Harvest management and postharvest technology

Scientific and technologic research article

Physicochemical parameters of avocado *Persea americana* Mill. cv. Hass (Lauraceae) grown in Antioquia (Colombia) for export

Parámetros fisicoquímicos del aguacate *Persea americana* Mill. cv. Hass (Lauraceae) producido en Antioquia (Colombia) para exportación

Camilo Ernesto Astudillo-Ordóñez,[1] Pablo Rodríguez[2*]

[1] Agroindustrial Engineering Student, Universidad Nacional de Colombia, Facultad de Ingeniería y Administración. Palmira, Colombia. Email: ceastudilloo@unal.edu.co

[2] PhD Researcher, Corporación Colombiana de Investigación Agropecuaria (Corpoica), Centro de Investigación La Selva. Rionegro, Colombia. Email: prodriguezf@corpoica.org.co. orcid.org/0000-0003-4832-5771

Thematic editor: Sebastián Escobar Parra (Corporación Colombiana de Investigación Agropecuaria [Corpoica])

Receipt date: 11/07/2017
Approval date: 06/03/2018

How to cite this article: Astudillo-Ordóñez, C. E. & Rodríguez, P. (2018). Physicochemical parameters of avocado *Persea americana* Mill. cv. Hass (Lauraceae) grown in Antioquia (Colombia) for export. *Corpoica Ciencia y Tecnología Agropecuaria*, *19*(2), 393-402.

DOI: https://doi.org/10.21930/rcta.vol19_num2_art:694

* Corresponding author. Kilómetro 7, vía Rionegro-Las Palmas, sector Llanogrande. Rionegro, Antioquia, Colombia.

Abstract

Hass avocado is transported maintaining an unbroken cold chain and in the destination market, it is ripened under controlled conditions. Fruit quality depends on preharvest, factors, harvest time and postharvest treatments. Colombia has poor information on quality parameters despite the current growing and fruit export boom. Therefore, the aim of this study was to determine some important fruit quality parameters. For that, Hass avocado fruits were harvested considering three maturity indexes form exporting orchards in Antioquia, where fruits were stored and ripened. Temperature, relative humidity and shipment times to the European market were simulated. Dry matter content was used as harvest index. Soluble solids, pH, and titratable acidity were analyzed as quality parameters. Fruit origin, harvest index and storage time had a significant effect on quality parameters of avocado ($p \leq 0.05$). There was an increase in Brix degrees (5.07 to 7.26) and pH (6.58 to 7.14) throughout the storage time until the fourth week, where these decreased. In contrast, acidity dropped (19.47 to 9.24%) with storage time. These quality parameters can be considered quality indicators; however, more studies are required.

Keywords: avocado, °Brix, fruit quality, pH, ripening, titratable acidity

Resumen

El aguacate Hass se transporta conservando la cadena de frío, y se madura de forma controlada en el mercado de destino. La calidad del fruto depende de factores precosecha, el momento de cosecha y los tratamientos poscosecha. En Colombia, a pesar del auge de la producción y exportación de frutos, no se tiene suficiente información sobre parámetros de calidad. Teniendo en cuenta lo anterior, el objetivo de este trabajo fue determinar algunos parámetros fisicoquímicos de interés en la calidad de fruto. Con ese fin, se cosecharon aguacates en tres momentos de madurez de cosecha, en fincas exportadoras en Antioquia, y luego se almacenaron y maduraron. Se simularon la temperatura y la humedad relativa de la cadena de exportación, así como la duración del envío al mercado europeo. La materia seca se consideró el indicador de cosecha, y se realizaron análisis de sólidos solubles, pH y acidez titulable como parámetros de calidad. El origen de los frutos, el momento de cosecha y el tiempo de almacenamiento ejercieron un efecto significativo ($p \leq 0,05$) en los parámetros fisicoquímicos del aguacate. Los grados Brix (5,07 a 7,26) y el pH (6,58 a 7,14) se incrementaron con el tiempo de almacenamiento hasta la semana cuatro, y después disminuyeron. En cambio, la acidez bajó (19,47% a 9,24%) en el transcurso del almacenamiento. Estos parámetros pueden ser indicadores de calidad, pero se requieren más estudios.

