACC synthase and ACC oxidase mRNA which triggered the ethylene burst followed after removal from cold storage (Candan *et al.*, 2008). Previous research reported that the onset of CI symptoms occurred after 5 and 2 weeks in Blackamber plums stored at 0 and 5°C, respectively (Crisosto *et al.*, 1999). Hartmann *et al.*, (1988) observed that the Songold plum tissue breakdown occurred immediately under the fruit's epidermis.

### Fruit Weight Loss (%):

Data from table (2) showed that fruits of all cvs. stored at 20°C (shelf life of zero time cold storage period) for 2 days lost less than 1 % of its initial weight and Sapphire fruits lost the lowest percent after 4 days (less than 1%) in both experimental seasons.

During cold storage period at 0°C there was no significant difference between weight loss percentages of Sapphire and Santa Rosa. On the other hand, Celebration had the highest significant weight loss percentages during both seasons. All cvs. weight loss increased with the advancing of cold storage time ( $r^2$  values were highly significant).

Weight loss averages of all cvs. were less than 1 % after 2 days of shelf life. Those averages increased after 4 days and Sapphire fruits had the lowest percentages of weight loss.

The weight loss is mainly a result of water loss from the fruit tissues and partially of the respiration process. The higher storage temperatures increase the respiration rate and then fruit weight loss. From the above results weight loss was also cv. dependant. Guerra and Casquero (2008) found that the weight loss of Green Gage plums increased significantly in cold store and during shelf life period (3 days at 20°C), the loss was between 1.7 and 6.0 %. Also, Valero *et al.*, (2003)

**Table 2. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Weight Loss (%) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	0.00c	0.66fgh	1.16b	1.59ab	1.90a	2.48a	2.75a	3.22a	0.992**
0°C+Shelf life2d.	0.90b	1.21def	0.84bc	0.96cd	0.77de	0.99cd	0.86bc	0.66c	
0°C+Shelf life4d.	1.61a	1.55cde	1.99a	1.37abc	1.75ab				
0°C+Shelf life6d.		2.15c							
<b>Sapphire</b>									
0°C	0.00c	0.28h	0.56c	0.85cd	1.04cd	1.67b	1.59b	2.09b	0.988**
0°C+Shelf life2d.	0.77b	1.04efg	0.84bc	1.08bcd	1.17bcd	1.04bcd	1.02bc	0.66c	
0°C+Shelf life4d.	1.15ab	2.20bc	2.09a	1.85a	1.48abc				
0°C+Shelf life6d.		3.06a							
<b>Santa Rosa</b>									
0°C	0.00c	0.41gh	0.56c	0.80cd	1.04cd	1.29bc	1.61b	1.68b	0.976**
0°C+Shelf life2d.	0.82b	1.71cde	0.59c	0.60d	0.38e	0.38d	0.32c	0.39c	
0°C+Shelf life4d.	0.83b	1.82cd	0.83bc	1.37abc	0.99cde				
0°C+Shelf life6d.	0.96b	2.83ab	1.27b	1.83a					
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	0.00d	0.59f	1.06cd	1.48bc	1.87a	2.41a	2.71a	3.10a	0.994**
0°C+Shelf life2d.	0.94bc	0.90def	0.84defg	1.18cd	0.77bc	1.02bc	0.64c	0.61c	
0°C+Shelf life4d.	1.42b	1.80bc	1.55b	2.20a	2.04a				
0°C+Shelf life6d.		2.40b							
<b>Sapphire</b>									
0°C	0.00d	0.33f	0.40fg	0.58d	0.83bc	1.23b	1.40b	1.417b	0.976**
0°C+Shelf life2d.	0.24d	1.41cde	0.37g	0.71d	0.18c	0.51c	0.53c	0.49c	
0°C+Shelf life4d.	0.81c	1.52cd	0.91de	1.14cd	1.09b				
0°C+Shelf life6d.	1.21bc	3.88a	1.38bc	1.92ab					
<b>Santa Rosa</b>									
0°C	0.00d	0.35f	0.54efg	0.66d	0.88b	1.35b	1.42b	1.61b	0.979**
0°C+Shelf life2d.	0.85c	0.75ef	0.86def	1.14cd	0.97b	0.81bc	0.48c	0.72c	
0°C+Shelf life4d.	2.14a	1.96bc	2.55a	1.90ab	1.83a				
0°C+Shelf life6d.		2.26b							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

found weight loss of 4.05 and 6.12 % in President plums during 7 days shelf life.

#### Flesh Firmness (lb/in<sup>2</sup>):

The initial flesh firmness values (average of two seasons) of Celebration Sapphire and Santa Rosa fruits were 5.54, 8.34 and 5.53 lb/in<sup>2</sup>, respectively (table 3). All those values declined significantly when the fruits stored at 20°C (shelf life of zero time cold storage period) and Sapphire fruits had the longest shelf life with the highest flesh firmness.

After 8 days of cold storage at 0°C and respectively in 2007 and 2008 seasons, the fruits of Celebration cv.

lost 5.00 and 7.05 % of its initial firmness while Sapphire fruits lost 10.13 and 25.80 % of the initial firmness. On the other hand, Santa Rosa fruits lost from its initial firmness 19.89 and 10.29 %. When those fruits were transferred to 20°C, the longest shelf life period was recorded for Sapphire cv. in both seasons with the lowest firmness loss after 4 days (24.30 and 31.64 %) compared with Celebration (54.58 and 58.82 %) and Santa Rosa (33.86 and 61.77 %) cvs.

After 16 days at 0°C the three cvs. fruits had good quality with good firmness values but when the fruits were transferred to 20°C the firmness values decreased significantly after 2 and 4 days.

