

Effect Of Light Environment On Harvest Quality And Postharvest Behavior Of Minimally Processed Sweet Pepper

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Abstract

The aim of this study was to evaluate the effect of two light environments on two maturity stages of sweet pepper and the postharvest behavior of minimally processed product using passive modified atmosphere. The size and fruit morphology were measured at harvest. Overall visual quality, gas concentration inside the bags, weight loss, soluble solids, firmness, electrolyte leakage, carotenoids and ascorbic acid were determined during the storage period. Results showed that quality parameters were affected by radiation and processing. Shaded pepper fruits showed higher water content and lower size compared to fruits exposed to full radiation. Fruit nutritional value was maintained, but after six days was not marketable. Visual quality of intact fruit was not affected without differences between treatments. Shelf life processed red fruits as julienne was reduced, being the worst performing during storage. Post-harvest visual quality was in relation to gases composition (O₂ and CO₂) inside the trays.

Keywords: *Capsicum* sp, radiation, modified atmosphere, appearance, nutrition value.

Introduction:

Sweet pepper is widely distributed in Argentina. Abiotic stress by high or low temperature, water deficit, salinity, excess or reduction of radiation has great influence on the yield and quality of the crop.

Fruits and vegetables quality depend on preharvest, harvest and postharvest conditions. Radiation level is reported as the first and most important climate factor. Radiation intensity has the ability to modify plant and fruit morphology and the fruit composition. According to Azcón-Bieto and Heel (2000) leaves grown in weak light conditions may reach a greater surface area than those developed in bright light. Jaimez and Rada (2006) found that plants without shade and under 40% shade showed no significant differences, Jaimez et al. (2010) concluded that shadow under 40% increased production as a consequence of increasing of fruit number and weight per plant.

Vitamin C (including ascorbic acid + dehydroascorbic acid) is one of the most important nutritional value parameter and it has diverse biological activity in the human body. Sweet pepper fruit provides vitamin C and vitamin A, flavonoids and antioxidants too (Lee and Kader, 2000).

There are dramatic qualitative and quantitative changes during sweet pepper ripening (Rodriguez-Amaya et al., 2008) like carotenoids synthesis (Hornero-Méndez et al., 2000), and their accumulation (Howard et al., 1994; Markus et al., 1999; Navarro et al., 2006; Xavier and Pérez-Gálvez, 2016).

The aim of this study was to evaluate the effect of two light environments on sweet pepper harvest and on their postharvest behavior in two stages of pepper fruit maturity, minimally processed (intact and julienne), stored in passive modified atmosphere in refrigerated chamber.

Material and methods:

Plant Material

This work was carried out in the experimental field of the Department of Horticulture, in a parabolic, metallic NE-NW oriented greenhouse (34°58'31'). Pepper plants (*Capsicum annuum* L.cv Yatasto) were transplanted in plastic containers filled up with a mixture of substrate (1perlite:1peat). Plant density was 2 plants/m². Fertirrigation with a complete nutrient solution was applied. The light treatments were: a) plants with shade screen (50 %) and b) unshaded plants (100%). Plants were conducted to 3 stems. Air temperature (°C), substrate temperature (°C), relative humidity (%) and radiation intensity (lum/feet²) were recorded every hour.

At harvest, fruits were classified as: a) immature green fruit and b) mature red fruit. Fruits harvested were separated in two groups: a) intact fruits and b) cut fruits into julienne (12 x 1cm) manually with a steel knife properly sharpened. All treatments were packed in passive modified

atmosphere using an expanded polystyrene tray covered with PVC film with the following properties: 0.0177 mm thickness, oxygen and carbon dioxide permeability 11.232 and 48.552 cm³/m²/atm/day respectively, and water permeability of 40 g/m²/ day. All trays were stored in refrigerated chamber at 10°C for 12 days. Thirty fruits per treatment were used.

Measurements

Fruits morphology: length, width and thickness of fruit were measured. Numbers of cores and fruit weight were recorded. Results were expressed in the following units according to their respective magnitudes: centimeter (cm), square feet (cm²), cubic centimeter (cm³) and gram (g).

Dry matter: Fruits were dried in an oven for 48 hours at 75°C to constant weight, and dry matter (%) was calculated.

Overall visual quality: according to Özden and Bayindirli scale (2002).

