Physicochemical quality parameters in guava fruit with presence of larvae of *Conotrachelus dimidiatus* (Champion) (Coleoptera: Curculionidae)

Parámetros fisicoquímicos de calidad en frutos de guayaba con presencia de larvas de *Conotrachelus dimidiatus* (Champion) (Coleoptera: Curculionidae)

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Abstract

This research aimed to evaluate some physicochemical quality parameters in guava fruit with presence of *Conotrachelus dimidiatus* (Champion) in larval stage. A completely randomized experimental design with 15 and 24 replicates was established. The weight, firmness, diameter, length, color, total soluble solids, titratable acidity and vitamin C in fruit of guava variety Media China were determined. The presence of *C. dimidiatus* larvae significantly decreased fruit weight, length and equatorial diameter, presenting values of 20.73 g, 37.96 mm and 31.36 mm, respectively. Vitamin C content decreased from 11.71 to 2.80 mg∙100 g⁻¹. The growth and development of *C. dimidiatus* inside the fruit makes it necessary to implement efficient control methods that allow the harvesting of innocuous fruit for consumption.

Keywords: *Psidium guajava* L., guava weevil, post-harvest handling, total soluble solids, ascorbic acid.

Resumen

El objetivo de esta investigación fue evaluar algunos parámetros fisicoquímicos de calidad en frutos de guayaba con presencia de *Conotrachelus dimidiatus* (Champion) en estado larval. Se estableció un diseño experimental completamente al azar con 15 y 24 repeticiones. Se determinó el peso, firmeza, diámetro, longitud, color, sólidos solubles totales, acidez titulable y vitamina C en frutos de guayaba variedad Media China. La presencia de larvas de *C. dimidiatus* disminuyó significativamente el peso, la longitud y el diámetro ecuatorial del fruto al presentar valores de 20.73 g, 37.96 mm y 31.36 mm, respectivamente. El contenido de vitamina C decréció de 11.71 a 2.80 mg∙100 g⁻¹. El crecimiento y desarrollo de *C. dimidiatus* al interior del fruto hace necesario implementar métodos eficientes de control que permitan la cosecha de frutos inocuos para su consumo.

Palabras clave: *Psidium guajava* L., picudo de la guayaba, manejo poscosecha, sólidos solubles totales, ácido ascórbico.
Introduction

*Psidium guajava* L. is among the most cultivated and consumed tropical fruits in the world, both fresh and processed (Gill, Dhaliwal, Mahajan, Paliyath, & Boora, 2016). According to official data, in 2018 the production volume of this fruit in Mexico amounted to 324,665 t, with a planted area of 22,561 ha. The main producing states are Aguascalientes, State of Mexico, Michoacán and Zacatecas, among which Michoacán stands out with 11,079 ha and an average yield of 14.6 t·ha⁻¹ (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2018). About 99.2 % of guava production in Mexico destined for export is marketed in the United States, Canada, United Kingdom, Germany and Spain (SIAP, 2018), where it is considered an exotic fruit.

Guava fruit quality is defined by the genotype and agronomic management of the trees (Damián-Nava et al., 2004; Salas-Araiza & Romero-Nápoles, 2012), in which the inclusion of harvest indices is important because they guarantee the producer fruit with the minimum quality for post-harvest handling and marketing (Azzolini, Jacomino, & Urbano, 2004). These indices include physical (color, firmness and characteristic shape) and chemical ones (titratable acidity, total soluble solids and ascorbic acid) (Herman-Fisher et al., 2011), and it is essential to know their response to the presence and attack of pests and diseases (Delgado & Sáenz-Aponte, 2016).

Pests that attack guava include the guava fruit fly (*Anastrepha striata*), temolillo (*Cyclocephala lunulata*), glasshouse whitefly (*Trialeurodes vaporariorum*), green shield scale (*Pulvinaria psidii*), aphids (*Aphis gossypii* and *Myzus persicae*), thrips (*Frankliniella spp.*), mealy bug (*Pseudococcus spp.*), potato leafhopper (*Empoasca fabae*) and mites (*Eotetranychus sp.*, *Panonychus sp.*, *Tetranychus urticae* and *Oligonychus sp.*) (Salas-Araiza & Romero-Nápoles, 2012). However, in recent years the guava weevil (*Conotrachelus* spp.) has become one of the phytosanitary management problems with the greatest economic impact within the main guava production areas in Mexico (Vargas-Madríz, Martínez-Damián, & Mena-Nevárez, 2017).

