

Postharvest quality and shelf life of green pepper (*Capsicum annuum* L.) grown under open-field and greenhouse conditions

*Calidad de postcosecha y vida de anaquel de chile verde (Capsicum annuum L.)
cultivado bajo condiciones de campo abierto e invernadero*

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ABSTRACT

In order to assess the influence of two production systems on postharvest quality and shelf life of two green pepper hybrids (*Capsicum annuum* L.), Anaheim-types 'Cardon' (mild hot) and '118' (mid hot), two experiments were carried out. In the first, plants were grown in open-field, and in the second under greenhouse conditions (soil directly and soilless). From each production system, fifty freshly harvested fruits were picked and stored at 20 °C during 14 days. Weight loss, color analysis measured as lightness (L), chromaticity (C), and shade (°Hue), pH, titratable acidity, and total soluble solids were determined every three days until each individual fruit was considered unacceptable for sale. The results indicated that 'Cardon' grown in soil-greenhouse showed the highest weight loss (38.1%), followed by 'Cardon' and '118' grown in open-field conditions (37.5 and 35%, respectively). Hydroponic-greenhouse 'Cardon' presented the lowest weight loss (24.9%). Luminosity in fresh fruit was greater in hydroponic-greenhouse 'Cardon'. Fruit chromaticity and tone began to decrease at four days after harvest (DAH) changing color from the green color tone until a final red color at 14 DAH. The pH changed from 4.62 to 5.91 while titratable acidity changed from 0.14 to 0.37 (% of citric acid) and the total soluble solids changed from 3.4 to 10 °Brix. Fresh chile pepper grown under hydroponic-greenhouse conditions presented a better quality and shelf life (10 DAH) while those in open-field conditions showed a marketing limit of 5 DAH.

Key words: Anaheim Chile, postharvest, fruit quality, shelf life.

RESUMEN

A fin de evaluar la influencia de dos sistemas de producción en la calidad de postcosecha y vida de anaquel de dos híbridos de chile verde (*Capsicum annuum* L.) tipo Anaheim de nombres 'Cardón' (picosidad leve) y '118' (picosidad media), dos experimentos fueron llevados a cabo. En el primero, plantas de chile fueron cultivadas en condiciones de campo abierto y en el segundo bajo condiciones de invernadero (directamente en el suelo y sin suelo). De cada sistema se cosecharon cincuenta frutos frescos y fueron almacenados a 20 °C durante 14 días y la pérdida de peso, análisis de color como la luminosidad (L), cromaticidad (C) y tono (°Hue), pH, acidez titulable y sólidos solubles totales fueron determinados cada tercer día hasta que cada fruto individual fue considerado inaceptable para su venta. Los resultados indicaron que 'Cardón' cultivado directamente en el suelo dentro del invernadero mostró la pérdida de peso más alta (38,1%), seguido por 'Cardón' y '118' cultivados en condiciones de campo abierto (37,5 y 35%, respectivamente), presentando 'Cardón' cultivado en condiciones hidropónicas en el invernadero la pérdida de peso más baja (24,9%). La luminosidad en los frutos frescos fue más alta en 'Cardón' cultivado hidropónicamente en el invernadero. La cromaticidad y tono del fruto comenzaron a disminuir a los cuatro días después de la cosecha (DDC), cambiando de color de un tono verde hasta un color rojo a los 14 DDC. El pH cambió de 4,62 a 5,91, mientras la acidez titulable cambió de 0,14 a 0,37% y los sólidos solubles totales aumentaron de 3,4 a 10 °Brix. Chiles verdes frescos cultivados hidropónicamente bajo condiciones de invernadero presentaron una mejor calidad y vida de anaquel (10 DDC), mientras que aquellos cosechados en condiciones de campo abierto mostraron un límite de mercado de 5 DDC.

Palabras clave: Chile Anaheim, postcosecha, calidad de fruto, vida de anaquel.

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Introduction

Chile pepper is a popular vegetable consumed fresh or in a variety of processed products in many cuisines worldwide. It is known fact that chile pepper is a symbolic part as much in the cultural aspect as in the culinary art of Mexico. This fruit is everywhere, in markets, food stalls, industrial food, in all dishes, even children's candies, as they are eaten from an early age (Katz, 2009).

