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QUALITY VARIABLES OF "HASS" AVOCADO STORED IN MODIFIED ATMOSPHERE PACKAGING

Yessica **Vázquez-López**[1], Rosalina **Iribe-Salazar**[2], Marco **Carrazco-Escalante**[2], Soila **Gaxiola-Camacho**[1], José **Caro-Corrales**[2*]

[1] Universidad Autónoma de Sinaloa. Facultad de Medicina Veterinaria y Zootecnia. Posgrado en Ciencias Agropecuarias. Boulevard San Ángel No. 3886, Fraccionamiento San Benito, Culiacán, Sinaloa, México. C. P. 80260.

[2] Universidad Autónoma de Sinaloa. Facultad de Ciencias Químico Biológicas. Posgrado en Ciencia y Tecnología de Alimentos. Calzada de las Américas Norte No. 2771, Burócrata, Culiacán, Sinaloa, México. C. P. 80013.

* Corresponding author: josecaro@uas.edu.mx

ABSTRACT

Modified atmosphere packaging (MAP) and refrigeration of fruits and vegetables are used to extend their shelf life. The hypothesis of this study is that quality attributes of avocados stored in MAP at 8 °C can be preserved for a longer period, compared to room temperature (RT) or refrigeration (REF) storage; however, during post-storage ripening (PSR), these quality variables approach those of refrigeration or room temperature in a brief time. The objective of this research was to evaluate quality variables in avocado (*Persea americana* Mill.) *cv*. "Hass" during storage in MAP at 8 °C and PSR at 21 °C and contrast them to those obtained during storage at RT or REF. Fruits at physiological maturity and MAP bags were used. A completely randomized design was used; factors were type of storage (RT 21 °C, REF 8 °C, and MAP 8 °C), storage time (0, 8, 16, 24, and 32 d), and PSR time at 21 °C (0, 2, 4, and 6 d). Quality variables were firmness (penetration force), total colour difference (ΔE) in exocarp and mesocarp (colorimeter), pH (potentiometry), and total soluble solids (*TSS*, refractometry). Avocados stored in MAP retained firmness, which was higher compared to REF and RT during the storage period. Firmness retention for avocados at RT, REF, and MAP, at day 16, was 5.7, 32.6, and 87.2 %, and at day 32, it was 0 (no reading), 9.5, and 78.2 %, respectively. Total colour difference in exocarp and mesocarp, pH, and *TSS* ranged from 3.8 to 25.6, 3.2 to 20.3, 6.7 to 7.1, and 5.3 to 7.7 °Brix, respectively. During the storage period, fruits stored at MAP showed a firmness, ΔE of exocarp and mesocarp similar to those of fresh fruit. Type of storage showed no effect on pH and *TSS*, during the storage period. Modified atmosphere at 8 °C allows to extend the shelf life of "Hass" avocado for a period twice as long as that at room temperature, based on the changes in firmness and colour are reduced, properties that are important quality benchmarks.

Keywords: *Persea americana* Mill., avocado, modified atmosphere, postharvest, refrigeration.

INTRODUCTION

Avocado (*Persea americana* Mill.) is a very important fruit for the economy of México (Arana-Coronado *et al*., 2012). In 2019, the world production was estimated at 7.3 million Mg; México was the main producer, generated 2.3 million Mg and exported 1.2

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million Mg (FAO, 2019). In México, Michoacán is the state that generates the highest production of this fruit; in 2020, it harvested 1.7 million Mg (SIAP, 2020).

Postharvest handling is very important to preserve the quality of fruits and vegetables (Espinosa-Moreno *et al*., 2018); improper management causes economic losses. The fruits at harvest maturity continue with the ripening process after harvesting. Ripening is the process that starts from the last stages of growth and development of the fruit until the first stages of senescence. Therefore, the ripening process is an important phase to preserve quality attributes. Some of the modifications associated with the ripening process are changes in colour, firmness, sugar content, production of volatile compounds, respiratory metabolism, and ethylene production (Pech *et al*., 2018).

Refrigeration is one of the most widely used technologies to preserve avocado fruit. Commercially, avocado is stored between 5 and 6 °C; if storage is performed at a lower temperature, it can cause chilling injury (Bill *et al*., 2014).

Modified atmosphere packaging for fruits and vegetables is used to extend their shelf life by reducing the respiration rate, and consequently, its degradation rate; this reduction is achieved by modifying the atmosphere inside the package (Vázquez-López *et al*., 2020). The positive effects of the atmosphere can be verified mainly by measuring the firmness and colour of the fruits which are properties that depend on the conversion of carbohydrates from cell walls into sugars and on the degradation of chlorophyll in the peel. The modified atmosphere can be created by injection into the package with a gas mixture of desired composition (active atmosphere) or from product respiration (passive atmosphere).

