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Article

Descriptors in fruits of avocado in Mexico

Nayeli Sarahí Quiñones-Islas[1§]
Juan Fabricio Lazcano-Escobar[2]
Carolina Ramírez-López[2]
Sergio Rubén Trejo-Estrada[2]

[1]Tecomán Experimental Field-INIFAP. Colima-Manzanillo km 35 highway, Tecomán, Colima, Mexico. CP. 28100. Tel. 800 0882222, ext. 84307. [2]Research Center in Applied Biotechnology-National Polytechnic Institute. Former hacienda San Juan Molino, State TecuexComac-Tepetitla km 1.5 highway, Tepetitla de Lardizábal, Tlaxcala, Mexico. CP. 90700. (jlazcanoe1700@alumno.ipn.mx; caramirezl@ipn.mx; strejo@ipn.mx).

[§]Corresponding author: quinones.nayeli@inifap.gob.mx.

Abstract

Persea schiedeana Nees is a fruit tree native to Mesoamerica, partially endemic to Mexico, found along the plain of the Gulf of Mexico. The objective was to evaluate the edaphoclimatic, morphological and chemical descriptors and compare the differences between the study regions that allow their revaluation. The study regions were: Soconusco in Tuxtla Chico, Chiapas, Selva in Palenque, Chiapas; Chontalpa in Comalcalco, Tabasco and Sierra Nororiental in Teziutlán, Puebla. In July 2019, 5 trees were randomly selected from each region for the harvest of 44 fruits, giving a total of 176 fruits and 1 584 determinations. An analysis of variance was performed to find the differences between regions and a Tukey test for the comparison of means of the morphological and physicochemical parameters evaluated, using the statistical software Minitab®. The fruits from the Selva region in Palenque, Chiapas, presented greater value in weight (417.5 ±69.7 g), length (18.48 ±1.56 cm), pulp (282.09 ±54.72%) and fat (50.29 ±2.03%). The Soconusco region, Chiapas reached the highest percentages of protein in pulp (2.79 ±0.54%), seed (1.76 ±0.14%) and peel (2.64 ±0.19%). The results obtained suggest the existence of variation between the materials of *Persea schiedeana* Nees in the regions studied, allowing the identification of those with agroindustrial potential, constituting an alternative to diversify the production of *Persea* spp., in Mexico.

Keywords: *Persea schiedeana* Nees, coyo, endemic.

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Introduction

In Mexico, there is a great diversity of avocados *Persea* spp. (Corona-Jácome *et al*., 2016), distributed according to their variability of environmental and genetic conditions (SIAP, 2017). Within this diversity, there is a species of avocado tree called *Persea schiedeana* Nees, commonly known as Chinín in Mexico, Supte in Honduras, Yas in Costa Rica and Coyo in Guatemala (Cruz-Castillo *et al*., 2017). Chinine is a fruit tree native to Mesoamerica, belongs to the dicotyledonous Lauraceae family, is partially endemic to Mexico (Boza *et al*., 2018), is distributed along the plain of the Gulf of Mexico, which comprises southern Tamaulipas (pagua or forest avocado), Veracruz (chinene), Puebla (chinini), Oaxaca (chinina), Tabasco (chinín or butter avocado) and Chiapas (chinín) (Cruz-Castillo *et al*., 2017).

It grows in rainforests, forests and tropical mountains at altitudes of 90 to 2 000 masl (Hurtado-Fernández *et al*., 2018; López-Arce *et al*., 2019). It has been studied for the control of the disease caused by the oomycete *Phytophtora cinnamomi* Rands, due to its tolerance to flooding in the root of the avocado tree (Reeksting *et al*., 2016). It is possible to find this species in some cacao farms to take advantage of its shade (Morales-Ramos, 2018). It has been considered an underutilized species (Nair *et al*., 2017; Leakey, 2019), which does not appear within the Statistical Yearbook of Agricultural Production (SIAP, 2020) but of importance in specific local and regional diets (Bost, 2014).