Surface colour: Three colour determinations along the equatorial axis were taken for each fruit (Minolta CR 300 colorimeter). Colourimeter parameters: the lightens L* ranges from no reflection (L*= 0; Black) to perfect diffuse reflection (L*=100, white), a* is a positive or negative coordinate defining a locus relative to a purplish-red-bluish-green axis, and b* is positive or negative coordinate defining a locus relative to a yellow-blue axis. Numerical values of a* and b* are converts into saturation variable or chroma ($C = \sqrt{a^2 + b^2}$), and a mesure of chromaticity, the hue angle ($h^\circ = \arctan b^*/a^*$). (Frezza et al., 2011).

Gas concentration (O₂ and CO₂) inside the packing (%): a Dansensor gas analyser (Frezza et al., 2010) was used.

Firmness (kg) was determined with an Effegi FT 327 penetrometer equipped with a 7.9 mm tip.

Electrolyte leakage (%) was analyzed at the end of storage according to the method described by Frezza et al., 2011.

Soluble solids (°Brix) were measured using a refractometer (Atago).

Weight loss (%): between harvest and at the end of the storage period was calculated.

Carotenoids (mg/g FW) were determined according Nagata and Yamashita (1992).

Ascorbic acid (mg AA/100 g FW) was measured using a technique described by Valente et al. (2011).

Statistical analysis. Experimental design was completely randomized with factorial arrangement with following factors: radiation level, maturity stage, processing degree and storage time with three replicates for each treatment. Analysis of the results was performed by ANOVA and means were compared by Tukey test at 5 % (Statistical software: Infostat).

Results and discussion:

Radiation level and fruit morphology. The environmental factors affected size and shape of fruits and the product postharvest performance. Radiation intensity during growth and maturity stage had significant effect on the measured parameters of size and morphology fruit (Table 1). Green fruits were larger than red fruits, but there were no significant differences in width. Radiation level affected these two dimensions regardless of the maturity stage. Unshaded fruits were larger and heavier than shaded fruits. Furthermore, it is related to dry matter content. Fruits exposed to higher radiation level accumulated more dry matter. Potential production of a crop, expressed as total dry matter and considering that no other limiting factor will depend on the amount of radiation intercepted. Linear relationship was established between potential productivity and the amount of intercepted radiation (Maroto, 2000). Neither thickness nor the number of cores was affected by the factors evaluated. Probably; genetic factor has a great influence on these parameters.

Table 1. Length (cm), width (cm), thickness of flesh fruit (cm), and weight (g) of pepper fruits harvested at two stages of maturity (green and red) exposed to two radiation levels (50 % and 100%)

Maturity stage	Radiation	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
Green	100 %	11.86 a	7.18 a	0.43 a	175.66 a
Green	50 %	11.46 a	6.39 b	0.42 a	133.41 b
Red	100 %	11.13 a	6.86 b	0.41 a	149.13 ab
Red	50 %	10.03 b	6.61 b	0.41 a	128.62 b

Different letters means significant difference ($p \leq 0.05$)

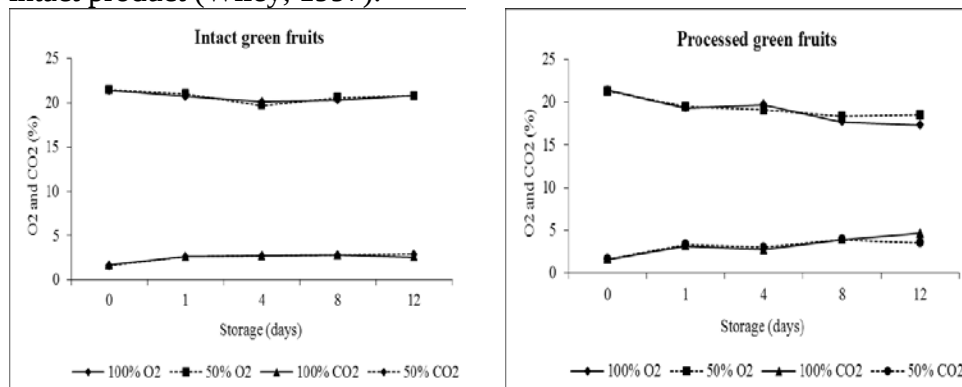
Fruit appearance. The appearance of a food product is the most obvious attribute for the consumer, and powerfully affects the decision to buy (Toivonen and Brummell, 2008). Fruit appearance changes during storage period were evaluated throughout overall visual quality. Thus, statistical analysis showed significant differences between treatments ($p \leq 0.0001$), except for level of radiation. In processed fruits overall visual quality decline progressively over storage period and the product was not marketable at the end of storage. Browning of plant tissue, the occurrence of *Alternaria* sp. and the water condensation inside of packaging were the main factors that affected the visual quality of minimally processed peppers.