The active modified atmosphere is created with a continuous flow of the gaseous mixture to replace the air. The passive atmosphere is achieved with the O_2 consumption and CO_2 production, generated by the fruit inside the package. In both cases, the permeability of the packing material is important to allow the diffusion of the gases between the package and the outside, until reaching the stable modified atmosphere. Russo *et al.* (2014) reported that a modified atmosphere of 7.0 % CO_2 and 4.0 % O_2 at 10 °C was the most effective method of storage to minimize weight loss and CO_2 production in "Fuerte" avocado.

The avocado fruits are packed mainly in cardboard boxes during storage. Nowadays, bags for modified atmosphere are offered in the market to extend the shelf life of fruits and vegetables during storage. However, these packages are not always used; sometimes, they are used in generic form for diverse fruits, and there are few packages for a specific fruit; these, in some cases, do not meet the requirements to generate the optimum atmosphere, maximize preservation, and maintain the appropriate quality.

Modified atmosphere packaging (MAP) storage slows down metabolic processes; however, when the fruit is removed from the bag, these processes increase, and after a few days the quality variables are closer to those of the control fruit (Nakhasi *et al*., 1991). The hypothesis of this study is that avocados stored in MAP at 8 °C have better quality variables than those stored in refrigeration (REF) or room temperature (RT). In addition, once avocados are kept out of MAP, at 21 °C, during post-storage ripening, these quality variables approach those of refrigeration or room temperature in a short period. The objective of this research was to evaluate quality variables in "Hass" avocado during storage in AG Fresh® bags for modified atmosphere at 8 ± 1 °C and post-storage ripening at 21 °C, contrasting them with those obtained during storage at refrigeration or room temperature.

MATERIALS AND METHODS

"Hass" avocados (*Persea americana* Mill.) were harvested 35 weeks after flowering, at physiological maturity stage, were selected based on size (220.4 ± 11.8 g) and colour (L*= 36.5 ± 2.1, a*= –13.2 ± 2.1, and b*= 18.0 ± 3.1). Avocados came from Tacámbaro, Michoacán, México. Fruits were sanitized with a 1 % sodium hypochlorite solution for 20 min (Russo *et al*., 2014). They were stored in three lots: (1) room temperature at 21 ± 1 °C (RT-21), (2) refrigeration at 8 ± 1 °C (REF-8), and (3) modified atmosphere at 8 ± 1 °C (MAP-8) in bags (AG Fresh® Liner Box) made from a commercial plastic film (Low Density Polyethylene/Ethylene vinyl alcohol/Low Density Polyethylene) with a thickness of 0.20 mm (8 mil) and dimensions of 73.7 × 66 cm. Initial concentrations of O_2 and CO_2 were those of normal atmosphere, 21 and 0.03 % mol, respectively. The bags were closed with plastic ties and fruit respiration generated a passive modified atmosphere.

Statistical Analysis

A completely randomized design was used. The response variables were firmness, total colour difference in exocarp and mesocarp, pH, and total soluble solids. Three factors were selected: (1) type of storage (room temperature at 21 °C, refrigeration at 8 °C, and modified atmosphere at 8 °C), (2) storage time (0, 8, 16, 24, and 32 d) and (3) post-storage ripening time at 21 °C (0, 2, 4, and 6 d). In each treatment, the experimental unit consisted of three fruits. Six replicates were performed. This throws a total of 1080 avocados. For avocados from MAP at 8 °C, after each storage time, 72 fruits were removed from the bags, kept at 21 °C in normal atmosphere (air), and 18 of them (3 fruits per unit, 6 replicates) evaluated during each post-storage ripening time (0 to 6 days). Differences were evaluated using Fisher's means difference test at $p \leq 0.05$.

Physical analysis

Firmness

Firmness was evaluated with a digital force gauge (Chatillon, DFE 100, Scientific Co., Chicago Il., USA) with a spherical tip 11 mm in diameter, which deformed the pulp up to 5 mm deep at a rate of 50 mm min^{-1}. Six replications were taken with three readings in each experimental unit. Firmness was expressed as the maximum compression force (N).

Total colour difference in exocarp and mesocarp ($\Delta E_{exocarp}$ and $\Delta E_{mesocarp}$)

Colour variables in exocarp and mesocarp were determined with a portable colorimeter (Minolta CR-210, Osaka, Japan) according to the methodology reported by Barriada-

Bernal *et al*. (2018). Six replications were taken with three readings in each experimental unit. The total colour difference was calculated with the following equation:

$$\Delta E = \left[\left(a^* - a_i^* \right)^2 + \left(b^* - b_i^* \right)^2 + \left(L^* - L_i^* \right)^2 \right]^{1/2}$$

L_i*, a_i*, and b_i* variables before treatments were taken as reference.