The information reported on studies on fruits of *Persea schiedeana* Nees is limited. The above leads to the objective of evaluating the edaphoclimatic, morphological and physicochemical descriptors in fruits of *Persea schiedeana* Nees that allow knowing the genetic, agroindustrial and nutritional value to promote the conservation and protection of this traditional species.

Materials and methods

Description of the study area

The research was carried out in the laboratories of the company BioAgrovia, SA de CV, located at calle 18 Oriente #3007, Colonia Humbolt, Puebla, Puebla (west longitude 98° 17’ 38.76” - 98° 01’ 12.72” and north latitude 18° 50’ 12.48” - 19° 13’ 51.24” and 2 140 masl). The municipality has a temperate subhumid climate with average annual temperature of 17 ºC, minimum of 10 ºC, maximum of 25 ºC and average rainfall of 961 mm per year (INEGI, 2017). Minimum temperatures occur from November to February and maximums from June to September. The characterization of the physicochemical and morphological descriptors was carried out in 2019, during the month of July, under laboratory conditions, temperature of 24 ºC and humidity of 17%.

Collection of fruits of *Persea schiedeana* Nees

In July 2019, five trees were randomly selected for the manual harvest of 44 fruits of *Persea schiedeana* Nees in their physiological stage of maturity, reached between 91 and 97 days after fruit setting (Cruz-Castillo *et al*., 2007), in private backyard cultivation orchards in the regions of Soconusco in Tuxtla Chico, Chiapas (SCH); Selva in Palenque, Chiapas (PCH); Chontalpa in Comalcalco, Tabasco (CHT) and Sierra Nororiental in Teziutlán, Puebla (TPU). Immediately after cutting, the fruits were accommodated one by one on a plastic crate and packed with kraft paper to avoid mechanical damage during their transfer.

The transfer to the laboratory occurred on the same day of the harvest, the transfer time was 3 h for TPU, 9 h for CHT, 11 h for PCH and 14 h for SCH. In the laboratory, each fruit was unpacked, washed with 10% detergent solution, rinsed with running water, dried with cotton towel and placed on a worktable to allow acclimatization to laboratory conditions (LC) of 24 ºC and 17% humidity. Immediately, the measurement of some of the morphological descriptors of the unopened fruits (weight, length, diameter, color and shape) began and at the end of the measurements the fruits were kept at LC. The rest of the morphological and chemical analyses were carried out during the following seven days after their arrival at the laboratory. During the evaluations, the pulp and peel were stored separately in Ziploc bags at refrigeration temperature (4 ºC) and the seed was stored in raffia sacks at room temperature (26 ºC).

Characterization of edaphoclimatic, morphological and physicochemical descriptors

The collected materials of *Persea schiedeana* Nees were characterized edaphoclimatically according to the data recorded in 2019 in the geographical digital atlas of the environment, of the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT, 2019). The morphological characteristics were evaluated using the descriptors for *Persea* spp., reported by the International Plant Genetic Resources Institute, currently Bioversity (IPGRI, 1995), and it is consistent with those established by the Union for the Protection of New Varieties of Plants for *Persea americana* Mill. (UPOV, 2006).

In fruit: weight (g), shape, diameter (mm), length (mm), shape of the base, shape of the apex, position of the apex and position of the pedicel. In peel: surface, weight (g), thickness (mm), color and adhesion. In pulp: weight (g), color close to the peel and close to the seed. In seed: shape, diameter (mm), length (mm), weight (g), cover, position, cotyledon (surface, adhesion and color), cavity of the seed (length, diameter and free space), cross-sectional shape and position of the embryonic axis.

Those morphological characteristics that do not report units were evaluated visually qualitatively by descriptive assessment scale according to what was reported by the IPGRI, 1995. The fresh weights of the fruit, pulp, seed and peel of the 176 fruits were measured on a digital scale (model CS2000, Ohaus brand, United States) and the percentage of each variable within the fruit was calculated. The length, diameter of the fruit, diameter of the seed and thickness of the peel were measured with a digital vernier (Model HER-411, Steren brand, China).

