

IMPACT OF HUANGLONGBING ON THE MEXICAN LIME [*Citrus aurantifolia* (Christm.) Swingle] PHYSICOCHEMICAL QUALITY AND POSTHARVEST LIFE

Aideé Hernández-Rivera¹, María Alejandra Gutiérrez-Espinosa²,
Rigoberto González-Mancillas³, Apolinar González-Mancilla⁴,
María de Jesús Martínez-Hernández^{1*}

¹Universidad Veracruzana. Facultad de Ciencias Agrícolas. Xalapa-Enríquez, Xalapa, Veracruz, Mexico. C. P. 91090.

²Colegio de Postgraduados Campus Montecillo. Carretera México-Texcoco km 36.5, Montecillo, Texcoco, State of Mexico, Mexico. C. P. 56264.

³Tecnológico Nacional de México. Instituto Tecnológico de la Cuenca del Papaloapan. Juan de la Barrera No. 2, San Bartolo, San Juan Bautista Tuxtepec, Oaxaca, Mexico. C. P. 68446.

⁴Universidad Juárez del Estado de Durango. Facultad de Agricultura y Zootecnia. Carretera Gómez Palacio-Tlahualilo km 32, Venecia Gómez Palacio, Durango, Mexico. C. P. 35170.

* Author for correspondence: mhernandezmj@gmail.com

ABSTRACT

Huanglongbing (HLB), the most devastating citrus disease, severely impacts the physicochemical quality and postharvest life of Mexican lime fruit [*Citrus aurantifolia* (Christm.) Swingle]. It increases susceptibility to cold-induced damage, accelerates weight loss and senescence, and reduces the content of key components, such as ascorbic acid, ultimately limiting storage time. This study aimed to evaluate the physicochemical quality and postharvest life of Mexican lime fruits, obtained from HLB asymptomatic and symptomatic trees, under ambient and refrigerated storage conditions. Lime fruits were harvested and classified based on the disease status of the source trees (symptomatic and asymptomatic). Two storage conditions were evaluated: room temperature (22 ± 2 °C) for 0, 4, and 8 d and refrigeration (9 ± 1 °C) for two weeks. During the storage period, titratable acidity, ascorbic acid content, weight loss, total soluble solids, and color index were analyzed. Results showed rapid weight loss in the fruits with HLB symptoms, suggesting sensitivity to cold-induced damage. Titratable acidity increased by 40 % in the fruits obtained from symptomatic trees. The color index was also affected in fruits from symptomatic trees after 4 and 8 d of storage at room and refrigeration temperatures, showing signs of senescence compared to asymptomatic fruits. A decrease in ascorbic acid content was also observed, affecting the fruit's nutritional quality and limiting its storage time. In conclusion, HLB significantly affects various quality parameters of the Mexican lime fruit, which increases its susceptibility to cold-induced damage and, consequently, limits its shelf life during storage.

Keywords: color index, weight loss, ascorbic acid, refrigeration, *Candidatus Liberibacter*, physiological disorders.

Citation: Hernández-Rivera A, Gutiérrez-Espinosa MA, González-Mancillas R, González-Mancilla A, Martínez-Hernández MJ. 2025. Impact of huanglongbing on the Mexican lime [*Citrus aurantifolia* (Christm.) swingle] physicochemical quality and postharvest life. *Agrociencia*. <https://doi.org/10.47163/agrociencia.v59i4.3333>

Editor in Chief:
Dr. Fernando C. Gómez Merino

Received: October 31, 2024.

Approved: June 10, 2025.

Published in *Agrociencia*:

June 13, 2025.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0 International license.



