Composition and removal of nutrients by the harvested fruit of avocado cv. Hass in Antioquia

Composición y remoción nutrientes por la cosecha de aguacate cv. Hass en Antioquia

Álvaro Tamayo V *, Jorge A. Bernal E. and Cipriano A. Díaz D.

Corporación Colombiana de Investigación Agropecuaria - agrosavia. C.I. La Selva.
Kilómetro 7, vía a Las Palmas, vereda Llano Grande, Rionegro, Colombia.
* Corresponding author: <atamayo@agrosavia.co

Abstract

In three Antioquia producing areas (El Retiro, El Peñol and Amagá), three orchards of cv. Hass avocado were selected, in order to quantify the amount of nutrients removed by the fruit. A completely randomized design with 12 replications (trees) was used, for which 25 fruits/tree were collected, from which the fresh and dry weight of the epidermis, pulp, testa and seed were obtained. In each fruit structure, the concentration of N, P, K, Ca, Mg, Fe, Cu, Mn, Zn and B was determined and the removal of each was calculated. The tissue with the highest concentration of nutrients was the testa. The nutrient with the highest concentration in the four tissues was K followed by N. The total removal by the fresh fruit, in kg t^{-1}, for K was 4; N, 3.3; S 0.56; Mg 0.51; Ca 0.31, 0.48 P and in g t^{-1} for Fe was 0.45; B 0.2; Zn 0.11; Mn 0.01 and Cu 0.03.

Key words: *Persea americana* Miller., Seed, testa, pulp, epidermis, mineral nutrition.

Resumen

En tres zonas productoras de Antioquia (El Retiro, El Peñol y Amagá), se seleccionaron tres huertos de aguacate cv Hass, con el fin de cuantificar la cantidad de nutrientes removidos por el fruto. Se usó un diseño completamente al azar con 12 repeticiones (árboles), para lo cual se colectaron 25 frutos/árbol, de donde se obtuvo el peso fresco y seco de la epidermis, la pulpa, la testa y la semilla. En cada estructura del fruto, se determinó la concentración de N, P, K, Ca, Mg, Fe, Cu, Mn, Zn y B y se calculó la remoción de cada uno de ellos. El tejido con mayor concentración de nutrientes fue la testa. El nutrimento con mayor concentración en los cuatro tejidos fue K seguido de N. La remoción total por el fruto fresco, en kg t^{-1}, para K fue de 4; N 3,3; S 0,56; Mg 0,51; Ca 0,31 , 0,48 P y en g t^{-1} para el Fe fue 0,45; B 0,2; Zn 0,11; Mn 0,01 y Cu 0,03.

Palabras claves: *Persea americana* Miller., semilla, testa, pulpa, epidermis, nutrición mineral.

Introduction

In order to have an appropriate management of fertilization and production and maintain adequate levels in both, size and quality of fruits is important to know the amount of nutrients that are extracted from the soil by a harvest. Currently, the nutritional requirements of avocado fluctuate, according to the oil content in the fruits of each variety, which could be between 3-20%. Therefore, factors such as size and quality (external and internal) of the fruit are important in the productivity of commercial crops. This is why the more oil the fruit has, the greater its nutrient extraction will be (Salazar-García *et al.*, 2013).

After the roots absorb nutrients from the soil, these are transformed into organic and inorganic compounds, which are transported to the different organs of the plant. In each crop, a large quantity of nutrients is removed permanently, and another important portion is temporarily removed by flowers, leaves, small aborted fruits and roots, which can be cycled in the crop (Tamayo, 2016).

The decomposition of leaf litter is the set of physical and chemical processes by which its basic chemical constituents are removed (Rincón *et al.*, 2017). It is also the most important process of nutrient cycling in any ecosystem (Wang *et al*., 2008; Castellanos and Léon, 2011), because through the decomposition of leaf litter, nutrients are again available to plants. Processes regulate both amount and biochemical content of organic matter produced in an ecosystem, and they are responsible for the formation of humic substances that contribute to soil quality/fertility (Versini *et al*., 2014; Rashida *et al.*, 2016).