Fruit color changes is the result of the chlorophyll degradation and carotenoids synthesis affected by temperature and lighting to which the fruit was exposed (Perez-Lopez et al., 2007). Red fruit exposed to 100% of the radiation received showed more opaque colours ($L^* 50\% = 33.76$, $L^* 100\% = 31.37$), and also showed lower values of b^* and h .

Thus, the radiation determined a chlorophyll loss, greater for fruit unshaded. These were more opaque than 50% fruits exposed radiation fruits.

Type of minimally processed treatments. Cut into strips determined an intensification of the colour of the fruit (values higher C) and slightly more yellow (b*). Intact fruit showed lower h°, while the opposite occurred in green pepper julienne, associated with the loss of chlorophyll. According to Guerra et al. (2011) the fruit red colour enhances during storage period (a* value increased to 24.65% in 10 days of refrigerated storage at 8°C). In our experiment, red fruits were less affected compared with Guerra et al. (2011), an increase of 13 % in a* value was recorded). On the other hand, Smith et al. (2006) reported in your research the relationship between water losses with brightness losses. However, in this experience has not been possible to correlate weight losses with any colour coordinates.

Package gas atmosphere. Gas concentration inside the packaging was modified significantly ($p < 0.01$) by the effect of maturity stage, processing and storage period. On the first day, O₂ decreased 11% and CO₂ increased 60- 98% compared to the initial gas concentration. These changes were probably due to tissue acclimatization to this condition in early hours, since there was no remarkable change for intact fruits during rest of storage. The situation was completely different to processed fruits. Gas concentration inside the package was affected clearly by the maturity stage and storage period. Results showed that processed fruits increased the respiration rate due to an increasing of the surface area exposed (Figure 1). Furthermore, respiration acceleration in red fruits was higher than green fruits because the advanced maturity stage. Gas concentrations were below 15 % and above 6 % for O₂ and CO₂ respectively. It has been shown that storage life was extended by modified atmosphere packaging (Ward, 2016) and processing of vegetables induces rapid deterioration in order of three to five times to the intact product (Wiley, 1997).



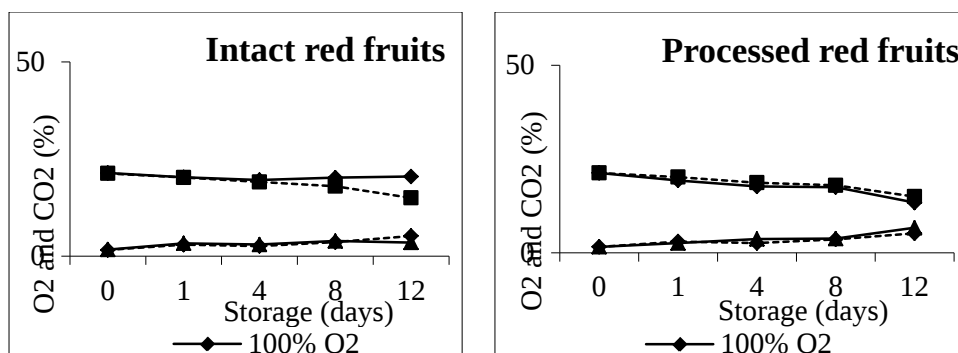


Figure 1. Gas (oxygen and carbon dioxide) concentration (%) inside the container with pepper fruits exposed to two solar radiation levels (50% and 100%), at two maturity stages (green and red), intact and minimally processed and refrigerated at 10 °C for 12 days.

Water loss. The main physiological factor that impact negatively during storage and marketing is water loss, which is evaluated by weight loss (Smith et al., 2006; Raffo et al., 2007). Weight loss changes between treatments were observed. Statistical analysis demonstrated that the magnitude of this loss depends directly on maturity stage, processed, storage period and radiation conditions during season crop.