Chemical analysis

pH

The pH was evaluated according to method 981.12 of AOAC (AOAC, 2012). A solution with 10 g of pulp and 20 mL of neutral water (pH 7) was prepared and mixed for 30 s with a homogenizer (Ultra-Turrax IKA, T18 basic S1, Germany). Subsequently, the filtered solution was placed into a 100 mL graduated flask and made up to the mark with neutral water. An aliquot of 20 mL was taken, and the pH was determined with a potentiometer (520-A, Orion Research Inc., Boston, USA). Six replications were taken with three reading in each experimental unit.

Total soluble solids (*TSS*)

The total soluble solids were evaluated according to Terán-Erazo *et al*. (2019). A refractometer (300001, Sper Scientific) was used and drops of the pulp extract were placed in the prism. The results were expressed in °Brix. Six replications were taken with three reading in each experimental unit.

RESULTS AND DISCUSSION

Physical analysis

Firmness

The initial firmness of avocados was 96.6, 86.5, and 93.7 N for RT-21, REF-8, and MAP-8, respectively (Figure 1). Comparing among types of storage ($p > 0.05$), during the storage period, avocados stored in MAP-8 retained firmness which was higher ($p \leq 0.05$) compared to RT-21 and REF-8. At 16 d of storage, firmness retention of avocados at RT-21, REF-8, and MAP-8 was 5.7, 32.6, and 87.2 %, respectively. Firmness for fruits at RT-21 was only possible to be measured up to day 16, where the lowest firmness retention was obtained; after 18 d, fruits were in poor condition (spoiled). This condition made the experimental design became unbalanced. Firmness evaluation showed that avocados in MAP-8 delayed softening, since at 32 d of storage, firmness retention was 78.2 %, while fruits at REF-8 retained only 9.5 % of initial firmness. The combination of low temperature and modified atmosphere packaging (MAP-8) exerted a higher positive effect on firmness retention compared to REF-8. After each storage time, avocados from MAP-8 were removed from the bags, kept at 21 °C, and continued the post-storage ripening (PSR) process in air at normal atmosphere (MAP-21PSR). The equilibrium atmosphere generated in MAP-8 during storage avoided drastically decreasing firmness at the first two days of post-storage ripening at 21 °C in normal atmosphere (air), MAP-21PSR (10, 18, 26, and 34 days) with 60.3 %

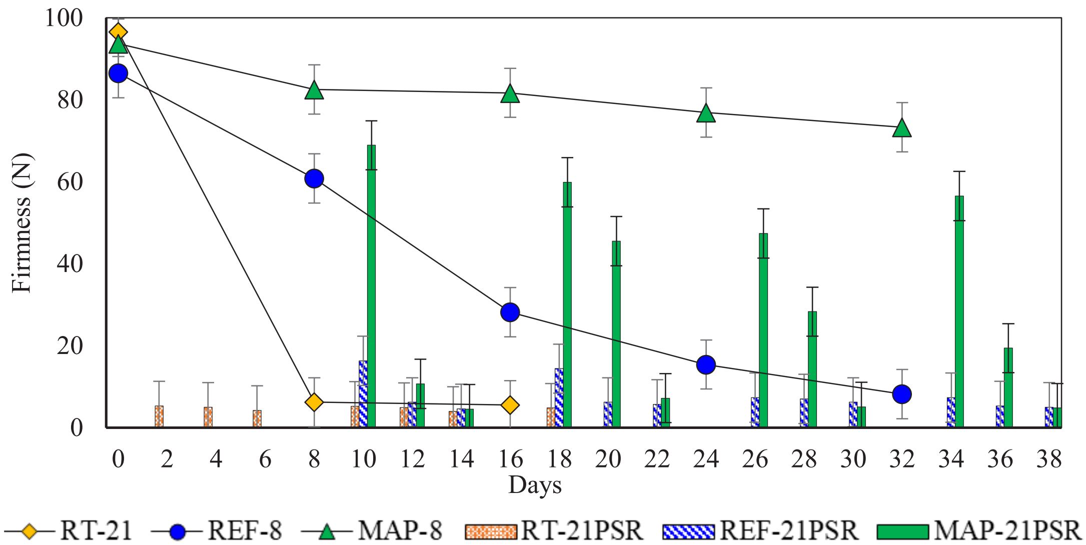

Figure 1. Firmness of "Hass" avocado during storage at room temperature at 21 °C (RT-21), refrigeration at 8 °C (REF-8), and modified atmosphere packaging at 8 °C (MAP-8) for 8, 16, 24, and 32 days and post-storage ripening (PSR) at 21 °C for 2, 4, and 6 days. Vertical bars represent LSD = 12 N (Fisher, $p \leq 0.05$).

of firmness retention at day 34; while for REF-21PSR it was 8.4 %. At six days of post-storage ripening (14, 22, 30, and 38 days), firmness of fruit from MAP-21PSR reached that of REF-21PSR or RT-21PSR.