Once the fruit has reached physiological maturity, it can be harvested and removed from the tree, taking with it important quantities of various nutrients that, if not reintegrated into the soil, through fertilization, could decrease the fertility of the soil and cause its depletion. Therefore, it is necessary to know the amount of nutrients that were removed by the fruits, since these nutrients were definitely removed from the soil.

The postharvest quality of the avocado fruit is influenced by the concentration of its nutrients at the time of harvest (Arpaia *et al*.,2015); increasing in the N concentration in the leaf, increase the N content in the pulp, as it been reported in avocado cv. Hass (Pérez de los Cobos, 2012). Similarly, applications of Ca to the soil increased the concentration of Ca in the pulp and delayed the ripening of the fruits in the postharvest in avocado (Barrientos-Priego *et al.*, 2016).

Currently in Antioquia, there are no documented works on the nutritional requirements in the avocado cv. Hass. Therefore, it is essential to know the removal of nutrients by the harvest, which allows an adequate management of fertilization that helps to obtain quality fruits. The objectives of this work were to know the nutritional composition of the different tissues of the fruit (epidermis, pulp, testa and seed) and to determine the amount of removed nutrients by the Hass cv avocado, in different localities of the department of Antioquia.

The objectives of this work were to know the nutritional composition of the different fruit tissues (epidermis, pulp, testa and seed), and the amount of nutrients removed by the avocado harvest cv. Hass, in different localities of the department of Antioquia.

Materials and methods

Soil sampling

In each selected tree, four equidistant sampling sites were chosen, which are located under the tree, in the area between the middle of the crown and the perimeter of it. Then, the sub samples were mixed to obtain a composite sample that was taken to the soil laboratory of Corpoica for its respective chemical analysis.

The contents of the macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Cu, Mn, Zn, B) were determined pH in water (1:2); soil organic matter (SOM), Walkley and Black; Al, 1 *M* KCl; Ca, Mg, K and Na, 1 *M* ammonium acetate; P, Bray II; S, 0.008 *M* calcium phosphate; Fe, Mn, Cu and Zn, Olsen-EDTA; B, hot water

Fruit analysis

In each orchard, 12 trees of 7 years of age were selected and planted at a distance of 7 x 6 m, in each of which 25 fruits were harvested at physiological maturity, with a dry matter content ≥ 23%.

Each fruit was separated into epidermis, pulp, testa and seed and recorded its fresh weight was recorded. Each tissue was cut into thin slices, which were dehydrated in an oven with forced air at 60 °C until constant weight was obtained. The dried samples were sprayed on a Thomas Scientific stainless steel mill (Wiley Mini Mill 3383-L10) with sieve 40 (0.425 mm mesh light). The nutritional composition was determined in three composite samples, each conforming to the tissues of the 25 fruits of each tree, of 12 trees (replications). The dried samples were sent to the soil and plant tissue chemistry laboratory of Corpoica-Tibaitatá (Mosquera, Cundinamarca, Colombia). There the contents of total N (Kjedhdhal) and the extractable fractions of P (Bray II) were established; Ca, Mg and K (1N ammonium acetate, pH 7.0), Fe, Mn, Zn, Cu (modified Olsen) and B (monobasic calcium phosphate). The protocols are described in Westermann (1990).

Statistical analysis

For the analysis of the information, we used an experimental design with 12 replications (trees), where each repetition consisted of 25 fruits of the same tree. The removal of nutrients per ton of fresh fruit (Rt) was calculated according to the formula described by Mellado-Vázquez *et al.* (2017):

$$Rt = ((CNe \times DWe) + (CNp \times DWp) + (CNt \times DWt) + (CNseed \times DWseed)) / 100 \times Ft$$

Where:

CNe = Concentration of the nutrient in the epidermis; DWe = Dry weight of the epidermis; CNp = Concentration of the nutrient in the pulp; DWp = Dry weight of the pulp; CNt = Concentration of the nutrient in the testa; DWt = Dry weight of the testa; CNseed = Concentration of the nutrient in the seed; DWseed = Seed dry weight; Ft = Number of fruits in one ton (obtained from the quotient 1,000 kg between the fresh weight of the whole fruit).

For each element, a variance analysis was performed, with the statistical package SAS for Windows V 9.3. The comparison of means was done with the Tukey test ($P \leq 0.05$).