It is important to highlight that within the genus *Conotrachelus*, the species *C. dimidiatus* is one of the most aggressive, especially when it is in larval state because it feeds on the fruit and seeds causing petrifaction and premature ripening of the fruit, giving it an unpleasant appearance that prevents its marketing (Gill et al., 2016; Augusto-Monroy & Ildefonso-Insuasty, 2006). Infestation levels can reach 70 % of the planted area and generate losses of 60 % of the production value (Aragón-García, Pérez-Torres, Vera-Cano, Trejo-Vázquez, & Mota-Nava, 2015; Delgado & Sáenz-Aponte, 2016).

Introducción

*Psidium guajava* L. se encuentra entre los frutales de origen tropical más cultivados y de mayor consumo a nivel mundial, tanto en fresco como procesada (Gill, Dhaliwal, Mahajan, Paliyath, & Boora, 2016). De acuerdo con datos oficiales, en 2018 el volumen de producción de esta fruta en México ascendió a 324,665 t, con una superficie sembrada de 22,561 ha. Los principales estados productores son Aguascalientes, Estado de México, Michoacán y Zacatecas, dentro de los que destaca Michoacán con 11,079 ha y un rendimiento promedio de 14.6 t·ha⁻¹ (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2018). El 99.2 % de la producción de guayaba en México destinada a exportación se comercializa en Estados Unidos, Canadá, Reino Unido, Alemania y España (SIAP, 2018), donde se considera como fruto exótico.

La calidad del fruto de guayaba está definida por el genotipo y el manejo agronómico de los árboles (Damián-Nava et al., 2004; Salas-Araiza & Romero-Nápoles, 2012), en el que la inclusión de índices de cosecha es importante debido a que garantizan al productor frutos con la calidad mínima para su manejo poscosecha y comercialización (Azzolini, Jacomino, & Urbano, 2004). Entre estos índices se encuentran los físicos (color, firmeza y forma característica) y los químicos (ácidez titulable, sólidos solubles totales y ácido ascorbico) (Herman-Fisher et al., 2011), y se hace prescindible conocer su respuesta a la presencia y ataque de plagas y enfermedades (Delgado & Sáenz-Aponte, 2016).

Entre las plagas que atacan a la guayaba se encuentran la mosca de la fruta (*Anastrepha striata*), temolillo (*Cyclocephala lunulata*), mosca blanca (*Trialeurodes vaporariorum*), escama (*Pulvinaria psidii*), áfidos (*Aphis gossypii* y *Myzus persicae*), trips (*Frankliniella spp.*), piojo harinoso (*Pseudococcus spp.*), chicharrita (*Empoasca fabae*) y ácaros (*Eotetranychus sp.*, *Panonychus sp.*, *Tetranychus urticae* y *Oligonychus sp.*) (Salas-Araiza & Romero-Nápoles, 2012). Sin embargo, en los últimos años el picudo de la guayaba (*Conotrachelus* spp.) se ha convertido en uno de los problemas de manejo fitosanitario con mayor impacto económico dentro de las principales zonas de producción de guayaba en México (Vargas-Madríz, Martínez-Damián, & Mena-Nevárez, 2017).

Es importante resaltar que dentro del género *Conotrachelus*, la especie *C. dimidiatus* es una de las más agresivas, sobre todo cuando se encuentra en estado larval debido a que se alimentan del fruto y las semillas provocando la petrifacción y la maduración premature del fruto, confiándole un aspecto desagradable que impide su comercialización (Gill et al., 2016; Augusto-Monroy & Ildefonso-Insuasty,
2016), which makes it necessary to carry out research aimed at the efficient control of Conotrachelus spp. in its larval stage.