Fresh green chile peppers are highly perishable and are preferentially consumed in fresh; in consequence, the fruit quality and shelf life are important factors in its commercial value. Temperature management is the most effective tool for extending the shelf life of fresh horticultural commodities. Cooling peppers as soon as possible after harvest will extend their shelf life. Once the fruit is cooled, peppers can be stored for two to three weeks under the proper conditions (Coolong, 2010). The external appearance of fruits, particularly their color, is of crucial importance when considering the different characteristics which define quality, and in the case of fruits destined for fresh consumption, a visual impression which does not coincide with the established standard easily leads to refusal (Gómez-Ladrón de Guevara *et al.*, 1996).

In recent years extending shelf-life of this perishable fruit has been accomplished (Banaras *et al.*, 2005). The losses in vegetable quality and quantity between harvest and consumption affect the crop productivity. It is estimated that the magnitude of the postharvest losses of fresh horticultural crops is from 5 to 25% in developed countries and of 20 to 50% in developing countries (Kader, 2007).

Actually, the commercialization with high levels of quality and food safety is becoming little by little the key in success of the national or international trade (Avendaño *et al.*, 2006). Unfortunately there is little information about the postharvest quality behavior of green chile pepper produced in México. Therefore, this study was carried out to characterize postharvest water loss and the evolution of color during fruit ripening and shelf life in two hybrids of completely developed green chile pepper in two production systems. In addition, the final quality of each hybrid was determined.

Materials and Methods

This study was carried out during the summer-fall season of 2011 at the Experimental Field of The

University of Sonora located at Hermosillo, Sonora, México (29° 00 51" N, 111° 07 59" W) with a very arid, and hot climate. The study consisted of two experiments, one at open-field conditions transplanted on August 24 and the other under greenhouse conditions transplanted on August 24. In this last condition, pepper plants were transplanted in two ways: directly in the soil, and in 3-gallons plastic bags. In both experiments, fruits of two Anaheim chile pepper (*Capsicum annuum* L.) F-1 hybrids ('Cardon' and '118') were harvested manually and subsequently used. The open-field experiment was fertilized with a 145N-85P-190K-55Ca-45Mg kg ha⁻¹ formula and a density of 25,000 plants ha⁻¹ using a drip (tape) irrigation system in a sandy loam soil. Under greenhouse conditions, the two cultivars were planted directly in the soil (sandy loam), irrigated with a drip (tape) irrigation system and fertilized with a 290N-155P-380K-110Ca-85Mg kg ha⁻¹ formula. In the second system, seedlings of both cultivars were planted in perlite-peat moss mix (1:1) substrates in plastic bags fertilized with a nutrient solution proposed by Sonneveld and Straver (1994) with an EC of 2.0 dS m⁻¹ and adjusted pH of 6.0. The plant density in both greenhouse systems was 33,000 plants ha⁻¹.

Fifty fresh mature fruits of each system were harvested manually on January 28, 2012 and subsequently stored at 20 °C during 14 days. The following parameters were evaluated:

Fruit weight loss

Fruit weight loss was determined by weighing freshly harvested fruits every day until no weight change occurred. Ten fruits of each treatment were selected and weighed individually. The results were expressed as percentage of loss from initial weight (Díaz-Pérez *et al.*, 2007). Weight changes were calculated using the following formula:

$$\% \text{ weight loss} = \frac{100\% - (\text{storage peppers wt} \times 100\%)}{\text{initial fresh wt}}$$

Color analysis

An X-Rite® SP60 sphere spectrophotometer was used to measure lightness (L), chromaticity (C), and shade (°Hue) over the same fruit face every three days. Ten fruits of each treatment were used to measure these color characteristics.

pH, Titratable acidity, and Total Soluble Solids

Extracts for pH, titratable acidity (TA) and total soluble solids (TSS) were obtained according to AOAC (1998). From each treatment, three samples of 10 g of chile pepper fruit pulp was liquefied in 50 mL distilled water pH 7.0. Subsequently the mixture was filtered and the pH was measured with a Hach HQ11d digital potentiometer. To determine the TA (% citric acid), a 10 mL aliquot was taken from the extract which was titrated in a Mettler Toledo DL-50 automatic titrator with 0.1 N NaOH to an end point of pH = 8.2. To determine the TSS, 1.0 mL aliquot was placed in a Reichert AR200 digital refractometer and the results were expressed in °Brix.