**Table 3. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Flesh Firmness (lb/in<sup>2</sup>) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	5.40bc	5.17bc	5.13bc	5.07ab	5.90ab	4.77b	4.33b	4.40a	0.415
0°C+Shelf life2d.	3.53d	4.00cd	3.90cd	3.53cd	3.67de	2.47c	2.93c	2.47cd	
0°C+Shelf life4d.	1.67f	3.43d	2.33e	1.73e	2.00f				
0°C+Shelf life6d.		1.90e							
<b>Sapphire</b>									
0°C	7.60a	7.13a	6.83a	5.63a	6.67a	7.50a	5.73c	3.37abc	0.493
0°C+Shelf life2d.	6.00b	5.07bc	5.03bc	4.63abc	5.13bc	3.67bc	3.00c	1.97d	
0°C+Shelf life4d.	5.13c	5.07bc	5.17bc	4.17bc	2.67ef				
0°C+Shelf life6d.	4.17d	6.03ab	5.63ab	2.67de					
<b>Santa Rosa</b>									
0°C	5.53bc	6.30ab	4.43bc	4.33bc	5.07bcd	3.87bc	4.50b	3.87ab	0.553*
0°C+Shelf life2d.	3.77d	3.53d	3.83cd	4.00bc	4.13cd	3.13c	3.20c	3.00bcd	
0°C+Shelf life4d.	2.73e	3.20d	2.93de	1.77e	2.33ef				
0°C+Shelf life6d.		3.70d							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	5.67bc	5.50bc	5.27b	5.73a	6.07a	5.17b	5.27a	3.60ab	0.375
0°C+Shelf life2d.	4.17d	4.07de	3.87c	3.83bc	3.90bc	2.67d	3.07b	3.23abc	
0°C+Shelf life4d.	1.33e	3.57e	2.17d	1.67e	2.13d				
0°C+Shelf life6d.		1.80f							
<b>Sapphire</b>									
0°C	9.07a	6.63a	6.73a	5.73a	6.33a	8.00a	5.97a		0.454
0°C+Shelf life2d.	6.43b	5.57bc	5.77ab	4.90abc	5.17ab	4.50bc	3.80b	3.47abc	
0°C+Shelf life4d.	5.33bcd	4.70cd	4.60bc	4.30abc	3.33cd			2.10c	
0°C+Shelf life6d.	4.83cd	5.93ab	5.07bc	3.50cd					
<b>Santa Rosa</b>									
0°C	5.54bc	3.73e	4.97bc	5.20ab	5.07ab	3.77bcd	3.87b	4.07a	0.277
0°C+Shelf life2d.	4.63cd	3.47e	3.93c	3.50cd	3.80bc	3.23cd	2.87b	2.33bc	
0°C+Shelf life4d.	2.37e	3.23e	1.90d	2.17de	2.57cd				
0°C+Shelf life6d.		4.83cd							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

With the progress of cold storage in both experimental seasons, the fruits firmness of all cvs. reached near the average of 3.50 lb/in<sup>2</sup> and shelf life fruits reached around the average of 2.50 lb/in<sup>2</sup>.

Loss in fruit firmness during cold storage or shelf life period is mainly due to decomposition, enzymatic degradation of insoluble protopectins to more simple soluble pectins, solubilization of cell and cell wall contents as a result of the increasing in pectinesterase activity, and subsequent development of juiciness and the loss in peel and pulp hardness. The above results and discussion agree with those of Picchioni *et al.*, (1995)

and Siddiqui and Bangerth, (1995) on apple; El-Naggar and El-Saedy, (2008) on peach; Crisosto *et al.*, (2004); Candan *et al.*, (2006); Vangdal *et al.*, (2007) and Cantin *et al.*, (2008) on plums.

#### Soluble Solids Content (SSC %):

Sapphire fruits had the highest initial SSC values, then Celebration fruits and the lowest values were for Santa Rosa cv. (table 4). When the fruits were stored at 20°C (shelf life of zero time cold storage period), the initial SSC values of Celebration and Santa Rosa cvs. decreased significantly after 4 days but Sapphire fruits

**Table 4. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Soluble Solids Content (SSC %) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	16.57abc	13.87cde	15.80ab	14.40a	15.00bc	15.27a	15.67ab	15.67ab	0.003
0°C+Shelf life2d.	14.40de	14.93bc	15.60ab	16.13a	16.00ab	16.06a	16.07ab	15.80ab	
0°C+Shelf life4d.	13.73e	15.07bc	15.67ab	14.93a	16.13ab				
0°C+Shelf life6d.		12.07f							
<b>Sapphire</b>									
0°C	17.47a	15.20b	16.10ab	16.43a	16.00ab	15.97a	15.10b	16.20a	0.162
0°C+Shelf life2d.	17.07ab	14.97bc	13.97b	16.43a	16.00ab	15.37a	17.13a	16.90a	
0°C+Shelf life4d.	17.33a	16.50a	15.10ab	14.67a	16.87a				
0°C+Shelf life6d.	9.60f	13.43de	16.67a	15.57a					
<b>Santa Rosa</b>									
0°C	15.90bc	12.73ef	15.07ab	16.07a	14.33c	14.20a	14.67b	13.60c	0.078
0°C+Shelf life2d.	15.27cd	15.00bc	16.33a	15.27a	15.47bc	15.07a	15.20b	13.87bc	
0°C+Shelf life4d.	13.93de	15.13b	15.73ab	15.27a	14.93bc				
0°C+Shelf life6d.		14.20bcd							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	16.63bcd	15.00bc	16.60bc	14.93d	15.07cd	15.40c	16.07ab	15.67b	0.041
0°C+Shelf life2d.	14.27e	16.27ba	15.27d	16.07abcd	16.07bc	15.93abc	16.33ab	15.40b	
0°C+Shelf life4d.	14.40e	15.27abc	15.53cd	15.33cd	15.93bc				
0°C+Shelf life6d.		13.13d							
<b>Sapphire</b>									
0°C	17.20ab	16.27ab	18.13a	15.80bcd	16.23bc	16.73a	16.90a	16.80a	0.020
0°C+Shelf life2d.	17.07bc	16.07ab	17.57ab	16.67ab	16.43b	16.43ab	16.20ab	16.60a	
0°C+Shelf life4d.	18.13a	16.70a	17.53ab	16.23abc	18.00a				
0°C+Shelf life6d.	9.07f	14.30cd	17.97a	17.33a					
<b>Santa Rosa</b>									
0°C	15.67d	11.53e	14.93d	15.33cd	14.67d	14.07d	15.27b	14.13c	0.011
0°C+Shelf life2d.	16.13cd	15.20bc	16.13cd	15.13cd	15.93bc	15.67bc	15.67b	14.33c	
0°C+Shelf life4d.	13.93e	15.00bc	16.07cd	15.67bcd	15.20cd				
0°C+Shelf life6d.		14.53cd							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

kept its SSC for 4 days and decreased significantly on the 6<sup>th</sup> day.