Palabras clave: acidez titulable, aguacate, calidad de la fruta, grados Brix, madurez, pH

Introduction

In Colombia, the cultivation of Hass avocado has increased, driven by exports to Europe, mainly to the United Kingdom, Spain and The Netherlands. According to Asociación Nacional de Comercio Exterior [National Association of Foreign Trade] (Analdex, 2017) in 2016, 18,200 t of this fruit were exported, compared to only 5,543 t exported the previous year, representing an increase of 241%.

Cerdas-Araya, Montero-Calderón and Somarribas-Jones (2014) point out that there is a relationship between harvest maturity indices and the postharvest fruit quality. Currently, harvest maturity indices as fruit length and diameter, presence or absence of skin brightness, skin color, time to fruit development, number of days remaining to reach maturity, respiration and ethylene production, pulp firmness, dry matter and oil content, among others, are currently used (Cerdas-Araya, Montero-Calderón, & Díaz-Cordero, 2006; Herrera-González, Salazar-García, Martínez-Flores, & Ruiz-García, 2017).

According to international standards, Hass avocado must have a dry matter content higher than or equal to 21%. However, this parameter can be affected by the avocado variety, the production area, agronomic management practices and climate, among other conditions.

In Colombia, there are no certified planting materials, and the agronomic practices as well as soils and climatic conditions are diverse in different farms, hindering a homogeneous fruit production (Carvalho, Velásquez, & Van Rooyen, 2014). In the country, fruits are harvested when they reach a percentage of dry matter equal to or higher than 23% (Henao-Rojas & Rodríguez, 2016).

Although for several fruit trees, there are values for physicochemical variables (acidity, Brix degrees and pH, among others) that are considered as harvest maturity and consumption indicators. However, in the case of Colombian avocados, there is not enough information to verify if it is possible to include these criteria for quality control in the productive sector.

Taking into account the above mentioned, the aim of this study was to evaluate the effect of the locality and the harvest maturity index on physicochemical variables of interest in Hass avocado fruits to establish the quality of fruits harvested in the Department of Antioquia. These were subjected to storage processes and controlled ripening, simulating shipment conditions for fruits destined to the European market.

Materials and methods

Fruit harvest and conditioning

Hass avocado fruits were harvested from three farms in the Department of Antioquia (Colombia) (table 1) in three harvest maturity stages, i.e. at 23 % ± 1.5 % (early harvest), 26% ± 1.5% (intermediate harvest) and 29% ± 1.5% (late harvest), taking into account the commercial export window that ranges from 23 % to 30 %.

During harvesting, the experimental lots were monitored taking at random five fruits in each farm and establishing dry matter content (Association of Official Analytical Chemists [AOAC], 1999). Once fruits reached the desired maturity stage (table 2), 32 were collected for each harvest maturity index in each farm (96 per farm and 288 in total). Fruits were examined to verify their compliance with export requirements regarding physical damage and presence of pests.

Later, these were coded and taken to the postharvest laboratory of Centro de Investigación La Selva (Rionegro, Antioquia) where they were conditioned according to commercial criteria: disinfection with prochloraz (active component: 0.05 % imidazole w/v) was carried out for 30 seconds and packed in commercial corrugated cardboard boxes.

Table 1. Location and climatic conditions of the avocado farms studied (2016)

Farm code	Bella Vista (BV)	El Banco (EB)	La Escondida (LE)
Region	Southwest	North	East
Latitude	05°35'51.2"	06°29'41.5"	06°05'53"
Longitude	75°48'39.3"	75°31'42"	75°26'31"
m a.s.l.	1,932	2,473	2,248
Average annual temperature (°C)	18.47	15.42	17.54
Average annual relative humidity (%)	80.92	77.63	81.30
Average solar radiation (W/m^2)	392.71	423.76	451.23
Precipitation (mm)	1,715.1	1,902.5	1,733.4

Source: Elaborated by the authors

Table 2. Dry matter content from different Hass avocado harvest times

Farm	Bella Vista		El Banco		La Escondida	
Index or maturity state	Dry matter (%)	SD	Dry matter (%)	Deviation	Dry matter (%)	Deviation
20-23 (early)	22.04	1.13	22.58	2.11	21.73	1.94
24-27 (intermediate)	26.24	1.25	26.48	2.08	24.49	1.75
28-31 (late)	29.49	0.72	30.73	1.54	29.51	1.41

Average for n = 5.
Source: Elaborated by the authors

Storage and ripening

Fruits were stored for different time periods: one control (0 weeks) and three treatments of 3, 4 and 5 weeks of storage (8 fruits per storage time) in climatic chambers (Memmert HPP 110 at 5 °C and 90 % relative humidity), simulating the commercial export process. Then, fruits were ripened in climatic chambers (Memmert HPP 110 at 20 °C and 90 % relative humidity).