The study of the damage of Conotrachelus spp. larvae on the quality of guava fruit is recent, since there is little or no information on it, which includes aspects such as the reproductive habits of Conotrachelus spp. (Aragón-García et al., 2015), rearing (Iglesias, Lucía & Machado, 2014), hydrothermal control treatments (Vargas-Madríz et al., 2017) and biological control in the field and greenhouse (Delgado & Sáenz-Aponte, 2016). Therefore, the objective of this research was to evaluate some physicochemical quality parameters in guava fruit with presence of C. dimidiatus (Champion) in larval stage.

Materials and methods

Location of the experiment and plant material. The experiment was carried out during August and September 2016 in the Fruit Physiology Laboratory of the Department of Plant Science at the Universidad Autónoma Chapingo, Mexico. Guava fruit of the commercial variety Media China were used, infested with C. dimidiatus larvae, from the “Rancho La Abuela” orchard located in the municipality of Toluimán, Querétaro de Arteaga, Mexico (20° 53' 38.8” NL and 99° 54' 59.9” WL, at 1,167 masl), with a mean annual temperature of 24.9 °C.

Fruit were collected according to harvest indices used by producers in the Queretaro region, i.e. with firm pulp and the onset of the change from dark green to light green (yellowish). In order to ensure the presence of C. dimidiatus larvae, each fruit was visually recorded and corroborated with an optical microscope in the laboratory.

Experimental design. A completely randomized design was established, where the experimental unit was a set of nine fruit with 15 replicates in the determinations of fruit weight, firmness, length, diameter and color, and three fruit as the experimental unit with 24 replicates for the titratable acidity, total soluble solids and vitamin C analyses.

Variables evaluated

Fruit weight (g). It was determined by means of a portable electronic scale (Scout Pro SP202, Ohaus®, USA) with a precision of 0.01 g.

Firmness (N). It was measured in the equatorial zone of the fruit with a digital texturometer (Compact Gauge, Mecmesin CE®, USA) fixed on a table, with a conical strut of 9 mm in diameter and height.

2006). Los niveles de infestación pueden alcanzar el 70 % de la superficie plantada y generar pérdidas del 60 % del valor de la producción (Aragón-García, Pérez-Torres, Vera-Cano, Trojo-Vázquez, & Mota-Nava, 2015; Delgado & Sáenz-Aponte, 2016), lo que hace necesario realizar investigaciones dirigidas al control eficiente de Conotrachelus spp. en su etapa larval.

El estudio del daño de larvas de Conotrachelus spp. sobre la calidad en frutos de guayaba es reciente, ya que existe poca o nula información al respecto, la que hay abarcan aspectos como los hábitos reproductivos de Conotrachelus spp. (Aragón-García et al., 2015), crianza (Iglesias, Lucía & Machado, 2014), tratamientos de control hidrotérmico (Vargas-Madríz et al., 2017) y control biológico en campo e invernadero (Delgado & Sáenz-Aponte, 2016). Por ello, el objetivo de esta investigación fue evaluar algunos parámetros físicos-químicos de calidad en frutos de guayaba con presencia de C. dimidiatus (Champion) en estado larval.

Materiales y métodos

Ubicación del experimento y material vegetal. El experimento se realizó durante agosto y septiembre de 2016 en el Laboratorio de Fisiología de Frutales del Departamento de Fitotecnia de la Universidad Autónoma Chapingo, México. Se emplearon frutos de guayaba de la variedad comercial Media China, infestados con larvas de C. dimidiatus, provenientes del huerto “Rancho La Abuela” ubicado en el municipio de Toluimán, Querétaro de Arteaga, México (20° 53’ 38.8” latitud norte y 99° 54’ 59.9” longitud oeste, a 1,167 msnm), con temperatura media anual de 24.9 °C.

Los frutos se colectaron de acuerdo con índices de cosecha utilizados por los productores de la región de Querétaro, es decir, con pulpa firme e inicio del cambio de coloración verde-oscuro a verde-claro (amarillento). Con el propósito de asegurar la presencia de larvas de C. dimidiatus, se registró de manera visual cada fruto y se corroboró con microscopio óptico en laboratorio.

