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Full Length Research Paper

Quality and shelf life of oranges within polystyrene containers in refrigerated chamber

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ABSTRACT

The objective of this research was to determine the shelf life of 'Valencia' sweet oranges (*Citrus sinensis* (L.) Osbeck) stored in sealed polystyrene containers, within a refrigerated chamber with temperature 3 to 9 °C, high relative humidity (85%) and frequent air exchange by chamber compressor. Oranges were harvested directly from the orchard and washed with water with 150 mg L^{-1} sodium hypochlorite. We measured the color of the flavedo (peel) and the endocarp (pulp), polar and equatorial diameter, firmness of the pulp and total soluble solids concentration (°Brix) in the endocarp. The tone and purity of the yellow color of the flavedo and endocarp of the oranges increased significantly within the polystyrene containers. Within the containers, fruit quality was preserved and shelf life was extended for more than 100 days without symptoms of deterioration, reduction of polar and equatorial diameter or decrease in total soluble solids. Inside the polystyrene closed containers, the temperature was 2.0 °C less than in the refrigerated chamber. Thus the polystyrene provided thermal insulation and was useful for storing fruits while reducing the incidence of postharvest disease, prolonging its shelf life and enhancing its appearance.

Keywords: Variety 'Valencia', Postharvest, Quality, Color, Firmness, Soluble Solids.

INTRODUCTION

One of the most popular fruits in Mexico is orange, of which one of the most cultivated varieties is Valencia, which goes into production in May, is juicy, sweet and its production is oriented to the production of juice. During the last ten years, 341 thousand hectares were allocated for this crop, with an average annual growth of 0.2 percent. In 2007 the orange harvest was just over four million tons, which placed the country in the fourth place in the world, surpassed only by Brazil, the United States and India. Veracruz is the leading state in orange production in Mexico, followed by Tamaulipas, San Luis Potosí, Puebla and Nuevo León, although in Sonora it is where the highest national yield has been recorded, with 25 t ha^{-1}, which has allowed Exports to the United States, Japan, the United Kingdom and other European countries (SIAP, 2016).

There is an increasing consumer demand for high quality fruits and vegetables. Locally–sourced produce that visually appeals to the buyer at the time of purchase and is still attractive and tasty upon consumption is considered to be high quality. The ideal solution is to preserve the overall quality (organoleptic, commercial, microbiological and nutritional) of horticultural products and to meet the demands of the market by to improving post-harvest storage life (Artés, 1995, 1999, 2000). improving post-harvest handling and therefore, the quality and shelf life of oranges, the Mexican producers will be better able to take advantage of market windows and increased profitability in its production system.

Post-harvest storage techniques, employed once the fruits have been packed for fresh marketing, are intended to preserve the fruit quality by maintaining ideal environmental conditions. These conditions reduce respiration and promote a longer shelf-life which allows for shipments to distant markets with reduced loss. Among the techniques used for preserving fruits and vegetables are cooling, the use of controlled atmospheres, the use of ethylene absorbers, application of opaque films, and exogenous application of plant growth regulators (Parikh et al., 1990).

Respiration is the main physiological process that leads to the deterioration of the fruit. Respiration is attenuated by low temperatures that reduce the respiratory rate, reduce excessive loss of water, and slow biochemical and enzymatic reactions. Maturity is a physiological and biochemical process that is under genetic and hormonal control, is a process that is accompanied by multiple changes at the cellular level, rather than an increase in size (Wills et al. 1998).

The respiration rate of the fruit is reduced by half for every 10 °C reduction in temperature (Guerra, 1996). In climacteric fruits such as mango, temperatures above 40°C cause an increase in respiratory activity; by contrast, temperatures below 13 °C decrease respiration and prolong shelf life (Ponce de Leon and Bósquez, 1997).

Respiration-induced water losses in fruits cause a reduction of fruit weight, leading to a decrease in the fruit quality and acceptability (Jimenez et al., 1983), these losses often lead to higher losses than 5% during marketing, up to 7% in cold storage for three months and commercialization (Jimenez et al., 1983). The low humidity conditions lead to increased transpiration and therefore a high loss of water, which accelerates fruit senescence and a marked loss of quality, both wrinkles in the cortex as shrinkage and softening (Guerra, 1996).

During postharvest storage, fruit senescence can lead to a loss of fruit quality, including flesh softening, loss of acidity, reduction of vitamin C and changes in organoleptic characteristics (taste and palatability) (Martinez, 1997). The reaction rate of metabolic processes, which lead to loss of quality, doubles for every 10 °C increase in temperature, and in the range of 0 to 10 °C may even six-fold (Martinez, 1997).