During cold storage period there was no clear trend for SSC values but generally the values of all cvs. decreased by the end of the storage period which may be due to its consumption in respiration processes (r<sup>2</sup> values were not significant) and Santa Rosa cv. lost the highest percent of SSC (14.47 and 9.83 %) compared with Celebration (5.43 and 5.77 %) and Sapphire (7.27 and 2.33 %) fruits respectively in both seasons. When the fruits were transferred to 20°C (shelf life fruits) after cold storage there were no significant changes in SSC for the three cvs. during most intervals in both seasons.

Crisosto *et al.*, (2004); Candan *et al.*, (2005); Cantín *et al.*, (2008) and Guerra and Casquero (2008) recorded no significant differences in SSC during ripening and cold storage of plums.

#### Titrateable Acidity (%):

The data of table 5 showed that Celebration fruits had the lowest initial acidity values compared with the other two cvs. and the fruits of Santa Rosa had the highest initial content of malic acid.

With the storage of fruits at 20°C (shelf life of zero time cold storage period) the acidity percents of Sapphire and Santa Rosa fruits declined significantly whereas it increased significantly in Celebration ones.

**Table 5. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Plum Fruits Flesh Malic Acid Content (%) in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	0.85d	0.79c	0.76cd	1.06a	0.60c	0.84bc	0.74c	0.75b	0.068
0°C+Shelf life2d.	0.79d	0.89c	0.56f	0.77b	0.63c	0.68c	0.58d	0.69bc	
0°C+Shelf life4d.	1.40a	0.86c	0.86bc	0.67bc	0.58c				
0°C+Shelf life6d.		0.86c							
<b>Sapphire</b>									
0°C	1.18b	0.57de	0.75cd	0.67bc	0.67c	0.67c	0.58d	0.57c	0.417
0°C+Shelf life2d.	0.75d	0.43f	0.59ef	0.57c	0.68c	0.72c	0.65cd	0.67bc	
0°C+Shelf life4d.	0.71d	0.47ef	0.65def	0.58c	0.67c				
0°C+Shelf life6d.	0.79d	0.64d	0.84bc	0.61bc					
<b>Santa Rosa</b>									
0°C	1.32ab	1.19b	0.93b	1.18a	1.12a	1.11a	1.25a	1.12a	0.025
0°C+Shelf life2d.	1.02c	1.19b	0.70de	1.18a	1.15a	1.00ab	0.88b	0.69bc	
0°C+Shelf life4d.	0.75d	1.31a	1.23a	1.14a	0.90b				
0°C+Shelf life6d.		1.08b							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	0.84c	1.00b	0.98b	1.05b	0.80c	0.86c	0.76c	0.84b	0.254
0°C+Shelf life2d.	0.81cd	0.94bc	0.68d	0.71cd	0.66de	0.60e	0.64c	0.69cd	
0°C+Shelf life4d.	1.11b	0.76cde	0.81cd	0.77c	0.60e				
0°C+Shelf life6d.		0.90cde							
<b>Sapphire</b>									
0°C	1.12b	0.56e	0.90bc	0.75cd	0.64e	0.74cd	0.65c	0.67cd	0.287
0°C+Shelf life2d.	0.74cd	0.65e	0.75cd	0.68cd	0.78c	0.68de	0.64c	0.61d	
0°C+Shelf life4d.	0.63e	0.71de	0.82bcd	0.65d	0.75cd				
0°C+Shelf life6d.	0.73cde	0.69de	0.76cd	0.65d					
<b>Santa Rosa</b>									
0°C	1.17b	1.22a	1.30a	1.20a	1.31a	1.37a	1.27a	1.26a	0.290
0°C+Shelf life2d.	1.46a	1.29a	0.82bcd	1.17ab	1.30a	1.16b	0.95b	0.79bc	
0°C+Shelf life4d.	0.73de	1.29a	1.31a	1.19a	0.92b				
0°C+Shelf life6d.		1.11ab							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

During the first cold storage periods (4 and 8 days) the acidity values of all cvs. decreased slightly but it increased when the fruits were transferred to 20°C. With the progress of cold storage the fruits of the three cvs. had less acidity content compared with the initial values and those values declined again during subsequent shelf life due to the consumption of malic acid in respiration process.

The reduction of acidity during cold storage and ripening of plums are associated with the works of Crisosto *et al.*, (2004); Candan *et al.*, (2006); Cantin *et al.*, (2008) and Guerra and Casquero, (2008) on plums.

#### Peel Anthocyanin Content (mg /100 g):

Santa Rosa fruits had higher significant values of peel anthocyanin (table 6) compared with Celebration fruits and the lowest initial values were in Sapphire peel (yellow cv.).

Peel anthocyanin content of Santa Rosa decreased with the advancing of cold storage while that content of Celebration increased slightly. On the other hand, the yellow Sapphire cv. showed the greatest increase in peel anthocyanin content (10.82 and 12.99 fold, respectively in 2007 and 2008 seasons) and changed to full red peel (r<sup>2</sup> values were highly significant).

**Table 6. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Peel Anthocyanin Content (mg/100g peel) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	1.300b	2.203a	1.200a	1.407c	1.133b	1.300bc	1.377b	1.393b	0.092
0°C+Shelf life2d.	1.327b	2.300a	1.333a	1.540bc	1.247b	1.817a	1.873a	1.577b	
0°C+Shelf life4d.	1.400b	2.567a	1.500a	1.604ab	1.227b				
0°C+Shelf life6d.		2.263a							
<b>Sapphire</b>									
0°C	0.200c	0.113b	0.343b	0.443d	1.930a	1.547abcd	1.513b	2.163a	0.804**
0°C+Shelf life2d.	0.117c	0.097b	0.260b	0.393de	1.893a	1.697ab	2.097a	2.200a	
0°C+Shelf life4d.	0.103c	0.267b	0.373b	0.263de	2.163a				
0°C+Shelf life6d.	0.077c	0.263b	0.673b	0.227e					
<b>Santa Rosa</b>									
0°C	2.313a	2.703a	1.137a	1.670ab	0.973b	1.067c	1.307b	1.370b	0.454
0°C+Shelf life2d.	2.333a	2.703a	1.267a	1.717ab	1.110b	1.600ab	1.873a	1.393b	
0°C+Shelf life4d.	2.433a	2.747a	1.383a	1.770a	1.223b				
0°C+Shelf life6d.		2.817a							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	1.363b	2.527a	1.433ab	1.483c	1.263cd	1.367a	1.490ab	1.457b	0.128
0°C+Shelf life2d.	1.407b	2.633a	1.633ab	1.633bc	1.663abc	1.913a	1.930ab	1.550b	
0°C+Shelf life4d.	1.457b	2.900a	1.767a	1.693abc	1.763ab				
0°C+Shelf life6d.		3.000a							
<b>Sapphire</b>									
0°C	0.167c	0.090b	0.247c	0.503d	1.857a	1.580a	1.547ab	2.170a	0.834**
0°C+Shelf life2d.	0.147c	0.083b	0.263c	0.310de	1.823a	1.733a	1.797ab	2.340a	
0°C+Shelf life4d.	0.107c	0.217b	0.360c	0.437de	2.070a				
0°C+Shelf life6d.	0.090c	0.237b	0.467c	0.253e					
<b>Santa Rosa</b>									
0°C	2.367a	2.800a	1.233b	1.733ab	1.087d	1.437a	1.350b	1.410b	0.462
0°C+Shelf life2d.	2.267a	2.823a	1.333b	1.793ab	1.183cd	1.660a	1.990a	1.490b	
0°C+Shelf life4d.	2.400a	2.900a	1.527ab	1.857a	1.287bcd				
0°C+Shelf life6d.		2.987a							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

