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Morphological and biochemical characteristics in fruits of *Mangifera indica* L. var. Ataulfo with and without conventional management

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ABSTRACT

Objective: To identify the morphometric and biochemical variation in mango fruits var. Ataulfo (*Mangifera indica* L.) in two contrasting environments with and without conventional management.

Design/methodology/approximation: Morphological and biochemical variables were studied in mango fruits var. Ataulfo in two environments, one of them (La Norteña) with Leptosol soil and Aw climate with conventional agrochemical-based management and the other (Santa Cecilia) on Acrisol soil and Am climate with agroecological management. There were 30 fruits used, all from five trees (n=150) per study garden in a state of commercial maturity. Each fruit was considered as an experimental unit, and morphological and biochemical variables were evaluated for each fruit.

Results: Increase in fruit weight, higher pH and increase in total soluble solids, but decrease in pulp weight on site with conventional handling. Increase in pulp content and firmness in fruits from the site without handling.

Study Limitations/implications: Changes in the amount and distribution of rainfall in both environments each year.

Findings/conclusions: Morphological and biochemical modifications are presented. Greater size and weight, pH and TSS content in the conventional production system, but increased pulp and greater firmness, as well as higher citric acid content in the agroecological system. The results suggest differential effects in mango fruits according to the management and environment where they develop.

Key words: Fruit morphometry, color, pH, Total soluble solids (TSS).

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INTRODUCTION

The mango (*Mangifera indica* L.) var. Ataulfo has a Mexican origin with a designation of origin from Soconusco, Chiapas, Mexico (NOM-188-SCFI-2012) and preference in national and international markets for its firmness, flavor, shelf life (Palacio and Avendaño, 2019), color, smell and consistency (De Gyves *et al.*, 2009). It has been distributed to various tropical regions of Mexico and some of Central and South America (Infante *et al.*, 2011).

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The mango fruit is a source of carbohydrates, amino acids, vitamins, and minerals (Maldonado-Celis *et al.*, 2019) with nutraceutical properties due to the antioxidant content of phenols and carotenoids (Maldonado-Astudillo *et al.*, 2014) or the inhibition of pro-inflammatory cytokines formation (Márquez *et al*, 2012). At present, campaigns have been promoted to disseminate the nutritional value of mango to encourage its consumption and add value to the production chain (Sumaya-Martínez *et al.*, 2012) with an emphasis on production without agrochemicals.

The increase of the mango yield is traditionally addressed through conventional agrochemical-based practices, such as synthetic chemical fertilization and chemical control of weeds, pests and diseases (Prieto Martínez *et al.*, 2005; Palacio *et al.*, 2011), however, the increase in organic products consumption derives on the strategy of using other sources of nutrition (Márquez *et al.*, 2013; Berdeja-Arbeu *et al.*, 2018), due in part, to the increase in the costs of synthetic chemical fertilizers, in addition to their polluting effects and alteration of the microbiota in the rhizosphere (Caballero-Mellado and Martínez-Romero, 1999), which are fundamental elements in the sustainability and productivity of agrosystems.

By applying organic sources of nutrients, the physical and chemical properties of soils are improved and concomitantly it is expressed in the crop development without detriment of the yield or quality of the fruit (Aguirre *et al.*, 2009). In various crops, the application of chemical and or organic nutrition presents a different response in some morphometric and biochemical characteristics of the fruits. In general, the morphometric characteristics of the fruits vary according to the soil and management (Maldonado-Astudillo *et al.*, 2016) and the quality of the fruits in physiological maturity and consumption is influenced by the supply of nutrients in the different stages of growth (García *et al.*, 2015), in addition, its scarcity induces biochemical and physiological changes that generate softening of the fruits.