There are limitations as to the minimum temperatures that can be applied in cold storage. Some tropical and subtropical fruit show sensitivity to low temperatures, which is manifested by different alterations and spots on the skin, usually known as injury or chilling injury and can cause significant loss of merchantable quality (Martinez, 1997). Fruits should not be frozen while in storage. Fruits and vegetables for fresh consumption must maintain an active metabolism, which can only be achieved in the liquid phase, so they cannot be subjected to temperatures below freezing between 0 and -1.5 °C. (Martinez, 1997).

Fruits in cold storage should be stored under high humidity to avoid dehydration (Guerra, 1996). The appropriate relative humidity for a given product depends on the surface to volume ratio. As this ratio increases, respiration increases as well. A relative humidity level between 85 and 95% is advisable to achieve the goal of conservation (Guerra, 1996).

Renewal and air circulation in cold chambers are essential to maintain appropriate levels the concentration of O2 and CO_2. The renewal Periodic atmosphere is justified by the need to remove gases and volatile undesirable produced, many of them arising from the metabolic activity of fruits (Caceres et al., 2006).

Postharvest Cavendish Giant bananas (AAA) have been shown to increase shelf life when stored it's in polystyrene containers closed within a refrigerated chamber at temperatures of 10-12 °C (Reyes et al., 2015).

The objective of this research was to determine whether the shelf life of oranges increases, when they are stored in polystyrene containers sealed, placed in enclosed environments with low temperature, high humidity and frequent exchange of air in the storage space.

MATERIALS AND METHODS

Valencia' oranges were harvest February 04, 2015 in an orchard in the La Guamuchilera community, municipality of Mocorito, Sinaloa, with coordinates 24^{o} 25' 21" N and 107^{o} 33' 22" W. Non-damaged fruit (Figure 1) were harvested and were subsequently washed with water containing 150 mg·L^{-1} of sodium hypochlorite and then were dried manually. This treatment was intended to prevent the growth and development *Penicillium italicum*

Figure 1. Oranges of cv 'Valencia' harvested on 04/02/2015 in La Guamuchilera, Culiacan, Sinaloa, Mexico.

that usually grow on oranges (Guedez et al., 2010).

After drying, 12 oranges were placed each of 8 polystyrene containers. Each container had a Height 0.24 m Width 0.31 m Depth 0.21 m. capacity of 10 kg and was sealed with polypropylene adhesive tape Subsequently, the containers were placed into a refrigerator of 0.39 m^3 (FRTG144DKG, Frigidaire, U.S.A.), where the temperature ranged from 3 to 9 °C and relative humidity ranged from 40 to 45%. Additional oranges were also placed on plastic trays (Not in a polystyrene container) in the refrigerator. These oranges were the refrigerated controls. The containers were opened at 06-10-2015 (90) and 06-20-2015 (100) days after storage, this portion of the experiment was conducted in the city of Culiacan, Sinaloa, Mexico, (24° 48' 15'' N and 107° 25' 52'' W), in an enclosure equipped for storage climacteric fruits such as citrus.

Fruit measurements were collected from the freshly harvested oranges, the refrigerated oranges stored in the polystyrene containers and the refrigerated controls. These measurements included the color of the peel and pulp (brightness, angle hue (°Hue) and chroma (C), firmness, total soluble solids, polar and equatorial diameters. We used portable spectrophotometer spheres (SP-62, X-rite, U.S.A) to determine L* c* h* a* b*, which indicate brightness, chroma (saturation), hue (tone) and the tendency of red-green and blue- yellow, respectively. Oranges were sliced in half and firmness was evaluated using a digital penetrometer (Chatillon DFX II, Ametek, U.S.A.). The total soluble solids were analyzed with a digital refractometer (AR 200, Reichert, EU). The weight loss of the samples was determined with a scale (V11P3, Ohaus, U.S.A.). Fruit acidity was determined by titration using the methodology of Garcia-Lopez (2015), to calculate the percentage of acidity equation was used [(NaOH volume spent on titration) (normality of NaOH) (milliequivalents)] / 1 [(total volume) (sample weight) (extract volume titled)]. The loss of juice oranges was examined with a glass of graduate precipitate, making measurements on days 0, 90 and 100.

The analysis organoleptic or sensory characteristics were performed in the laboratory of Postharvest Institute of Agricultural Sciences of the Autonomous University of Baja California (UABC), located in the Ejido Nuevo Leon, the city of Mexicali, Baja California, Mexico, with coordinates 32° 24' 26'' N 115° 11' 47'' W.

The experimental design was a randomized complete block design with four treatments: Freshly harvested oranges, oranges stored for 90 or 100 days in sealed polystyrene containers and oranges placed in the refrigerator tray for 100 days (refrigerated control). There were four replications.

