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POST-HARVEST CHARACTERISTICS OF MANGO FRUITS (*Mangifera* sp.) FROM SOCONUSCO, CHIAPAS

Berenice Karina **Flores-Hernández**[1], Ma. de Lourdes **Arévalo-Galarza**[1*], Rubén **San Miguel-Chavez**[2], Saúl **Espinosa-Zaragoza**[3], Noé Delfino **Pérez-Díaz**[3], Víctor Heber **Aguilar-Rincón**[1]

[1] Colegio de Postgraduados Campus Montecillo. Recursos Genéticos y Productividad. Carretera México-Texcoco km 36.5, Montecillo, Texcoco, Estado de México, México. C. P. 56264.
[2] Colegio de Postgraduados Campus Montecillo. Posgrado en Botánica. Carretera México-Texcoco km 36.5, Montecillo, Texcoco, Estado de México, México. C. P. 56264.
[3] Universidad Autónoma de Chiapas. Facultad de Ciencias Agrícolas Campus IV. Entronque Carretera Costera y Estación Huehuetán, Chiapas, México. C. P. 30660.
* Author for correspondence: larevalo@colpos.mx

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ABSTRACT

Mango (*Mangifera indica* L.) is the second most important tropical fruit in the world. In the Soconusco region of Chiapas, Mexico, there is a large number of mango genotypes with a broad range of shapes, flavors, and aromas, with the potential to increase its cultivation. Therefore, the post-harvest characteristics of three creole mango genotypes, 'Manililla', 'Cuero', and 'Manzana' were evaluated and compared with the variety 'Ataúlfo'. Fifty fruits from each genotype were harvested and stored at 20 °C and 75 % relative humidity; quality characteristics (epidermis/seed/pulp ratio, weight loss, color, firmness, °Bx, titratable acidity, ascorbic acid, pectimethylesterase enzymatic activity, phenolic acid and flavonoid content in epidermis) were evaluated under a completely randomized design. The results showed that 'Manililla' and 'Cuero' fruits had a significantly higher weight loss, while 'Manzana' and 'Ataúlfo' were similar in pulp content. The creole genotypes 'Cuero' and 'Manzana' had an attractive yellow-orange color, with red shading on the shoulders and orange in the pulp. The SST/AT ratio in 'Manililla' and 'Cuero' (71.1 and 62.6, respectively), was significantly higher in relation to 'Ataúlfo' (39.1) due to low acidity. 'Manzana' had higher total sugar content (30.3 g 100 g^{-1}) and a firmer texture after six days of storage (dda). 'Cuero' showed greater weight loss and higher ascorbic acid content, 32 % more than 'Ataúlfo'. The pulp content of 'Manzana' fruits was similar to that of 'Ataúlfo', with less weight loss and greater firmness, making it appealing for marketing.

Keywords: Plant genetic resources, outstanding genotypes, postharvest quality, shelf life.

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most commercially important tropical fruits in the world, with Thailand being the main exporting country with 18.91 % of the world market, followed by Mexico with 11.82 %, with a value of USD 734 M and USD 458.8 M respectively by 2020 (Tridge, 2021). Consumer acceptance of the fruit is due to its distinct flavor, sweetness, succulence and varied composition (carbohydrates,

phenolic acids, vitamins A, B_3, B_5, E, and K) with a nutraceutical role (Maldonado-Celis *et al*., 2019).

In Mexico, mangoes have adapted well to the environmental conditions in the tropical zone; April and July are the months with the highest exports. 'Tommy Atkins', 'Haden', 'Kent', 'Keitt', 'Ataulfo', 'Manila' and creole mangoes are grown (SIAP, 2018). The Mexican state of Chiapas is characterized by favorable climatic and soil conditions for mango cultivation, with approximately 38 000 ha of which 84 % are planted with 'Ataúlfo' (Mazariegos-Sánchez *et al*., 2016; SIAP, 2019). However, there is a wide range of regionally-named mangoes with potential for marketing and genetic breeding improvement that are not being exploited. In the Soconusco region of Chiapas, several mango genotypes have been characterized, such as: 'Coche', 'Piña', 'Madura verde', 'Manzana', 'Manilón', 'Tapanero', 'Tecolote', 'Amate', 'Alcamfor', 'Oro', 'Amatillo', 'Pomarrosa', 'Canela', 'Blanco', 'Melocotón', 'Manililla', 'Cachetio', 'Pepino', 'Papaya', 'Agua', and 'Cuero', with different skin and pulp color shades and distinct flavors which make them attractive to local consumer, but no studies have been conducted to evaluate their post-harvest characteristics with the objective of determining their market potential (Gálvez-López *et al*., 2007).

The consumption of fresh mangoes in the world has increased. In 2004, per capita consumption in the United States was 0.92 kg, and in 2013 it was 1.31 kg, representing a 4.24 % annual growth rate (USDA, 2014). Mango consumers prefer smaller fruits, with attractive skin color and different flavors, so it is important to know the post-harvest characteristics of outstanding mango genotypes from the Soconusco region in order to diversify the market supply. In this study, the postharvest quality variables of three types of outstanding Criollo mangoes ('Manililla', 'Cuero' and 'Manzana') were evaluated and compared with fruits of the 'Ataúlfo' variety.