Diseño experimental. Se estableció un diseño completamente al azar, donde la unidad experimental fue un conjunto de nueve frutos con 15 repeticiones en las determinaciones de peso, firmeza, longitud, diámetro y color de frUTO, y tres frutos como unidad experimental con 24 repeticiones para los análisis de ácido titulable, sólidos solubles totales y vitamina C.

Variables evaluadas

Peso de fruto (g). Se determinó mediante balanza electrónica portátil (Scout Pro SP202, Ohaus®, EUA) con precisión de 0.01 g.
Fruit length and equatorial diameter (mm). They were obtained with a digital Vernier caliper (model 122200, Surtek®, México).

Color: It was determined on the epidermis of the equatorial part of the fruit by means of a portable sphere spectrophotometer (X-Rite, SP-62®, USA), in which the CIE 1976 color coordinates (L*a*b*) (Voss, 1992) were obtained; later, the chromaticity \(C* = (a^2 + b^2)^{1/2}\) and hue \(\text{arctan}^{-1}(b/a)\) values were determined.

Titratable acidity (% citric acid). It was determined according to the methodology proposed by the Association of Official Analytical Chemists (AOAC, 1990), with slight modifications. Ten g of fruit were homogenized with 50 mL of distilled water; from this mixture, 10 mL were taken to be neutralized with a 0.1 N NaOH solution, in which 1 % phenolphthalein was used as indicator.

Total soluble solids (°Brix). The concentration of soluble solids was quantified with a portable digital refractometer (PAL-1®, Atago, EUA), which uses a scale of 0-53°.

Vitamin C (ascorbic acid). It was estimated according to the Tillman method (AOAC, 1990), known as DFI-2, 6 dichlorophenol-indophenol, for which an aliquot of 10 mL was taken from a mixture of 5 g of finely chopped fruit homogenized with 50 mL of oxalic acid.

Statistical analysis

The data obtained were analyzed with Student’s t-test \((P \leq 0.05)\) for two populations, using Sigma Stat 4.0 (Systat Sofware, Inc., San José California, USA).

Results and discussion

Fruit weight

Determining the commercial value of any fruit and vegetable product begins with a subjective inspection of its size and morphology; therefore, adequate nutritional management and phytosanitary control is important (Damián-Nava et al., 2004; Herman-Fisher et al., 2011). According to the statistical analysis, guava fruit infested with _C. dimidiatus_ larvae showed a weight decrease of 61.2 % with respect to those not infested, with an average value of 20.73 g (Table 1). Aragón-García et al. (2015) report that the female _C. dimidiatus_ oviposits larvae in the early stages of fruit development, and that this behavior could suggest an alteration of the continuous flow of sap and nutrients through the phloem and xylem, which alters fruit development and growth (Tafoya, Perales-Segovia, González-Gaona, & Calyecac-Cortero, 2010). Also, Rajan, Yadava, Kumar, and Saxena (2008) indicate that the high concentration of auxins, vitamin C (ácido ascórbico). Se estimó de acuerdo con el método de Tillman (AOAC, 1990), conocido como DFI-2, 6 diclorofenol-indofenol, para lo cual se usó una alícuota de 10 mL tomada de la mezcla de 5 g de fruto finamente picado homogenizados con 50 mL de ácido oxálico.

Sólidos solubles totales (°Brix). La concentración de sólidos solubles se cuantificó con un refractómetro digital portátil (PAL-1®, Atago, EUA), el cual utiliza una escala de 0-53°.

Vitamina C (ácido ascóbico). Se estimó de acuerdo con la metodología propuesta por la Association of Official Analytical Chemists (AOAC, 1990), con ligeros modificaciones. Se homogeneizaron 10 g de fruto con 50 mL de agua destilada; de esta mezcla se tomaron 10 mL para ser neutralizados con una solución de NaOH a 0.1 N, en la que se empleó fenolftaleína al 1 % como indicador.