In mandarin (*Citrus reticulata*), weight, fruit diameter, vitamin C content, concentration of total soluble solids, citric acid percentage and maturity index are not affected by conventional and organic handling, but they did increase the mineral content of Ca, Mg, K, Na, Fe, Cu, Mn, and Zn in fruits with organic management (Pérez-López *et al.*, 2007). The tomato production *Solanum lycopersicum* Saladette type, Sahel variety, produced in a mixture (v/v 80:20) of sand plus vermicompost in the greenhouse, it was statistically similar when using Steiner solution, also without variation, in the lycopene content (González *et al.*, 2016). In eggplant (*Solanum melogena* L.) the number and width of fruits increased when growing only in worm humus compared to the fertilized treatment and other combinations of worm humus plus fertilization (Montaño-Mata *et al.*, 2009). Therefore, the objective of this work was to identify the morphometric and biochemical variation of the mango var Ataulfo in two contrasting environments with and without conventional management.

MATERIALS AND METHODS

The research was developed in two mango orchards in the region of the Soconusco, Chiapas, Mexico, in contrasting soil and climate environments and differences in agronomic management. One of them, "La Norteña", belonging to the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) (14° 45' 36.8" N and 92° 23' 4.61" O) at 22 m altitude, at the Km 20.5 of the Tapachula-Puerto Chiapas highway section, municipality of Tapachula, Chiapas. The trees are 18 years old and have a distance between plants of 15×15 m. The soil presents the following physicochemical characteristics; clay-loam texture, pH 6.53 (1: 2 water), Organic Matter (OM) 1.9%, NO_3^- 12.0 (mg kg^{-1}), NH_4^+ 14 (mg kg^{-1}), P 13 (mg kg^{-1} Olsen), Fe_2^+ 21.9 (mg kg^{-1}), Mn_2^+ 19.8 (mg kg^{-1}), Zn_2^+ 9.1 (mg kg^{-1}), B 6.1 (mg kg^{-1}), K^+ int. 289 (mg kg^{-1}), Ca_2^+ 2863 (mg kg^{-1}) y Mg_2^+ 185 (mg kg^{-1}), CE 0.07 (Dsm^{-1} a 25 °C), 2% slope, medium superficial drainage of slow infiltration and apparent density of 1.53. The climate corresponds to the Aw_2 (w") ig type, with 1200 to 1500 mm of annual rainfall, distributed between the months from June to November and an average annual temperature of 28 °C (García 1973).

The general management of the plantation is based on practices of cleaning with tractor and edge bander and pruning after harvest. The nutrition through chemical fertilization with the application of 150 kg of urea ha^{-1} (46-0-0), and 90 kg of potassium sulfate ha^{-1} (20.5-0-0). As a flowering inducer, from the beginning to mid-October, 7 kg of potassium nitrate ha^{-1} (22.5-0-52) are applied. In addition, at the beginning of flowering they were sprayed with mL ha^{-1} of fungicide (Trifloxystrobin) in a preventive way. During the months of february and march, auxiliary irrigation by sub foliar sprinkling is applied every two weeks for two hours.

The "Santa Cecilia" orchard is located in the municipality of Huehuetán, Chiapas (15° 03' 12.4" N and 92° 20' 60" O) and 311 m altitude. The trees are 21 years old and the distance between plants is 20×20 m and one in the center at "five of golds". The vegetative soil cover is dominated by bijahua (*Calathea lutea* (Aubl.) E.Mey. ex Schult.) and kudzu (*Pueraria phaseoloides* (Roxb.) Benth.), also has intercropping of *Theobroma cacao* L., *Ananas comosus* (L.) Merr. and *Cedrela odorata* L. The dominant soil group is Acrisol, with a clay-loam texture, pH 6.12 (1:2 water), MO 3.4 %, NO_3^- 3.16 (mg kg^{-1}), P 1.72 (mg kg^{-1} Bray), Fe_2^+ 22.9 (mg kg^{-1}), Mn_2^+ 13.4 (mg kg^{-1}), Zn_2^+ 0.1 (mg kg^{-1}), B 0.1 (mg kg^{-1}), K^+ int. 58.7 (mg kg^{-1}), Ca_2^+ + 397 (mg kg^{-1}) y Mg_2^+ 98.3 (mg kg^{-1}), CE 0.07 (Dsm^{-1} a 25 °C) and slope ≥18%, a 63% saturation point, field capacity of 33.8%, permanent wilting point of 20.1%, hydraulic conductivity of 0.90 cm.h^{-1} and an apparent density of 1.03. The climate belongs to the Am (w") ig type with 3000 to 3500 mm of precipitation and temperatures of 19, 27 and 35 °C (minimum, average and maximum) (García, 1973).