MATERIALS AND METHODS

Fruits at physiological maturity were harvested from trees with an average age of 20 years from different orchards in the Soconusco region, Chiapas. The fruits of 'Manililla' were harvested in the municipality of Mazatán (14° 56′ 38″ N, 92°30′6″ W), 'Cuero' and 'Ataúlfo' in the municipality of Huehuetán (15° 00′ 43. 8″ N, 92° 22′ 39.8″ W; 15°00′28.7″ N, 92° 24′02.2″ W, respectively) and those of 'Manzana' in the municipality of Tuzantán (15° 07′17.0″ N, 92° 26′23.6″ W). From each material, fifty fruits were harvested at physiological maturity and transferred to the Laboratory of Postharvest Physiology at the Colegio de Postgraduados, where they were selected for color, absence of damage and diseases. They were washed in a sodium hypochlorite solution (70 mg L^{-1}), dried and stored at 20 °C and 75 % RH. The evaluation of post-harvest quality parameters was carried out on 4 fruits every 2 days until consumption maturity. Each fruit shoulder was sampled once, for a total of eight replicates, except for the fruit weight, pulp/seed/epidermis ratio and weight loss variables in which each fruit was a replicate.

Variables evaluated

Fruit weight, pulp/seed/epidermis ratio and weight loss

To determine fruit weight and pulp/seed/epidermis ratio, 10 fruits were taken at day zero of storage. Weight loss was measured by weighing 20 fruits daily and reporting the losses as a percentage (%) of their initial weight. A digital balance with 0.001 g precision (Ex2200 Alsep®, A&D Company, Tokyo, Japan) was used.

Dry matter and moisture

A forced-air oven (Lab-Line Imperial®, AM Inc; El Paso, TX, USA) was used to dry 500 mg of pulp in trays at 80 °C for 48 h, until constant weight. Subsequently, the dry matter content was calculated with the moisture percentage.

Epidermis and pulp color

For the color of both tissues, the reading was taken at the equatorial section of the fruit using a colorimeter (Ci60, X-rite; Grand Rapids®, MI, USA), the values were expressed in L (lightness), C (chromaticity) and °H (Hue angle).

Titratable acidity

Determined by the volumetric method (AOAC, 1990), 10 g of pulp were weighed and liquefied with 50 mL of distilled water. Three drops of phenolphthalein were added to a 5 mL aliquot of the mixture as an indicator for color change; it was subsequently titrated with NaOH (0.1N) to pH 8. The results were reported as citric acid percentage.

Total soluble solids

Determined by weighing 5 g of the middle section of the fruit pulp and placing them in a sieve to be squeezed. The juice drops were set on the optical sensor of a digital refractometer (300033, Sper Scientific; Milton Freewater®, OR, USA); the results were expressed in °Brix (°Bx).

Total sugars

One gram of pulp was weighed and boiled with 50 mL of ethanol (80 % v v^{-1}), for 20 min. It was completely evaporated without caramelization and 50 mL of distilled water was added. From this homogenate, 1 mL was taken and made up to 3 mL with distilled water. To each tube, 6 mL of anthrone solution (0.04 %) in sulfuric acid was added, keeping the tubes in ice bath. Absorbance was measured at 600 nm in a spectrophotometer (Genesys 10 UV-Vis, Thermo Spectronic®; Madison, WI, USA). The blank was made with 3 mL of distilled water and 6 mL of the anthrone solution. A glucose standard curve was performed and the results were reported as g 100 g^{-1} (Witham *et al*., 1971).

Ascorbic acid

Based on the 2.6 dichlorophenol indophenol method (AOAC, 1990) in which 2 g of pulp were taken and homogenized in 20 mL of oxalic acid (5 %). Subsequently the mix was titrated with Tillman's solution until it turned pink. The results were expressed in mg 100 g^{-1}.

Chlorophyll and carotenoids

Obtained by weighting 0.1 g of pulp and macerating it in a mortar with 10 mL of acetone (80 %), which was then made up to 10 mL. The extract was centrifuged at 2000 x g for 20 min. Absorbances at 470, 646, and 663 nm were measured using a spectrophotometer (Genesys 10 UV-Vis, Thermo Spectronic®; Madison, WI, USA) (Figueroa-Cares *et al*., 2010). Chlorophyll and carotenoid contents were calculated using the formulas of Lichtenthaler (1987) and expressed as mg 100 g^{-1}.

Firmness

It was determined with a texturometer (Chatillon DFE-050, Ametek®; Largo, FL, USA) equipped with a 7 mm diameter conical strut, by measuring the force required to penetrate the pulp in whole fruit after 1 cm of the epidermis was removed. Values are reported in Newtons (N).

Pectinmethyl esterase activity (PME)

Pectin supplied by Sigma-Aldrich® (Massachusetts, USA) was used to prepare a solution in water (1 %) and its pH was adjusted to 4 using NaOH (1 N); the solution was made up to 200 mL. Subsequently, the potentiometer was immersed in the solution, followed by the addition of 0.8 mL of enzyme extract (20 g pulp + 50 mL NaOH 0.2 N), and the time was registered. Using NaOH (0.01 N) for 10 minutes at 40 °C maintained the pH at 4 throughout the analysis. Finally, the amount of NaOH spent was calculated. The results were reported as mEq mL^{-1} min (Rangana, 1979).

Phenolic acids and flavonoids in the epidermis

Extracts were obtained using the ultrasonic technique to identify and quantify flavonoids and phenolic acids in epidermis (Kim *et al*., 2002). One gram of fresh frozen sample was placed in N_2 and macerated with the help of quartz sand supplied by Sigma-Aldrich® (Massachusetts, USA). They were then transferred to polypropylene tubes, 5 mL of aqueous methanol (80 %) were added and placed in a vortex shaker (VORTEX GENIE 2 SI-0236, Scientific Industries®; Madrid, Spain) for 1 min. They were then subjected to sonication in an ultrasonic bath (Emerson® Cpx2800h Bransonic, Danbury, CT, USA) for 30 min, giving a five-minute rest for every 10 min of sonication. Upon completion, they were centrifuged for 5 min at 5000 rpm in a centrifuge (Eppendorf 5804®, Hamburg, Germany). It was decanted and finally filtered using a nylon membrane (0.45 µm/13 mm). Extracts were stored in 1.5 mL amber glass vials (Agilent®) at 4 °C until analysis.