Análisis estadístico

Los datos obtenidos se analizaron con la prueba t de Student \((P \leq 0.05)\) para dos poblaciones, en la que se empleó el programa Sigma Stat 4.0 (Systat Sofware, Inc., San José California, EUA).

Resultados y discusión

Peso de fruto

La determinación del valor comercial de cualquier producto hortofrutícola inicia con la inspección subjetiva del tamaño y morfología; por ello es importante un adecuado manejo nutricional y control fitosanitario (Damián-Nava et al., 2004; Herman-Fisher et al., 2011). De acuerdo con el análisis estadístico, los frutos de guayába infestados con larvas de _C. dimidiatus_ mostraron una disminución del peso de 61.2 % con respecto a los no infestados, con un valor medio de 20.73 g (Cuadro 1). Aragón-García et al. (2015) reportan que la hembra de...
gibberellins and cytokines in immature seeds is directly related to the final size of the fruit. Additionally, it is known that most varieties of guava are diploid (2n=22) and have a very variable number of seeds (2-463) (Gill et al., 2016), and that the proportion of pulp in the fruit is closely correlated with its weight and number of seeds (Pandey, Jain, Sharma, & Tiwari, 2002).

**Firmness**

Changes in fruit firmness are associated with the degree of pectin solubilization due to the enzymatic activity of pectinesterase, polygalacturonase and pectate lyase (Azzolini et al., 2004; Gill et al., 2016), and it manifests itself during the ripening process with the weakening of the primary cell wall and middle lamina (Parra, 2014). In this case, the firmness showed a statistically different behavior ($P < 0.05$) between fruit with and without the presence of larvae, with values of 23.32 and 16.55 N, respectively (Table 1).

Delgado and Sáenz-Aponte (2016) observed that the presence of *C. psidii* Marshall larvae causes growth to stop and the volume of fruit juice to decrease, negative aspects that contribute to the reduction of its final size and the appearance of petrified fruit, without this meaning its senescence; i.e., it increases the synthesis and autocatalytic accumulation of ethylene that leads to a heterogeneous ripening process, and in most cases it concludes with the presence of fruit that are not suitable for consumption (Aragón-García et al., 2015). In this regard, Tafoya et al. (2010) suggest that this is attributable to a decrease in the photoassimilate translocation rate of the leaves through phloem, which initially affects the hardening of the constituent polymers of the cell walls (Farenczi, Gambetta, Franco, Arbiza, & Gravina, 1999; Parra, 2014) and culminates with the fall of the fruit and the exit of the larva for its later concealment in the soil.

### Table 1. Mean values of physical parameters of guava fruit with and without the presence of guava weevil (*C. dimidiatus* [Champion]) larvae.

| Treatment / Tratamiento | Fruit weight (g) | Firmness (N) | Fruit length (mm) | Equatorial diameter (mm) |
|-------------------------|-----------------|--------------|-------------------|-------------------------|
|                         | Peso fruto (g)  | Firmeza (N)  | Longitud de fruto (mm) | Diámetro ecuatorial (mm) |
| PL ¹                   | 20.73           | 23.32        | 36.96             | 31.76                   |
| NL / SPL                | 53.54           | 16.55        | 48.73             | 44.75                   |
| Probability /Probabilidad | <0.001**       | <0.001**     | <0.001**          | <0.001**                |
| CV (%)                  | 23.46           | 22.11        | 7.71              | 4.82                    |

¹PL = presence of larvae; NL = no larvae; CV = coefficient of variation. **Highly significant according to Student’s$\cdot t$ test ($P < 0.01$).

¹PL = presencia de larvas; SPL = sin presencia de larvas; CV = coeficiente de variación. **Altamente significativo de acuerdo con la prueba $t$ de Student ($P < 0.01$).
where it continues with its development as a pupa (Iglesias, Lucia, & Machado, 2014).