Firmness is the most representative variable of the ripening process of "Hass" avocado and is considered an important criterion to evaluate the postharvest life. In general, these results coincide with those reported by Espinoza-Cruz *et al*. (2014), who concluded that the use of microperforated bags for "Hass" avocado allows to maintain a better firmness in relation to fruits stored in normal atmosphere. Valle-Guadarrama *et al*. (2013) evaluated the effect of changing the O_2 concentration on "Hass" avocado fruits stored in normal atmosphere (21 mol % O_2) and controlled atmosphere (5.3 mol % O_2) at 20 °C. Those researchers found a firmness retention of 7 % in fruits stored at normal atmosphere after 11 days of storage and 30 % for fruits at controlled atmosphere. In comparison, in the present study, at day 16 of storage firmness retention was 87.2 % for fruits in MAP at 8 °C (MAP-8). The decrease of firmness can be attributed to the activity of polygalacturonase (Magallanes-López *et al*., 2020) and pectin methylesterase (Defilippi *et al*., 2018). Pectin methylesterase removes methoxyl groups from the pectic constituents of the cell wall, which are subsequently depolymerized by polygalacturonase, reducing cell wall turgidity, structure, and composition (Uscanga-Sosa *et al*., 2019).

On the other hand, temperature influences the rate of metabolic reactions; as temperature increases, enzymatic processes are accelerated, until senescence is reached. The better firmness retention in modified atmosphere is mainly due to the O_2 and CO_2 concentrations generated inside the package and to low temperature.

A reduction in oxygen concentration causes a decrease in respiration rates, slowing down ripening.

Total colour difference in exocarp ($\Delta E_{exocarp}$)

Total colour difference in peel of avocado ranged from 3.8 to 25.6. For fruit in MAP-8 ranged from 3.8 to 5.6 (Figure 2). Avocados in MAP-8 retained ($p > 0.05$) the proper colour for a longer period (32 d) compared to those at RT-21 (24 days), showing the positive effect of low temperature and modified atmosphere packaging during storage. Change in exocarp colour at days eight and 16 at RT-21 was higher ($p < 0.05$) than that at REF-8 or MAP-8; while these last two storage methods did not cause a difference ($p > 0.05$). External colour of avocado stored at MAP-8 did not change ($p > 0.05$) during the storage period; this indicates they had a colour more similar to that at day 0, compared to the other two types of storage. Additionally, the *a** colour coordinate, during storage at RT-21 from the first day to day 16, increased from –13.0 to –2.0, while *L** and *b** colour variables decreased from 36.2 to 26.7 and 17.7 to 3.0, respectively. This implies that avocados at RT-21 showed a change in peel colour from dark green to dark gray.

The post-storage ripening process of avocado from MAP-8 was accomplished in normal atmosphere at 21 °C (MAP-21PSR). As expected, total colour difference showed an increase for the three storage methods during ripening after storage. In addition, the effect of type of storage on colour attributes in the fruit is appreciable, since fruit from MAP showed smaller total colour differences (MAP-21PSR). At two days of ripening