Periodic inspections of all samples were carried out to suspend ripening when fruits reached their consumption ripeness, taking into account the scales defined by the international avocado quality manual (White, Woolf, Hofman, & Arpaia, 2009), the purple color of the epidermis and a moderate deformity to soft touch.

Physicochemical parameters

Physicochemical parameter analyses were carried out when fruits reached consumption ripeness. Each fruit was divided into halves, the seed and the skin were removed, and the pulp was homogenized. Tests were performed in duplicate for each analysis.

Dry matter was established according to the AOAC (1999) method (Stove Binder FD 115 UL) through convective drying at 105 °C for 24 hours or until achieving a constant weight.

To measure pH and acidity (percentage of tartaric acid) a potentiometer (Accumet Basic Cole-Parmer AB 15) was used following the AOAC protocols (1998) and the Ecuadorian technical standard (Ecuadorian Standardization Institute [INEN], 2009), respectively.

Regarding soluble solids (°Bx), the methodology published by Maftoonazad and Ramaswamy (2008) was used, in which an avocado pulp solution with distilled water was prepared in a 1:3 ratio, which was centrifuged (centrifuge Jouan G4.11) at 3,000 r. p. m. for 15 minutes, and then the measurement was made to the supernatant using a digital refractometer (Atago PAL-BX / RI).

Statistical analysis

A factorial design of 3 (maturity indices) by 3 (localities) by 4 (storage times) was used to compare means and establish the degree of difference among treatments; moreover, the significant differences and the Dunnett tests were carried out, the latter to establish differences among the control and the treatments for storage time. Analyses were performed using the Statgraphics Centurion XVI program with a 95 % confidence.

Results and discussion

Locality, time of harvest and storage time had significant effects on the physicochemical parameters of Hass avocados when fruits reached consumption ripeness (table 3). These results are similar to those obtained by Soto (1995) in Hass avocado produced in Valparaíso (Chile) in two harvest maturity stages and different storage times.

Differences regarding harvest moments are related to the processes that the fruit continues to perform while it is still on the tree, such as accumulation of solids or dry matter and fatty acids, increase in sugar content, decrease in organic acids, and formation of volatile substances (Pérez de los Cobos, 2012).

As for storage conditions, these retard certain processes that influence fruit maturation, especially ethylene production, which allows fruit to be stored for a time period without maturing completely or not maturing at all. However, the longer the time in which the fruits are stored, the greater the rates of formation or degradation of the compounds present in these (such as sugars or fatty and organic acids).

Table 3. Effect of various factors on the physicochemical parameters of avocado cv. Hass

Physicochemical parameters	Locality	Harvest moment	Storage time
°Bx	0	0.3627	0
pH	0	0	0
Acidez	0	0.0141	0

p-values lower or equal to 0.05 indicate significant differences (with a 95 % confidence).
Source: Elaborated by the authors

In addition, quality conditions may be affected, mainly in fruits subjected to long cooling times (Soto, 1995). For these reasons, collecting Hass avocados at different harvesting times and keeping them stored for a prolonged time period influences physicochemical parameters.

Soluble solids (Brix degrees)

A range between 5.07 and 7.26 °Bx was observed (table 4), and these results are in accordance with those obtained by Burdon et al. (2007) and Buelvas-Salgado, Patiño-Gómez and Cano-Salazar (2012).

