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Color variation in the apex of the avocado fruit (*Persea americana* Mill.) cv. 'Hass'as harvest index

Variación del color del ápice en el fruto de palto (*Persea americana* Mill.) cv. 'Hass' como índice de cosecha

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Abstract

The objective of this investigation was to establish as a harvest index in avocado fruits cv. Hass the changes in pigmentation and color at the level of the apex of the fruit. For this, from week 23 after maximum flowering to week 29, 30 fruits by week of similar and homogeneous conditions were taken from panicles previously marked at the beginning of flowering were analyzed. Changes in pigmentation and color on the apex side of the fruit were evaluated through the chromatic parameters L*, a*, b*, C*, h°, and the color index (CI) was estimated. of avocado maturity (AMI) the concentration of chlorophylls a, b and total and the quantification of the percentage of lenticellar coverage (LC) all of which were related to the percentage of matter of the apical (DMA), central (DMC) and basal sides. (DMB) of the fruit. The results had statistical differences between the color parameters and the dry matter of the fruit but with low correlation and determination coefficients. The h° hue was the only chromatic parameter that had a better relationship with the percentage of dry matter (r= -0.42). The behavior of the lenticellar coverage with respect to the weeks of evaluation and the percentage of dry matter of the fruit are explained through a third-degree polynomial curve with relationship coefficients (R^2=0.97) and (R^2=0.84) respectively. This would make it possible to estimate based on the percentage of lenticellar coverage of the apex of the avocado cv. Hass the percentage of dry matter of the pulp, the lenticellar coverage must be at least 6.7 % to ensure a percentage of dry matter (22 %) ideal to start the fruit harvest. Regarding the concentrations of chlorophyll *a, b,* and total, these did not present differences or variations in the apex side of the fruit.

Keywords: *Maturity, lenticellar coverage, dry matter, harvestin*

Resumen

La presente investigación tuvo como objetivo establecer como índice de cosecha en frutos de palto cv. Hass los cambios en la pigmentación y color a nivel del ápice del fruto. Para ello desde la semana 23 después de máxima floración hasta la semana 29 se analizaron 30 frutos por semana de igual condición homogénea y similar tamaños tomados de panículas previamente marcadas al inicio de floración. Los cambios en la pigmentación y el color en el lado del ápice del fruto se evaluaron a través de los parámetros cromáticos

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L*, a*, b*, C*, h°, además se estimó el índice de color (CI) el índice de madurez de palta (AMI) la concentración de clorofilas *a, b* y total y la cuantificación del porcentaje de cobertura lenticelar (LC los cuales se relacionaron con el porcentaje de materia de los lados apical (DMA), central (DMC) y basal (DMB) del fruto. Los resultados muestran diferencias estadísticas entre los parámetros de color y la materia seca de la fruta, pero con coeficientes de correlación y determinación bajos. Siendo el matiz h° el único parámetro cromático que tuvo una mejor relación con el porcentaje de materia seca (r= -0.42). El comportamiento de la cobertura lenticelar con respecto a las semanas de evaluación y al porcentaje de materia seca del fruto se explican a través de una curva polinómica de tercer grado con coeficientes de relación (R^2=0.97) y (R^2=0.84) respectivamente. Ello permitiría estimar en base al porcentaje de cobertura lenticelar del ápice de los frutos de palto cv. Hass el porcentaje de materia seca de la pulpa debiendo la cobertura lenticelar ser al menos de 6.7 % para asegurar un porcentaje de materia seca (22 %) ideal para iniciar la cosecha de frutos. Respecto de las concentraciones de clorofila *a, b* y total, estas no presentaron diferencias ni variaciones en la zona apical del fruto.

***Palabras clave**:* Madurez, cobertura lenticelar, materia seca, recolección, aguacate

Introduction

There are several research papers that mention dry matter and oil content as the most useful maturity indices to define the harvest time of avocado fruits (Parodi et al., 2007). However, to obtain this information, an extraction of fruits must be carried out, the quantity of which depends on the productive area to be evaluated, and this sample must be representative of the total fruit existing in the evaluated field (Waissbluth & Valenzuela, 2007). Subsequently, the fruit is subjected to a laboratory analysis to determine the dry matter content, either by drying it in an oven or by microwave oven (Parodi, 2014). However, the precision of the data depends on the size of the sample (fruits) and its location in the tree (Venturo, 2021) in addition to the extraction procedure of the pulp sample (Arpaia et al., 2001) and the application of the technique. drying (Dorta et al., 2021). If the level of maturity of the avocado fruits is not adequate, a heterogeneous ripening of the fruit will be observed in the boxes (Hernández et al., 2016), an aspect that generates rejection by the consumer and cost overruns due to the need to reorganize it in the boxes and pallets, since the ripest ones have to be separated from those that are not ripe each time when the fruit arrives at the unloading area of the final market (Defilippi et al., 2012). Added to this is the fact that, in recent years, as there has been a greater production of avocados, there is greater pressure to harvest before the fruits present the optimum value of oil percentage, thereby affecting their reaching an adequate ripeness for consumption (Coggins, 1984).