Agricultural practices carried out by the producer have been cleaning with a machete and pruning after harvest.

The physical and biochemical analysis of the fruits were carried out in the Postharvest Physiology Laboratory and the Integral Laboratory of the Faculty of Agricultural Sciences of the Autonomous University of Chiapas, located in Huehuetán, Chiapas, Mexico.

Variables

There were 30 fruits used in a state of commercial maturity as experimental units from five trees per study orchard (n=150), physical and biochemical variables were evaluated for each fruit. The fruits were weighed individually with a digital scale (Ohaus® USA) with a 0.1 g sensitivity.

The CIE (International Commission of the Illumination) system was used to evaluate the color of the epicarp of the fruits in the L*C*h° (L* luminosity, C* chromaticity and h° hue or tone) space, which were measured with an X-Rite® brand colorimeter. In the end, the colors obtained from the fruits of both orchards were compared, expressed as the color difference:

$$(\Delta)\text{ leaving }\Delta L^*,\ \Delta C^*\text{ and }\Delta h^\circ$$

where: ΔL^*=difference in the brightness value; +=lighter, −=darker; ΔC^*=difference in the chroma; +=saturated, −=opaque; Δh°=difference in the hue.

For the fruits shape, polar or longitudinal diameter (DL) and equatorial diameter (DE) (mm) were measured with SureBilt® (USA) digital vernier.

The firmness of the epicarp in the fruits was determined following the Official Mexican Standard NMX-FF-058-SCFI-2006, which establishes the minimum quality specifications that *Mangifera indica* L. must meet, with the help of a texturometer (Chatillon, FDV-30 model, USA) measuring the necessary force to penetrate the fruit peel expressed in Newtons (N).

Destructive sampling was carried out to quantify the morphological and biochemical components of the fruit. The weight of the peel, pulp and seed was obtained. With these values the pulp/seed ratio was determined.

Additionally, the total soluble solids (TSS) expressed as °Brix. For this purpose, 10 g of fresh pulp (mesocarp) were homogenized and adjusted to a final volume of 50 mL with distilled water. The °Brix were determined with a refractometer (ATAGO Model Pallete PR-32đUSA: 0-32%) following the AOAC (1990) methodology. The pH was determined with a potentiometer (Thermo Orion, Model 230A USA).

The titratable acidity quantification (expressed as citric acid %) was carried out by the AOAC (2000) volumetric method. 10 g of liquefied pulp were used in 50 mL of distilled water. An aliquot of 20 mL was taken from the mixture and titrated with NaOH (0.1 N). The result was expressed as citric acid percentage. With the previous data, the °Brix/acidity ratio was calculated, using the quotient of the variables °Brix and the percentage of acidity that is expressed as % °Brix / acidity and represents one of the fruit maturity indices. The data obtained were processed with the help of the SAS software ver. 9.0 (SAS Institute, 2009), to establish the statistical difference between the mango orchards, an analysis of variance (ANOVA) was performed, and the differences were compared with the Tukey's mean test ($r\leq 0.05$).