For shelf life fruits, there was no significant increase in peel anthocyanin content of all stored cvs. and the highest increasing changes recorded for Sapphire cv.

Similar results of peel anthocyanin increasing were reported on Green Gage plums by Guerra and Casquero, (2008). On the other hand, Cantin *et al.*, (2008) reported that after 60 days of cold storage plus 7 days ripening at 20°C, there was no difference in dark skin color of Friar plum fruits.

The increment in anthocyanin content may be due to the continued biosynthesis of phenolic compounds after harvest, related to the ripening process and that was

correlated with the activity of the enzymes of the anthocyanin biosynthetic pathway (Miguel *et al.*, 2004).

#### **Flesh Anthocyanin Content (mg /100 g):**

Flesh of Santa Rosa had the highest initial content of anthocyanin (table 7) compared with the other two cvs. Those initial contents increased during the first 12 days of cold storage then decreased with the advancing of cold storage in both seasons.

No significant changes were recorded during shelf life period for flesh anthocyanin content of all cvs. except the fruits kept for 6 days.



**Table 7. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Flesh Anthocyanin Content (mg/100g peel) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	0.207b	0.190c	0.347b	0.487ab	0.120ab	0.180bc	0.207ab	0.217a	0.032
0°C+Shelf life2d.	0.210b	0.207bc	0.367b	0.523ab	0.143ab	0.227b	0.227a	0.257a	
0°C+Shelf life4d.	0.223b	0.230abc	0.383b	0.530ab	0.151a				
0°C+Shelf life6d.		0.253abc							
<b>Sapphire</b>									
0°C	0.010c	0.017d	0.042c	0.079c	0.047c	0.054c	0.031c	0.033b	0.099
0°C+Shelf life2d.	0.013c	0.020d	0.093c	0.086c	0.043c	0.067c	0.043c	0.041b	
0°C+Shelf life4d.	0.015c	0.048d	0.135c	0.089c	0.045c				
0°C+Shelf life6d.	0.022c	0.058d	0.643a	0.213bc					
<b>Santa Rosa</b>									
0°C	0.330a	0.267abc	0.430b	0.690a	0.107b	0.150a	0.143b	0.197a	0.077
0°C+Shelf life2d.	0.333a	0.273ab	0.443b	0.703a	0.123ab	0.547a	0.157b	0.223a	
0°C+Shelf life4d.	0.343a	0.280ab	0.460b	0.717a	0.136ab				
0°C+Shelf life6d.		0.290a							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	0.230c	0.220a	0.367c	0.463a	0.133ab	0.273b	0.227ab	0.247a	0.017
0°C+Shelf life2d.	0.240c	0.227a	0.400bc	0.490a	0.163ab	0.310b	0.253a	0.273a	
0°C+Shelf life4d.	0.253c	0.243a	0.417bc	0.497a	0.177a				
0°C+Shelf life6d.		0.260a							
<b>Sapphire</b>									
0°C	0.011d	0.015b	0.047d	0.080b	0.049c	0.053c	0.032c	0.037b	0.112
0°C+Shelf life2d.	0.011d	0.010b	0.079d	0.083b	0.046c	0.062c	0.035c	0.044b	
0°C+Shelf life4d.	0.014d	0.045b	0.120d	0.140b	0.042c				
0°C+Shelf life6d.	0.028d	0.047b	0.760a	0.219b					
<b>Santa Rosa</b>									
0°C	0.347b	0.260a	0.463bc	0.583a	0.127b	0.510a	0.160b	0.210a	0.100
0°C+Shelf life2d.	0.353b	0.273a	0.483b	0.603a	0.138ab	0.570a	0.183b	0.233a	
0°C+Shelf life4d.	0.383a	0.272a	0.500b	0.617a	0.148ab				
0°C+Shelf life6d.		0.292a							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

The results of flesh anthocyanin increasing during storage and ripening were reported by Dong *et al.*, (2002) on Royal Zee plums; Candan *et al.*, (2006) on Blackamber plums; Manganaris *et al.*, (2007) on Harrow Sun plums and Cantin *et al.*, (2008) on Friar plums.

Flesh reddening is regarded as chilling injury symptom in stone fruits and associated with the normal ripening. Also, red pigment accumulation during cold storage and subsequent shelf life reported to be an ethylene dependent and associated with increasing phenylalanine ammonia-lyase enzyme activity Jiang *et al.*, (2001); Crisosto *et al.*, (2004); Lurie and Crisosto, (2005) and Manganaris *et al.*, (2007).

#### POD and PPO Enzymes Activity (O.D):

Sapphire fruits had the lowest initial POD activity in both seasons (table 8). During cold storage, POD activity of all cvs. decreased then increased again during the last intervals. Similar trend was reported for the fruits of shelf life of zero time cold storage period.

There was general trend of decreasing POD activity in shelf life fruits of all cvs. on the first 12 days of the experiment. During the last 16 days, POD activity of all cvs. increased when the fruits were transferred to 20°C.