The physicochemical characterization was carried out separately for each of its components (pulp, peel and seed), according to the methodologies described by the Association of Official Analytical Chemists (AOAC, 2000). The percentage of moisture (%M) and dry matter (%DM) was determined by the gravimetric method 2.166 of the AOAC, it consists of drying the sample at 105 ºC for 12 h to constant weight in a drying oven (Model DX-61, American Scientific Products brand, United States), the calculation of %M was determined by the weight difference due to the loss of water in the sample and the calculation of %DM by difference (100 - %M); the ash content (%A), method 2.173 of the AOAC, is defined as the total mineral content obtained after calcination of 5 g of dry sample at 550 °C for 12 h in a muffle (model MF4, Prendo brand, Mexico) and %A was calculated by the difference in weight divided by the grams of the sample.

The protein analysis was evaluated by the Kjeldahl method (method 2.055 of the AOAC), it measures the total nitrogen content in the sample (%N), the digestion of 1 g of sample was performed in a micro Kjeldahl digestion and distillation unit (Model DEK-1, Prendo brand, Mexico), with sulfuric acid in the presence of a mercury catalyst and its subsequent titration with hydrochloric acid, the calculation was performed by multiplying the %N by the conversion factor 6.25. The crude fat analysis was carried out based on method 5.011 of the AOAC, where the fat of 5 g of sample extracted in a Soxhlet distillation apparatus (Model MC 301-4x4, Prendo brand, Mexico) with petroleum ether for 6 h was quantified and evaluated as a percentage of the weight after evaporating the solvent.

Experimental analysis

The morphological and physicochemical characterization was evaluated using 44 fruits of *Persea schiedeana* Nees collected completely at random from each of the municipalities in the four regions studied, giving a total of 176 fruits. Determinations were made in triplicate for each of the components of the fruit (pulp, seed and peel), giving a total of 1 584 analyses by analytical methodology. The results were performed a one-factor analysis of variance (Anova) to find the differences between the municipalities of each study region and a Tukey test ($p \leq 0.05$) for the comparison of means of the morphological and physicochemical parameters evaluated, using the statistical software Minitab® (Minitab, 2019) and recording experimental data in a spreadsheet of Excel® version 16.45.

Results and discussion

Edaphoclimatic descriptors

In the study regions, there were differences in the environmental temperature recorded in the year of collection of the fruits of *Persea schiedeana* Nees (Figure 1), it was observed that, for the region of Sierra Nororiental in Puebla, there was a temperate humid climate (15.5 ºC) compared to the Soconusco region in Chiapas, where a warm subhumid climate (35 ºC) prevailed, and the regions in Selva (26 ºC) and Chontalpa (27 ºC) which had a warm humid climate. The average humidity among regions was 80%, equivalent to high humidity. Rainfall averages were similar between the regions of Soconusco (2 433 mm), Selva (2 763 mm) and Chontalpa (2 550 mm) in contrast to the Sierra Nororiental region whose record was below 2 000 mm (Table 1).

The type of soil in the four regions was different from each other, in relation to the parameter of texture of the soil, there was similarity between them as they presented a clayey loam soil, this type of soil is characterized by being rich in organic matter and containing percentages of 15-52% silt, 27-40% clay and 20-45% sand (FAO, 1990). According to the recorded edaphoclimatic results (Table 1) and their relationship with the results of the morphological descriptors (Table 2), it was possible to appreciate that they are a determining factor in the development and characteristics of the fruits. This coincides with Cruz-Castillo *et al*. (2017), who, in their study on the 'distribution of *Persea schiedeana* in Mexico and potential for fruit production with high quality oil', identified that the best places for optimal crop development are temperate humid, warm subhumid and warm humid climates.

Figure 1. Climate distribution of the different regions of collection of fruits of *Persea schiedeana* Nees in Mexico (SEMARNAT, 2019; modified by Quiñones-Islas, 2022).

Table 1. Edaphoclimatic descriptors of the different regions of collection of fruits of *Persea schiedeana* Nees in Mexico (SEMARNAT, 2019).