In the case of Peru, the officially approved method to allow the export of avocado to the international market is the determination of the percentage of dry matter, this method has been approved by SENASA for which the avocado cv. Hass (samples) must have a minimum of 21.5 percent dry matter (Resolución Directorial N° 0009-MIDAGRI-SENASA-DSV, 2014). A characteristic of the fruits of cv. Hass to the maturity of consumption is the variation of the color of the epidermis which goes from an intense green to a dark purple due to the degradation of chlorophyll and the increase of anthocyanins (Pérez de los Cobos, 2012). Another phenomenon appreciated in the maturity of the avocado fruit is the change of stomata to lenticels, which vary according to the specific sites expanding and increasing during fruit growth (Blanke, 1992).

The present research was oriented to establish an alternative harvest index of the relationship between the percentage of dry matter with the pigmentation, the color changes, and the level of coverage of the lenticels on the apex side of the avocado cv. Hass with the purpose of having a parameter that indicates the optimal moment of its collection and as a technique that allows to visually and practically identify which are the fruits that are with homogeneous maturity at the moment of being harvested.

Materials and methods

For the development of this research, avocado fruits were taken from 8-year-old trees of cv.

Hass grafted on rootstock cv. Top Top. The trees were selected from lot B of Fundo "La Victoria" located in Quilmaná, Cañete-Lima (Latitude: -12.972379, Longitude: -76.390126, Altitude: 150 m.a.s.l). For this, 80 panicles per tree were marked in 10 trees (800 panicles in total) previously selected for homogeneous conditions of size and canopy. The identification of the panicles was carried out at the moment of maximum flowering. The sampling and extraction of the fruits were carried out on the same day per week of evaluation starting from week 23 after maximum flowering (WAMF) until week 29 after maximum flowering. In each evaluation week, 30 random fruits of homogeneous condition were taken (Waissbluth & Valenzuela, 2007) from the selected trees and panicles. Once the fruits were collected, they were transferred to the UNALM Horticulture Laboratory located in La Molina, Lima for the respective physical-chemical analysis. For their transfer, the fruits were conditioned inside expanded polystyrene boxes which contained bags of refrigerant gel in order to maintain the temperature at approximately 14 °C. Upon arrival at the laboratory, the fruits were stored at 12 °C for 10 hours for further evaluation. Before starting the evaluation of the fruits in the laboratory, they were cleaned by washing only with water using a fine sponge in order to remove any impurities or traces of dust from their surface, to later proceed with the following evaluations on each harvested fruit:

Percentage of dry matter (DM).

It was determined on three sides of the fruit; apex (DMA), central (DMC), and basal (DMB) sides (Figure 1). To do this, the procedure was as follows: The pulp samples from the central (DMC) and apex (DMA) sides were extracted with a 1.6 cm diameter punch according to the procedure mentioned by Arpaia et al. (2001). While the sample of the basal side (DMB) was obtained by cutting with a knife directly from this portion. Once each sample of fresh pulp was extracted, the epidermis was removed as well as any trace of the seed structure and then with a grater obtain a sample of pulp of 15 gr. Then the samples were placed inside an aluminum foil bag

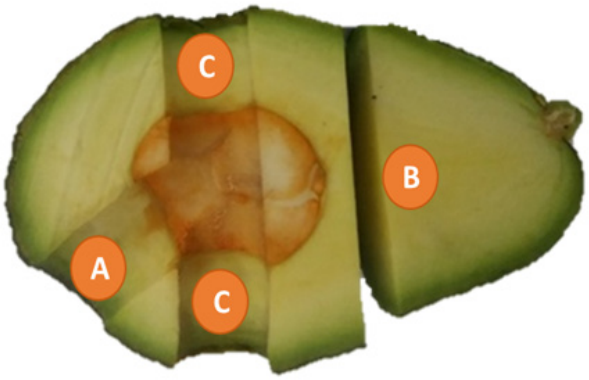

Figura 1. Location of the sides in which the pulp samples were extracted to determine the percentage of apex dry matter (A), central dry matter (C) and basal dry matter (B) in avocado cv. Hass.

to finally be placed in an oven at a temperature of 80 °C for 24 hours (Parodi, 2014; Waissbluth & Valenzuela, 2007), the dry weight of the pulp sample was recorded after verifying that it no longer contained water and did not show any variation in its weight. The percentage of dry matter was obtained with an electronic scale with two decimal places of the Adam Equipment™ brand, model Eclipse EBL 6202i, calculated based on the following equation:

$$\%\ Dry\ Matter = (Dry\ weight\ of\ the\ pulp\ sample) \times 100\ \% / (Fresh\ weight\ of\ the\ pulp\ sample)$$

Epidermis color (EC).

The Konica Minolta CR-400 colorimeter was used, and the registered values were given under the CIE-Lab and CIE-LCh color system, obtaining for each measurement the indicators: L* (Lightness), a* (range of red-green chromatic coordinates), b* (yellow-blue chromatic coordinate range) and C* (Chroma), h° (Hue) respectively. The color measurement was taken in the portion of the epidermis located in the apical zone of the organ in a radius of approximately 4 mm around the stylar scar. In addition, the Avocado Maturity Index (AMI) was used based on what was proposed by Osuna-García et al. (2011) and the Color Index (CI) mentioned by Zarazúa-Escobar et al. (2005) according to the formulas:

AMI = (a*/L*) x (1) (1000)/ [(a*)2 + (b*)2]1/2
and CI= -10 (a*) x (b*)/ (L*)

Lenticellar coverage (LC).