For the identification and quantification of flavonoids and phenolic acids, methanolic extracts were analyzed on a liquid chromatograph (Infinity 1220 series, Agilent Technologie, Santa Clara, CA, USA) at 30 °C, using a Hypersil® ODS-2 column (125 x 4 mm), 5 µm particle size with a water-acetonitrile mobile phase (65:35 v v^{-1}) and pH adjusted to 2.5 with trifluoroacetic acid. The sample injection volume was 20 µL at 1 mL min^{-1} flow conditions and 114 bar pressure (Svedström *et al*., 2006). The standards used for phenolic acids were: gallic, sinapic, p-hydroxybenzoic (pOHa), syringic, β-resorcylic, vanillic, 3,5-dihydroxybenzoic, ferulic, protocatechuic and *p*-coumaric; for flavonoids: rutin, catechin, myricetin, quercetin, naringenin and floretin (Svedström *et al*., 2006).

Statistical analysis

Data were expressed as mean ± standard deviation; they were compared by analysis of variance (ANOVA) and Tukey's test (α = 0.05), under a completely randomized design. All analyses were performed using SAS® version 9.0 software (SAS Institute, Cary, NC, USA) and the graphs were created with GraphPad Prism version 7.0. To visualize the differences in postharvest quality parameters, a heat map was created with the Rstudio pheatmap package version 4.1.0.

RESULTS AND DISCUSSION

Appearance of the epidermis and pulp

According to external appearance and post-harvest changes, genotypes reached consumption maturity at six days of storage (Figure 1). Gálvez-López *et al*., (2007)

Figure 1. External appearance of skin color and morphological characteristics of mango genotypes according to days of storage.

mention that between the creole genotypes and the commercial varieties ('Ataúlfo', 'Kent' and 'Tommy Atkins') produced in Soconusco, Chiapas, there is a morphological similarity of 20 to 75 %, due to the fact that they share some progenitor due to genetic recombination.

At consumption maturity, the epidermis of all genotypes had an intense yellow tone. 'Manililla' and 'Cuero' presented °Hue values of 74.4 and 64.5 at day six of storage, while for 'Manzana' it was 81, with red hues on the shoulders making the epidermis more conspicuous. Similar values are reported for commercial cultivars such as 'Edward', 'Kent', 'Osteen' and 'Fabian' (79, 83, 82 and 80 *H, respectively) (Siller-Cepeda *et al*., 2009). 'Manililla' and 'Ataulfo' presented higher values of chromaticity and luminosity on day six of storage, revealing a fainter color. Epidermis and pulp color have potential for commercial exploitation if targeted to specific markets, as there is a growing preference for mangoes with red epidermis (Human and Rhedder, 2004). Regarding flesh color on day six of storage, the genotypes presented an attractive yellow-orange hue in the flesh (Figure 2). There were no significant differences in the Hue angle tone. Chromaticity (C*) increased independently of genotype, with 'Cuero' fruit showing the highest values (70.6), visually distinguished by a better yellow-orange hue. In 'Cuero' and 'Manililla' the lightness (L*) values for day six of storage were lower and the flesh was darker unlike 'Manzana' and 'Ataúlfo', similar to those reported in the cultivar 'Alphonso' (56) at consumption maturity (Nambi *et al*., 2016).

Fruit weight, pulp/seed/epidermis ratio and weight loss

NMX-FF-058-SCFI-2006 8/20 classifies mango fruit into different sizes, indicating the number of fruits per 10 lb (4.536 kg) box. According to this standard, 'Manzana' and

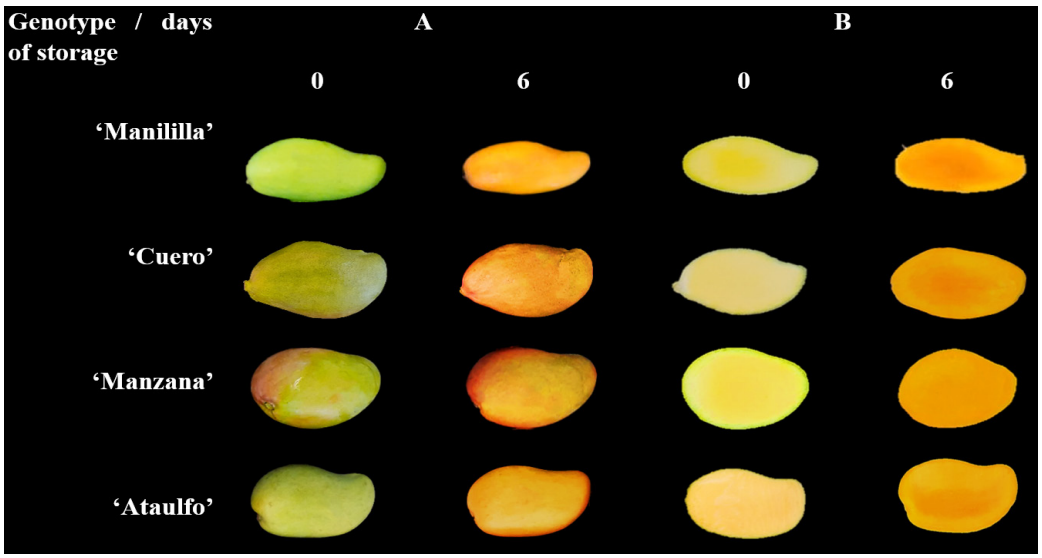

Figure 2. Color of A: epidermis; B: pulp, of four mango (*Mangifera* sp.) genotypes from Soconusco, Chiapas, at days 0 and 6 of storage.