Results and Discussion

Soil analysis

According to Table 1, the soils of the three locations had an extremely acidic pH, with little saturation of aluminum (20-26%), with high contents in organic matter for El Retiro and El Peñol, and low in the location of Amagá; they also have low Ca and Mg contents and medium in K. Minor elements are low and with exception of Fe, which is high in all locations, a situation that is common in moderate climate soils. Generally speaking they are soils with low natural fertility.

Soil chemical characteristics were very similar in all three regions. The pH fluctuated between acids and strongly acid, with low saturation of interchangeable bases and with contents of medium to low in minor elements, with the exception of the Fe that are high. In general, they are soils of low fertility.

Table 1. Chemical characteristics of soils in the municipalities of El Retiro, El Peñol and Amagá (Antioquia).

Locality	pH	MO	Al	Ca	Mg	K	Na	P	S	Fe	Cu	Mn	Zn	B
		(%)	--------------cmolc kg^{-1}---------					-----------------------mg kg^{-1}------------------						
El Retiro	4,8	20,4	1,1	2,3	0,8	0,34	0,05	2,3	5,4	122	1	2,3	7,4	0,55
El Peñol	5,1	17,3	1,1	1,4	0,6	0,40	0,08	2,7	8,6	69	2,1	3,9	1,8	0,19
Amagá	4,9	4,80	1,2	2,1	0,8	0,40	0,04	2,8	21,2	284	2,2	3,8	1,8	0,24

Concentration of nutrients in tissues

The concentration of the different nutrients showed significant differences between the tissues of the fruit (Table 2). The testa was the tissue that presented a greater number of nutrients with higher concentration (%).The highest concentrations of P and K were present in the pulp (0.29 and 1.21 %, respectively). The concentrations of N, Fe and B were high in the epidermis, this agrees with that found by Salazar *et al.* (2011) in Michoacán México. The epidermis presented the lower values of Ca, Mg and S (0.033, 0.049 and 0.13 %, respectively); A similar situation was observed for the minor elements Cu, Mn, Zn and B with 4.9, 8, 12 and 23 mg kg^{-1}, respectively).

Table 2. Concentration of nutrients in tissues of avocado fruit cv. Hass in Antioquia.

Tissue	N	P	K	Ca	Mg	S	Fe	Cu	Mn	Zn	B
				%					mg.kg^{-1}		
Epidermis	0.893 a	0.105 b	0.943 ab	0.081 b	0.133 b	0.133 c	116.4 a	8.57 ab	20.1 b	38.2 b	64.7 a
Pulp	0.892 a	0.291 a	1.211 a	0.048 b	0.120 c	0.153 a	89.9 a	6.55 ab	16.3 bc	22.5 c	34.7 b
Seed	0.594 b	0.107 b	0.777 b	0.033 c	0.049 d	0.1278 d	117.7 a	4.92 b	7.98 c	12.3 d	23.8 b
Testa	0.918 a	0.092 b	1.074 a	0.140 a	0.212 a	0.148 b	131.9 a	10.9 a	64.3 a	46.6 a	78.2 a
P***	<0.00001	<0.0095	<0.0028	<0.00001	<0.00001	<0.00001	<0.024	<0.0194	<0.001	<0.00001	<0.00001

Means with different letters in the same column are statistically different, according to Tukey's ($P \leq 0.05$).

Removal of nutrients by fruit

Fruit tissues showed differences in the quanty of removed nutrients (Table 3). The most removed elements in all tissues were K, N and S. The pulp showed the greatest removal of all nutrients analyzed both major and minor. Removal by the epidermis and seed was intermediate, although it was higher in the seed. The total removal of macronutrients by avocado cv. Hass was higher for K (4 kg t^{-1}), N (3.3 kg t^{-1}), P (0.48 kg t^{-1}). For the minor elements, Fe and B (0.45 and 0.2 g t^{-1}, respectively) were the most removed (Figure 1).

Table 3. Amount of removed nutrients by the tissues of the avocado fresh fruit cv. Hass in Antioquia.