**Table 8. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Peroxidase Activity (O.D) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	0.111a	0.089a	0.096a	0.080a	0.061de	0.055c	0.055b	0.064b	0.799**
0°C+Shelf life2d.	0.067de	0.081ab	0.077b	0.056b	0.072cd	0.096a	0.077ab	0.083ab	
0°C+Shelf life4d.	0.085bcd	0.066ab	0.071bc	0.053b	0.094ab				
0°C+Shelf life6d.									
<b>Sapphire</b>									
0°C	0.069de	0.071ab	0.066bc	0.070ab	0.071cd	0.070bc	0.110a	0.087a	0.430
0°C+Shelf life2d.	0.064de	0.063b	0.068bc	0.083a	0.081bc	0.096a	0.070ab	0.088a	
0°C+Shelf life4d.	0.061e	0.071ab	0.070bc	0.060b	0.067cde				
0°C+Shelf life6d.	0.076cde	0.080ab	0.083ab	0.058b					
<b>Santa Rosa</b>									
0°C	0.105ab	0.087ab	0.053cd	0.080a	0.050e	0.077b	0.071ab	0.082ab	0.105
0°C+Shelf life2d.	0.072cde	0.077ab	0.046d	0.059b	0.078bcd	0.100a	0.087ab	0.097a	
0°C+Shelf life4d.	0.095abc	0.065ab	0.100a	0.060b	0.099a				
0°C+Shelf life6d.		0.076ab							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	0.098a	0.066de	0.062cd	0.095a	0.062c	0.059b	0.069b	0.083b	0.061
0°C+Shelf life2d.	0.074abcd	0.089ab	0.051d	0.059de	0.066bc	0.098a	0.094a	0.104a	
0°C+Shelf life4d.	0.090abc	0.078abcd	0.061cd	0.052e	0.093a				
0°C+Shelf life6d.		0.057e							
<b>Sapphire</b>									
0°C	0.071cd	0.086abc	0.064cd	0.071bcd	0.061c	0.086a	0.059b	0.086b	0.004
0°C+Shelf life2d.	0.070cd	0.073bcde	0.069bc	0.086ab	0.078ab	0.089a	0.098a	0.089ab	
0°C+Shelf life4d.	0.059d	0.065de	0.061cd	0.060de	0.080ab				
0°C+Shelf life6d.	0.071cd	0.063de	0.098a	0.079bc					
<b>Santa Rosa</b>									
0°C	0.094abc	0.093a	0.070bc	0.079bc	0.055c	0.059b	0.070b	0.083b	0.251
0°C+Shelf life2d.	0.074abcd	0.092a	0.079b	0.068cd	0.094a	0.095a	0.089a	0.098ab	
0°C+Shelf life4d.	0.096ab	0.069cde	0.095a	0.056de	0.089a				
0°C+Shelf life6d.		0.088ab							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

The results of flesh anthocyanin increasing during storage and ripening were reported by Dong *et al.*, (2002) on Royal Zee plums; Candan *et al.*, (2006) on Blackamber plums; Manganaris *et al.*, (2007) on Harrow Sun plums and Cantín *et al.*, (2008) on Friar plums.

Flesh reddening is regarded as chilling injury symptom in stone fruits and associated with the normal ripening. Also, red pigment accumulation during cold storage and subsequent shelf life reported to be an ethylene dependent and associated with increasing phenylalanine ammonia-lyase enzyme activity Jiang *et*

*al.*, (2001); Crisosto *et al.*, (2004); Lurie and Crisosto, (2005) and Manganaris *et al.*, (2007).

#### POD and PPO Enzymes Activity (O.D):

Sapphire fruits had the lowest initial POD activity in both seasons (table 8). During cold storage, POD activity of all cvs. decreased then increased again during the last intervals. Similar trend was reported for the fruits of shelf life of zero time cold storage period.

There was general trend of decreasing POD activity in shelf life fruits of all cvs. on the first 12 days of the

**Table 9. Effect of Cold Storage at 0°C and Subsequent Storage at 20°C on Polyphenoloxidase Activity (O.D) of Plum Fruits in 2007 and 2008 Seasons**

Treatment	Cold storage period (days)								r <sup>2</sup>
	0	4	8	12	16	20	24	28	
<b>1<sup>st</sup> Season</b>									
<b>Celebration</b>									
0°C	0.030c	0.028c	0.025d	0.030bc	0.030b	0.051a	0.052a	0.048a	0.684*
0°C+Shelf life2d.	0.034bc	0.024cd	0.064a	0.051a	0.029bc	0.037b	0.039ab	0.050a	
0°C+Shelf life4d.	0.023cd	0.043ab	0.050b	0.057a	0.053a				
0°C+Shelf life6d.		0.050a							
<b>Sapphire</b>									
0°C	0.075a	0.023cd	0.023d	0.026cd	0.026bcd	0.034b	0.029b	0.023c	0.248
0°C+Shelf life2d.	0.047b	0.012d	0.034cd	0.039b	0.021d	0.024c	0.026b	0.015d	
0°C+Shelf life4d.	0.032c	0.025cd	0.025d	0.031bc	0.025bcd				
0°C+Shelf life6d.	0.031c	0.036abc	0.027d	0.017e					
<b>Santa Rosa</b>									
0°C	0.024cd	0.022cd	0.027d	0.020de	0.031b	0.049a	0.025b	0.032b	0.222
0°C+Shelf life2d.	0.015d	0.028c	0.043bc	0.026cde	0.029bc	0.034b	0.041ab	0.031b	
0°C+Shelf life4d.	0.032c	0.035bc	0.022d	0.033bc	0.024cd				
0°C+Shelf life6d.		0.023cd							
<b>2<sup>nd</sup> Season</b>									
<b>Celebration</b>									
0°C	0.022de	0.044a	0.033c	0.024cd	0.033b	0.053a	0.058a	0.055a	0.577*
0°C+Shelf life2d.	0.033bc	0.034bc	0.046b	0.047a	0.039b	0.041b	0.042b	0.062a	
0°C+Shelf life4d.	0.025cde	0.049a	0.060a	0.045ab	0.053a				
0°C+Shelf life6d.		0.044a							
<b>Sapphire</b>									
0°C	0.054a	0.021e	0.029cd	0.018d	0.033b	0.023d	0.029c	0.019c	0.269
0°C+Shelf life2d.	0.026cd	0.022e	0.023d	0.027cd	0.023cd	0.024cd	0.018d	0.021c	
0°C+Shelf life4d.	0.024de	0.024de	0.026cd	0.026cd	0.020d				
0°C+Shelf life6d.	0.013f	0.032bcd	0.024cd	0.021d					
<b>Santa Rosa</b>									
0°C	0.027cd	0.025cde	0.030cd	0.020d	0.033b	0.034bc	0.029c	0.034b	0.310
0°C+Shelf life2d.	0.017ef	0.027cde	0.026cd	0.035bc	0.031bc				
0°C+Shelf life4d.	0.036b	0.026cde	0.027cd	0.033c	0.024cd				
0°C+Shelf life6d.		0.039ab							

Means within columns (in same season) having a common letter are not significantly different.

r<sup>2</sup> = Determination coefficient

experiment. During the last 16 days, POD activity of all cvs. increased when the fruits were transferred to 20°C.