It was determined, for each week of evaluation; the percentage of lenticels covering the apex side of the fruit. For this, the epidermis around the apex was photographically recorded. The fruits were placed inside a 31 cm x 35 cm x 50 cm wooden box whose interior walls were covered with matt white cardboard. For the taking of images, the fruits were arranged in a vertical position on a cylindrical support and with the pedicel side down, generating a separation of the fruit with the base of the box of 10 cm in height. Subsequently, the camera was placed on a support about 50 cm above the inner side of the base of the box and approximately 30-33 cm above the fruit. The photographic camera used was a semi-professional Olympus model SZ-10 with 14 Megapixels set to ISO 64, without flash, in macro mode, and with a 3X zoom. The environment around the box was illuminated by white light fluorescent and before each photograph the intensity of the light in the environment was measured with an Extech Instruments model HD450 photometer to ensure a light intensity of 285 Lux. Each photograph was cut using the Adobe Photoshop CS5 ® version 2010 program for the Windows platform, to later take them to print size and then cut a square of five centimeters on each side of the image, considering the central point of reference of the grid to the stylar scar. All the images were subsequently transferred to an A4 sheet in Word for Windows® 2013 format to be later printed, and placed under a transparent millimeter sheet in order to count the grids where the lenticels appeared visibly. Lenticel coverage was determined according to the equation (Figure 2):

%CL= (Number of squares where lenticels appear x 100)/Total squares

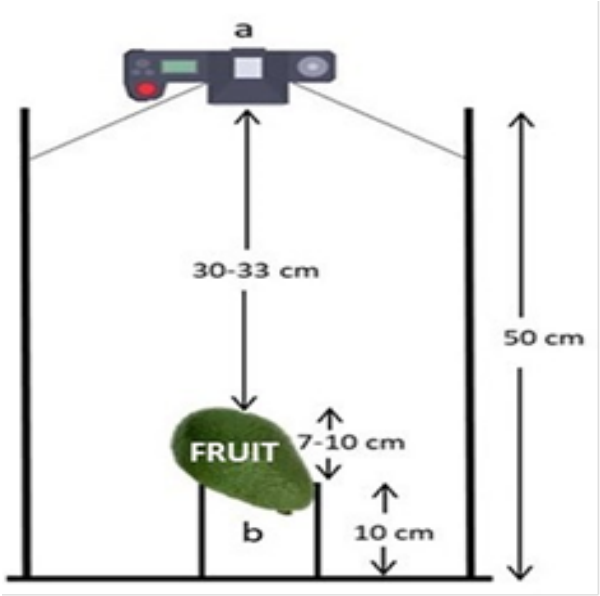

Figure 2. Diagram of the photographic record to estimate lenticellar coverage at the apex of the fruit a). photographic camera; b). fruit support.

Chlorophyll content (CC):

According to the UTIM protocol (2018), the chlorophyll content of the apex of the fruit was determined in the region located around the stylar scar. For this, 0.05 g of the epidermis from this area was taken. Subsequently, the tissue was placed in a mortar and 80 % ethanol was added, grinding until the pigment was extracted, then the mixture of ethanol and plant tissue was placed in a test tube and centrifuged at 5000 RPM for two minutes using a Sigma 2 model centrifuge. -16P. An aliquot of the preparation was then taken with a pipette and placed in a cell for absorbance reading in a Labomed Inc. Spectro 22 model spectrophotometer at 645 and 663 nm previously calibrated to zero using only the 80 % ethanol solution for said calibration. The content was calculated using the following equations:

Chlorophyll a = 12.7 x A663 – 2.69 x A645

Chlorophyll b = 22.9 x A645 – 4.68 x A663.

Where A663 and A645 are the measurements at 663 and 645 nm. The result of the equation was expressed in µg/g of fresh weight.

***Statistical tests*:**

These were carried out based on a completely randomized statistical design to determine the differences between the weeks evaluated from week 23 to week 29 after maximum flowering (WAMF) and where each week was considered as if it were a treatment each with 30 repetitions (evaluated fruits) which generated a total of 210 evaluated fruits during the seven weeks of harvest. Likewise, the Duncan test and the Kruskall-Wallis test were used as comparative tests of means with a significance level of α=0.05. Pearson's correlation coefficients were also established with α=0.05 and correlation models were made between the following evaluated variables: Weeks after maximum flowering (WAMF)versus; (parameters of epidermis color, percentage of dry matter in apex, central and basal sides of the fruit, concentration of chlorophyll a, b and total and lenticellar coverage). Also, it correlated; chlorophyll *a, b* and total concentration versus epidermis color parameters and percentage of dry matter in apex, central, and basal sides and also evaluated the degree of correlation between the percentage of dry matter in apex, central, and basal sides of the fruit versus lenticellar coverage. The statistical data was analyzed through the Info-Stat statistical program (Di Rienzo et al., 2018).

Results and discussion

Percentage of dry matter.

When analyzing the data of the variables DMA, DMC, and DMB in each of the evaluation weeks after maximum flowering (WAMF), significant statistical differences were obtained in the samples on each evaluation date, observing an increase in the dry matter values in all sections of the fruit (Figure 3). In this case, the Pearson correlation coefficients between the percentage of dry matter versus WAMF were 0.77, 0.88, and 0.79 on the apex, central, and basal sides respectively (Table 1). In this case, the general pattern of distribution of the dry matter percentage in the fruits coincides with what was indicated by Schroeder, (1987), since a higher dry matter content could be observed in the basal portion of the fruit, followed by the apex portion and in less quantity in the central portion.