'Cuero' fruits are classified as size fourteen with a weight range of 305–349 g (Figure 3). 'Manililla' was characterized as a small fruit (CODEX STAN 184-1993) that is ideal for marketing in size 20 (227–233 g), but does not meet international market demand standards for medium (250–323 g) and large (600 g) sizes (Méndez *et al*., 2010).

Breeding studies have been conducted in India focusing on mango genetic diversity, as market demand shifts towards smaller sized fruits with the characteristics that a heavier fruit can offer (Kulkarni *et al*., 2019). On average, the materials evaluated contained 77.5 % of their weight in pulp, with the remainder made up of epidermis and seed (Figure 3). Fruits of commercial cultivars, such as 'Gaylour' produced in Hawaii and 'Ah ping' from Egypt, weigh between 348 and 500 g, with pulp percentage between 60 and 90 % of their total weight (Lu, 2018). Regarding the percentage of epidermis and seed, values were low (20-25 %) compared to 'Haden' and 'Tommy Atkins', which recorded weights from 400 to 600 g, with 40 % of their weight divided between seed and epidermis on average (Vega-Vega *et al*., 2013). However, it is important to note that all the creole fruits had larger seed than 'Ataulfo' (Figure 3).

Regarding weight loss, the fruit of 'Cuero' showed the greatest decrease after six days of storage (18.79 % of its initial weight, with losses of 3 % per day), followed by 'Manililla' (12.26 %, 2 % per day). The fruits of 'Manzana' were similar to 'Ataúlfo', with average daily losses of 1.7 %. In fruits of genotypes 'Chokanan', 'Golden Phoenix' and 'Water Lily' (Malaysian varieties), daily weight losses of approximately 1.12 % have been reported (Lawson *et al*., 2019).The genotypes had an average dry matter content of 17.6 %. This value is comparable to the dry matter percentage used as harvest index for the cultivar 'Mahajaneka' (16.89–19.22 %) when it reaches eating maturity with the development of all organoleptic characteristics (Saranwong *et al*., 2004). Famiani *et al*. (2012) mention that fruits with high dry matter content have higher specific weight and may have higher sugar and organic acid content, which is another quality indicator.

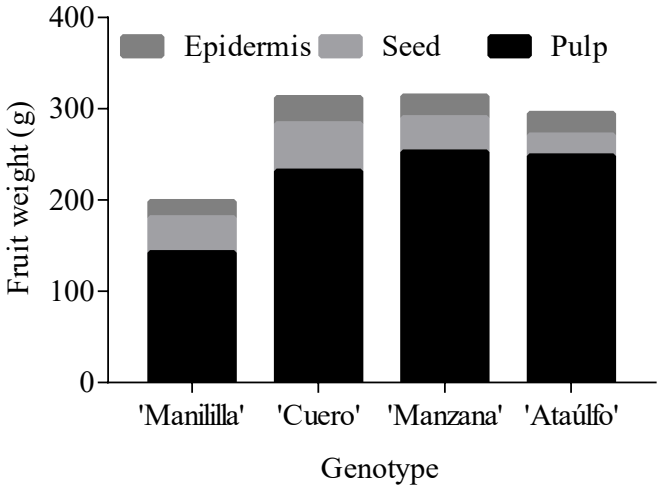

Figure 3. Fruit weight (g) and pulp/seed/epidermis ratio of mango (*Mangifera* sp.) genotypes from Soconusco, Chiapas. n = 10.

Titratable acidity (TA) and total soluble solids (TSS)

NMX-FF-058-SCFI-2006 8/20 for 'Ataúlfo' mentions a minimum acceptable value of 2.9 °Bx at physiological maturity, with fruits of all genotypes having a value of 7.7 °Bx at harvest. 'Manililla' fruits increased 58 % TSS during storage while TA decreased 86 % (Figure 4A). In 'Cuero', they had a 67.5 % increase in TSS, and a decrease in acidity of 74.8 % (Figure 4B), with significant changes from the second day of evaluation. 'Manzana' had no significant statistical differences ($p > 0.05$) in the first days and showed the least increase in TSS (Figure 4C). The genotypes studied comply with the values of 10 to 20 °Bx for ripe mangoes for export. Indian cultivars ('Alphonso' and 'Banganapalli') have reported 19.3 and 16. 5 °Bx, and 0.3 and 0.1 % TA at consumption maturity, respectively (Nambi *et al*., 2015). As for the TSS/TA ratio at day six of storage, the fruits of 'Cuero' and 'Manililla' presented an average value of 67, while for 'Manzana' and 'Ataúlfo' it was 32. The fruits of 'Cuero' and 'Manililla' are less acidic, with an attractive flavor because these values represent their palatability. Siller-Cepeda *et al.* (2009) reported a TSS/acidity ratio in 'Ataulfo' and 'Haden' of 33.64 and 23.71, respectively, similar to those obtained in 'Ataulfo' and 'Manzana'.