Descriptors	Central area	Southeastern areas		
	Sierra Nororiental in Teziutlán, Puebla	Soconusco in Tuxtla Chico, Chiapas	Selva in Palenque, Chiapas	Chontalpa in Comalcalco, Tabasco
Altitude	1920 m	318 m	60 m	20 m
Coordinates	19° 49’ 03” N 97° 21’ 39” O	14° 56’ 00” N 92° 10’ 00” O	17° 30’ 33” N 91° 58’ 56” O	18° 16’ 48” N 93° 12’ 06” O
Average temperature (ºC)	15.5	35	26	27
Average humidity (%)	80	86	74	80
Average rainfall (mm)	1648	2433	2763	2550
Type of soils	Andosol	Lithosol	Leptosol	Vertisol
Texture of soils	Clayey loam	Clayey loam	Clayey loam	Clayey loam

Table 2. Morphological descriptors in fruit, pulp, seed and peel of *Persea schiedeana* Nees from the different collection regions.

Region	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pulp weight (g)	%pulp in fruit	Seed weight (g)	Seed length (cm)	Seed diameter (cm)
SCH	326.9±76.3$_b$	13.3±0.93$_c$	7.79±0.34$_c$	213.35±58.4$_b$	64.64±3.9$_a$	79.8±13.61$_b$	7.94±0.68$_c$	4±0.52$_c$
PCH	417.5±69.7$_a$	18.48±1.56$_a$	7.62±0.47$_c$	282.1±54.72$_a$	67.5±5.98$_a$	90.05±28.1$_b$	9.37±2.64$_b$	4.51±1.02$_b$
CHT	338.55±51.2$_b$	16.03±1.3$_b$	20.4±1.16$_a$	165.6±31.7$_c$	49.03±7.2$_b$	135.06±33.5$_a$	11.5±0.45$_a$	4.9±0.31$_b$
TPU	165.6±19.73$_c$	11.26±0.96$_d$	18.4±0.88$_b$	84.98±12.81$_d$	51.42±5.5$_b$	59.16±12.15$_c$	8.51±0.77$_c$	12.4±1.03$_a$

	%Seed in fruit	Seed cavity length (mm)	Seed cavity diameter (cm)	Embryonic axis position (mm)	Peel weight (g)	Peel thickness (mm)	%peel in fruit
SCH	24.99±3.97$_c$	71.19±3.34$_d$	4.33±0.27$_a$	19.35±1.97$_b$	33.8±9.35$_b$	1.01±0.011$_c$	10.36 ±1.61$_c$
PCH	21.67±6.21$_d$	100.3±16.77$_b$	4.63±0.64$_a$	19.83±1.38$_b$	45.4±9.3$_a$	2.01±0.004$_b$	10.82 ±10.77$_{b, c}$
CHT	39.81±7.11$_a$	136.22±5.26$_a$	15.1±69.4$_a$	28.10±0.14$_a$	37.9±6.4$_b$	3.01±0.007$_a$	11.16 ±0.27$_b$
TPU	35.63±5.5$_b$	83.94±8.34$_c$	4.15±0.42$_a$	17.20±0.23$_c$	21.4±2.56$_c$	3.02±0.009$_a$	12.94 ±0.06$_a$

SCH= Soconusco, Chiapas; PCH= Selva, Palenque Chiapas; CHT= Chontalpa, Tabasco; TPU= Sierra Nororiental, Teziutlán Puebla; $^{a, b, c, d}$= different letters indicate a statistical difference (Tukey, $p \leq 0.05$).

Morphological and physicochemical descriptors

In the morphological characterization carried out on *Persea schiedeana* Nees (Table 2), in relation to the weight of the whole fresh fruits, pulp and peel, the highest values were recorded in the region of Selva, Palenque Chiapas (PCH). In addition, it was observed that, for the region of Soconusco, Chiapas (SCH) and the region of Chontalpa, Tabasco (CHT), in the weights of fresh fruit there was no significant difference. In the weight of seeds, the highest value was recorded by the CHT region (135.06 ±33.52 g) and the results for this variable in the two regions of Chiapas (SCH and PCH) were not significant.