At the end of storage, processed red fruits cultivated without shade reached the greatest weight loss (6.37%) ($p \leq 0.05$). By contrast, whole green fruit regardless of radiation treatment had the lowest weight loss (2.21%), although the differences with the other treatments were not significant. Raffo et al. (2007) found that fruit pepper is susceptible to serious loss of water due to high area/volume ratio, although these losses are substantially reduced in plastic packaging. According to Gonzalez-Aguilar and Tiznado (1993), the first symptoms of wilt appear from weight loss of 5% of the initial fruit weight. In this research, only red fruits processed and exposed to full radiation exceeded that threshold. These fruits lost weight and showed the appearance of *Alternaria alternate* that decreased product quality to unmarketable levels.

Soluble solids. Sugars represent the main fraction of total soluble solids of the fruit, reaching almost 60% of dry matter in red pepper (Raffo et al., 2007). Soluble solids loss during storage is normal because of cellular respiration in postharvest (Özden and Bayindirli, 2002). According to Raffo et al. (2008) radiation during the crop and minimal processing did not affect soluble solid content, whereas, maturity stage and storage period affected reduction and accumulation.

Red fruits had higher values (twice, approximately) than green (Figure 2). Tadesse et al. (2002) reported that the change of colour and total soluble solids are very good index of maturity stage of sweet pepper. In the

same work, 6° Brix is set as the minimum for optimally ripe fruits of cv. “Sunday.

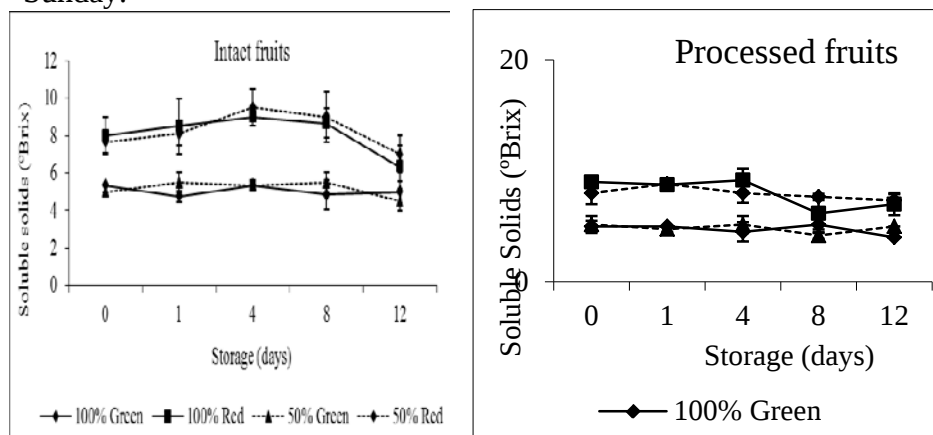


Figure 2. Soluble solids (° brix) for pepper fruits exposed to two solar radiation levels (50% and 100%), at two maturity stages (green and red), intact and minimally processed, refrigerated at 10 °C for 12 days.

Initial content of fruits decreased at the end of the storage. Two phases are recognized during storage: a first phase in which accumulate soluble solids for 4-5 days, reaching a maximum relative concentration followed by a second phase that begin to decay. The increase in the soluble solids during the first days of storage may be due to concentration effect because of water loss in those days (González-Aguilar and Tiznado, 1993; Özden and Bayindirli, 2002; Raffo et al., 2008). Subsequent decreasing is due to its use as substrate in the process of cellular respiration (Conesa et al., 2007).

Firmness. Firmness is one of many attributes used to determine the texture of fruits and vegetables (Lin and Zhao, 2007). In our experiment maturity stage was affected by firmness, and as it was expected, green fruits showed greater resistance to penetration than red fruits as consequence of firmness increase of plant tissues. Tadesse et al. (2002), which measured the firmness of the fruits during plant development observed that the strength of green fruit increased with fruit size (fresh weight) until colour change occurred when firmness decreased. Radiation levels did not affect fruit firmness, but storage period had a significant effect on firmness ($p=0.0052$). Guerra et al. (2011) reported that during storage certain biochemical and structural modification occurs that cause changes in the texture of peppers.

Modified atmosphere packaging effect on firmness should not be underestimated. Özden and Bayindirli, (2002) and Raffo et al. (2007) reported that pepper fruits in modified atmosphere showed no significant changes in firmness over storage period.

In general, electrolyte leakage is an indirect measurement of the properties of the cell membrane (Fan and Sokorai, 2005) and it is associated with the onset of symptoms due to chilling injury of plant tissues. Temperature at which they begin to appear in pepper is 7°C (Lim et al., 2007). Refrigerated storage of these trials resulted without chilling injury in the fruit.