Analyses of variance were done with SAS statistical software (1996) version 5.6, while multiple comparisons of means were performed through Tukey test with $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

The skin color of freshly harvested oranges (0 days) was light yellow, but after 90 and 100 days of storage the color was bright yellow or bright orange (Figure 2). After 90 and 100 days of refrigerated storage in polystyrene containers, the peel luminosity increased. After 90 and 100 days of refrigerated storage in polystyrene containers, there was a significant increase in the peel luminosity. Peel luminosity increased by 4.2 and 4.4 respectively, compared to the freshly harvested fruit. This corresponded to a 6.1 and 6.4% increase. Similarly, there was significant increase in peel luminosity of the stored fruit compared with the refrigerated controls, 6.1 and 6.4% respectively, compared to the freshly harvested fruit (Table 1), and it increased by 4.6 and 4.8% respectively,

a b c

Figure 2. Condition of oranges cv 'Valencia' stored for (a) 90 days, or (b) 100 days in sealed polystyrene containers under refrigeration, or (c) stored and refrigerated for 100 days in the tray the refrigerated chamber (c).

Table 1. Components of color (brightness and chromaticity °Hue) in orange peel cv 'Valencia' freshly harvested, stored for 90 and 100 days in polystyrene containers or 100 days in the bottom tray of the refrigerator (control).

Treatments	Luminosity (L)	hue angle (°Hue)	Chromaticity (C)
0 days	69.1 b	77.0 a	70.1 c
90 days	73.3 a	78.0 a	75.2 b
100 days	73.5 a	71.3 b	77.4 a
Control	70.1 b	78.6 a	73.7 b

Means with the same letter in each column are statistically equal (Tukey, $\alpha \leq 0.05$).

Table 2. Components of the color (brightness and chromaticity ° Hue) pulp of oranges cv 'Valencia' freshly harvested, stored for 90 and 100 days in polystyrene containers or 100 days in the bottom tray of the refrigerator (control).

Treatments	Luminosity (L)	hue angle (°Hue)	Chromaticity (C)
0 days	45.4 b	85.4 b	26.7 a
90 days	43.6 c	86.0 ab	21.9 b
100 days	49.4 a	75.8 c	23.2 b
Control	44.9 b	86.6 a	23.3 b

Means with the same letter in each column are statistically equal (Tukey, $\alpha \leq 0.05$).

compared with the refrigerated control (Table 1).

The hue angle, which defines the color, decreased by 0.8% in oranges stored for 90 days, and 9.3% in those with 100 days of stored and 2.0% in the freshly harvested oranges, compared with the refrigerated controls (Table 1), but the trend was toward the yellow (<90). The chromaticity, indicating the color purity, is increased by 2.0 and 5.0%, respectively, in oranges stored at 90 and 100 days, compared to the chromaticity of the controls, but for oranges freshly harvested increases the increase was 7.3 and 10.4%, respectively.

The hue angle, which defines the color, only had a statistically significant difference in oranges stored for 100 days in polystyrene containers, decreased 7.3 in those with 100 days of storage and 0.6 in oranges stored for 90 days and 1.6 in oranges freshly harvested, compared with the refrigerated controls (Table 1), but the trend was towards yellow (<90). This corresponds to a decrease of 0.8% Hue angle oranges stored for 90 days, 9.3% those with 100 days of storage and 2.0% in the freshly harvested oranges.

Chromaticity, indicating the color purity is increased by 1.5 and 3.7 respectively in oranges stored at 90 and 100 days, compared to the chromaticity control but over freshly harvested oranges the increase was 5.1 and 7.3, respectively, there was statistically significant difference between the control and stored for 100 days and as well as with the freshly harvested, however no significant difference with stored for 90 days and control refrigerated. It increased 2.0% in 90 days and 5.0% 100 days storage in polystyrene containers, compared to control chromaticity, but with respect to freshly harvested oranges the increase was 7.3% 90 days and 10.4% 100 days of storage.

The pulp (endocarp) luminosity increased significantly by 10.0% in the oranges stored for 100 days compared with the refrigerated controls, by 8.8% compared with the freshly harvested fruit (Table 2). However, °Hue

Table 3. Color parameters (a * and b * in peel and pulp) of oranges (cv 'Valencia') freshly harvested, stored for 90 and 100 days in polystyrene containers or refrigerated control

Temperature	Parameter a* peel	Parameter b* Peel	Parameter a* pulp	Parameter b* pulp
0 days	16.0 b	68.2 b	2.1 b	26.7 a
90 days	15.6 bc	73.5 a	1.5 c	21.8 b
100 days	25.4 a	73.3 a	5.7 a	22.5 b
Control	14.1 c	66.4 b	1.4 c	23.3 b

Means with the same letter in each column are statistically equal (Tukey, $\alpha \leq 0.05$).