Visual fruit quality

A rating scale for assessing chile pepper visual quality was based on the following subjective values: 9 = excellent, 7 = good, 5 = regular, 3 = fair and 1 = unusable, where an average of 6 is fruit in the limit of shelf life. Observations in 10 fruits of each treatment were made each three days and changes in the general appearance of the fruit were recorded (Kader and Cantwell, 2010).

Statistical analysis

Each experiment was set up using a completely randomized design. Analysis of variance (ANOVA) was conducted using GLM procedure with mean separation performed by a Tukey test in a multiple comparison procedure at a significance level of 0.05 using the SAS package version 9.0 (Statistical Analysis System Institute Inc., 2006).

Results and Discussion

Fruit weight loss

In this study, peppers in all the conditions exhibited a general reduction in weight as expected (Fig. 1). ANOVA (data not shown) on weight loss of fruits of two green pepper hybrids stored at 20 °C showed significant variations ($P \leq 0.05$) during the storage period. At harvest, 'Cardon' from hydroponic-greenhouse conditions had significantly more weight content than 'Cardon' grown under both soil-greenhouse and open-field conditions. The 118 pepper hybrid did not show difference in water loss in both open-field and greenhouse conditions. After 14 days, hydroponic-grown 'Cardon', soil-greenhouse grown '118' and hydroponic-grown

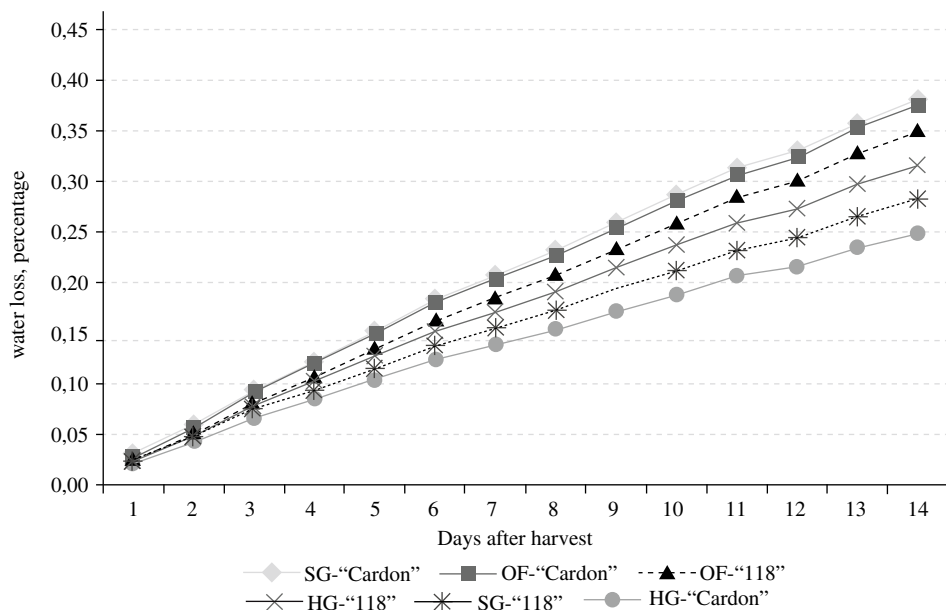


Figure 1. Cumulative weight (water) loss as percentage of initial weight of two green peppers hybrids stored at 20 °C for 14 days grown under different conditions (HG = Hydroponic-Greenhouse; SG = Soil- Greenhouse; OF = Open-Field).

'118' lost 24.9, 28.2 and 31.6 %, respectively. Under open-field conditions, '118' and 'Cardon' lost 35.0 and 37.5 % and finally, 'Cardon' grown in soil-greenhouse had a weight loss of 38.1% at the end of the storage period (Figure 1).