The fruits from the Selva region showed the highest weight of fresh pulp, with an average value of 282.09 ±54.72 g, unlike the fruits from Sierra Nororiental (TPU), which had the lowest weight of fresh pulp, with an average of 84.98 ±12.81 g. The highest percentage of pulp with respect to whole fruit was recorded in samples from the Soconusco region (64.64 ± .85%) and the Selva region (67.49 ±5.98%), both of Chiapas. In the percentage of seed in whole fruit, the highest percentage occurred in the fruits from the Chontalpa region (39.81 ±7.11%), while the highest percentages of peel in whole fruit were those of the Sierra Nororiental region (12.94 ±0.06%).

The fruits from the Selva region (PCH) were the ones with the highest weight and size in whole fruit, showing a greater length and greater content of pulp. On the other hand, the value for the case of the percentage of seed in fruit and percentage of peel in whole fruit was lower.

It was observed that the fruits of PCH had a claviform shape, while the regions of SCH and CHT showed wide obovate and curved claviform shapes, respectively. Unlike the central area, in which the shape was rhomboidal. The above is similar to the results obtained in fruits of *Persea*

schiedeana Nees distributed in Los Tuxtlas, Veracruz (Joaquín-Martínez *et al*., 2007). The four regions evaluated had similarities for the parameters of base of fruit sunken type, cylindrical pedicel, shades in the peel from green to dark green and from green to black. The regions of Sierra Nororiental and Soconusco presented a rounded apex shape.

The position of the apex in the fruits from the regions of Sierra Nororiental and Chontalpa were of the central type, unlike the regions of Selva and Soconusco, which was asymmetrical. The position of the pedicel of the fruit was of the central type for the regions of Sierra Nororiental and Selva; and between the regions of Chontalpa and Soconusco it was asymmetric (Figure 2).

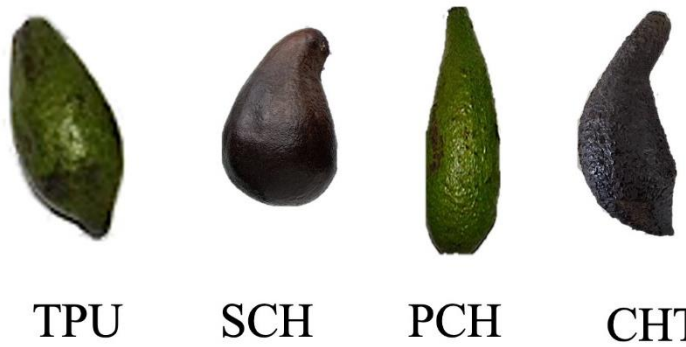

Figure 2. Morphological descriptors in fruit of *Persea schiedeana* Nees from the different regions in Mexico. (Source: Quiñones-Islas). TPU= Sierra Nororiental, Teziutlán Puebla; SCH= Soconusco, Chiapas; PCH= Selva, Palenque Chiapas; CHT= Chontalpa, Tabasco.

Regarding the pulp and seed of *Persea schiedeana* Nees (Figure 3), similarity was observed between the fruits of the four areas evaluated, among which the following stand out: intermediate adhesion of the peel to the pulp, light yellow color in the pulp close to the peel and seed, adhesion of the cotyledon to the seed of the adhered type, a central position of the seed, without free space of the seed cavity and an elliptical shape of the cross section of the seed. In the shape of the seed, the regions that showed similarities were Soconusco and Sierra, with a shape of the wide obovate type.