INTRODUCTION

Mexican lime [*Citrus aurantifolia* (Christm.) Swingle] belongs to the Rutaceae family, which comprises 150 genera and 900 species (Mohammed and Ayoub, 2016). This species is widely used as a raw material in food flavorings, beverage flavor enhancers, and as an ingredient in traditional medicine and cosmetics (Swandiny *et al.*, 2021; Indriyani *et al.*, 2023). Additionally, it is attributed with various biological activities, such as insecticidal, larvicidal, and repellent properties (Galovičová *et al.*, 2022), as well as antioxidant, antineoplastic, and antimicrobial properties (Asmah *et al.*, 2020; Julaeha *et al.*, 2022). This species also exhibits antiseptic, antiviral, antifungal, astringent, anti-cholesterol, diuretic, appetite-stimulating, and laxative properties (Jeffrey *et al.*, 2020). It is also notable for its anti-inflammatory and analgesic properties (Shchérázade *et al.*, 2021). These properties are attributed to the content of secondary metabolites (Kazeem *et al.*, 2020), making lime a phylogenetic resource with high commercial value.

Lime production faces several yield-impacting challenges, with huanglongbing (HLB) being one of the most devastating citrus diseases worldwide. This disease is associated with bacteria from the *Candidatus Liberibacter* genus, including *Ca. L. asiaticus* (CLAs), present in Asia, Africa, and America; *Ca. L. africanus* (CLaf) in Africa (Jagoueix *et al.*, 1994); *Ca. L. americanus* (CLam), reported in Brazil and Asia (Teixeira *et al.*, 2005; Antunes *et al.*, 2010); and *Ca. L. caribbeanus* (CLca) in Colombia (Folimonova and Achor, 2010; Vitor *et al.*, 2013). These bacteria are mainly transmitted by insect vectors. The Asian citrus psyllid (*Diaphorina citri* Kuwayama) is responsible for transmitting CLAs, CLam, and CLca (da Graça and Kornsten, 2004; Antunes *et al.*, 2010), while the African citrus triozid (*Trioza erythrae* Del Guercio) transmits CLaf (da Graça and Kornsten, 2004). These insects inoculate the bacteria while feeding on the sap of the leaves (Halbert and Manjunath, 2004; Belasque *et al.*, 2010).

Candidatus Liberibacter spp. are Gram-negative bacteria (α -proteobacteria) that are restricted to the phloem of plants, interfering with the translocation of photosynthates and disrupting the movement of nutrients and sugars within the plant's internal tissues (Bendix and Lewis, 2018). This causes the yellowing of new shoots and leaf loss and alters fruit characteristics, such as deformities, changes in size, delayed ripening, modifications in flavor and texture, reduced yield, and decreased commercial quality. Finally, they cause premature fruit drop and tree death (Magomere *et al.*, 2009; Bojórquez-Orozco *et al.*, 2023). HLB symptoms can be confused with nutrient deficiency or the damage caused by pests and other diseases (Gottwald *et al.*, 2007). Therefore, evaluating the physicochemical quality of fruits is fundamental to prevent changes in their properties during postharvest. Nutritional quality has become an essential component of overall quality, serving as a key factor in consumer preference. This study aimed to evaluate the physicochemical quality and postharvest life of Mexican lime fruits obtained from HLB asymptomatic and symptomatic trees under ambient and refrigerated storage conditions.

MATERIALS AND METHODS

Plant material

Mexican lime fruits (*Citrus aurantifolia*) were harvested in a plot located at km 35 of the Colima-Manzanillo highway in Tecomán, Colima, Mexico. A total of 300 asymptomatic fruits were collected from the greenhouse, and 300 HLB-symptomatic fruits were collected from an open field. The fruits were selected based on their uniform size, homogeneous green color, and absence of visible damage. Then, the fruits were washed with running water and commercial soap. Of the total collected, 150 asymptomatic and 150 symptomatic fruits were selected for storage at room temperature (20 ± 2 °C, 55 ± 5 % relative humidity (RH)) for 0, 4, and 8 d. The remaining were stored under refrigeration (9 ± 1 °C, 85 ± 5 % RH) for two weeks. Subsequently, the refrigerated fruits were transferred to room temperature conditions for 4 and 8 additional days to simulate the commercialization process.