Table 4. Physicochemical parameters of avocado cv. Hass at the consumer maturity stage

Farm (locality)	Harvest index	Physicochemical parameters		
		°Bx	pH	Acidity
Bella Vista	Early	7.26^{d}	6.85^{b}	12.37^{cde}
	Intermediate	6.22^{c}	6.87^{b}	13.88^{d}
	Late	5.90^{bc}	7.08^{cd}	11.09^{bcd}
El Banco	Early	5.07^{a}	6.58^{a}	19.47^{e}
	Intermediate	6.19^{c}	6.96^{bc}	13.14^{cd}
	Late	5.82^{b}	6.61^{a}	19.02^{e}
La Escondida	Early	5.12^{a}	6.70^{a}	10.74^{bc}
	Intermediate	5.28^{a}	6.71^{a}	11.92^{cde}
	Late	6.07^{bc}	7.14^{d}	9.24^{a}

Averages in parameters with different letters indicate significant differences ($p \leq 0.05$; $n = 32$). Eight fruits were studied per treatment at 0, 3, 4 and 5 weeks of storage.
Source: Elaborated by the authors

The °Bx tended to increase in the in early maturity stages, except at Bella Vista farm, where there was a decrease in mature fruits and previously stored fruits for four and five weeks under refrigeration conditions (figure 1a). A similar trend was observed in avocados harvested with intermediate and late maturity indices (figures 1b and 1c), but at the El Banco and La Escondida farms, sugars decreased in avocados subjected to five weeks of refrigeration (figures 1b and 1c).