Tissue	N	P	K	Ca	Mg	S	Fe	Cu	Mn	Zn	B
				kg. t^{-1}					g. t^{-1}		
Epidermis	0.280 c	0.032 b	0.310 c	0.025 b	0.039 b	0.043 c	34.8 bc	2.5 b	6.1 b	11.77 b	20.7 b
Pulp	1.296 a	0.266 a	1.758 a	0.090 a	0.174 a	0.222 a	126.7 a	9.4 a	23.6 a	32.71 a	50.7 a
Seed	0.465 b	0.083 b	0.611 b	0.027 b	0.037 b	0.099 b	88.7 b	3.8 b	1.7 b	9.56 c	18.7 b
Testa	0.025 d	0.002 c	0.031 d	0.004 b	0.006 b	0.004 d	3.67 c	0.3 d	6.09 b	1.3 c	2.22 c
P***	<0.00001	<0.0015	< 0.00001	< 0.00001	< 0.00001	< 0.00001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001

Means with different letters in the same column are statistically different, according to Tukey's ($P \leq 0.05$).

These results are similar to those reported by Salazar-García *et al.* (2011), in avocado cv. Hass in Michoacán (Mexico); however, they differ slightly from what was obtained by the same authors, with cv. Méndez in Jalisco (Mexico), where N removal was lower (2.7 kg t^{-1}) but higher in Cu, Mn, Zn and B (3.23, 2.05, 4.08 and 7.35 g t^{-1}, respectively).). Research carried out by Rebolledo and Dorado (2017) in the municipalities of Rionegro, Herveo and Morales found, in relation to the content of N in fruits, values of extraction of 62 Kg of N for the location of Rionegro, 96 Kg for Morales and 74 Kg for Herveo.

Some authors (Salazar-García and González-Duran, 2005; Tapia-Vargas *et al*., 2007; Tapia-Vargas et al., 2008) affirm that there is a wide variation for nutrients extracted by the fruit in avocado; however, all agree in a noteworthy way, that K is the element of greatest demand, even more than N in proportions ranging from 1: 1.5-2. This is consistent with studies done by Montgomery-Taboada *et al* (2017) in the northern Peruvian coast, where the K extraction was between 3-5 kg per ton of harvested fruit, depending on the rootstock, being the Antillean-type the most extracted. In the present study, greater amounts of B, Fe and Mn were removed than those reported in Mexico and the North Coast of Peru.

The removal of B that is greater than the other micronutrients, close to that of P and other macronutrients Ca, Mg and S.

The high contents in Fe are explained because in these soils it is common to find high concentrations of this element; however, the opposite happens with B, since despite having low available contents of this element in the soil, it is fixed, and the Hass cultivar has the capacity to remove it, a situation most commonly observed in andisoles soils (Osorio, 2014) .This assessment is worthy of consideration in fertilization programs.

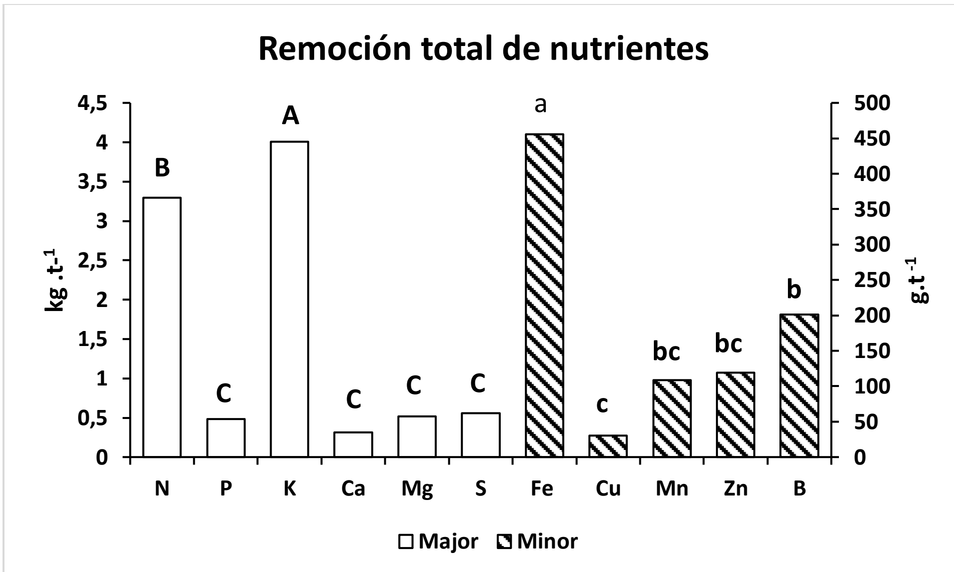

Figure 1. Total removal in kg t^{-1} for fresh avocado fruit cv. Hass in Antioquia. Means with different capital letters (macronutrients) or lowercase (micronutrients) in g t^{-1} are statistically different according to Tukey's test ($P \leq 0.05$).