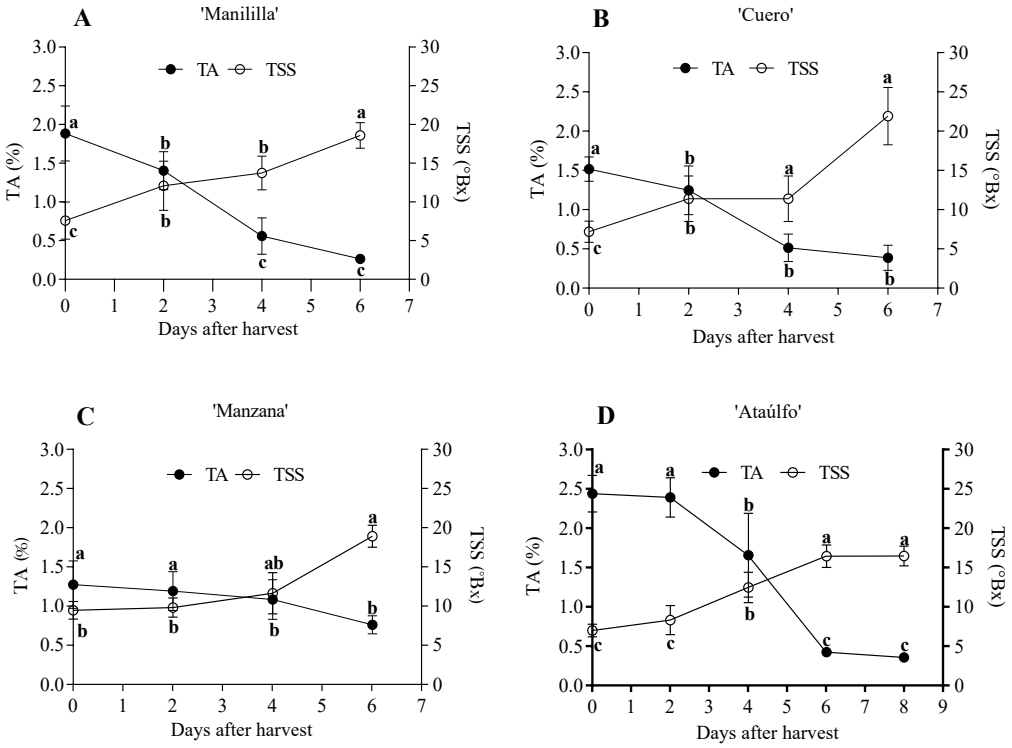

Figure 4. Changes in titratable acidity and total soluble solids of fruits in four mango genotypes (*Mangifera* sp.) from Soconusco, Chiapas. A: 'Manililla'; B: 'Cuero'; C: 'Manzana'; D: 'Ataúlfo' (20 °C and 75 % RH). Values with different letters indicate statistically significant differences (Tukey, $p \leq 0.05$) for each mango genotype. n = 8 ± standard deviation. TA (%): Titratable acidity; TSS (°Bx): Total soluble solids.

Total sugars

Sucrose is the predominant sugar in mango fruits (70 %), while the remaining proportion corresponds to fructose and glucose. At day six of storage, there were no significant statistical differences ($p \leq 0.05$) with values in 'Ataúlfo' (24.6 g 100 g^{-1}), 'Manililla' (25 g 100 g^{-1}), 'Cuero' (27.2 g 100 g^{-1}) and 'Manzana' (30.3 g 100 g^{-1}). These values are similar to those found in fruits of 'Ataúlfo', 'Manila', 'Criollo', and 'Irwin' (27.1, 21.7, 16.4, 31.0 g 100 g^{-1}, respectively) harvested in Guerrero, Mexico (Maldonado-Astudillo *et al*., 2016).

Firmness and enzymatic activity of pectinmethyl esterase (PME)

Firmness is a variable considered to be one of the main quality attributes of the fruit. This is relevant because in quarantine situations, fruits are subjected to hydrothermal treatment (Luna-Esquivel *et al*., 2006). The fruits of 'Manililla' and 'Cuero' (Figure 5A and B) showed 50% less firmness than 'Manzana' and 'Ataúlfo' (Figure 5C and 5D) during storage. 'Manzana' and 'Ataúlfo' have an advantage in packing and logistics practices due to the resistance that confers them high firmness values (Luna-Esquivel *et al*., 2006).

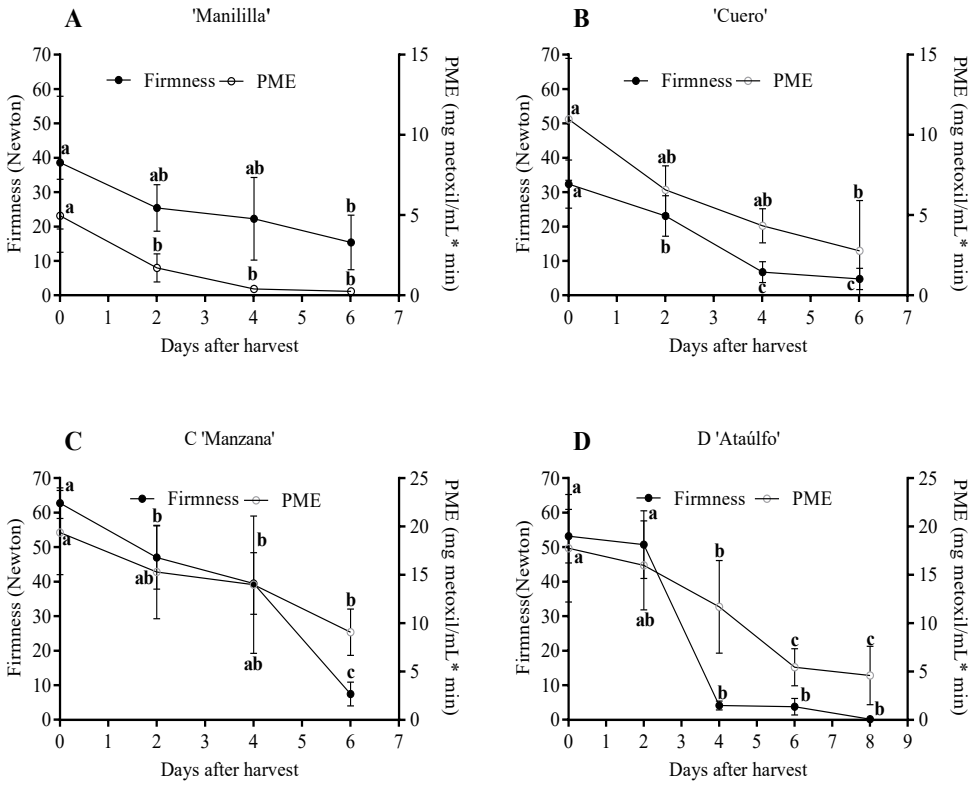

Figure 5. Changes in firmness and pectinmethyl esterase (PME) activity in fruits of four mango (*Mangifera* sp.) genotypes from Soconusco, Chiapas, during storage (20 °C and 75 % RH). A: 'Manililla'; B: 'Cuero'; C: 'Manzana'; D: 'Ataúlfo'. Values with different letters indicate statistically significant differences (Tukey, $p \leq 0.05$) for each mango genotype. n = 8 ± standard deviation.