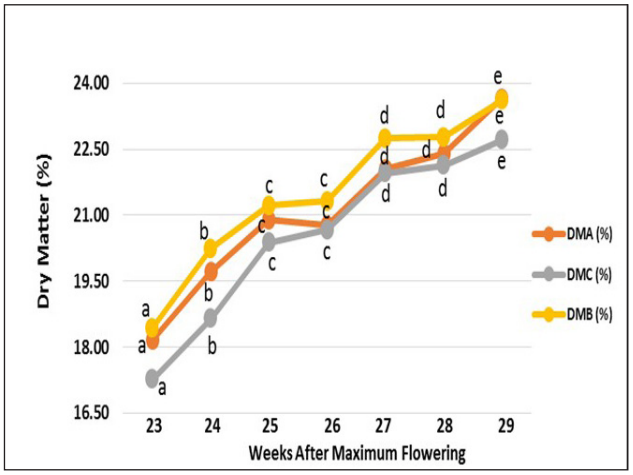

Figure 3. Percentage of dry matter in the apex (A), central (C) and basal (B) sections of avocado fruits cv. Hass from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05)

Epidermis color.

The color parameters of the CIELab system (Figure 4) presented significant differences (p< 0.05) as the fruits were evaluated in the different weeks after maximum flowering (WAMF). In the case of the chromatic parameters a* and b*, the trend was towards a reduction in values, a trend that would indicate a slightly perceptible loss of light colors of the epidermis to go to darker colors and that are in accordance with a tendency to fade. Loss of the L* value (Lightness). However, it was possible to determine that the chromatic parameters of color a* and b* presented greater variability (CV 15 %). In contrast to the chromatic

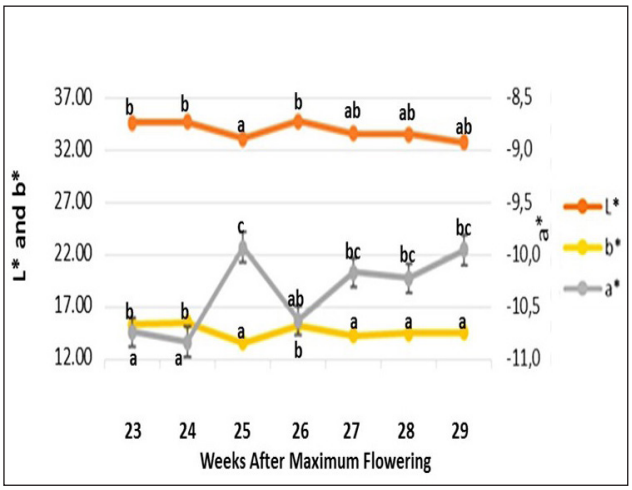

Figure 4. Color index L* a* and b* in the apex side of avocado fruits cv. Hass from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05).

Table 1. Pearson coefficients between the variables of dry matter, color parameters and chlorophyll (Clor) evaluated in avocado cv Hass fruits. Where; (WAMF): Weeks After Maximum Flowering; DMA: (Dry Matter in Apex side); DMB (Dry Matter in Base side) ; DMC (Dry Matter in Central side); AMI: (Avocado Mature Index); CI: (Color index); LC: (Lenticellar coverage) (p=0.05)

Varibles	WAMF	DMA (%)	DMA (%)	DMB (%)	Clor. a (µg/g)	Clor. b (µg/g)	Total Clor. (µg/g)
DMA (%)	0.77 *	1.00	-	-	-	-	-
DMC (%)	0.88 *	-	1.00	-	-	-	-
DMB (%)	0.79 *	-	-	1.00	-	-	-
L*	- 0.29 *	- 0.17 *	- 0.22 *	- 0.25 *	- 0.26 *	- 0.05	- 0.17 *
a*	0.25 *	0.16 *	0.22 *	0.24 *	0.32 *	0.10	0.23 *
b*	- 0.11	- 0.03	- 0.10	- 0.14 *	- 0.31 *	- 0.14	- 0.24 *
AMI	- 0.02	0.08	0.01	0.07	- 0.22 *	- 0.13	- 0.19 *
CI	- 0.15 *	- 0.07	- 0.14 *	- 0.17 *	- 0.31 *	- 0.12	- 0.24 *
C*	- 0.14 *	- 0.05	- 0.11	- 0.15 *	- 0.33 *	- 0.13	- 0.25 *
h°	- 0.42 *	- 0.41 *	- 0.42 *	- 0.30 *	0.08	0.20 *	- 0.15 *
Clor. a (µg/g)	0.01	0.03	0.09	0.06	1.00	-	-
Clor. b (µg/g)	- 0.16 *	0.12	0.07	- 0.06	-	1.00	-
Total Clor. (µg/g)	- 0.08	- 0.05	0.02	0.0047	-	-	1.00
LC (%)	0.42 *	0.34 *	0.39 *	0.38 *	-	-	-

component L* which presented a variability that did not exceed 5 %. This change in the chromatic patterns observed at the apex level would be related to the higher concentration of lenticels and the changes that these undergo as the avocado fruits develop and mature on the tree (Schroeder, 1950). Osuna-Garcia et al. (2011) observed a similar trend regarding the changes in the hue of the values of the chromatic components a* and b* in the epidermis of avocado ´Hass' fruits but did not find a direct relationship with the ripening of the fruits once that these were withdrawn and put to mature in post-harvest.