Physical and chemical analyses

Changes in physical and chemical quality were evaluated by measuring total soluble solids (TSS) in degrees Brix (°Brix) using a digital refractometer (ATAGO PR-100, Bellevue, USA). Titratable acidity was expressed as grams of citric acid per 100 mL of juice ($\text{g } 100 \text{ mL}^{-1}$). The ascorbic acid content (vitamin C) was quantified in milligrams of ascorbic acid per 100 ml of juice ($\text{mg } 100 \text{ mL}^{-1}$) through extraction with oxalic acid and titration with 2,6-dichlorophenol-indophenol, following the AOAC (2023) method. The external color was determined in the equatorial zone of all fruits using a reflection color meter (Hunter Lab D-25, Reston, VA, USA) based on the CIELab scale. The L^* , a^* , and b^* parameters were used to calculate the color index (CI) using the equation proposed by Jiménez-Cuesta *et al.* (1981):

$$IC = \frac{1000 \times a^*}{b^*L}$$

where a^* defines the direction and degree of chromaticity on the red/green axis, b^* defines the direction and degree of chromaticity on the yellow/blue axis, and L represents luminosity or lightness of a color, from 0 (black) to 100 (white).

The fruit's weight loss (WL) was calculated with the following equation:

$$\% WL = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Statistical analysis

This study followed a completely randomized design. Each fruit was considered an experimental unit, and 50 fruits were used per treatment. All experiments were

carried out in triplicate. The experimental data were subjected to analysis of variance (ANOVA), followed by mean comparison by Tukey test ($p < 0.05$), using the SPSS 23 statistical software (IBM Corporation, Armonk, NY, USA). Normality and homogeneity of variance assumptions were verified using the Shapiro-Wilk and Bartlett tests, respectively. The percentage data were transformed using the following equation:

$$Y = \arcsen\left(\sqrt{\frac{x}{100}}\right)$$

where X is the percentage value.

RESULTS AND DISCUSSION

Storage at room temperature

Significant differences in organoleptic quality and postharvest life of the fruits were observed between the evaluated treatments (Table 1). The greatest weight loss was recorded in HLB-symptomatic fruits after 8 d of storage, reaching 17.25 %. On the contrary, the lowest weight loss was observed in asymptomatic fruits after 4 d of storage, with 7.29 %. Regarding internal quality, an increase in titratable acidity was observed, with 9.24 % citric acid in HLB-symptomatic fruits at harvest. The lowest citric acid content (3.53 %) was observed in HLB-symptomatic fruits after 8 d of storage. As for total soluble solids, there were no significant differences between treatments. For the color index, the highest value (-22.06) was observed in asymptomatic fruits at harvest, showing a homogeneous green hue. The lowest color index (-8.46) was observed in HLB-symptomatic fruits after 8 d of storage. These fruits were characterized

Table 1. Organoleptic quality and postharvest life of huanglongbing (HLB) symptomatic and asymptomatic Mexican lime fruits [*Citrus aurantifolia* (Christm.) Swingle] stored under commercialization conditions (20 ± 2 °C, 55 ± 5 % relative humidity).

Treatment	Storage time (days)	Weight loss (%)	Citric acid (%)	Total soluble solids (%)	Color index (1000 a^*/b^*L)	Ascorbic acid (mg 100 mL ⁻¹)
Fruits with HLB symptoms	0	0.0 d	9.24 a	7.83 a	-18.19 b	41.24 b
	4	10.77 bc	6.40 b	7.46 a	-14.04 c	30.84 c
	8	17.25 a	3.53 d	6.83 a	-8.46 d	21.10 d
Fruits HLB asymptomatic	0	0.0 d	8.36 ab	7.60 a	-22.06 a	50.37 a
	4	7.29 c	7.44 b	7.40 a	-16.18 bc	44.85 b
	8	13.71 b	5.47 c	7.13 a	-12.75 d	33.15 c

Means with different letters within columns are statistically different (Tukey, $p < 0.05$).

by a yellowish hue that deteriorated their appearance, as their postharvest life was reduced due to the senescence process.