Regarding PME activity, it catalyzes the hydrolysis of C-6 methyl esters of galacturonic acid residues, resulting in the demethylation of pectins facilitating the degradation of pectic polymers and the action of endopolygalacturonases that contribute to cell wall relaxation (Diaz-Cruz *et al*., 2016; Khaliq *et al*., 2017). Increased PME activity precedes the drop in firmness in all genotypes (Figure 5). The fruits of 'Manzana' and 'Ataúlfo' presented higher enzymatic activity related to higher firmness, however, it is interesting that the fruits of the former maintain firmness two days longer than 'Ataúlfo', which is interesting considering that the fruits are subjected to hydrothermal treatment where the loss of firmness is a factor of deterioration. Luna-Esquivel *et al*. (2006) report that this treatment causes a 50 % loss in fruit firmness of the 'Ataúlfo' variety.

Ascorbic acid

The initial ascorbic acid content in 'Cuero' was 81.4 mg 100 g^{-1}, while 'Ataulfo' had 61.4 mg 100 g^{-1}, 'Manililla' with 32.8 mg 100 g^{-1} with the lowest content, and 'Manzana' with 48.9 mg 100 g^{-1}. Ascorbic acid is easily oxidized when exposed to different factors such as high temperatures, some divalent cations (copper or iron), oxygen, alkaline pH, light or degradative enzymes. These values are within the average reported for mango, with 36.4 mg 100 g^{-1} of vitamin C (Lebaka *et al*., 2021). During the ripening process, ascorbic acid degradation normally occurs, with the 'Manililla' fruit showing the least degradation at day six of storage (15 %). Hu *et al*. (2018) showed ascorbic acid losses in different mango cultivars such as 'Keitt' (163.94–46.87 mg 100 g^{-1}), 'Sensation' (176.03–29.34 mg 100 g^{-1}) and 'Xiangya' (160.35–30.84 mg 100 g^{-1}) with high degradation percentages (71, 83 and 80 %, respectively).

Phenolic acids and flavonoids in the epidermis

Regarding phenolic acid content, mangoes contain two main categories of phenolic acids: hydroxybenzoic acid and hydroxycinnamic acid derivatives. These phenolic acids can occur in free forms or conjugated with glucose or quinic acid (Burton-Freeman *et al*., 2017). Mango epidermis contains significant amounts of dietary fiber (45–78 %), phenolic acids, flavonoids, xanthones, carotenoids, vitamin C and tocopherol. The hydroxybenzoic acids detected in mango are gallic acid, vanillic acid, syringic acid, protocatechuic acid, and *p*-hydroxybenzoic acid (*p*OHa). The hydroxycinnamic acid derivatives found include *p*-coumaric, chlorogenic, ferulic and caffeic acids (Ediriweera *et al*., 2017). In pulp, Palafox-Carlos *et al.* (2012) identified chlorogenic, gallic, vanillic and protocatechuic acids in mango pulp by HPLC-DAD.

The content and characteristics of phenolic acids depend on cultivar and maturity stage (Corrales-Bernal *et al*., 2014). In this study, 10 phenolic acids were identified in mango epidermis, predominantly: gallic, *p*-coumaric, *p*-oligohyaluronic, syringic and vanillic acids. On day zero of storage, the creole genotypes presented higher phenolic acid content than the 'Ataúlfo' variety with significant statistical differences ($p \leq 0.05$), which presented a higher incidence of anthracnose with the exception of 'Manililla'.

However, this behavior is similar to 'Golden Delicious' and 'Jonagold' apple cultivars infected by *Venturia inaequalis*, where infected tissue presented higher phenolic acid content (114.1 mg 100 g^{-1} DW) compared to non-infected tissue, which presented 91.4 mg 100 g^{-1} DW (Mikulič-Petkovšek *et al*., 2009). The production and accumulation of phenolic acids occur in healthy cells surrounding infected cells, and are stimulated by damaged cells. Phenolic acids can oxidize and react with proteins, causing a loss of enzymatic function and restricting pathogen viability, or they can be deposited within the cell wall as an important first line of plant defense against infection (Agrios, 2005). Gallic acid has the highest content in the mango epidermis. In different mango varieties at consumption maturity, the presence of higher contents of gallic (72.0–1450 mg 100 g^{-1} FW), protocatechuic (3.9–64.3 mg 100 g^{-1} FW) and chlorogenic (4.4–27.1 mg 100 g^{-1} FW) acids has been observed (Ramirez *et al*., 2014; Abbasi *et al*., 2015). In the case of 'Manililla' and 'Ataúlfo', total phenolic acids increased on the sixth day; gallic acid was found in higher concentration in the fruits of 'Manililla', 'Cuero' and 'Ataúlfo', while 'Manzana' presented a lower content and its susceptibility to anthracnose was higher (Table 1).

Table 1. Phenolic acid content in the fruit epidermis of four mango (*Mangifera* sp.) genotypes from Soconusco, Chiapas, at days 0 and 6 of storage (20 ± 2 °C and 60 % RH).