The extraction of elements such as N and K with the crops exhausts the natural reserve of the soil, therefore fertilization should be done not only with a view to nourishing the tree, but also to maintain the fertility levels of the root zone, necessary for the balance and sustainability of the soil resource. The crop nutritional requirements must be based on what happens under the management conditions where it is cultivated (Salazar-García *et al*., 2013)

The differences in the amount of removed nutrients by the tissues are due to the proportion of each structure in the fruit. The pulp presented the highest amount of removed nutrients and the epidermis presented intermediate values. The highest pulp removal was due to the fact that the highest percentage of fruit biomass corresponded to this tissue (Salazar-García, *et al*., 2015). The testa was the tissue with less removed nutrients, which coincided with the reports of Mellado-Vásquez *et al.* (2015), in fruits of avocado cv. Méndez in the south of Jalisco (Mexico).

Conclusions

The tissue with the highest concentration of nutrients was the testa. The nutrient with the highest concentration in the four tissues was K, followed by N. The highest amount of nutrients removed was found in the pulp, followed by the seed, the epidermis and finally the testa. The order of total nutrient removal per ton of fresh fruit was: K> N> S> Mg> P> Ca> Fe> B> Zn> Mn> Cu.

Disclaimer of Liability

The authors do not show any conflicts of interest

References

Alcaraz ML, Thorp TG, Hormaza JI. 2013. Phenological growth stages of avocado (Persea americana) according to the bbch scale. Scientia Horticulturae. 164:434-439. https://doi.org/10.1016/j.scienta.2013.09.051

Arpaia ML, S Collin, J Sievert and D Obenland. 2015. Influence of cold storage prior to and after ripening on quality factors and sensory attributes of "Hass" avocados. Postharvest Biology Technology 110, 149-157. Doi: 10.1016/j.postharvbio.2015.07.016

Barrientos-Priego, Alejandro F, Martínez-Damián, María Teresa, Vargas-Madríz, Haidel, and Lázaro-Dzul, Martha Olivia. 2016. Effect of preharvest calcium spraying on ripening and chilling injury in 'Hass' (Persea americana Mill.) avocado. Revista Chapingo Serie horticultura *22*(3) 145-159.https://dx.doi.org/10.5154/r.rchsh.2016.04.010

Castellanos J y León JD. 2011. Descomposición de hojarasca y liberación de nutrientes en plantaciones de *Acacia mangium* (Mimosaceae) establecidas en suelos degradados de Colombia. Revista de Biologia Tropical . 59 (1):113-128. ISSN: 0034-7744.

Mellado-Vázquez A, Salazar-García S, Álvarez-Bravo A, Ibarra Estrada M E, González-Valdivia J. 2015. Remoción de nutrimentos por el fruto de aguacate "Mendez" en el sur de Jalisco, México. En VIII congreso Mundial de la Palta. Actas. Proceedings. Lima, Perú.

Mellado-Vázquez A, Salazar-García S, Álvarez-Bravo A, Hernández-Guerra C. 2017. Remoción de nutrimentos por cosecha de limón persa en Nayarit y Veracruz, México. Revista. Mexicana. Ciencias Agrícolas. 19:3939-3952. ISSN: 2007-9230

Montgomery-Taboada, L.; Alegre-Mendoza, J.; Castro-Cuba, S. 2017. Remoción nutrimental del fruto del aguacate ´Hass´ en la costa norte del Perú. Memorias del V Congreso Latinoamericano del Aguacate. 04 - 07 de septiembre 2017. Ciudad Guzmán, Jalisco, México 233-242.