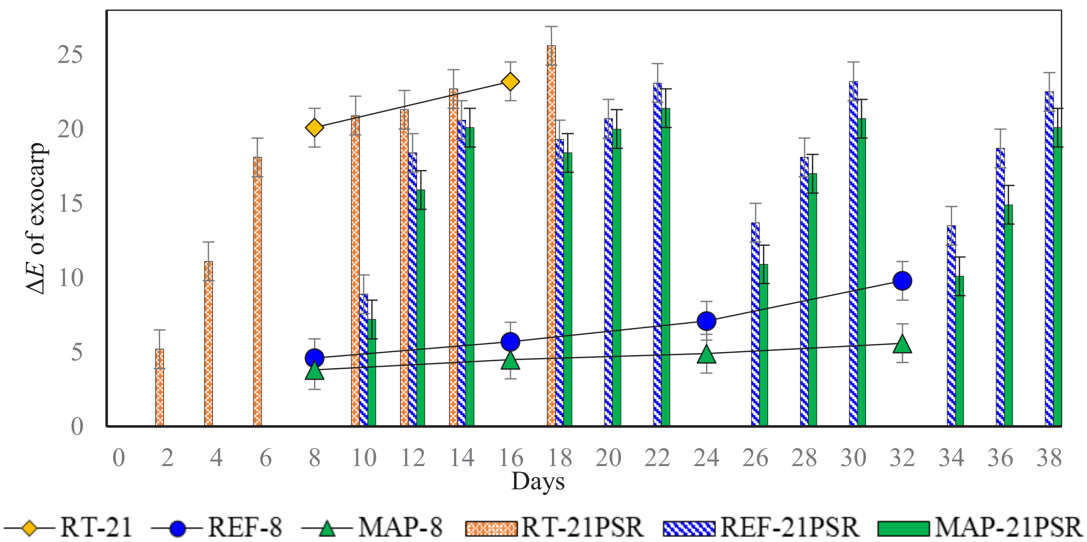

Figure 2. Total colour difference in exocarp of "Hass" avocado during storage at room temperature at 21 °C (RT-21), refrigeration at 8 °C (REF-8), and modified atmosphere packaging at 8 °C (MAP-8) for 8, 16, 24, and 32 days and post-storage ripening (PSR) at 21 °C for 2, 4, and 6 days. Vertical bars represent LSD = 2.6 (Fisher, $p \leq 0.05$).

in normal atmosphere at 21 °C (MAP-21PSR) plus eight days in MAP-8 (day 10), fruit maintained 34 % of total colour difference, respect to those at RT-21PSR. On the other hand, from day 10 to day 14, and day 18, fruit at RT-21PSR showed an advanced degree of ripening (black/dark), while those from REF-21PSR or MAP-21PSR still had dark green areas. At the final stage of analysis, specifically during days 34 and 36, the storage method had an effect on fruit external colour. Fruits from MAP-21PSR at day 36 showed the smallest changes in exocarp colour, compared to fruit from REF-21PSR. However, after 6 d of post-storage ripening (day 38), fruit external colour reached that of REF-21PSR or RT-21PSR.

Skin blackening is one of the features directly related to the degree of ripening in "Hass" avocado. The obtained evolution of colour coordinates agrees with the behaviour reported by Marquez *et al*. (2014) [a^* (–6 to 2), b^* (14 to 2), and L^* (36 to 25)] when studying the peel colour change during the postharvest period at 20 °C in "Hass" avocado. Tropical fruits stored in normal atmosphere (air) lose their green colour faster than those stored in MAP; this effect is attributed to a desynchronization of the ripening process. The variation of total colour difference during ripening of fruit is visually associated with a decrease in the bright green to dark/black colour, a distinctive colour of a ripened avocado. The presence of chlorophyllide and phytol, due to the degradation of chlorophyll *b* by enzymatic action, are probably responsible for colour variations; as well as, by the degradation of carotenoids producing an apparent increase in anthocyanins.

Total colour difference in mesocarp ($\Delta E_{mesocarp}$)

Total colour difference in pulp ranged from 3.2 to 20.3. For fruit stored in MAP-8, it ranged from 4.0 to 4.9 (Figure 3). There was no difference ($p > 0.05$) in ΔE for RT-21, REF-8, and MAP-8, when compared at day eight. Moreover, the internal colour of fruits stored in REF-8 or MAP-8 did not show difference ($p > 0.05$) for any level of storage time, ranging from 4.0 to 6.2. In addition, during storage the only condition that exerted an effect was RT-21 at day 16, showing a ΔE of 16.6. The latter can be attributed to the excessive ripening of the fruits, since flesh of avocados turned to brown colourations, mainly affecting the behaviour of L^* and b^* variables. The b^* variable for RT-21 was 30.5 when evaluated at day 16, while at day 32, REF-8 and MAP-8 showed similar b^* variables (35.4 and 38.2, respectively), corresponding to a light yellow-green colour ($L^* = 80$ and $a^* = -12$). On the other hand, the L^* variable showed an analogous behaviour, since avocados at day 16 for RT-21 had the lowest luminosity (66.8), while L^* at REF-8 and MAP-8 at day 32 remained around 80. The post-storage ripening process of avocados from MAP-8 was carried out at 21 °C in air (MAP-21PSR). In concordance to the ΔE behaviour of exocarp, this variable showed an increase for the three storage methods when evaluated in the mesocarp of the fruits. The highest colour variation was obtained at day 18 for the RT-21PSR condition (20.3). In contrast, avocados stored at MAP-21PSR for 32 days at 8 °C plus two and four days at 21 °C in air (days 34 and 36) had a closer colour (ΔE of 5.2 and 8.0) to the fresh fruits,