Phenolic acids (mg 100 g^{-1} FW)	Day	Genotype			
		'Manililla'	'Cuero'	'Manzana'	'Ataúlfo'
Sinapic	0	0.08 ± 0.01 b	0.14 ± 0.00 a	0.13 ± 0.00 a	0.09 ± 0.00 b
	6	0.17 ± 0.00 a	0.14 ± 0.01 ab	0.14 ± 0.01 ab	0.11 ± 0.00 b
*p*OHa	0	0.05 ± 0.00 c	3.64 ± 0.48 a	1.16 ± 0.24 b	0.04 ± 0.02 c
	6	ND	4.08 ± 1.01 a	1.17 ± 0.37 b	0.72 ± 0.05 b
Siringic	0	0.65 ± 0.02 ab	0.61 ± 0.00 bc	0.66 ± 0.00 a	0.60 ± 0.00 c
	6	0.68 ± 0.00 a	0.60 ± 0.00 b	0.69 ± 0.02 a	0.68 ± 0.03 a
β-resorcylic	0	ND	0.23 ± 0.02 a	0.15 ± 0.005 b	ND
	6	ND	0.18 ± 0.03 a	0.14 ± 0.01 a	0.18 ± 0.06 a
Ferulic	0	0.05 ± 0.01 b	0.09 ± 0.01 a	0.06 ± 0.01 ab	0.05 ± 0.00 b
	6	0.08 ± 0.00 a	0.07 ± 0.01 a	0.08 ± 0.02 a	0.07 ± 0.00 a
3,5-diOHbenzosoic	0	0.17 ± 0.03 ab	0.11 ± 0.01 b	0.13 ± 0.01 b	0.30 ± 0.10 a
	6	0.22 ± 0.01 b	0.09 ± 0.00 d	0.15 ± 0.01 c	0.36 ± 0.03 a
Gallic	0	4.93 ± 1.08 a	3.91 ± 0.37 a	1.20 ± 0.14 b	2.08 ± 0.23 b
	6	8.27 ± 0.25 a	3.57 ± 1.19 b	1.35 ± 0.26 c	2.98 ± 0.53 bc
p-coumaric	0	0.31 ± 0.12 b	0.24 ± 0.06 b	0.24 ± 0.01 b	0.57 ± 0.07 a
	6	0.47 ± 0.09 a	0.20 ± 0.02 b	0.22 ± 0.03 b	0.19 ± 0.07 b
Protocatechuic	0	0.19 ± 0.000 b	0.28 ± 0.03 a	0.23 ± 0.01 ab	0.24 ± 0.00 ab
	6	0.20 ± 0.01 b	0.23 ± 0.00 ab	0.22 ± 8.7 ab	0.24 ± 0.00 a
Vanillic	0	0.15 ± 0.09 b	0.21 ± 0.04 b	0.55 ± 0.04 a	0.04 ± 0.00 b
	6	0.21 ± 0.08 b	0.28 ± 0.08 b	0.60 ± 0.6 a	0.33 ± 0.05 b
Total	**0**	**6.58 ± 0.13**	**9.46 ± 0.10**	**4.51 ± 0.04**	**4.01 ± 0.04**
	6	**10.3 ± 0.04**	**9.44 ± 0.23**	**4.76 ± 0.06**	**5.86 ± 0.07**

Values with different letters in the same row indicate statistically significant differences (Tukey, $p \leq 0.05$). n = 3 ± standard deviation. ND: Not detected

The flavonoids present in mango are: catechins, quercetin, kaempferol, rhamnetin, anthocyanins, tannic acid, and xanthones such as mangiferin (Masibo and Quian, 2008). On days zero and six of storage, catechin and rutin predominated in the epidermis of mango fruits. 'Ataulfo' presented the highest flavonoid content at day zero, which increased at day 6 to 152.43 mg 100 g^{-1}. However, only four of the six flavonoids identified in the creole genotypes could be quantified. On day six, 'Manililla' presented the highest flavonoid content, significantly higher than the rest of the creole genotypes. Generally, these molecules are involved in protecting plants from ultraviolet radiation, reactive oxygen species (ROS) and pathogen attack (Sudheeran *et al*., 2020). According to research on 23 black currant (*Ribes nigrum*) cultivars with varying degrees of infection caused by black currant leaf spot (*Drepanopeziza ribis*) and leaf spot (*Septoria ribis*), cultivars with severe symptoms of leaf spot infection had high levels of hydroxycinnamic acids, epicatechin (6.31 mg 100 g^{-1}) and myricetin (6.5 mg 100 g^{-1}). While cultivars with minimal symptoms of leaf spot infection were detected, higher contents of kaempferol glycosides (38.4 mg 100 g^{-1}) and quercetin were found (1.3 mg 100 g^{-1}) (Mikulič-Petkovšek *et al*., 2013). Based on the above, the total flavonoid content was also lower in 'Manzana' fruits which may partly explain its susceptibility to disease; however, further studies are needed (Table 2).

Fruits were grouped in a heat map according to their postharvest characteristics (Figure 6); at day zero, 'Cuero' and 'Ataúlfo' fruits were similar in soluble solids/acidity ratio, as well as in firmness and sugar content. However, at day six, the 'Manzana' and 'Ataúlfo' fruits were the most similar in firmness, skin color, pulp content, and ascorbic

Table 2. Flavonoid content in fruit epidermis of four mango (*Mangifera* sp.) genotypes from Soconusco, Chiapas, at days 0 and 6 of storage (20 ± 2 °C and 60 % RH).