Smith *et al.* (2006) establish that one of the principal physiological factors that negatively impacts pepper fruit quality during shipment and storage and subsequent marketing is water loss. The quality of most fruits and vegetables declines very fast with only small weight loss (3% to 10%) and may make them unacceptable for sale (Robinson *et al.*, 1975). Anaheim or New Mexican-type peppers become flaccid in 3 to 5 days at 20 °C (7% to 10% weight loss) and lose water twice as fast as bell or jalapeño types (Lownd and Bosland, 1988). Diaz-Perez *et al.* (2007) mention that the weight loss rates in pepper is smaller as the size and maturity of the fruit increase. Wills *et al.* (1998) reported that a 5% weight loss in bell pepper is the maximum allowed. In our study, a fruit weight loss of 10% that occurred between 3 and 5 DAH resulted in poor appearance of the fruit.

Fruit color components

Fruit luminosity. The value on luminosity behavior during the 14 days is observed in Table 1 where both 'Cardon' and '118' grown under hydroponic-greenhouse conditions exhibited the higher luminosity (38-40 values). In contrast, '118' grown in soil-greenhouse and 'Cardon' grown in open-field conditions presented the lower values in luminosity (33-34). Luminosity values increased with storage time. However, significant differences were observed only during the first 6 DAH. Fruit color turned to matte green increasing luminosity values in all treatments at 14 days after harvest indicating a fruit lightening. In our results the slight increase of luminosity during fruit ripening probably indicated that fruits become lighter by changing in color from green to yellow-red as is indicated by Kader and Cantwell (2010) in the color scale for green peppers. The luminosity increases were comparable to luminosity values for bell peppers (Fox *et al.*, 2005). Contrarily to these results, Pérez- López *et al.*, (2007) found that as luminosity decreases, pepper fruits become darker.

Fruit chromaticity. In general, chromaticity increased in all treatments due to turning in fruit color. Similarly as luminosity, significant differences in

fruit chromaticity were observed during first 6 DAH: Fruits grown in greenhouse conditions maintained the highest chromaticity values (Table 1) indicating fruit color more intense while those grown in field conditions or soil-greenhouse presented the lowest chromaticity values. Likewise, this study indicated that fruit chromaticity increased with storage time. Gómez-Ladrón de Guevara *et al.* (1996) found that all chromaticity values in paprika pepper move from the negative a^* (green component) to the positive a^* values (red component). Similar results were obtained by Fox *et al.* (2005) in bell pepper when developed typical red color during storage. Ferrer and Costa (1991) argue that at different stages of fruit ripening, green chromaticity value decreases, due to the disappearance of chlorophyll and the gradual increase in the chromoplasts or polyphenol compounds present in the tissues to contribute varying degrees of enzymatic browning (Lee, 1992).

Fruit tone. The pepper fruits had hue angle that were in the 80° to 120° values of the color sphere, that is, from green skinned to red-orange. Tone (°Hue) changes were insignificant but decreasing with the treatment time (Table 1). After four days of storage, fruits of all treatments kept a green color (average Hue values of 117), turning to a clear green during the sixth day (average Hue values of 109), and yellowish green at the eighth day (average Hue values of 103). At tenth day, fruits turning their color to yellow, continuing to a red-yellowish (average Hue values of 94), and finally to red at 14th day (average Hue values of 81). Initial ripening hue angle (°Hue = 120) agree on those obtained by Gómez-Ladrón de Guevara and Pardo-González (1966) on 13 paprika pepper varieties, and advanced stage of ripening (°Hue = 79) determined by Barrera *et al.* (2005) in hot pepper. Mizrach *et al.* (2009) report that under certain conditions the green peppers begin to ripen, become lighter and change color during storage. Hornero-Mendez and Minguez-Mosquera (2002) state that in many fruits including *Capsicum* species, there is a strong reduction in chlorophyll content associated with an increase in the synthesis of carotenoids as a result of the conversion of chloroplasts to chromoplasts.

pH, Titratable acidity, and Total Soluble Solids

Pepper fruits from each treatment had pH values that ranged from 4.62 to 5.91. These changes are

Table 1. Development of fruit colour components of two green peppers hybrids stored at 20 °C for 14 days grown under different conditions (HG = Hydroponic-Greenhouse; SG = Soil-Greenhouse; OF = Open-Field).