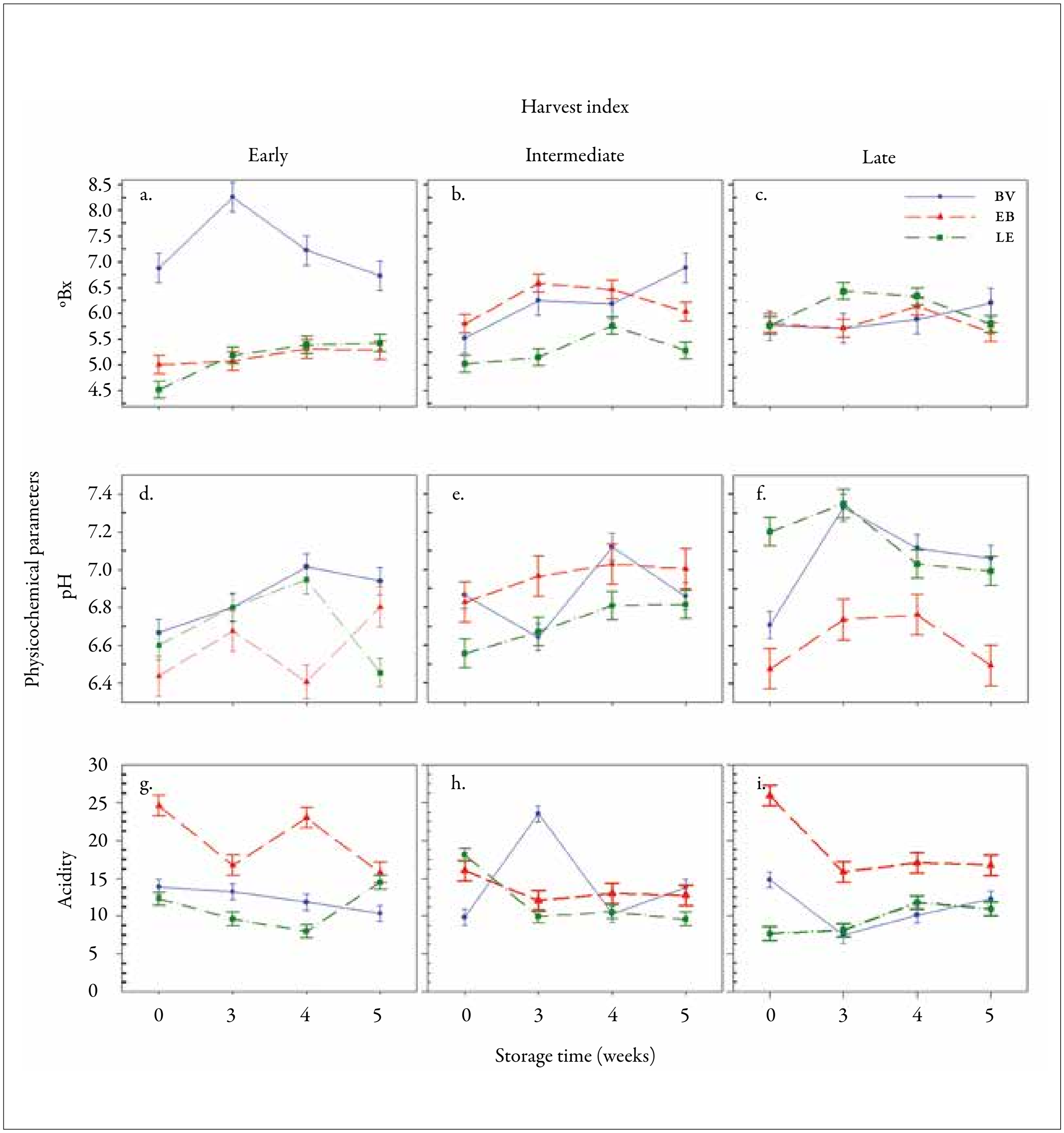

Figure 1. Behavior of physicochemical variables (°Bx, pH and acidity) of avocado cv. Hass in consumer maturity stage from different locations, harvest indexes and storage times. BV: Bella Vista; EB: El Banco; LE: La Escondida. Vertical bars represent standard deviation ($n = 8$).
Source: Elaborated by the authors

Previous behaviors could be due to different processes and biochemical changes that occur in fruits simultaneously. An increase in Brix degrees is related to the conversion of polysaccharides and organic acids into sugars or short-chained acids (Caparrotta et al., 2015; Vinha, Moreira, & Ferreira, 2013).

In this regard, Buelvas-Salgado et al. (2012) reported increases in °Bx during maturation. This was due to transpiration processes in which the fruit has a lower amount of water, and at the same time, a higher concentration of sugars due to the respiration phenomenon, both originated by the climacteric behavior of the avocado. However, Buelvas-Salgado et al. (2012) did not evaluate the effect of storage in °Bx.

According to the results obtained in our study, we can affirm that storing avocados for long periods (five weeks in this case), causes a decrease in °Bx. This may be associated with higher sugar degradation rates, which occur in greater proportion during the fruit ripening stage, when these compounds are used as a source of carbon and energy for the production of ethylene, enzymatic processes and color changes in the skin (from green to purple or black) (Liu, Robinson, Madore, Witney, & Arpaia, 1999).

Likewise, the locality had a significant influence on the °Bx (table 3). In consumer ripening stage, Vinha et al. (2013) characterized Hass avocado of Portuguese origin and reported values of 6.68 °Bx. On the other hand, Henríquez, Patiño and Salazar (2012) mentioned a lower value of 5.51 °Bx for the Colombian Hass avocado. Furthermore, Márquez, Yepes, Sánchez and Osorio (2014) found even lower values of 2.45 and 2.0 °Bx in four farms in the Department of Antioquia (Colombia) located in the municipalities of El Carmen de Viboral and El Retiro. These differences may be due to the origin of the plant material, soil type, climatic conditions, and preharvest and postharvest management.

In addition, Burdon et al. (2007) found that the °Bx of Hass avocados from the same farm, but evaluated in different harvest years, were not similar. These differences were attributed to competitive growth aspects of the trees (blooming, root activity and increase in number of shoots, among others) regarding the higher or lower load that the fruit tree had, i.e. the more fruits the trees had, less carbohydrates were available for each, and vice versa. Moreover, these differences were also credited to specific site conditions, such as temperature or rainfall.

Hydrogenionic potential (pH)

pH showed values between 6.58 and 7.14 (table 4), similar to the results reported by Henríquez et al. (2012). In general, an increase in fruit pH was observed between week 0 and 3 of storage (figures 1d, 1e and 1f), and their maximum values were reached after the third week in early and intermediate harvest. From this point onwards, a decrease was observed.

Buelvas-Salgado et al. (2012) indicated that in their results the pH increases in the fruit maturity stage until approaching neutrality, since most of the maximum values were equal or close to that point. On the other hand, during late harvest period, and when there are long storage times, i.e. periods of four and five weeks, a significant decrease is noticed (figure 1f).

pH behavior is associated to the organic acid content present in the fruit, since during maturation these tend to decrease as they are consumed at different metabolic cycles. In addition, many act as precursors of volatile substances during this stage (Márquez et al., 2014). Consequently, there is an inverse relation-ship between organic acid content and pH (Maftoonazad, & Ramaswamy, 2008).