Regarding the avocado maturity index (AMI) as well as the color index (CI) (Figure 5), they presented a similar behavior. Both showed statistical differences as the evaluation weeks progressed. In the case of AMI, the response was almost similar between the different evaluation weeks. While the CI presented a slight tendency to decrease as it went from 23 to 29 WAMF. In this case, both AMI and CI show that the color changes of the epidermis in the apical portion are not very useful as an alternative to establishing the ripening of avocado cv. Hass when these are still on the tree. It is clear that the color changes of the epidermis of avocado cv. Hass will only be observed after the harvest of the fruits and when they begin their stage of maturation and subsequent softening in postharvest (Eaks, 1978; Serrano-Garcia et al., 2022), not being useful to consider them as an alternative that

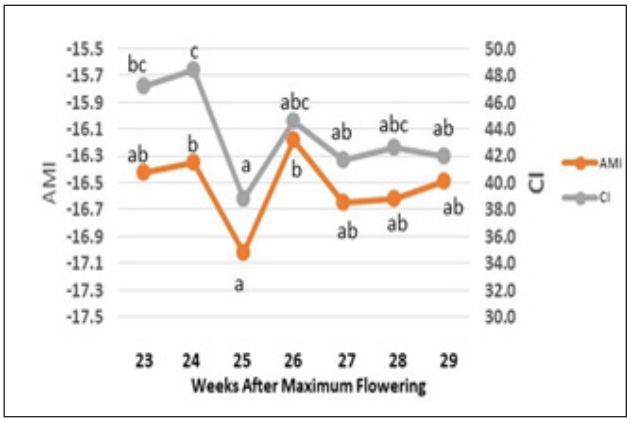

Figure 5. AMI and CI in the apex side of avocado fruits cv. Hass from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05).

allows estimating the maturity of avocado fruits (Escobar et al., 2019).

In the CIELCh system, the variation of the chromatic components L*, C*, and h˚ at the level of the epidermis of the apex of the fruit presented significant differences between the weeks evaluated (Figure 6), these differences, both in L* (Lightness) and in C*(Chroma), despite showing a slight tendency to decrease as you go from 23 to 29 WAMF; They do not turn out to be a sufficiently useful pattern to identify which are the fruits of avocado cv. Hass that are mature while they remain on the tree. It is important to mention that the values of h˚ (Hue) progressively decrease as the weeks in which the fruits were extracted progress, an aspect that coincides with what was mentioned by Escobar et al. (2019).

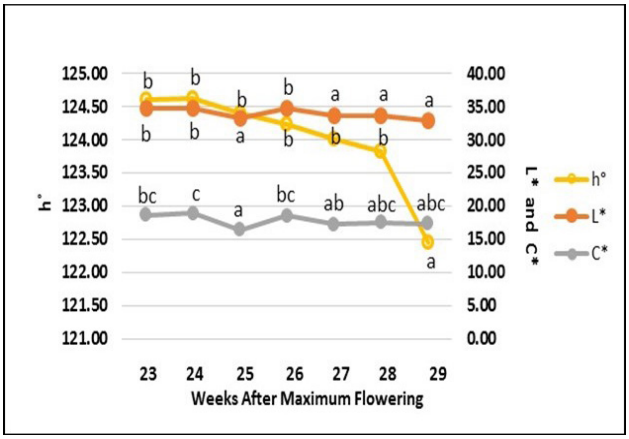

Figure 6. Color index L*. C* y h˚ in the apex side of avocado fruits cv. Hass from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05).

This decrease in the values of h˚, which is directly related to the levels of hue; indicates a change in the perception of the greenish color of the epidermis, a change generated by a change in the Hue value angle (h°) which goes from 124˚ Hue at week 23 (WAMF) to around 122° Hue at week 29 (WAMF) values that were also obtained by Escobar et al. (2019). It is clear that the chromatic indices L* and C* mentioned are not useful to define harvest maturity in avocado cv. Hass while it remains on the tree, but whose modification is better appreciated at the time than the fruits of cv. Hass begin their softening and ripening phase post-harvest (Osuna-Garcia et al. 2011) and whose variations were also clearly identified by Ashton et al. (2006) as part of the changes in the pigmentation of the epidermis of the avocado cv. Hass when these begin their postharvest ripening.