Factor	Treatment	Days after harvest							
		0	2	4	6	8	10	12	14
Luminosity	HG - 'Cardón'	40.19 a ²	39.10 a	40.20 a	40.64 a	40.06 a	40.98 a	42.25 a	41.84 a
	HG - '118'	37.96 ab	39.07 a	36.89 a	39.89 a	39.55 a	39.93 a	40.59 a	38.93 a
	SG - 'Cardón'	36.15 abc	37.47 ab	36.33 a	40.44 a	39.59 a	39.76 a	40.50 a	39.98 a
	OF - '118'	35.40 bc	37.37 ab	35.46 ab	39.20 ab	38.31 a	39.43 a	39.49 a	38.85 a
	OF - 'Cardón'	34.32 bc	32.53 ab	35.72 ab	38.79 ab	38.16 a	38.77 a	38.91 a	38.73 a
	SG - '118'	33.15 c	35.09 b	35.34 b	36.32 b	38.04 a	38.25 a	38.84 a	38.20 a
	Significance ¹	*	*	**	*	NS	NS	NS	NS
Chromaticity	HG - 'Cardón'	22.94 a	22.95 a	22.69 a	24.16 a	23.00 a	25.03 a	30.65 a	35.65 a
	HG - '118'	20.13 ab	20.13 ab	19.26 ab	22.72 ab	22.49 a	27.13 a	29.90 a	28.12 a
	SG - 'Cardón'	17.76 b	19.86 abc	17.70 ab	24.43 a	26.13 a	27.86 a	29.44 a	30.74 a
	OF - '118'	17.17 b	20.22 abc	16.55 b	21.72 ab	21.58 a	24.29 a	27.08 a	28.30 a
	OF - 'Cardón'	16.25 b	18.57 b	17.99 ab	22.81 ab	24.26 a	28.00 a	30.06 a	30.92 a
	SG - '118'	15.62 b	16.65 c	17.10 b	17.51 b	20.30 a	22.01 a	24.19 a	25.68 a
	Significance	*	**	*	*	NS	NS	NS	NS
Tone (°Hue)	HG ¹ - 'Cardón'	115.4 a ³	115.9 a	115.5 a	115.6 a	114.1 a	100.0 a	85.0 a	74.5 a
	HG - '118'	116.6 a	115.9 a	117.6 a	112.4 a	110.6 a	96.6 a	87.2 a	81.4 a
	SG - 'Cardón'	116.6 a	116.5 a	112.1 a	101.5 a	94.3 a	92.9 a	90.8 a	86.8 a
	OF - '118'	117.7 a	117.0 a	118.3 a	111.4 a	104.7 a	93.7 a	89.9 a	82.6 a
	OF - 'Cardón'	118.7 a	118.0 a	109.4 a	97.3 a	90.8 a	82.0 a	79.9 a	73.3 a
	SG - '118'	118.0 a	119.1 a	118.1 a	117.6 a	107.7 a	100.6 a	94.4 a	87.0 a
	Significance	NS	NS	NS	NS	NS	NS	NS	NS

¹** = highly significant; * = significant; NS = not significant.

² Means with the same letter within each column are significantly equal (Tukey $p \leq 0.05$).

attributed to the organic acids present in the vegetal tissue (Salisbury and Ross, 1994). The contents of titratable acidity were affected by the storage period and presented statistical differences among treatments (Table 2). Within the greenhouse, green pepper grown hydroponically had significantly greater citric acid content than those planted directly in the soil. In open-field, 'Cardón' contained the highest and '118' the lowest amount of citric acid. Results of TA values are comparable with values found in green and red bell pepper by Castro *et al.* (2008).

Similarly, TSS was relatively lower in all treatments (Table 3). The lowest TSS was observed

in both varieties grown in soil-greenhouse conditions, averaging 3.9 to 7.1 °Brix (initial and final storage time, respectively). The highest TSS was detected in green peppers harvested from hydroponic- greenhouse conditions (5.5 to 9.2 °Brix). Intermediate values were observed in pepper fruits harvested from field conditions (5.1 to 7.7 °Brix). Highest values in TA observed in pepper grown in hydroponic conditions coincided with fruits more intense in luminosity and consistent also with the highest values of TSS. Fox *et al.* (2005) found that TSS varied from 6.1 to 7.9 °Brix in pepper grown hydroponically in greenhouse.