In our study, no consistent trends were observed, possibly due to the conditions to which fruits were subjected. However, we must mention that, in general, pH had a tendency to increase with longer cooling and maturation times, contrary to what happened with acidity, which generally tended to decrease.

Titratable acidity

Regarding acidity, this variable had values ranging from 9.24 % to 19.47 % (table 4), and treatments subjected to storage behaved in a stable manner or without significant differences. This was mainly found in fruits harvested with intermediate and late maturity indexes (figure 1h and 1i), except for some treatments, such as those of the Bella Vista farm in intermediate maturity stages (figure 1h), where there was an increase in refrigerated fruits for three weeks.

As mentioned above, overall, the titratable acidity tends to decrease during fruit storage and maturation (figures 1g, 1h and 1i), a behavior that agrees with what was observed by Buelvas-Salgado et al. (2012).

This decrease is attributed to the consumption of organic acids in different metabolic cycles of the fruit, including tartaric acid, which predominates in avocado; Moreover, acids and carbohydrates are used to provide the energy that the fruit requires during the ripening process (Caparrotta et al., 2015).

In quality terms, physicochemical variables serve as inspection parameters. In the literature, pH and Brix degrees have been reported as quality indicators (Özdemir et al., 2009; Vinha et al., 2013). However, it is important to point out that it is necessary to carry out studies in other producing regions, and to correlate these variables with different quality criteria, such as sensory, microbiological and metabolic analyzes.

Conclusions

Harvest maturity as well as storage times and the origin of the plant material influences most of the physicochemical parameters of avocado cv. Hass in its consumer ripening state.

The variables did not show a consistent behavior in the assessed farms, but in general, acidity decreased when Brix degrees and pH tended to increase.

Disclaimer

This document was carried out within the framework of the project: "Desarrollo tecnológico, productivo y comercial del aguacate en el Departamento de Antioquia" [Technological, productive and commercial development of avocado in the Department of Antioquia"] Special Cooperation Agreement for Research N.º 4600001078, signed by the Secretaría de Agricultura [Secretary of Agriculture] of the department of Antioquia and the Universidad Nacional de Colombia sede Medellín. Accession Act N.º 2 "Índices cosecha y poscosecha para aguacate cv. Hass en Antioquia: cumplimiento de normas y requisitos demandados por los mercados internacionales" ["Harvest and postharvest indices for avocado cv. Hass in Antioquia: compliance with standards and requirements demanded by international markets"], in which Corpoica and Corpoaguacate participated.

This work is an original research carried out by the authors who agreed with the content of the manuscript and its submission to the journal. All authors have contributed significantly to this study. Moreover, they all agreed to be included on the list of authors and declare that no conflicts of interest exist that might affect the results.

References

Asociación Nacional de Comercio Exterior (Analdex). (2017). *Exportaciones de aguacate crecieron a todos los destinos en 2016*. Recuperado de http://www.analdex.org/2017/02/20/exportaciones-de-aguacate-crecieron-a-todos-los-destinos-en-2016/.

Association of Official Analytical Chemists (AOAC). (1998). *Official Method of Analysis 981.12. pH of Acidified Foods*. Gaithersburg, EE. UU.: AOAC.

Association of Official Analytical Chemists (AOAC). (1999). *Official Method of Analysis 934.1. Loss on drying (Moisture)*. Gaithersburg, EE. UU.: AOAC.

Buelvas-Salgado, G., Patiño-Gómez, J., & Cano-Salazar, J. (2012). Evaluación del proceso de extracción de aceite de aguacate Hass (*Persea americana* Mill.) utilizando tratamiento enzimático. *Revista Lasallista de Investigación, 9*(2), 138-150.

Burdon, J., Lallu, N., Haynes, G., Pidakala, P., Willcocks, P., Billing, D., … Boldingh, H. (2007). Carbohydrate status of late season 'Hass' avocado fruit. *New Zealand Avocado Growers Association Annual Research Report, 7*, 97-102.