Regarding nutritional quality, the highest concentration of ascorbic acid was observed in asymptomatic fruits, with 50.37 mg 100 mL⁻¹ of juice at harvest. The lowest concentration of ascorbic acid was recorded in HLB-symptomatic fruits, with 21.1 mg 100 mL⁻¹ of juice after 8 d of storage, showing a more pronounced loss of ascorbic acid in the HLB-symptomatic fruits.

The effects of HLB on fruit weight loss were significant, which reduced shelf life. Robles-González *et al.* (2013) reported that Mexican lime fruits from trees with 50–80 % of their canopy damaged by HLB showed reduced size and weight. Muñoz-Lazcano *et al.* (2011) mentioned that Mexican lime fruits have a thinner peel and smaller size, making them more prone to water loss via transpiration, which leads to dehydration and weight loss. In this study, lime fruits started dehydrating over the course of the days, leading to weight loss.

The decrease in citric acid content in the fruits stored at room temperature was more pronounced in those with HLB symptoms. This is similar to that reported by Bassanezi *et al.* (2009) in sweet oranges, where the fruits harvested from trees with HLB symptoms had a greater acidity. As for total soluble solids, no significant differences were observed between groups, which coincides with Robles-González *et al.* (2013), who reported that HLB had no significant effect on the °Brix values of the Mexican lime. On the contrary, Bassanezi *et al.* (2009) observed an increase in °Brix in HLB-symptomatic oranges.

On the other hand, fruits with HLB symptoms showed a greater decrease in green color compared to asymptomatic fruits. Sagaram *et al.* (2009) and Hernández-Rivera *et al.* (2018) reported that HLB-symptomatic Mexican lime fruits had a significantly lower color index as storage time increased. Goldschmidt (1997) observed that the yellowish color in citrus fruits, including Mexican limes, is an adverse effect that leads to quality loss. This is due to the biosynthesis of ethylene (C₂H₄) during postharvest, which accelerates the senescence process, increases respiratory activity, and causes chlorophyll degradation.

Storage under refrigeration conditions

Significant differences were observed in the quality of the fruits stored under refrigeration temperatures (9 ± 1 °C, 85 ± 5 % RH) (Table 2). The greatest weight loss was observed in fruits with HLB symptoms, with a 19.3 % loss after 8 d of storage. Asymptomatic fruits showed a lower weight loss, with 9.6 % after 4 d of storage.

As for internal quality, no significant differences were observed in citric acid content between HLB-asymptomatic and symptomatic fruits, with values of 8.13 and 7.26 %, respectively, after refrigerated storage. The lowest citric acid content was observed in fruits with HLB symptoms, with 2.9 % of citric acid. As for total soluble solids, there were also no significant differences between groups. The color index was higher in asymptomatic fruits (-14.14), with a light green-yellow color, while a lower index was

Table 2. Organoleptic quality and postharvest life of huanglongbing (HLB) symptomatic and asymptomatic Mexican lime fruits [*Citrus aurantifolia* (Christm.) Swingle] stored under refrigeration (9 ± 1 °C, 85 ± 5 % relative humidity) for two weeks, followed by storage at room temperature (20 ± 2 °C, 55 ± 5 % relative humidity).