Carotenoids. Carotenoids content showed significant differences ($p < 0.0001$) between red and green fruits, being approximately double for red (25.95 and 13.06 $\mu\text{g/g}$ fresh weight respectively). Our results are agree with Howard et al. (1994), Markus et al. (1999) and Navarro et al. (2006).

Processing was carried out at room temperature in the minimum time possible; however, carotenoid degradation was inevitable. Rodriguez-Amaya et al., (2008) reported that exposure to light can promote photodegradation of carotenoids.

Many environmental factors affect the biosynthesis and accumulation of carotenoids (Britton and Hornero-Méndez, 1997) although genetic is the main. Factor such as temperature, light regime, water availability, soil quality and pollution, have a great influence on growth and also affect carotenoid content.

Regarding green fruits, storage period had a significant influence in the pigment concentration, particularly in a loss ranging from 29-45%.

Ascorbic acid Lee and Kader (2000) reported that many factors, pre and post harvest, influence the content of vitamin C in many horticultural species. Among them, genetic factors, climatic conditions, cultural practices during growing season, maturity at harvest and handling and postharvest conditions were mentioned. In this study, levels of ascorbic acid ranged from 21.31 to 95.58 $\text{mg}/100 \text{ g}^{-1} \text{ FW}$ (Figure 3). No significant differences between maturity stages were detected; however, it was detected for the rest of the analyzed factors.

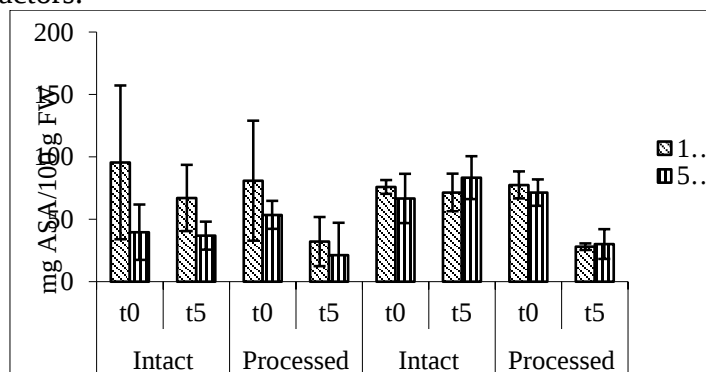


Figure 3. Ascorbic acid ($\text{mg}/100 \text{ g FW}$) for pepper fruits exposed to two levels of solar radiation, at two different maturity stages, minimally processed and refrigerated at 10 °C for 12 days.

Dependence of ascorbic acid content and maturity of fruits has not been clearly established. Ghasemnezhad et al. (2011) evaluated five genotypes and found that green fruits contained higher levels of ascorbic acid than red fruits. Navarro et al. (2006) obtained similar findings for the cultivar “Orlando”, by contrast, Howard et al. (1994).

Relative to radiation level during growth cycle. Fruits exposed to full radiation had higher concentration of ascorbic acid in accordance with Howard et al. (2000). Processing operation clearly affected ascorbic acid concentration, promoting its degradation by nearly 35%, according to Lee and Kader (2000). In addition, storage period was the factor that had the greatest influence on this parameter.

Vitamin C is the generic term for all compounds which share the same biological activity of ascorbic acid. Ascorbic acid is the main biologically active form, but L-dehydroascorbic acid, and oxidation product, also exhibits the same biological activity. L-dehydroascorbic is easily converted to ascorbic acid within the human body, it is important to measure both to know the real content of vitamin C in fruits and vegetable (Lee & Kader, 2000; Mazurek, & Pankiewicz, 2012).

Conclusion:

According the radiation during the crop growth, maturity at harvest and type of processed, shaded pepper fruits showed higher water content and less development compared to fruits exposed to full radiation. Fruit nutritional value was maintained till sixth day of storage. Both ascorbic acid and carotenoids were affected by the degree of maturity as well as processing, storage time and temperature. The radiation had only effect on ascorbic acid content, increasing it. Visual quality of intact fruit was not affected without differences between treatments. Shelf life of processed red fruits (julienne) was reduced, being the worst performing during storage. Post-harvest visual quality was highly related to gases composition (O₂ and CO₂) inside the trays.

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