Rashida,MI, Mujawar LH, Shahzade T, Almeelbi T, Ismail, I Oves M. 2016.Bacteria and fungi can contribute to nutrients bioavailability and aggregate formation in degraded soils Microbiological Research 183 26–41 https://doi.org/10.1016/j.micres.2015.11.007

Rebolledo-Roa A, y Dorado-Guerra DY. 2017. Criterios para la definición de planes de fertilización en el cultivo de aguacate Hass con un enfoque tecnificado. Mosquera, Colombia: Corpoica Corporación Colombiana de Investigación Agropecuaria.

Osorio, NW. 2014. Manejo de nutrientes en suelos del trópico. Segunda edición. 416p. SBN:978-958-44-9746-8.

Pérez de los Cobos R. 2012. Crecimiento y maduración del fruto en aguacate (*Persea americana* Mill.) cv. Hass. Escuela Politécnica Superior y Facultad de Ciencias Experimentales, Universidad de Almería, Almería, España. 76 p.

Rincón J, Merchán D, Sparer, A, Rojas D y Zarat, E. 2017. La descomposición de la hojarasca como herramienta para evaluar la integridad funcional de ríos altoandinos del sur del Ecuador. Revista de Biología Tropical [en linea] 2017, 65 [Fecha de consulta: 8 de febrero de 2018] Disponible en:<http://www.redalyc.org/articulo.oa?id=44950154025> ISSN 0034-7744

Salazar-García S y González-Duran I. 2005. Nuevas experiencias sobre el manejo de la nutrición del aguacate "Hass" en Nayarit. En II congreso Mexicano y Latinoamericano del aguacate. Resúmenes. Facultad de Agrobiología "Presidente Juárez". Uruapan, Michoacán. México.

Salazar-García S, LC Garner and CJ Lovatt. 2013. Reproductive Biology. pp. 118-167. In: Schaffer, B., B.N. Wolstenholme and A.W. Whiley (Eds.). The Avocado, 2nd Edition, Botany, Production and Uses. CABI, Oxfordshire, UK.

Salazar-García S, González-Duran IJL y Tapia-Vargas LM. 2011. Influencia del clima, humedad del suelo y época de floración sobre la biomasa y composición nutrimental de frutos de aguacate 'Hass' en Michoacán, México. Revista. Chapingo Serie. Hortícola. 17(2): 183-194. ISSN: 2007-4034.

Salazar-Garcia S, Gonzalez-Duran IJL, and Ibarra-Estrada LM. 2015. Identification of the Appropriate Leaf Sampling Period for Nutrient Analysis in 'Hass' Avocado. HortScience: a publication of the American Society for Horticultural Science. 50. 130-136. Online ISSN: 2327-9834

Tamayo A. 2016. Descomposición de hojarasca y liberación de nutrientes en plantaciones de aguacate cv. Hass en función de la inoculación con un hongo saprofito en tres pisos térmicos. Tesis de Doctorado en Ciencias Agrarias. Universidad Nacional de Colombia Sede Medellín, Facultad de Ciencias Agrarias. Medellín, Colombia. 125 p.

Tapia-Vargas L, Larios GA y Anguiano CJ. 2008. Uso y manejo del agua y nutrición. En: Tecnología para la producción de aguacate en México. (Coria, A.V.M. ed.) Libro Técnico No 8. Sagarpa-INIFAP 2ª Edición. Uruapan, Michoacán. pp. 54-92.

Tapia-Vargas L, Marroquín-Pimentel F, Cortes-Trejo I, Anguiano-Contreras J y Castellanos R J. 2007. Capítulo 4: Nutrición del aguacate. En: El aguacate y su manejo integrado (ed) Daniel Téliz y Antonio Mora. Ediciones Mundi-Prensa. pp. 87-105.

Versini A, Zeller B, Derrien D, Mazoumbou JC, Mareschal L, Saint-André L, Laclau P. 2014. The role of harvest residues to sustain tree growth and soil nitrogen stocks in a tropical Eucalyptus plantation. Plant and Soil 346: 245-260. DOI: org/10.1007/s 111 04-013-1963-y.

Wang Q, Wang S and Huang Y. 2008. Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China. Forest Ecology and Management 255: 1210-1218. DOI: 10.1016/j.foreco.2007.10.026

Westerman RL. 1990. Soil testing and plant analysis.-3rd ed.l editor (Soil Science Society of America book series; no. 3). 757 p. ISBN:0-89118-793-6