The Pearson correlation analysis (Table 1) between the dry matter values of the apical (DMA), central (DMC), and basal (DMB) sides of the fruit presented statistical differences with the color parameters, L*, a*, and h °. Likewise, in the case of DMC, these differences were also presented in relation to the color index (CI), in the case of DMB this also presented statistical differences with the chromatic index b*, the color index (CI), and with the Chroma values (C*) while DMC also presented statistical differences in relation to the color index (CI). However, the correlation coefficients (r) between the dry matter values of the different sides from which the pulp was extracted in relation to the different fruit chromatic parameters turned out to be very low, only the hue (h°) presented a better quality. degree of correlation which was r= -0.41 with DMA, -0.42 with DMC, and -0.30 in relation to DMB. The Pearson correlation analysis (Table 1) between the chromatic parameters and the weeks of fruit sampling showed significant differences with L*, a*, CI, C*, and h° but whose degree of relationship was very low with all the variables. color, except with h° (r= -0.42) which would indicate that this chromatic component has a medium negative influence on changes in the hue of the color of the epidermis in the apex portion of the cv Hass fruit. The results presented by the chromatic indicators, mainly those obtained by h°; are similar to those found by Pérez de los Cobos (2012) when they evaluated the color changes of the equatorial part of the ´Hass´ avocado during its development aspect that was also observed by Chen et al. (2009) in ´Sharwil´avocados during the harvest season. In this case, the gradual loss of h° values indicates a progressive change in the shade of the color of the epidermis on the apex side of the fruit. Change that was presented in a more noticeable way over the last weeks of evaluation. In this sense h° (Hue), as mentioned by Escobar et al. 2019; could turn out to be an alternative parameter for the identification of harvest maturity in avocados.

Chlorophyll content.

The concentration of chlorophylls *a, b,* and total evaluated in the ápex side of the fruit presented significant differences in all cases and for each of the evaluation dates. It was possible to verify that the chlorophyll *a, b,* and total, followed the same pattern of behavior, observing the increase in their values up to 25 WAMF and then maintaining and finally decreasing from 27 WAMF onwards (Figure 7). When performing the Pearson correlation analysis (Table 1), no relationship was found between the chlorophyll contents for the different weeks of evaluation, it was only possible to obtain significant differences in the comparison made with the levels of chlorophyll *b* without this implying a degree of high correlation. The low Pearson correlation coefficients obtained

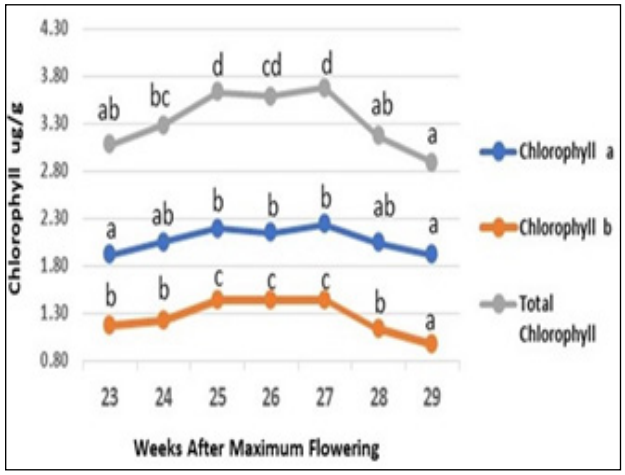

Figure 7. Chlorophyll a, b, and total concentration in the apex side of avocado fruits cv. Hass from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05).

in the analysis of chlorophyll *a, b,* and total in relation to the different WAMF in which avocado cv. Hass (Table 1) would confirm that there is no significant degradation in the concentration of said pigment at the level of the apex of the fruit. A condition that can determine a notorious persistence of chlorophylls *a, b,* and total observed on the different dates is due to the little or almost no loss of integrity by the chloroplasts present in the epidermis of the avocado fruits while they remain on the plant. as was observed in the case of cv Fuerte (Blanke, 1992). It has been mentioned that both the synthesis of anthocyanins and the degradation of chlorophyll would be influenced by both hormonal and environmental factors, light being one of these elements, as mentioned by Bouzayen et al. (2010). In this sense, it is important to take into account that the ripening process of avocado fruits related to the softening and pigmentation changes in the epidermis begins at the moment in which this fruit is removed from the tree and that this is evidently observed days after fruits were collected as mentioned by Bower and Cutting (1988). Therefore, it can be indicated that the changes in the chlorophyll concentration at the level of the epidermis in the avocado fruits will not show greater modification, these changes only being perceived during the ripening process of the fruit in postharvest. Likewise, the reduction in the levels of chlorophyll *a, b,* and total obtained after week 27 of evaluation would respond more to the condition of the time the fruit remains on the tree, an aspect that was also observed by different researchers (Hofman et al., 2000; Chen et al. 2009; Magwaza & Tesfay, 2015; Mathaba et al., 2015).

Lenticellar coverage percentage.

The statistical analysis using the Kruskal and Wallis test between the percentage of lenticel cover in relation to the different weeks of evaluation presented statistical differences, observing an increase in the lenticel cover of the apex of avocado cv Hass fruits until week 27, and then maintained until week 28 and subsequently decrease on week 29 (Figure 8). This increase in the number of lenticels observed at the apex of avocado cv. Hass coincides with what was mentioned by Valmayor (1964) who observed an increasing presence of lenticels in the fruits of different avocado varieties as they developed and matured on the plant and also responds to what was mentioned by Schroeder (1950) regarding the increasing appearance of lenticels as the exocarp in avocado fruits develops and matures. On the other hand, it is possible that the reduction in the proportion of lenticels observed in week 29 is related to the notorious change in the pigmentation of the epidermis influenced by the changes in the levels of hue (h°), which drop significantly and may affect proper identification of the lenticels present at the apex. The intensity of the lenticel cover in the