RESULTS AND DISCUSSION

The fruits weight from La Norteña site ranged from 256 to 320 g and they are classified as size 16 or large, and the fruits from the Santa Cecilia site weighed from 227 to 295 g within the 18 or medium caliber classification, according to the range standardized by the Official Mexican Standard (NOM-188-SCFI-2012). The differences in the weight of fruits produced with conventional management in the Aw climate and clay soils of La

Norteña Site represented 9.5% more, compared to the Santa Cecilia site, with Am climate, acrisol soils and with agroecological management. The difference is influenced by the weight of the peel and seed, morphological components that weighed 31.4 and 10% more respectively compared to the fruits produced at the Santa Cecilia site. However, the fruits of the Santa Cecilia Site registered an average increase of 9.3 g in the pulp weight, and it was statistically different ($P \leq 0.05$) compared to La Norteña site. This value increased its pulp/seed ratio (Table 1).

In other environments, such as in the agroclimatic conditions of Irapuato, Guanajuato, mango fruits var. Ataulfo weighed 223.9 g (Almanza *et al.* 2016), a lower weight than those found in the two sites on the Chiapas Coast, however, Maldonado-Astudillo *et al.* (2016) reported fruits of mango var. Ataulfo with an average weight of 387.8 g in the agroclimatic conditions of the Guerrero Coast and conventional management.

In relation to the morphological variables of the fruits such as the polar diameter of the mangoes that grown with conventional management was on average 4.8 mm higher compared to mangoes grown in the agroecological system. The equatorial diameter does not show changes in the fruits produced in both production systems. In this regard, Almanza *et al.* (2016) cite lower longitudinal diameter of mango fruits var Ataulfo with

Table 1. Morphological and biochemical variables of the fruits of *Mangifera indica* L. var. Ataulfo in two production systems at the Soconusco Chiapas, Mexico.

Variable	**La Norteña (Conventional Managementl)**	**Santa Cecilia (Agroecological Management)**	**CV %**
	Fruit Biomass		
Total Weight (g)	276.62±8.08 a*	251.43±6.56 b	15.27
Peel (g)	43.89±1.08 a	30.10±0.96 b	15.22
Pulp (g)	206.51±7.08 b	227.85±6.17 a	16.76
Seed (g)	26.19±0.94 a	23.56±0.85 b	19.77
Pulp/seed Ratio	8.11±0.31 b	9.96±0.37 a	21.01
	Fruit Morphology		
Polar diameter (mm)	122.51±1.25 a*	117.68±0.95 b	5.09
Equatorial diameter (mm)	71.09±0.70 a	71.87±0.47 a	4.58
Fruit indices (Polar/equatorial)	1.72±0.013 a	1.63±0.014 b	4.53
Firmness (N)	18.97±0.66 b	23.71±0.97 a	21.4
	Fruit Color		
Luminosity (L*)	66.40±0.51 a	64.91±0.44 b*	4.00
Chrome (C*)	53.93±0.71 a	53.06±0.73 a	7.42
Hue (h°)	69.02±0.52 a	69.38±1.27 a	7.74
ΔL*	−1.49		
ΔC*	−0.87		
Δh°	+0.36		

* Values with the same letter within each factor and column are equal according to Tukey's test at $P \leq 0.05$.
** CV: Coefficient of Variation.

conventional management. In contrast, Maldonado-Astudillo et al. (2016) describe larger fruits of mango var Ataulfo obtained from the municipality of Atoyac de Álvarez, Guerrero. In this regard, it is suggested that the differences in weights and sizes in the fruits of the same mango crops are influenced by environmental conditions and management (Santos-Villalobos *et al.*, 2011).

The firmness of the mango fruits produced in Santa Cecilia was 19.9% higher and statistically different ($P \leq 0.05$) compared with the mangoes produced in the La Norteña Site. On the other hand, in the Nayarit Coast, with the same mango variety, var Ataulfo, there were no statistical differences in the firmness of the fruits subjected to fertilized and unfertilized treatment (Nolasco-González *et al.*, 2016). Cancino-Vázquez *et al.* (2020) cite an inverse relationship between firmness and fibrousness in mango fruits var. Ataulfo, when treated with low dose of gamma irradiation on the Chiapas coast. During ripening there are physiological and biochemical activities, such as respiration, that affect the firmness of the fruits (Martínez-González *et al.*, 2017).