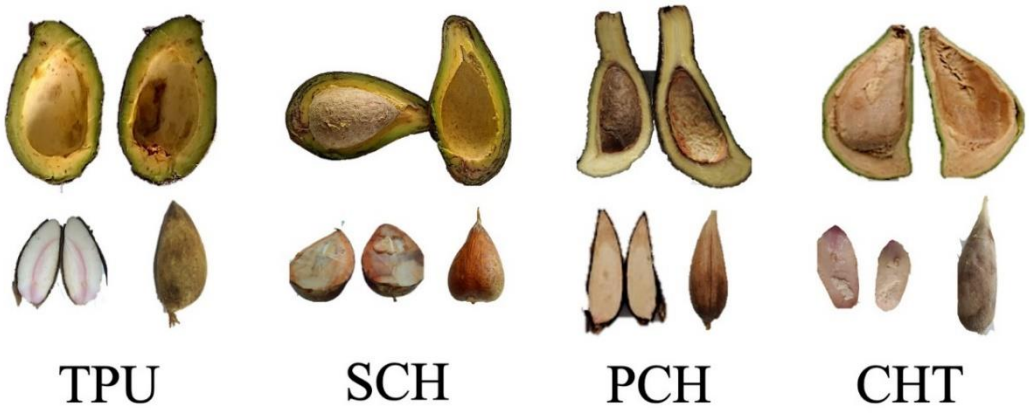

Figure 3. Morphological descriptors in pulp and seed of fruits of *Persea schiedeana* from the different regions in Mexico (Quiñones-Islas, 2022). SCH= Soconusco, Chiapas; PCH= Selva, Palenque, Chiapas; CHT= Chontalpa, Tabasco; TPU= Sierra Nororiental, Teziutlán, Puebla.

The surface and color of the cotyledon of the regions of Chontalpa and Sierra were similar, presenting a smooth surface and orange-yellow color. The seed cover was very different between each of the regions, showing a seed adhered to the cover without adhering to the pulp (Soconusco region), free seed with cover adhered to the pulp (Selva region), seed adhered with the cover adhered to the pulp (Chontalpa region) and seed adhered with cover adhered to the pulp (Sierra Nororiental region). In a study conducted by Rodríguez-Córdova *et al*. (2018), in the central region of the state of Veracruz, similar values were obtained for some of the study variables previously described for this species. The results obtained show the morphological diversity among the fruits of *Persea schiedeana* Nees from the regions evaluated, evidencing their potential as a source of germplasm.

In the physicochemical characterization in fruits of *Persea schiedeana* Nees from the collection regions (Table 3), the moisture in the pulp, seed and peel obtained were similar to those reported for *Persea americana* Mill. in its varieties Hass, Booth-8, Trinidad, Papelillo, Simmonds, Polloc, Choquette and Linda (Ceballos and Montoya, 2013; Fonseca-Duarte *et al*., 2016). The moisture content in climacteric fruits, such as *Persea schiedeana* Nees and *Persea americana* Mill, is an important postharvest quality factor to consider in conservation, as it indicates the stability of the fruit, representing the presence of oxidation reactions caused mainly by the enzyme polyphenol oxidase, in which a release of water is carried out which causes the softening of the tissues (Talabi *et al*., 2016; Márquez *et al*., 2016).

Table 3. Physicochemical descriptors expressed in percentage units of the average obtained per 100 grams of fruit of *Persea schiedeana* Nees from the different regions (dry basis).