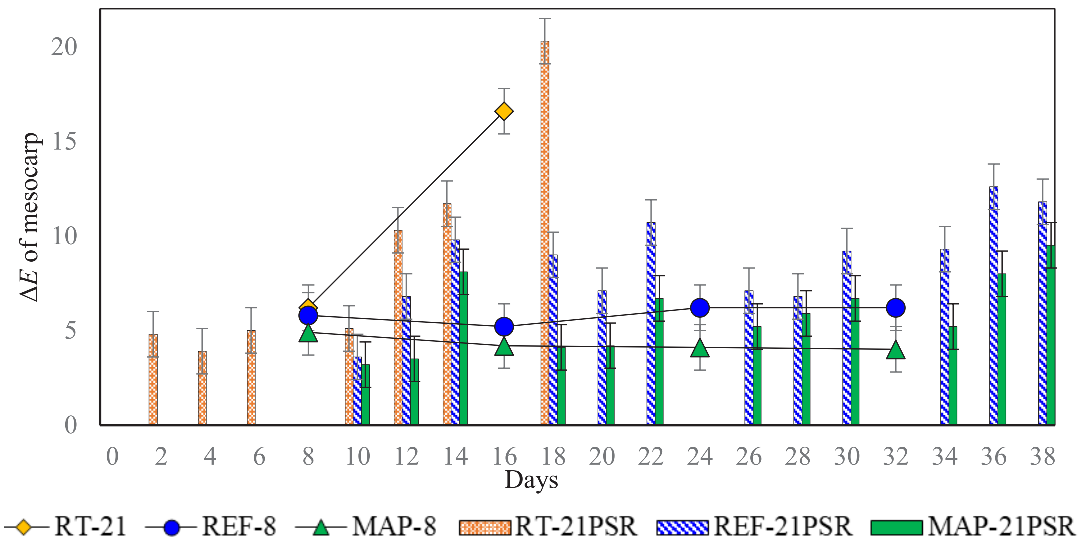

Figure 3. Total colour difference in mesocarp of "Hass" avocado during storage at room temperature at 21 °C (RT-21), refrigeration at 8 °C (REF-8), and modified atmosphere packaging at 8 °C (MAP-8) for 8, 16, 24, and 32 days and post-storage ripening (PSR) at 21 °C for 2, 4, and 6 days. Vertical bars represent LSD = 2.4 (Fisher, $p \leq 0.05$).

when compared to those at RT-21PSR stored for 14 days (ΔE of 11.7). On the other hand, after 8 d in MAP at 8 °C and 6 d in air at 21 °C, at day 14, fruit internal colour for MAP21-PSR was closer to fresh avocado pulp colour (ΔE of 8.1) than that of RT-21PSR (11.7). Avocados stored in MAP-21PSR showed the smallest ΔE (3.5 to 8.0) compared to those at REF-21PSR (6.8 to 12.6) at days 12, 18, 20, 22, 30, 34, and 36.

Regarding to the MAP-21PSR condition, fruits after two days of ripening (days 10, 18, 26, and 34) exhibited no increase ($p > 0.05$) in total colour difference. Moreover, the evolution of the colour coordinates was similar to that reported by Marquez *et al*. (2014) [b^* (35 to 45) and L^* (62 to 82)] in "Hass" avocado during the postharvest period at 20 °C. Furthermore, this behaviour was also similar to that reported by Zapata *et al*. (2016) in "Hass" avocado: immature [b^* (37.4) and L^* (79.9)] and ripened [b^* (36.9) and L^* (79.6)].

Chemical analysis

pH

During storage, pH ranged from 6.7 to 7.1. Comparing among types of storage, at days 8 and 16, pH of the fruit for RT-21, REF-8, and MAP-8 was not different ($p > 0.05$) (Figure 4). During the storage period, at each day of evaluation, pH of avocados for MAP-8 was not different from that for REF-8. Among days of storage, the pH of the fruits in MAP-8 did not change from days 0 to 16; however, at days 24 and 32 (pH of 7.0), it increased slightly ($p < 0.05$) compared to the initial day (pH of 6.7). In fruits