Caparrotta, S., Bazihizina, N., Taiti, C., Costa, C., Menesatti, P., Azzarello, E., … Giordani, E. (2015). Use of volatile organic compounds and physicochemical parameters for monitoring the post-harvest ripening of imported tropical fruits. *European Food Research and Technology, 241*(1), 91-102.

Carvalho, P., Velásquez, M. A., & Van Rooyen, Z. (2014). Determination of the minimum dry matter index for the optimum harvest of "Hass" avocado fruits in Colombia. *Agronomía Colombiana, 32*(3), 399-406.

Cerdas-Araya, M., Montero-Calderón, M., & Díaz-Cordero, E. (2006). *Manual de manejo pre y poscosecha de aguacate (Persea americana)*. San José, Costa Rica: Universidad de Costa Rica.

Cerdas-Araya, M., Montero-Calderón, M., & Somarribas-Jones, O. (2014). Verificación del contenido de materia seca como indicador de cosecha para aguacate (*Persea americana*) cultivar Hass en zona intermedia de producción de Los Santos, Costa Rica. *Agronomía Costarricense, 38*(1), 207-214.

Henao-Rojas, J., & Rodríguez, P. (2016). Evaluación del color durante la maduración del aguacate (*Persea americana* Mill. cv. Hass). *Agronomía Colombiana, 34*(1), 876-879.

Henríquez, L., Patiño, J., & Salazar, J. (2012). Aplicación de la ingeniería de matrices en el desarrollo de aguacate Hass (*Persea americana* Mill.) mínimamente procesado adicionado con vitamina C y calcio. *Revista Lasallista de Investigación, 9*(2), 44-54.

Herrera-González, J. A., Salazar-García, S., Martínez-Flores, E., & Ruiz-García, J. E. (2017). Indicadores preliminares de madurez fisiológica y comportamiento postcosecha del fruto de aguacate Méndez. *Revista Fitotecnia Mexicana, 40*(1), 55-63.

Instituto Ecuatoriano de Normalización (INEN). (2009). *Norma técnica ecuatoriana NTE INEN 0381. Conservas vegetales. Determinación de acidez titulable. Método potenciométrico de referencia*. Quito, Ecuador: INEN.

Liu, X., Robinson, W., Madore, M., Witney, W., & Arpaia, L. (1999). "Hass" avocado carbohydrate fluctuations. II. Fruit growth and ripening. *Journal of the American Society for Horticultural Science, 124*(6), 676-681.

Maftoonazad, N., & Ramaswamy, S. (2008). Effect of pectin-based coating on the kinetics of quality change associated with stored avocados. *Journal of Food Processing and Preservation, 32*(4), 621-643.

Márquez, J., Yepes, P., Sánchez, L., & Osorio, J. (2014). Cambios físico-químicos del aguacate (*Persea americana* Mill. cv. "Hass") en poscosecha para dos municipios de Antioquia. *Temas Agrarios, 19*(1), 32-47.

Özdemir, E., Çandir, E., Toplu, C., Kaplankiran, M., Demirkeser, H., & Yildiz, E. (2009). The effects of physical and chemical changes on the optimum harvest maturity in some avocado cultivars. *African Journal of Biotechnology, 8*(9), 1878-1886.

Pérez de los Cobos, R. (2012). *Crecimiento y maduración del fruto en aguacate (Persea americana Mill.) cv. Hass* (tesis de pregrado). Universidad de Almería, Almería, España.

Soto, A. (1995). *Evaluación del comportamiento y calidad del puré y trozos de pulpa de palta (Persea americana Mill.) en los cvs. Negra de La Cruz, Bacon y Hass, cosechadas con dos índices de madurez, conservadas en almacenaje refrigerado y con atmósfera modificada* (tesis de pregrado). Universidad Católica de Valparaíso, Valparaíso, Chile.

Vinha, A., Moreira, J., & Ferreira, V. (2013). Physicochemical parameters, phytochemical composition and antioxidant activity of the algarvian avocado (*Persea americana* Mill.). *Journal of Agricultural Science, 5*(12), 100-109.

White, A., Woolf, A., Hofman, P., & Arpaia, M. L. (2009). *The international avocado quality manual*. Auckland, Nueva Zelanda: Institute for Plant and Food Research.