**Fruit length and equatorial diameter**

Values related to the equatorial diameter of fruit infested with larvae were significantly ($P < 0.001$) lower (36.96 mm) compared to healthy fruit (48.73 mm); similar behavior was presented in fruit length with 31.76 and 44.75 mm, respectively (Table 1). Montoya-Holguín, Cortés-Osorio, and Chaves-Osorio (2014) point out that the relationship between the two parameters (length and diameter) is closely related to the characteristic shape pattern of the fruit of each variety, so if this relationship is $<1$ or $>1$ they are flattened or elongated shapes, respectively. In this case, the evaluated fruit had an elongated shape and only an important effect on fruit size was observed as a consequence of the feeding and development process of the *C. dimidiatus* larva. Farenczi et al. (1999) indicate that characters such as fruit diameter and length, in addition to being determined by the genotype, are regulated by environmental and internal factors of the plant, where the growth is based on the level of contribution of photoassimilates and the capacity of the developing organs to exert sufficient demand on the points of production (leaves).

**Color**

Statistical analysis did not reveal variation ($P \leq 0.05$) between treatments for color components related to brightness (L) and °Hue; however, significance was found for the chromaticity values determined in fruit with and without the presence of larvae with values of 38.75 and 35.56, respectively (Table 2), which was manifested in physical form with fruit of greater yellow coloration. Damián-Nava et al. (2004) report that the variety Media China has a climacteric behavior, and that one of its most outstanding quality characteristics is its distinctive yellow color, whose development and stability on the epidermis of the fruit already harvested is influenced by the agronomic management and environmental conditions present during its growth and onset of physiological maturity (Gill et al., 2016; Mercado-Silva, Benito-Bautista, & García-Velasco, 1998).

Herman-Fisher et al. (2011) and Parra (2014) emphasize that any mechanical damage suffered by the fruit during its pre- and post-harvest handling affects its ethylene autocatalysis, which prematurely activates the activity of various enzymes such as chlorophyllases, which cause the appearance of secondary colors (yellow) to the original (Azzolini et al., 2004). In this sense, the results observed in chromaticity or color purity can be explained, to a large extent, by the serious damage caused by the *C. dimidiatus* female when drilling a
2-mm-deep hole over the equatorial area of the fruit (Aragón-García et al., 2015; Tafoya et al., 2010), this without considering that the accumulated excrement of the larvae causes a slight fermentation of the fruit, negatively affecting the synthesis and accumulation of ethylene, which prevents its use in industry or as animal feed (Salas-Araiza & Romero-Nápoles, 2012).

**Titratable acidity**

Statistical analysis did not detect differences between fruit with and without larvae, whose values fluctuated between 9.11 and 11.90 % citric acid, respectively (Table 3). In contrast, Mercado-Silva et al. (1998) indicate a decreasing behavior in the acidity values of guava fruit in the growth stages (I and II), corresponding to the intervals of 13-43 and 43-98 days to flowering, respectively, and an increase in acidity at the beginning of the natural maturity of the fruit (stage III), in the interval of 98-133 days to flowering. In this context, it is important to point out that as part of the weevil’s reproductive habits, its attack is accentuated in the early stages of fruit development (I and II) (Iglesias, Lucia & Machado, 2014; Tafoya et al., 2010), which coincides with the fact that some larvae abandon the fruit, and those that do not move towards the inner part where they feed on seeds and pulp; this causes malfunction and premature and inhomogeneous ripening of the fruit (Vargas-Madríz et al., 2017). Salas-Araiza and Romero-Nápoles (2012) point out that it is common for stage III development to conclude with the abscission of the fruit.

**Total soluble solids (TSS)**

The polysaccharides that make up the cell wall function as substrates for obtaining energy during the metabolic respiration process (Parra, 2014), which generates simple sugars such as sucrose, glucose and fructose, which are considered essential components of the characteristic sweetness in the fruit (Herman-Fisher et al., 2011). As shown in Table 3, the TSS concentration did not vary \( (P \leq 0.05) \) between fruit with and without larvae, whose agronómico y las condiciones ambientales presentes durante su crecimiento e inicio de madurez fisiológica (Gill et al., 2016; Mercado-Silva, Benito-Bautista, & García-Velasco, 1998).