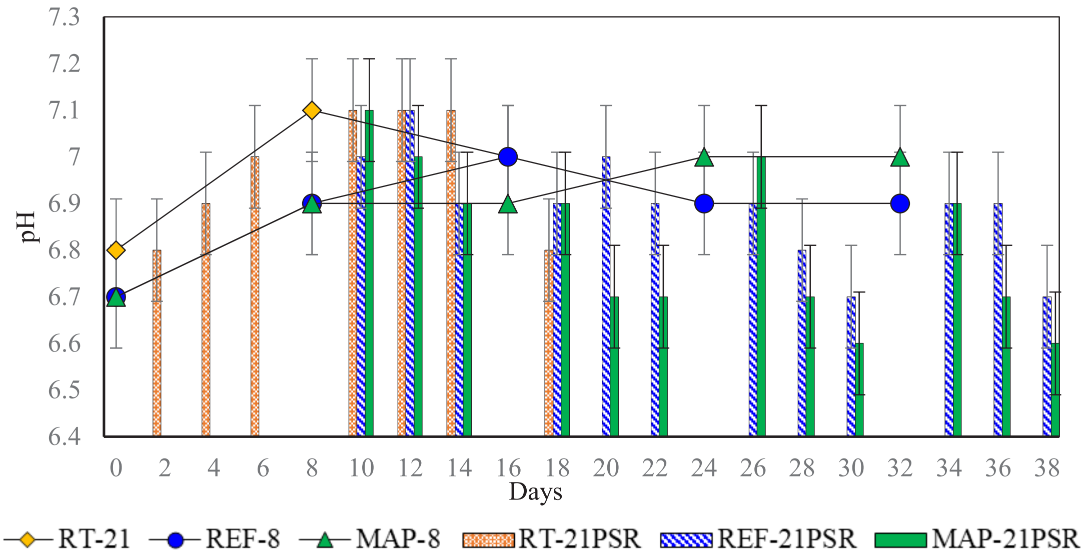

Figure 4. pH of "Hass" avocado during storage at room temperature at 21 °C (RT-21), refrigeration at 8 °C (REF-8), and modified atmosphere packaging at 8 °C (MAP-8) for 8, 16, 24, and 32 days and post-storage ripening (PSR) at 21 °C for 2, 4, and 6 days. Vertical bars represent LSD = 0.22 (Fisher, $p \leq 0.05$).

stored at RT-21, there was an increase in pH at 8 days of storage, compared to the initial pH. For REF-8, day 16 of storage, the pH also increased slightly, compared to the initial day.

During the post-storage ripening time of the fruit at 21 °C, a pH from 6.6 to 7.1 was found. Fruits with zero days of storage plus two, four, and six days of post-storage ripening are the control for RT. The pH for fruits with zero days of storage in REF-21PSR or MAP-21PSR are not shown, because it would be equivalent to zero days for both types of storage. For fruit stored in MAP-21PSR during eight days at 8 °C and four days at 21 °C in air (day 12) and for 24 days at 8 °C plus two days at 21 °C in normal atmosphere (day 26), an increase in 0.3 pH units was obtained, compared to day 0; although, not among them. At four and six days at PSR, after 16, 24, and 32 days in MAP-8 (days 20, 22, 28, 30, 36, and 38) the pH of fruits remained constant. Generally, during ripening of fruits, an increase in pH is observed because of the decrease in acidity. Astudillo-Ordóñez and Rodríguez (2018) studied quality variables related to the food quality and reported pH ranged from 6.6 to 7.1. In addition, they observed an increase in pH during the first days of storage, as well as a decrease after the third week of evaluation. This behaviour was also observed by Marquez *et al*. (2014) who reported an increase in pH after passing the postharvest days in "Hass" avocado fruit. The pH for fruits of two different municipalities (Carmen de Viboral and El Retiro) ranged from 6.4 to 6.6 and from 6.4 to 6.5, respectively. This agrees with reports from Torres *et al*. (2013) who determined the influence of the ripening state on the physicochemical properties of tropical fruits (mango, passion fruit, and papaya);

they found pH increased slightly with the increase in the state of ripening. Russo *et al*. (2014) evaluated the effect of the modified atmosphere on the activity and quality of "Fuerte" avocado; the effect of the atmosphere had a slight influence on the pH variation, they reported a pH from 6.4 to 7.1 during the 25 days of evaluation.

During the ripening process, a pH decrease is characteristic; this is attributed to the degradation of the cell wall by pectin methylesterase on galacturonic acid chains, increasing the number of free carboxyl groups. Subsequently, the polygalacturonase acts on the segments that have been demethylated by the pectin methylesterase, increasing the carboxyl groups.

Total soluble solids (*TSS*)

In the storage of avocado at RT-21, REF-8, and MAP-8, no differences ($p > 0.05$) were found among methods (Figure 5). Furthermore, storage time in MAP-8 had no effect on *TSS*. Franco-Gaytán *et al*. (2018) reported a similar behaviour for *TSS* during storage in MAP. The total soluble solids ranged from 6.3 to 6.9 and 5.3 to 7.7 °Brix during storage and post-storage ripening, respectively. For RT-21 storage at eight days plus four days of post-storage ripening (day 12), an increase of 18.5 % in total soluble solids was observed in regard to the second day of ripening (day 2). On the other hand, the *TSS* of fruits from RT-21PSR at day 12 (7.7 °Brix) was different ($p < 0.05$) respect to REF-21PSR and MAP-21PSR after 32 days at 8 °C plus six days at 21 °C (day 38), showing a decrease of about 22 % in both storage methods. Total soluble solids of fruits in REF-21PSR and MAP-21PSR showed no difference ($p > 0.05$) between days 14 and 38. This shows the benefit of using REF or MAP as preservation methods.