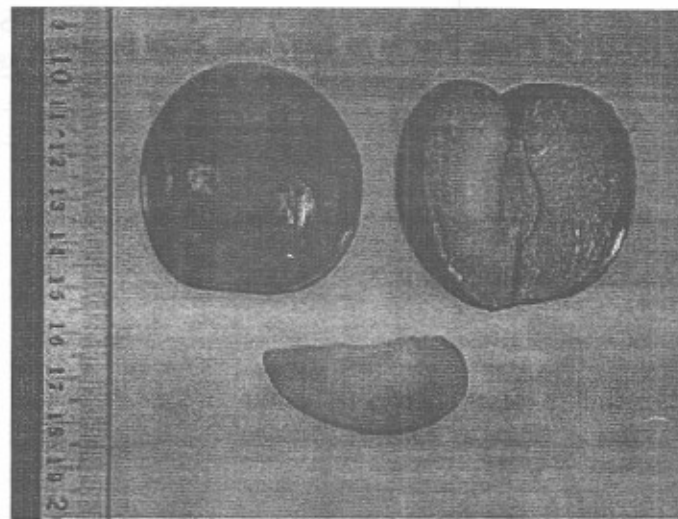
On the other hand, Sapphire fruits significantly had the highest initial values of PPO activity in 2007 and 2008 seasons (table 9). Those values decreased sharply by the end of cold storage period. Celebration and Santa Rosa cvs. showed contrast trend where the PPO activities showed an increasing trend with the progress of cold storage (r<sup>2</sup> values of Celebration were significant in both seasons).

Shelf life fruits of Celebration cv. showed an increasing trend during the storage at 20°C except the 20

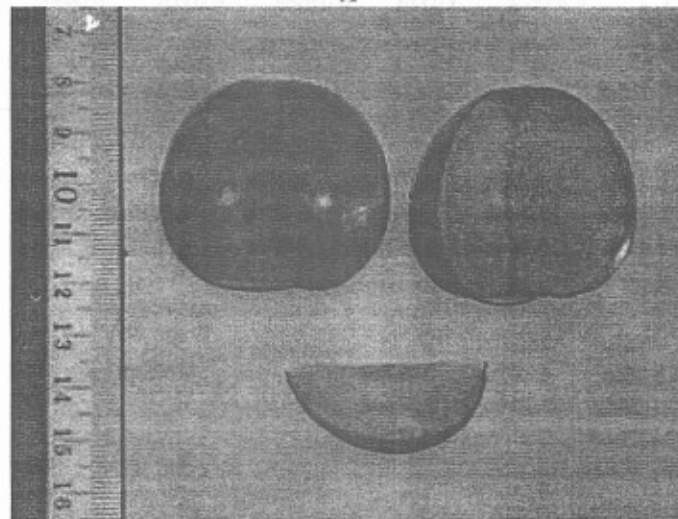
and 24 days intervals. The other two cvs. showed no constant trend during the shelf life intervals.

Larrigaudère *et al.* (2009) observed a significant increase of POD activity of Larry Ann plums during cold storage and reported that in plums, changes in POD activity are likely related to the ethylene signaling pathway.

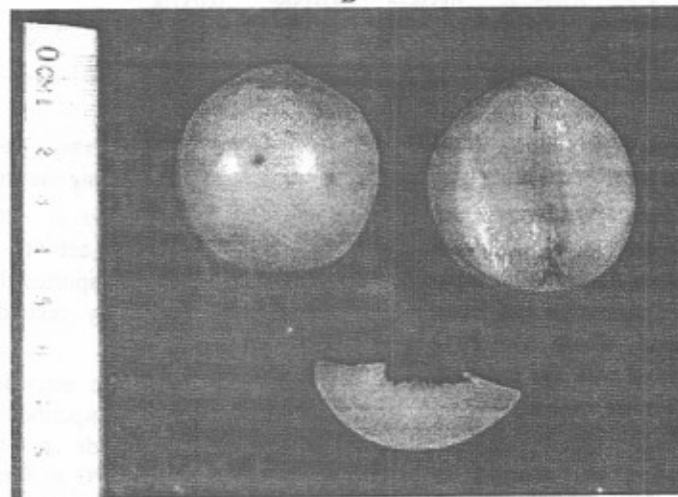
The enzymatic activities involve the oxidation of many organic compounds by POD in the presence of hydrogen peroxide or the oxidation of phenolic compounds by PPO to form quinines which are lightly unstable and polymerize quickly to form brown-colored products (Kader and Chordas, 1984).



A



B



C

Fig. 1. Initial Quality of Celebration (A), Santa Rosa (B) and Sapphire (C) Plum Fruits