Treatment	Storage time (days)	Weight loss (%)	Citric acid (%)	Total soluble solids (%)	Color index (1000 a^*/b^*L)	Ascorbic acid (mg 100 mL ⁻¹)
Fruits with HLB symptoms	0	0.0 d	7.26 a	7.53 a	-12.85 ab	40.48 b
	4	11.8 bc	5.97 b	7.30 a	-8.70 c	31.17 c
	8	19.3 a	2.90 c	6.80 a	-4.50 d	23.67 d
HLB-asymptomatic fruits	0	0.0 d	8.13 a	7.73 a	-14.14 a	47.34 a
	4	9.6 c	6.86 ab	7.66 a	-10.96 b	41.26 b
	8	14.9 b	4.60 b	7.03 a	-7.79 c	31.82 c

Means with different letters within columns are statistically different (Tukey, $p < 0.05$).

observed in symptomatic fruits, with a value of -4.5 after 8 d of storage, showing a yellow hue.

Regarding ascorbic acid, the highest concentration was detected in fruits with HLB symptoms, with 40.48 mg 100 mL⁻¹ of juice at harvest. This concentration decreased to 31.17 mg 100 mL⁻¹ after 4 d of storage and to 37.67 mg 100 mL⁻¹ after 8 d of storage, indicating a continuous loss of this compound. In asymptomatic fruits, the loss of ascorbic acid was lower, with a concentration of 47.34 mg 100 mL⁻¹ at harvest, 46.26 mg 100 mL⁻¹ at 4 d, and 24 mg 100 mL⁻¹ after 8 d of storage, highlighting a greater loss in fruits with HLB symptoms. It is likely that storage at low temperatures reduces the incidence of diseases by inhibiting microbial growth, restricting enzymatic and respiratory activities, inhibiting water loss, delaying quality loss, and reducing ethylene production (da Silva *et al.*, 2013).

Fruits with HLB symptoms exhibited faster softening and dehydration during refrigeration storage, along with increased senescence. As described by Cohen *et al.* (1994), Gaytán *et al.* (2012), and Hernández-Rivera *et al.* (2018), weight loss is an indicator of cold-induced damage, which reduces shelf life. Additionally, HLB-symptomatic fruits showed loss of green color and the appearance of brown spots, with some fruits showing signs of decay, further shortening their shelf life. According to Alferez *et al.* (2006), the loss of green color in citrus fruits is related to chlorophyll degradation and the progression of senescence, which explains the decrease in the color index observed during the storage periods. Muñoz-Lazcano *et al.* (2011) also reported a significant loss of green color in Mexican lime fruits without HLB and stored under refrigerated conditions for 2 or 4 weeks.

In this study, both groups of fruits showed a trend of acid content loss as storage days increased, which is consistent with the findings reported by Gaytán *et al.* (2012) in Mexican lime cultures. This group identified that the attack of microorganisms causing rot contributes to the loss of nutraceutical value due to the decrease in ascorbic acid and

the shortened shelf life. This decrease results from the oxidation of ascorbic acid due to senescence progression and hydric stress (Lee and Kader, 2000). According to Corzo-Martínez *et al.* (2012), ascorbic acid oxidation produces monodehydroascorbic acid, which reduces the biologic activity of vitamin C. The principal factors in this process are oxygen concentration, pH, and temperature. Despite the observed alterations, Mexican lime fruits with HLB symptoms could be used in agroindustry as they retain some organoleptic and nutraceutical characteristics.

CONCLUSION

The postharvest behavior of Mexican lime fruits was affected by the presence of huanglongbing symptoms in the source trees, altering their nutraceutical quality (ascorbic acid content), external quality (color index, weight loss), and internal quality (citric acid percentage), both under ambient and refrigerated storage conditions.

ACKNOWLEDGMENTS

Aideé Hernández Rivera thanks the Secretariat of Science, Humanities, Technology, and Innovation (SECIHTI) for the postgraduate scholarship awarded.