Russo *et al*. (2014) evaluated the effect of modified atmospheres on the activity and quality of "Fuerte" avocado; the effect of the atmosphere had a slight influence on the

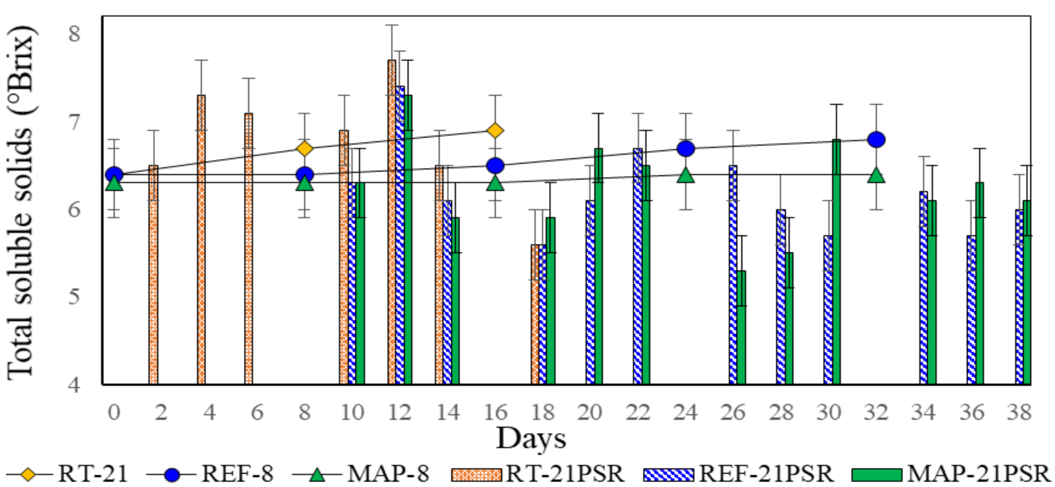

Figure 5. Total soluble solids of "Hass" avocado during storage at room temperature at 21 °C (RT-21), refrigeration at 8 °C (REF-8), and modified atmosphere packaging at 8 °C (MAP-8) for 8, 16, 24, and 32 days and post-storage ripening (PSR) at 21 °C for 2, 4, and 6 days. Vertical bars represent LSD = 0.8 °Brix (Fisher, $p \leq 0.05$).

variation of the total soluble solids. They reported, during the 25 days of evaluation, an interval from 5.9 to 7.9 °Brix. In addition, results of the present study are similar to those reported by Astudillo-Ordóñez and Rodríguez (2018) who found *TSS* from 5.1 to 7.3 °Brix; also, those researchers observed an increase in total soluble solids during the first four weeks. The physical and chemical variables in a fruit depend on both internal (cultivar and state of ripening) and external (environmental and storage conditions) factors. The increase of the total soluble solids obtained in this study can be explained because during ripening, starch is hydrolysed to organic acids, soluble pectin, and simple sugars; the latter constituting most of the total soluble solids. Total soluble solids decrease when the starch reserves are finished as a result of respiration.

CONCLUSIONS

"Hass" avocado stored in a modified atmosphere at 8 °C showed a firmness similar to that of the fresh fruit during the entire 32 d of storage. In contrast, fruits stored at room temperature showed a marked reduction in firmness during the first days of storage. In refrigeration, avocados showed a considerable reduction in firmness during the first eight days of storage.

Avocado stored in refrigeration or modified atmosphere at 8 °C showed a colour more similar to that of fresh avocado, with less total colour differences in exocarp and mesocarp, compared to those stored at room temperature. After storage at 8 °C in MAP, when avocados were transferred to normal atmosphere at 21 °C, firmness and external colour reached those of refrigeration or room temperature after six days of post-storage ripening. Avocado fruits stored at 8 °C in MAP should then be consumed in less than six days after disrupting the package.

The type of storage had no effect on pH and total soluble solids during storage for 8, 16, 24, and 32 d**.** The evaluated quality variables in "Hass" avocado during storage indicated that the use at 8 °C of AG Fresh® modified atmosphere packaging is a viable alternative in the preservation of these fruits. These storage conditions allow to extend the useful life of avocado for a period twice as long as that at room temperature, due to the firmness retention and lesser colour changes, properties that are important referents of quality.

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