The luminosity (L*) or color assessment in the epicarp (peel) of the var. Ataulfo mango fruits at La Norteña site presents a statistically different increase ($P \leq 0.05$) than the Santa Cecilia fruits. In the values of chroma (C*) and hue (h°) in the fruits, they did not present statistical differences between both sites (Table 1). If postharvest physical treatments are applied to the fruits, such as thermal and cold with coatings, both the luminosity as it is the hue and chroma, significant changes are obtained in that color space (L*C*h°) (Bello-Lara *et al.*, 2016; Ariza-Flores *et al.*, 2018).

When comparing the color of the fruits applying the difference Δ of the values for L*, C* and h°, it gives a negative result in luminosity ΔL^*. The above indicates that the fruits from La Norteña Site are lighter compared to the fruits from Santa Cecilia. For the ΔC^* chroma or saturation, the Santa Cecilia fruits are less saturated than La Norteña fruits and regarding the $\Delta h°$ hue, the positive value indicates a greener color tone in Santa Cecilia compared with La Norteña fruits. In this regard, it has been identified that the modification of the color of the fruits during maturity is influenced by changes in the content of chlorophyll, carotenoids, accumulation of flavonoids (Martínez-González *et al.*, 2017) and anthocyanins (Brownleader *et al.*, 1999), derived from environmental conditions, plantation management, especially fertilization, which influence its coloration (Bouzayen *et al.*, 2010).

In addition, during the ripening stage of the fruit, sugars, volatile compounds, and organic acids that affect the flavor, aroma, and nutritional quality, are modified (Martínez-González *et al.*, 2017). Among the components of the fruits flavor, the acidity, which is formed by organic acids such as malic, citric, oxalic, and tartaric, forms an important element for the palate of the consumers. Additionally, of being inversely related to pH and total soluble solids (TSS). The fruits pH of La Norteña site was higher compared to the Santa Cecilia fruits and statistically different ($p \leq 0.05$). Likewise, the citric acid content was 3.5% higher compared to the Santa Cecilia mangoes, but without statistical difference. The pH and the percentage of citric acid are related to organic acids, since they are used during the respiration process (Tsouvaltziz *et al.*, 2007), thus reducing acidity, and while acidity decreases pH, total soluble solids increase (Ortiz-Franco *et al.*, 2016).

On the other hand, under conditions of Galeana, Guerrero and with thermal and chemical treatment, the pH and citric acid values are 4.5 and 0.6%, respectively (Ariza-Flores *et al.*, 2018), and citric acid tends to change significantly if the mango fruits var Ataulfo are treated with gamma radiation (Cancino-Velázquez *et al.*, 2020).

The TSS found at La Norteña site are 31% higher compared to the Santa Cecilia site. This is very significant, since the flavor in the fruits is the TSS content, they are also an estimate of the total sugar content, and in mango var. Ataulfo this characteristic is very attractive due to its high sugar content (Cancino-Vázquez *et al.*, 2020).

During the ripening of the fruits the acidity content tends to decrease, therefore, the total soluble solids tend to increase. This relationship is expressed as the quotient of the soluble solids content (°Brix) between the titratable acidity values (TSS/Acidity ratio). In this work, a higher TSS/Acidity ratio was found in La Norteña site, and it is 30% higher compared to the Santa Cecilia fruits. This difference in between the values of the TSS/Acidity ratio is due to the citric acid content, the lower the acidity value, the greater the relationship with the TSS.

CONCLUSIONS

Morphological and biochemical modifications are presented in mangoes produced in the two production systems and contrasting environments. Greater size and weight, pH and TSS content in the conventional production system, but increased pulp and greater firmness, as well as higher citric acid content in the system with agroecological management. The results suggest differential effects in mango fruits according to the management and environment where they develop.

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