Herman-Fisher et al. (2011) y Parra (2014) hacen hincapié en que cualquier daño mecánico que sufra el fruto durante su manejo pre y poscosecha incide sobre la autocatálisis de etileno, el cual activa de manera prematura la actividad de varias enzimas como las clorofilas, las cuales provocan la aparición de colores secundarios (amarillo) al original (Azzolini et al., 2004). En este sentido, los resultados observados en cromaticidad o pureza de color se pueden explicar, en gran medida, por los graves daños que causa la hembra de *C. dimidiatus* al perforar un orificio de 2 mm de profundidad sobre el área ecuatorial del fruto (Aragón-García et al., 2015; Tafoya et al., 2010); esto sin considerar que el excremento acumulado de las larvas provoca una leve fermentación del fruto, incidiendo negativamente en la síntesis y acumulación de etileno, lo que impide su uso en la industria o como alimento para animales (Salas-Araiza & Romero-Nápoles, 2012).

**Acidez titulable**

El análisis estadístico no permitió detectar diferencias entre los frutos con y sin presencia de larvas, cuyos valores fluctuaron entre 9.11 y 11.90 % de ácido cítrico, respectivamente (Cuadro 3). En contraste, Mercado-Silva et al. (1998) señalan un comportamiento decreciente en los valores de acidez de frutos de guayaba en las etapas de crecimiento (I y II), que corresponden a los intervalos de 13-43 y 43-98 días a floración, respectivamente, y un incremento de acidez al inicio de la madurez natural del fruto (etapa III), en el intervalo de 98-133 días a floración. Bajo este contexto, es importante señalar que como parte de los hábitos reproductivos del picudo su ataque se acentúa en las primeras etapas de desarrollo del fruto (I y II) (Iglesias, Lucia & Machado, 2014; Tafoya et al., 2010), lo que coincide con que algunas larvas abandonan el fruto, y las que no lo hacen se desplazan hacia la estadística de los datos.”

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**Table 2. Color components in guava fruit with and without the presence of guava weevil (*C. dimidiatus* [Champion]) larvae.**

| Treatment / Tratamiento | L (brightness) / L (brillantez) | C (purity) / C (pureza) | °Hue / Tonalidad (°hue) |
|-------------------------|---------------------------------|-------------------------|------------------------|
| PL¹                      | 61.52                           | 38.75                   | 178.55                 |
| NL / SPL                 | 62.79                           | 35.56                   | 178.64                 |
| Probability / Probabilidad | 0.085**                         | 0.002**                 | 0.146**                |
| CV (%)                   | 3.01                            | 6.60                    | 0.08                   |

¹PL = presence of larvae; NL = no larvae; CV = coefficient of variation. ns = not significant; **Highly significant according to Student’s-t test \( P < 0.01 \).
Physicochemical quality parameters...

Table 3. Chemical properties analyzed in guava fruit with and without the presence of guava weevil \((C. \ dimidiatus [\text{Champion}])\) larvae.

| Treatment / Tratamiento | TA\(^1\) / \(\% \text{ citric acid} \) | TSS / \(\% \text{ solid solubles} \) | VC / \(\text{mg ascorbic acid} / 100 \text{ g}\) |
|------------------------|---------------------|---------------------|---------------------|
| PL                     | 9.11                | 8.33                | 2.80                |
| NL / SPL               | 11.90               | 9.12                | 11.71               |
| Probability / Probabilidad | 0.244\(^{**}\) | 0.083\(^{**}\) | <0.001\(^{**}\) |
| CV (%)                 | 18.77               | 17.71               | 32.20               |

\(^1\)TA = titratable acidity; TSS = total soluble solids; VC = vitamin C; PL = presence of larvae; NL = no larvae; CV = coefficient of variation. ns = not significant; \(^{**}\)Highly significant according to Student’s-t test \((P < 0.01)\).

value were 8.33 and 9.12 °Brix, respectively. It has been reported that the physiological behavior of the genus \(Psidium\) is variable (Damián-Nava et al., 2004) due to a varietal effect and at harvest time (Gill et al., 2016). In the first case, Damián-Nava et al. (2004) mention that the TSS concentration in genotypes with white and red pulp varies between 5.0 and 13.2 °Brix, while in the second case there is no consensus regarding the ideal maturity stage of this fruit, since its harvest is carried out considering commercial rather than physiological aspects (Vargas-Madríz et al., 2017), i.e., when the fruit is still firm and the change from dark green to yellowish tones begins. In this sense, the values obtained could be associated with the degree of maturity with which the fruit were harvested.