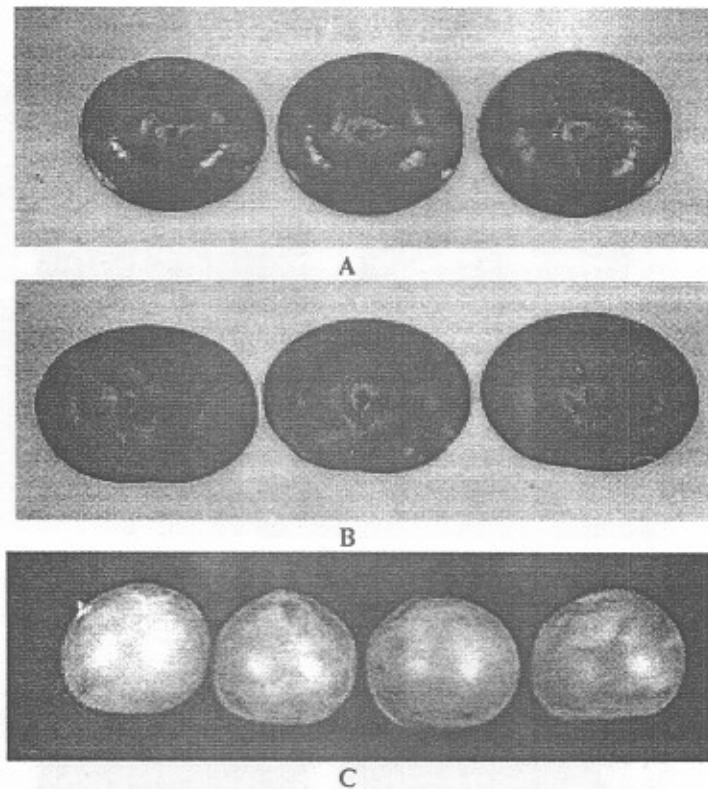


Fig. 2. Quality of Celebration (A), Santa Rosa (B) and Sapphire (C) Plum Fruits stored after Harvest at 20°C (zero time cold storage period)

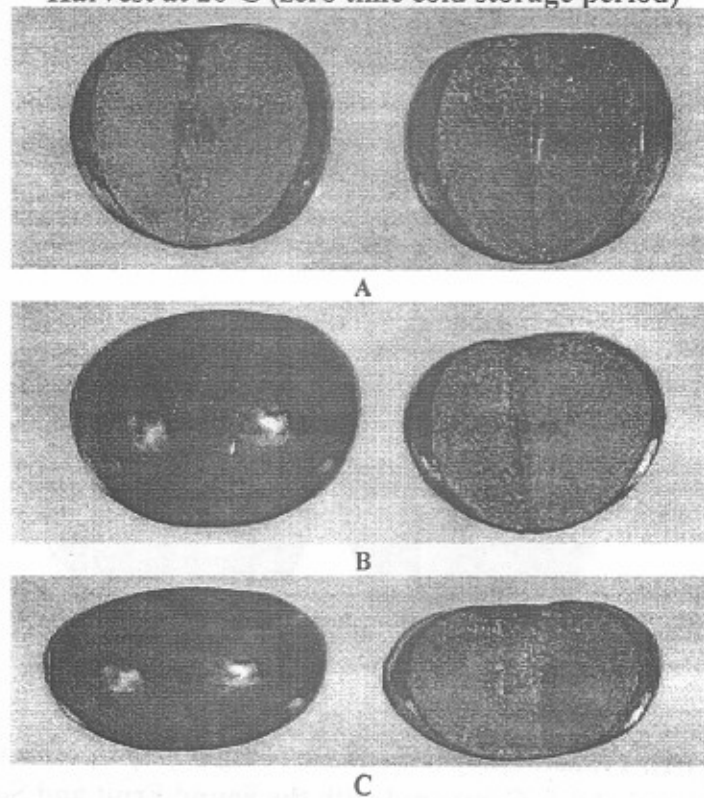
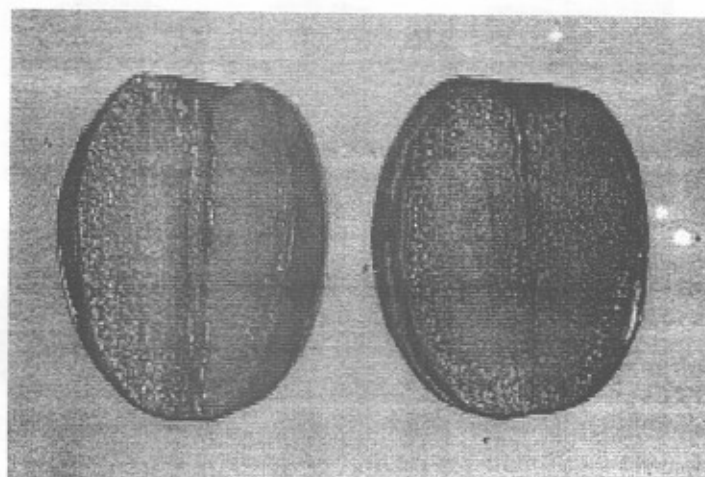
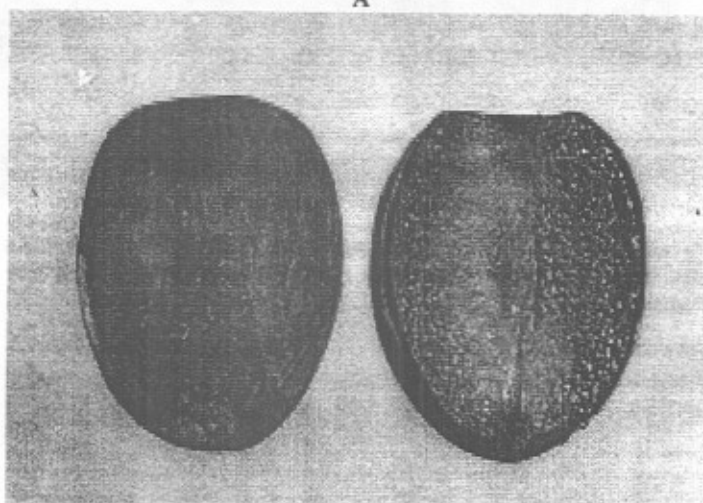


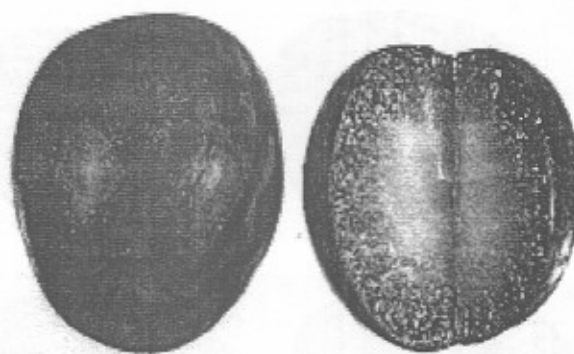
Fig. 3. Browning (A), Translucency (B) and Bleeding (C) Symptoms of Celebration Plum Fruits Stored at 0°C Compared with the Sound Fruit and Sound Flesh



A



B



C

**Fig. 4. Browning (A), Translucency (B) and Bleeding (C) Symptoms of Santa Rosa Plum Fruits Stored at 0°C Compared with the Sound Fruit and Sound Flesh**