Flavonoids (mg 100 g^{-1} FW)	Day	Genotype 'Manililla'	'Cuero'	'Manzana'	'Ataúlfo'
Rutin	0	1.26 ± 0.22 b	2.53 ± 0.07 a	0.95 ± 0.12 b	1.40 ± 0.001 b
	6	3.0 ± 0.09 a	2.33 ± 0.11 b	0.49 ± 0.02 c	2.05 ± 0.15 b
Quercetin	0	0.48 ± 0.04 b	0.17 ± 0.00 c	0.14 ± 0.01 c	0.83 ± 0.06 a
	6	0.23 ± 0.03 b	0.13 ± 0.00 c	0.14 ± 0.00 c	2.26 ± 0.001 a
Catechin	0	21.43 ± 1.32 b	20.93 ± 1.90 b	22.68 ± 0.95 b	62.23 ± 4.86 a
	6	157.55 ± 6.68 a	26.41 ± 1.73 b	38.91 ± 2.32 b	148.11 ± 2.13 a
Myricetin	0	0.30 ± 0.03 a	0.21 ± 0.01 b	0.16 ± 5.9 b	ND
	6	0.50 ± 0.00 a	0.16 ± 0.02 b	0.15 ± 0.01 b	ND
Naringenin	0	0.12 ± 0.00 b	0.12 ± 0.00 b	ND	0.99 ± 0.001 a
	6	0.12 ± 0.00 a	0.12 ± 0.00 a	0.11 ± 0.00 b	ND
Floretin	0	0.11 ± 0.00 a	0.10 ± 0.00 b	ND	ND
	6	0.10 ± 0.00 a	0.10 ± 0.00 a	0.09 ± 0.00 a	ND
Total	**0**	**23.7 ± 0.26**	**24.06 ± 0.33**	**23.93 ± 1.16**	**65.45 ± 0.82**
	6	**161.5 ± 1.33**	**29.25 ± 0.31**	**39.89 ± 0.39**	**152.42 ± 0.38**

Values with different letters in the same row indicate statistically significant differences (Tukey, $p \leq 0.05$). n = 3 ± standard deviation. ND: Not detected

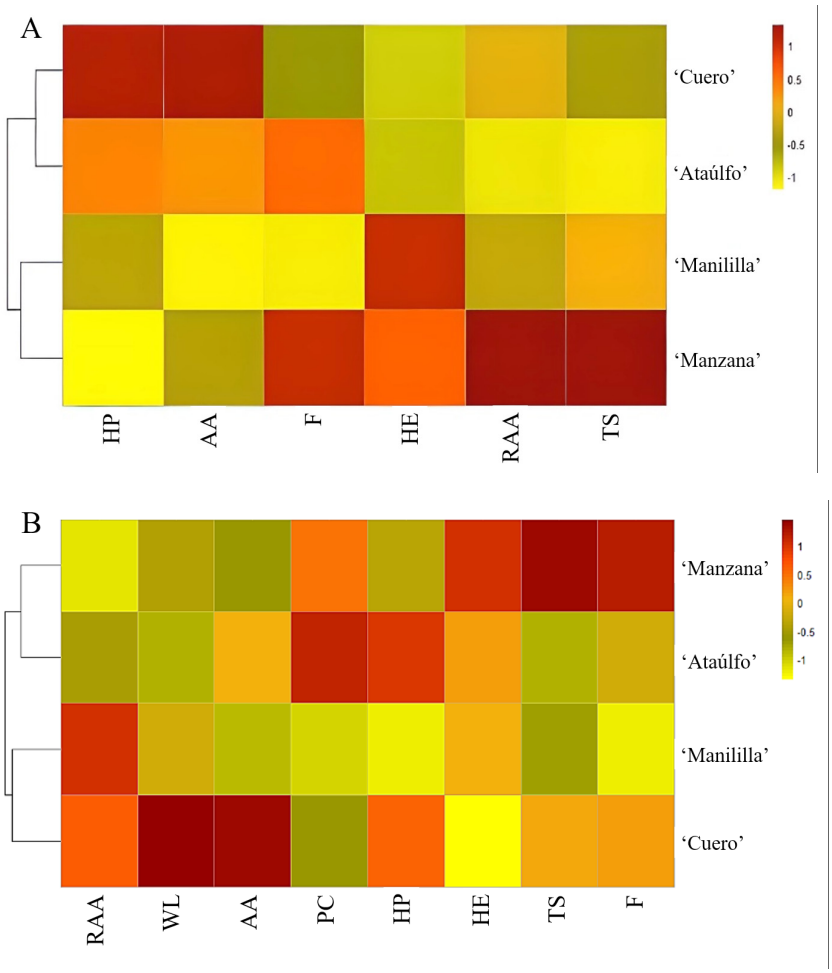

Figure 6. Fruit grouping of four mango (*Mangifera* sp.) genotypes from Soconusco, Chiapas, based on postharvest quality parameters. A: day 0; B: day 6; PC: pulp content; F: firmness; WL: Weight loss; HE: °hue epidermis; HP: °hue pulp; RAA: ratio of total soluble solids to titratable acidity; TS: total sugars; AA: ascorbic acid.

acid. It is important to highlight that the fruits of 'Ataúlfo' have a longer shelf life and significantly lower weight loss than other genotypes, making it an attractive variety. Even so, the fruits of 'Manzana' were distinguished by their greater firmness and color intensity of the pulp and epidermis. Furthermore, the high flavonoid content in the epidermis of 'Manililla' makes them materials for future studies and candidates for genetic improvement in order to diversify the mango supply.

CONCLUSIONS

Mango fruits of the genotypes 'Manzana' and 'Cuero' belong to the same commercial classification as 'Ataúlfo' according to NOM-188-SCFI-2012. It is important to note that 'Manzana' fruits have similar weight, TSS/AT balance and firmness, and that they

can compete with 'Ataúlfo' fruits. However, 'Cuero' fruits showed significantly higher weight losses, which reduced their shelf life. The fruits of 'Manililla' and 'Ataúlfo' were outstanding for their high flavonoid content in the epidermis, which offers resistance to pathogen attack. This information can be useful for growers and breeders to identify desirable traits and expand the mango supply in the market.

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