Region/part of the fruit	% Moisture	% Dry matter	% Ash	% Protein	% Fat
SCH-P	82.59 ±1.51$_a$	17.4 ±1.51$_c$	3.25 ±0.67$_a$	2.79 ±0.54$_a$	20.6 ±0.43$_d$
PCH-P	68.13 ±1.09$_c$	31.86 ±1.09$_a$	3.07 ±0.01$_a$	1.74 ±0.01$_{b,c}$	50.29 ±2.03$_a$
CHT-P	73.59 ±0.54$_b$	26.4 ±0.54$_b$	3.88 ±0.02$_a$	1.92 ±0.17$_b$	26.23 ±0.02$_c$
TPU-P	67.56 ±0.72$_c$	32.43 ±0.72$_a$	1.9 ±0.07$_b$	1.11 ±0.1$_c$	31.01 ±0.2$_b$
SCH-E	59.34 ±3.58$_b$	40.66 ±3.58$_a$	2.51 ±0.18$_c$	2.64 ±0.19$_a$	3.18 ±0.84$_d$
PCH-E	72.1 ±0.53$_a$	27.89 ±0.53$_b$	4.25 ±0.01$_{b,c}$	1.77 ±0.04$_{b,c}$	40.16 ±1.42$_a$
CHT-E	71.9 ±0.4$_a$	28.09 ±0.4$_b$	6.51 ±0.11$_{a,b}$	1.92 ±0.17$_b$	11.53 ±0.29$_b$
TPU-E	73.92 ±0.07$_a$	26.07 ±0.08$_b$	8.77 ±2.5$_a$	1.39 ±0.17$_c$	8.79 ±0.575$_c$
SCH-S	65.25 ±1.63$_{a,b}$	34.74 ±1.62$_{b,c}$	2.84 ±0.66$_{a,b}$	1.76 ±0.14$_a$	3.81 ±0.23$_b$
PCH-S	63.38 ±0.48$_b$	36.61 ±0.48$_b$	1.9 ±0.01$_c$	0.52 ±0.01$_c$	12.2 ±2.16$_a$
CHT-S	66.51 ±0.31$_a$	33.48 ±0.31$_c$	3.04 ±0.02$_a$	1.28 ±0.26$_b$	7.08 ±0.7$_b$
TPU-S	60.46 ±0.42$_c$	39.53 ±0.42$_a$	1.96 ±0.24$_{b,c}$	0.81 ±0.1$_c$	14.38 ±1.47$_a$

SCH= Soconusco, Chiapas; PCH= Selva, Palenque, Chiapas; CHT= Chontalpa, Tabasco; TPU= Sierra Nororiental, Teziutlán, Puebla; P= Pulp; E= Peel; S= Seed; $^{a, b, c, d}$= different letters indicate a statistical difference (Tukey, $p \leq 0.05$).

Dry matter content indicates the content of dry solids in which nutrients are concentrated (Obenland *et al*., 2012; Bayram and Seyla, 2019). In the fruits of *Persea schiedeana* Nees evaluated, this parameter ranged from 17.4 ±1.51% to 40.66 ±3.58%, presenting the highest percentages of dry

matter in pulp and seed for the region of Sierra Nororiental. In the peel, the highest percentage of dry matter was obtained in the fruits from the Soconusco region, showing a relationship with the protein content, as they obtained the highest percentage in the peel of the fruits of this same region. According to the results obtained, these showed a concentration of nutrients comparable to what was reported by Fonseca-Duarte *et al*. (2016), for *Persea americana* Mill.

Ash concentrations in the fruits studied ranged from 1.9 ±0.01% to 8.77 ±2.5%. In peel, the highest percentages were those of the Sierra Nororiental region. In pulp and seed, the highest percentages were obtained in the fruits from the Chontalpa region. The highest protein content in pulp was 2.79 ±0.54%, higher than that reported by Morales-Ramos (2018) in the pulp of *Persea schiedeana* from the western region of Honduras, with a value of 1.3%.

The highest protein contents in all parts of the fruit were found in those from the Soconusco region, Chiapas. The highest percentages of fat in pulp (50.29 ± 2.03%) were obtained in the fruits of larger size (Table 3), belonging to the Selva region, Chiapas. The determinations in the fruits of *Persea schiedeana* Nees in each of its components presented values very similar and comparable to those obtained in *Persea americana* for the varieties Booth8, Trinidad and Papelillo (Ceballos and Montoya, 2013).

Conclusions

It was possible to establish that the place where the fruits of *Persea schiedeana* Ness developed has an influence on the product. The fruits from the Selva region in Palenque, Chiapas stood out, which presented the highest percentages in pulp content and fat content in both pulp and peel. The highest protein contents in all parts of the fruit were found in those obtained in the Soconusco region, Chiapas. In general, the results obtained in the present study indicate the existence of an important diversity among the materials of *Persea schiedeana* Nees, based on the morphological and edaphoclimatic characteristics evaluated.

This represents a determining factor for its revaluation in the productive sector, which could contribute to stimulating local and regional economies. It also has the potential to be exploited in multiple industrial applications (oils, pulps, cosmetics, food and agroindustry), in genetic improvement programs and in programs of conservation of germplasm of traditional species in Mexico.

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