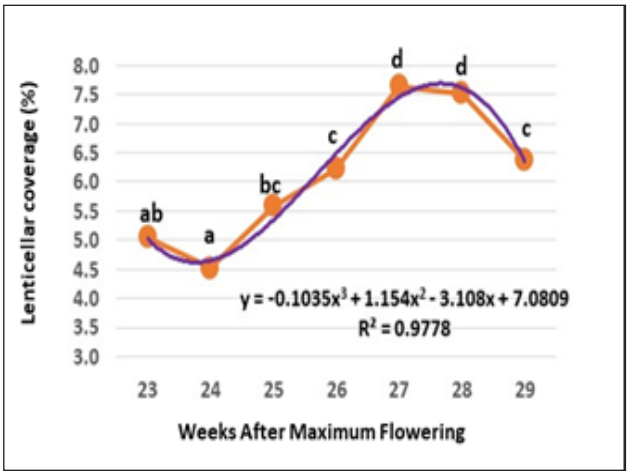

Figure 8. Percentage of lenticel coverage in the apex side of avocado fruits cv. Hass from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05).

apex side of the 'Hass' fruits is correctly plotted as a third-degree polynomial curve over time, which presents a high correlation between the percentage of lenticel cover/weeks of evaluation (R^2 =0.97). The behavior of the curve shows two inflection points, one almost at the beginning of the ripening process of the 'Hass' avocado and the second and most noticeable on weeks 27 to 28 of WAMF, moments in which the apex side of the fruit presents the maximum values of percentage of lenticel cover before beginning to decrease between parameters evaluated. When performing the Pearson correlation analysis (Table 1) between the dry matter values of the ápex (DMA), central (DMC), and basal (DMB) sides of the fruit with the color parameters, all the dry matter values of the three zones presented statistical differences with the color parameters L*, a* and h°. Likewise, in the case of DMC, these differences were also presented in relation to the color index (CI), in the case of DMB this also presented statistical differences in relation to the chromatic index b*, the color index (CI) and with Chroma values (C*) while DMC also presented statistical differences in relation to the color index (CI). However, the correlation coefficients (r) between the dry matter values of the different sides from which the pulp was extracted turned out to be very low and only the hue values (h°) presented a better degree of correlation with r. which fluctuated between -0.42 to -0.41.

Lenticellar coverage percentage and dry matter percentage.

The behavior of the lenticel cover (LC) in relation to the percentage of fruit dry matter (DMC) can be described as a third-degree polynomial curve (R^2=0.84) (Figure 9). When performing the Pearson correlation analysis (Table 1) between these two parameters, statistical differences with a degree of correlation (r=0.39) were presented, this would indicate that the lenticellar coverage, which is changing at the apex level in the fruits of avocado cv. Hass, in each evaluation period as observed in the mosaic of images (Figure 9); shows an increasing trend where values between 6.7 % to 7.6 % of lenticel coverage would indicate a certain estimate of the percentage levels of dry matter of the fruit (22 % -23 %),