Fig. 3. Browning

Fruits stored

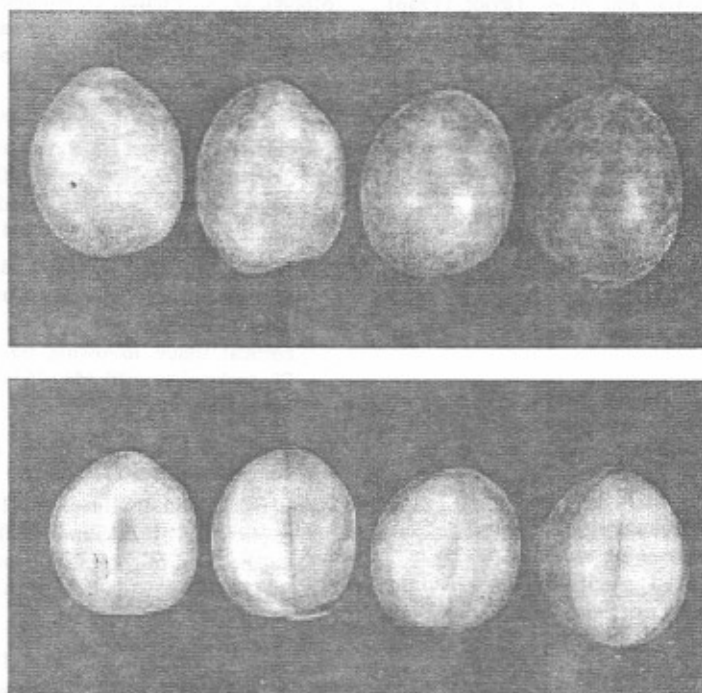


Fig. 5. Final Quality of Sapphire Plum Fruits Stored at 0°C

From the above results it was concluded that the fruit anthocyanin content and its enzymes activity are in relation with the browning potential of plum fruits and then with the storage and shelf life potential.

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## الملخص العربي

### محتوى الأنثوسيانين، نشاط أنزيمي البيروكسيداز والبولي فينول أوكسيداز وعلاقتها بالتلون البني لثمار البرقوق سليبريشن وسابفير وسانتا روزا أثناء التخزين المبرد

رجاء موسى الصعیدی، نرمين إسماعيل النجار

غالباً لم يكن هناك تغير معنوي في محتوى المواد الصلبة الذائبة عند نقل الثمار من التخزين المبرد إلى ٢٠ م. احتوت ثمار الصنف سليبريشن على أقل نسبة حموضة عند الجمع و خلال فترة التخزين المبرد الأولى (٨ و٤ أيام) انخفض محتوى الحموضة لكل الأصناف قليلاً لكنه زاد عند نقل الثمار من التخزين المبرد إلى ٢٠ م. انخفضت حموضة كل الثمار مع تقدم التخزين المبرد بالمقارنة بمحتواها عند الجمع و انخفضت أيضاً عند نقل الثمار من التخزين المبرد إلى ٢٠ م. قل محتوى قشرة ثمار الصنف سانت روزا من الأنثوسيانين مع التخزين المبرد في حين زاد هذا المحتوى قليلاً لثمار الصنف سليبريشن، و من ناحية أخرى أظهر الصنف الأصفر سابفير أعلى زيادة لمحتوى قشرة الثمار من الأنثوسيانين. احتوى لحم ثمار سانتا روزا عند الجمع على أعلى نسبة من الأنثوسيانين بالمقارنة بالصنفين الآخرين و كل هذه القيم زادت خلال ١٢ يوم الأولى من التخزين المبرد ثم قلت بعد ذلك. انخفض نشاط أنزيم البيروكسيداز خلال التخزين المبرد لجميع الأصناف ثم ارتفع مرة أخرى في نهاية التخزين. كان هناك اتجاه عام لانخفاض نشاط البيروكسيداز و وجد نفس الاتجاه للنقص بعد ١٢ يوم ثم الزيادة بعد ١٦ يوم للثمار التي تم نقلها من التخزين المبرد إلى ٢٠ م. احتوت ثمار الصنف سابفير عند الجمع على أعلى قيم لنشاط أنزيم البوليفينول أوكسيداز و قد انخفضت بوضوح مع نهاية التخزين و على العكس في الصنفين الآخرين حيث زاد النشاط مع تقدم التخزين المبرد.

أجريت هذه الدراسة خلال موسمي ٢٠٠٧ و ٢٠٠٨ على صنفين برفوق مستقدمين (من جنوب أفريقيا) هما سليبريشن وسابفير بالمقارنة بالصنف سانتا روزا المتررع بمصر. تم تخزين الثمار على درجة صفر م و رطوبة نسبية ٨٥-٩٠ % و تم متابعة الخواص الفسيو-كيميائية للثمار المخزنة كل ٤ أيام مع نقل عينة إلى ٢٠ م و متابعتها بعد ٢ و ٤ و ٦ أيام. و لقد أوضحت الدراسة أنه يمكن تخزين ثمار جميع الأصناف على صفر م لمدة ٢٨ يوم بصلابة جيدة لكنها فقدت صلابتها و بريقها عند نقلها من التخزين المبرد إلى ٢٠ م. و قد ظهرت علامات أضرار البرودة في فترتي التخزين المبرد الأخيرتين (٢٤ و ٢٨ يوم) عند نقل الثمار إلى ٢٠ م على هيئة تلون بني و زيادة نضج و تحول اللحم للون الأحمر. خلال التخزين على صفر م، كان للصنف سليبريشن أعلى نسب فقد وزن و قد زاد فقد وزن كل الأصناف معنويًا مع تقدم التخزين المبرد. كانت متوسطات فقد الوزن لثمار جميع الأصناف التي تم نقلها بعد التخزين المبرد إلى ٢٠ م أقل من ١ % بعد يومين و كانت أقل نسب للصنف سابفير. بعد ٨ أيام على صفر م ثم نقل الثمار إلى ٢٠ م الصنف سابفير كانت له أطول مدة تخزين مع أقل فقد صلابة. بعد ١٦ يوم من التخزين المبرد ثمار كل الأصناف كان لها صلابة جيدة لكن عند نقلها إلى ٢٠ م قلت الصلابة معنويًا بعد ٢ و ٤ أيام. فقدت ثمار الصنف سانتا روزا بعد التخزين المبرد أعلى نسبة من المواد الصلبة الذائبة بالمقارنة بالصنف سليبريشن و الصنف سابفير.