**Vitamin C (ascorbic acid)**

Guava fruit has several bioactive compounds of nutraceutical interest such as vitamin A, group B vitamins (thiamine and niacin), pectins and minerals (phosphorus, calcium, iron and potassium) (Delgado & Sáenz-Aponte, 2016); it is also an excellent source of antioxidants (such as phenolic compounds and ascorbic acid) (Restrepo-Sánchez, Narváez-Cuenca, & Restrepo-Sáenz, 2009). These compounds play an important role in the prevention of chronic and degenerative diseases (Rajan, Yadava, Kumar, & Saxena, 2008).

Therefore, the determination of ascorbic acid content (vitamin C) was of vital importance in this work, and it was found that fruit with \(C. \ dimidiatus\) larvae showed a significant decrease in vitamin C (2.8 mg ascorbic acid/100 g\(^1\)) in relation to what was observed in fruit without the presence of this insect (11.71 mg ascorbic acid/100 g\(^1\)) (Cuadro 3).

The dissimilarity in the concentration of this vitamin may be linked to the disorganization of the cell membrane caused by the damage produced by the larva. This is because the enzymatic system of ascorbic part interna donde se alimentan de semillas y pulpa; esto provoca malformación y maduración prematura y poco homogénea del fruto (Vargas-Madríz et al., 2017). Salas-Araiza y Romero-Nápoles (2012) señalan que es frecuente que la etapa III de desarrollo concluya con la abscisión del fruto.

**Sólidos solubles totales (SST)**

Los polisacáridos que conforman la pared celular funcionan como sustratos para la obtención de energía durante el proceso de respiración metabólica (Parra, 2014), en el que se generan azúcares simples como sacarosa, glucosa y fructosa, los cuales se consideran componentes imprescindibles del dulzor característico en los frutos (Herman-Fisher et al., 2011). Como se observa en el Cuadro 3, la concentración de SST no presentó variación \((P \leq 0.05)\) entre los frutos con y sin presencia de larvas, cuyos valores fueron de 8.33 y 9.12 °Brix, respectivamente. Se ha reportado que el comportamiento fisiológico del genero \(Psidium\) es variable (Damián-Nava et al., 2004) debido a un efecto varietal y al momento de la cosecha (Gill et al., 2016). En el primer caso, Damián-Nava et al. (2004) mencionan que la concentración de SST entre genotipos con pulpa blanca y roja varía entre 5.0 y 13.2 °Brix. Mientras que en el segundo caso no existe consenso respecto al estado de madurez ideal de este fruto, ya que su cosecha se realiza considerado aspectos comerciales más que fisiológicos (Vargas-Madríz et al., 2017), es decir, cuando el fruto aún se encuentra firme e inicia el cambio de color verde oscuro a tonalidades amarillentas. En este sentido, los valores obtenidos podrían estar asociado con el grado de madurez con el que se cosecharon los frutos.

**Vitamina C (ácido ascórbico)**

El fruto de guayaba posee diversos compuestos bioactivos de interés nutracéutico como vitamina A,
acid oxidation is controlled (Herman-Fisher et al., 2011; Mercado-Silva et al., 1998), and the damage caused by the larva activates the oxidation of this compound at a higher speed. Gill et al. (2016) indicate that the content of this acid varies depending on the state of maturity, storage conditions of the fruit and analysis method of the fruit, where temperature is an important factor of degradation.

Conclusions

Fruit with the presence of *C. dimidiatus* (Champion) showed a significant decrease in weight, size and vitamin C content, whereas titratable acidity and total soluble solids remained unchanged. However, an increase in firmness (23.32 N) (petrified fruit) and color purity was observed. Considering the above, it is suggested to conduct research to generate efficient control methods of this larva, due to the implications related to its development and growth.

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