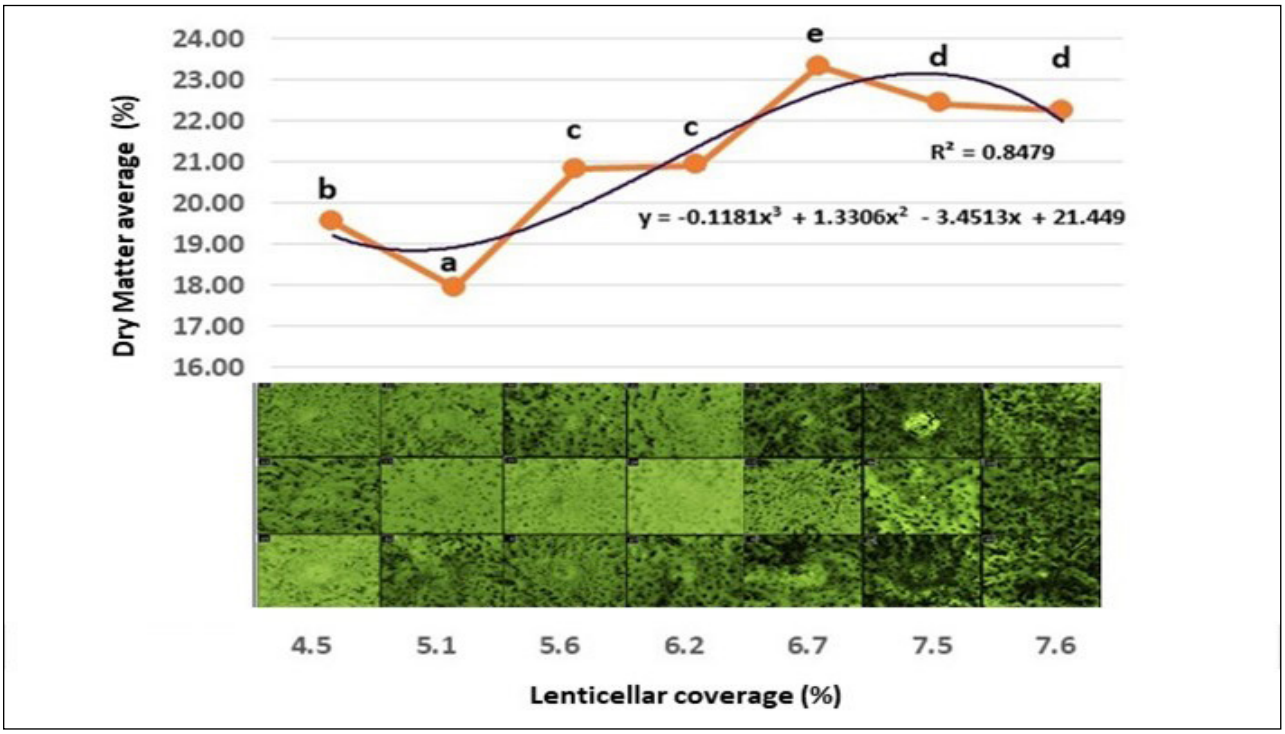

Figure 9. Comparison of the percentage of lenticellar coverage with the percentage of average dry matter and visual response of the lenticellar coverage in the apex side of avocado cv. Hass. from week 23 to 29 of evaluation. Values with the same letters do not differ statistically (p = 0.05).

levels that are considered adequate to establish that the fruits of avocado 'Hass' they are ripe for harvest (Parodi et al., 2007; Cerdas et al., 2014; Carvalho et al., 2014); It is very possible that the greater accumulation of stomata first and later their transformation into lenticels (Everett et al., 2008; Valmayor, 1964) in the apical portion of cv. Hass is more related to certain physiological processes such as water loss and changes typical of the ripening of the epicarp of the fruit when it is still on the tree (Schroeder, 1950). If we take this into account, and as mentioned by Cummings and Schroeder (1942); a greater formation of cork in the lenticels may turn out to be an indicator of avocado maturity, which would have a certain degree of certainty and would coincide with the increase in lenticel coverage at the apex level of avocado cv. Hass observed in the graphic records of the present investigation. Likewise, it is important to indicate that once the lenticels are present in the epicarp of the avocado fruits, they begin to gradually change color and that said change would be associated with the ripening process of the fruits (Scora et al., 2002). This could explain some of the results found regarding the changes in the epidermis color indices observed in this test, mainly in relation to the changes in the hue levels (h°) of the apical portion.

In general, the low determination and correlation coefficients show that the dry matter content in the evaluated sections of the fruit is not related to the changes observed in the color parameters considered in the present study, even at the instant in which the fruits of cv. Hass present the acceptable dry matter value to start their harvest. The results obtained in this work are similar to those found by Osuna-García et al. (2011), who did not find a correlation between the color parameters L*, a*, b*, and C* with the dry matter and are coincident with the h° values found by Pérez de los Cobos (2012) in the Hass cultivar. , who found that this value reached 125.4° at the physiological maturity of the fruit, and is also consistent with what was found by Chen et al. (2009), who observed that the green coloration of the fruit remained almost constant during the harvest season in the Sharwil variety.

It is important to consider that the color changes in the epidermis of avocado cv Hass fruits occur due to the generation and increase of ethylene days after they are removed from the tree, as mentioned by Bower & Cutting (1988), therefore the synthesis of this hormone is important for this fruit to reach maturity for consumption. In this case, ethylene would trigger the degradation of chlorophyll and the biosynthesis of anthocyanins in the epicarp of the harvested Hass avocado (Tingwa & Young, 1975; Cerdas et al., 2006).

Conclusion.

The results obtained in this trial allow us to establish a similar and ascending behavior in the accumulation of the percentage of dry matter (DM) in the central basal and apical sides in avocado fruit cv. Hass as they were harvested from 23 to 29 weeks after maximum flowering (WAMF). The chromatic parameters L*, a*, b*, C*, and IC, as well as the AMI evaluated at the apex of ´Hass´ fruits are not suitable to be able to estimate their maturation while they remain on the tree. Likewise, the concentration of the levels of chlorophyll a, b, and total did not present modifications at the level of the apex of the fruits during the period in which they were evaluated. Only the correlation between the values presented by h°(Hue) depending on the different weeks after maximum flowering (WAMF) in which the fruits were harvested, turned out to be medium-low and with a negative slope ($r = -0.42$) showing this variation was apparently influenced by the changes observed in the intensity of the lenticel cover (LC) in the different weeks of evaluation, which would have some relationship with the ripening of the fruit during its permanence on the tree. The variation of the percentage of lenticellar coverage (LC) in relation to the percentage of dry matter is appropriately described through a third-degree polynomial curve that would allow estimation based on the lenticellar coverage evaluated at the apex level of avocado fruits. cv. Hass the percentage of dry matter of the pulp. In this case, the lenticellar coverage values in that area of the fruit of at least 6.7 % would indicate that they have an adequate dry matter percentage for harvesting.

The practical use of this knowledge would be given for elaborating a guide or visual table in which the levels of lenticellar coverage are shown, this would help the operator or evaluator of the maturity of avocado cv. Hass in the field to collect only the fruits with dry matter and more homogeneous maturity, thus ensuring a uniform ripening of the fruits in postharvest.

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Authors contributions

GPM: Conceptualization of the work, experimental design and revision of the manuscript, support, and supervision of the study. SLV: Support and supervision in fieldwork, statistical analysis, discussion, and results of the study. GPM: Fieldwork carried out, review of statistical analysis of results, discussion, and conclusion of the study.

Conflict of interest:

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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