Table 4. Polar and equatorial diameter, firmness and ° Brix orange cv 'Valencia' freshly harvested, stored for 90 and 100 days in polystyrene containers or 100 days in the bottom tray of the refrigerated chamber (control).

Treatments	Polar diameter (cm)	Equatorial diameter (cm)	Firmness	°Brix
0 days	8.2 b	7.2 b	14.0 ab	15.4 a
90 days	8.8 a	8.5 a	15.5 a	12.8 b
100 days	9.0 a	8.4 a	13.8 b	11.9 b
Control	8.1 b	7.7 b	12.7 b	12.7 b

Means with the same letter in each column are statistically equal (Tukey, $\alpha \leq 0.05$).

decreased 11.2 and 12.5% compared with those obtained in the freshly harvested and in control; however, the color hue (°Hue) oranges stored up to 90 days was not different from that of the freshly harvested and refrigerated control fruit. The chromaticity of oranges stored up to 90 and 100 days in polystyrene containers also varied with respect to the refrigerated control, although it should be noted that their values were lower by 18.0, 13.1 and 12.7%, respectively, compared with freshly harvested fruit.

Considering that the negative or positive value of *a indicates color from green to red and the negative or positive values of b* indicate color from blue to yellow, Table 3 shows that the values of a* were positive but much lower than those of b*, which also confirms the bright yellow in the peel (epicarp) and pulp (endocarp) of oranges.

These results indicate that the increase in the yellow of the oranges stored in polystyrene containers increased sensory perception, since according to Schwab et al. (2013), there is a relationship between sensory perception of sweet and acid flavors with the intensity of color, yellow and green in oranges. In addition, with the use of closed polystyrene containers at an internal temperature of 6-7 °C in refrigerated chambers operated at temperatures 3-9 °C, peel coloration increased, which coincides with the work of Ariza et al. (2010), who found that the yellow hue intensifies with increasing low temperatures because of the promotion of carotenoid synthesis that leads to the coloring of the orange. Ariza et al. (2010), also stated that there was a need for post-harvest technologies that degreening the fruit without the use of chemicals. In our work, it was the use of polystyrene containers and low temperatures that cause the degreening, yet do not contaminate the fruit and, consequently, do not harm the health of consumers or harm the environment.

Results from Table 4 show that the polar diameter of the oranges was affected by the process of random selection, however, also it shows that the polar diameter of the refrigerated control fruit decreased by 7.9% compared to the fruit stored for 90 days, and by 10.0% compared to the fruit stored for 100 days in containers. The equatorial diameter of the refrigerated control fruit decreased by a respective 9.4 and 8.3% compared with oranges stored for with 90 or 100 days. This indicates that the refrigerated control oranges experienced a significant loss of water through transpiration.

Fruit firmness and Brix are two quality characteristics that will decrease with the passage of time, so for the refrigerated control oranges, there was a significant firmness decrease of 18.1% compared to those fruit stored for 90 days and 8.0% compared to fruit stored for 100 days (Table 4). However, the averages of total soluble solids (°Brix) was not affected by the storage.

Total soluble solids is one of fruit quality parameters most frequently evaluated in citrus, and is seen as a critical indicator of sensory quality (Matheis and Fellman, 1999). It has been shown that there is a good correlation between sensory attributes of acid and sweet taste with total acidity, expressed as percentage of citric acid and the concentration of total sugars of the juice (Schvab et al., 2013). According to the our work, the Brix of the oranges stored in polystyrene containers, did not decrease compared to the Brix of refrigerated control fruit, as the Brix values were statistically similar.

Oranges stored in polystyrene containers better preserved their appearance compared to oranges were only refrigerated, these differences can be seen easy, with this information available preservation appetizing appearance of oranges stored in polystyrene containers is an opportunity for Mexican producers of oranges, which may extend their selling season storing oranges in this system, it can reduce losses by accelerated ripening oranges and sell them for more time to market.

CONCLUSIONS

The tone and purity of yellowing of the skin and pulp of oranges increased significantly within polystyrene containers and, consequently, its life was extended to more than 100 days, they had symptoms of impairment loss of polar and equatorial diameter or decrease in total soluble solids, compared to those characteristics of oranges from the bottom tray of the refrigerated chamber.

Inside containers closed polystyrene temperature decreased to two degrees, with respect to the temperature inside the refrigerated chamber, so that the principle of thermal insulation polystyrene reasserted, and its usefulness for packaging products such as fruits and solve some of their own physiological problems, to prolong its shelf life and enhance your presentation**.**

This technology could be exploited by Mexican citrus producers which have more shelf life in its oranges to store them in polystyrene containers at low temperatures.

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