Table 2. Behavior of acidity (% citric acid) in of two green peppers hybrids stored at 20 °C for 14 days grown under different conditions (HG = Hydroponic-Greenhouse; SG = Soil-Greenhouse; OF = Open-Field).

Treatment	Days after harvest							
	0	2	4	6	8	10	12	14
SG - '118'	0.14 b ²	0.14 bc	0.21 ab	0.20 b	0.18 c	0.12 c	0.23 ab	0.27 b
SG - 'Cardón'	0.14 b	0.12 c	0.15 b	0.20 b	0.25 b	0.18 b	0.20 b	0.23 b
HG - '118'	0.17 ab	0.13 bc	0.23 a	0.27 ab	0.28 b	0.37 a	0.18 b	0.37 a
HG - 'Cardón'	0.14 b	0.17 ab	0.28 a	0.20 b	0.28 b	0.12 c	0.33 a	0.37 a
OF - '118'	0.19 ab	0.17 ab	0.29 a	0.24 ab	0.23 b	0.33 a	0.29 ab	0.28 b
OF - 'Cardón'	0.22 a	0.21 a	0.28 a	0.32 a	0.43 a	0.22 b	0.29 ab	0.37 a
Significance ¹	*	*	*	*	*	**	*	*

¹** = highly significant; * = significant; NS = not significant.

² Means with the same letter within each column are significantly equal (Tukey $p \leq 0.05$).

Table 3. Behavior of total soluble solids (°Brix) of two green peppers hybrids stored at 20 °C for 14 days grown under different conditions (HG = Hydroponic-Greenhouse; SG = Soil-Greenhouse; OF = Open-Field).

Treatment	Days after harvest							
	0	2	4	6	8	10	12	14
SG ¹ - '118'	4.4ab ²	5.0 b	5.2 d	7.8 a	6.6 ab	3.2 d	7.4 a	7.2 ab
SG - 'Cardón'	3.4 b	4.2 c	5.8 cd	7.2 ab	6.8 ab	5.6 c	6.4 a	7.0 b
HG - '118'	5.6 a	6.0 a	8.8 a	8.2 a	7.0 ab	9.8 a	7.2 a	10.0 a
HG - 'Cardón'	5.4 a	5.2 b	6.8 bc	6.2 b	7.0 ab	6.4 bc	7.8 a	8.4 ab
OF - '118'	5.2 a	6.2 a	7.4 ab	7.8 a	5.4 b	7.6 b	6.4 a	7.8 ab
OF - 'Cardón'	5.0 a	5.2 b	7.2 bc	7.8 a	8.2 a	6.8 bc	6.6 a	7.6 ab
Significance ¹	*	**	**	*	*	**	NS	*

¹** = highly significant; * = significant; NS = not significant.

² Means with the same letter within each column are significantly equal (Tukey $p \leq 0.05$).

Visual fruit quality

According to the appearance rating scale fruits harvested from open-field conditions reached its limit shelf life at three days after harvest while in Cardon fruits harvested from soil-greenhouse conditions its limit was 5 DAH. The others treatments reached the shelf life limit between 9 and 10 days. All fruits had an extremely poor fruit quality at 14 DAH, that is, fruits not usable. Kader (2002) reported that the qualitative aspects of quality have become more important than quantitative, because the sensory quality is the aspect that most directly affects the purchase decision. In our study, the overall external appearance changed with increasing storage period.

'Cardon' fruits had higher chromaticity values than fruits from '118' which means that these fruits attract more the attention.

Conclusions

Findings suggest that Anaheim pepper fruits produced under both soil- and hydroponic-greenhouse conditions presented the best quality and the major marketing limit, that is, more shelf life. Quality improved in pepper fruits grown in greenhouse conditions in terms of lower water loss, greater citric acid content, higher total soluble solids, and positive effects on some fruit color attribute like a green color more brilliant and intense.

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