REFERENCES

- Alferez F, Pozo L, Burns JK. 2006. Physiological changes associated with senescence and abscission in mature citrus fruit induced by 5-chloro-3-methyl-4-nitro-1H-pyrazole and ethephon application. *Physiologia Plantarum* 127 (1): 66–73. <https://doi.org/10.1111/j.1399-3054.2006.00642.x>
- Antunes LCM, Ferreira RB, Buckner MM, Finlay BB. 2010. Quorum sensing in bacterial virulence. *Microbiology* 156 (8): 2271–2282. <https://doi.org/10.1099/mic.0.038794-0>
- AOAC (Association of Official Analytical Chemists). 2023. Official methods of analysis (15th edition). Rockville, MD, USA. 1298 p.
- Asmah N, Suniarti DF, Margono A, Mas'ud ZA, Bachtiar EW. 2020. Identification of active compounds in ethyl acetate, chloroform, and N-hexane extracts from peels of *Citrus aurantifolia* from Maribaya, West Java, Indonesia. *Journal of Advanced Pharmaceutical Technology and Research* 11 (3): 107–112. https://doi.org/10.4103/japtr.japtr_177_19
- Bassanezi RB, Montesino LH, Stuchi ES. 2009. Effects of huanglongbing on fruit quality of sweet orange cultivars in Brazil. *European Journal of Plant Pathology* 125 (4): 565–572. <https://doi.org/10.1007/s10658-009-9506-3>
- Belasque JJ, Bassanezi RB, Yamamoto PT, Ayres AJ, Tachibana A, Violante AR, Tank AJ, di Giorgi F, Tersi FEA, Menezes GM, *et al.* 2010. Lessons from huanglongbing management in Sao Paulo State, Brazil. *Journal of Plant Pathology* 92 (2): 285–302.
- Bendix C, Lewis JD. 2018. The enemy within: Phloem-limited pathogens. *Molecular Plant Pathology* 19 (1): 238–254. <https://doi.org/10.1111/mpp.12526>
- Bojórquez-Orozco AM, Arce-Leal ÁP, Montes RAC, Santos-Cervantes ME, Cruz-Mendivil, A, Méndez-Lozano J, Leyva-López NE. 2023. Differential expression of miRNAs involved in

- response to *Candidatus Liberibacter asiaticus* infection in Mexican lime at early and late stages of huanglongbing disease. *Plants* 12 (5): 1039. <https://doi.org/10.3390/plants12051039>
- Cohen E, Shapiro B, Shalom Y, Klein JD. 1994. Water loss: Nondestructive indicator of enhanced cell membrane permeability of chilling injured citrus fruit. *Journal of the American Society Horticultural Science* 119 (5): 983–986. <https://doi.org/10.21273/jashs.119.5.983>
- Corzo-Martínez M, Corzo N, Villamiel M, del Castillo MD. 2012. Browning reactions. *Food Biochemistry and Food Processing*. In Simpson BK. (ed.), *Food Biochemistry and Food Processing* (Second Edition). John Wiley and Sons: Hoboken, NJ, USA, pp: 56–83. <https://doi.org/10.1002/9781118308035.ch4>
- da Graça JV, Kornsten L. 2004. Citrus huanglongbing: Review, present status and future strategies. In Naqvi AMH. (ed.), *Diseases of Fruits and Vegetables Volume I, Diagnosis and Management*. Springer: Dordrecht, Netherlands, pp: 229–245. https://doi.org/10.1007/1-4020-2606-4_4
- da Silva PG, Machado FL de C, da Costa JMC. 2013. Quality of ‘Delta Valencia’ orange grown in semiarid climate and stored under refrigeration after coating with wax. *Food Science and Technology* 33 (2): 276–281.
- Folimonova SY, Achor DS. 2010. Early events of citrus greening (huanglongbing) disease development at the ultrastructural level. *Phytopathology* 100 (9): 949–958. <https://doi.org/10.1094/phyto-100-9-0949>
- Galovičová L, Borotová P, Vukovic NL, Vukic M, Kunová S, Hanus P, Kowalczewski PŁ, Bakay L, Kačániová M. 2022. The potential use of *Citrus aurantifolia* L. essential oils for decay control, quality preservation of agricultural products, and anti-insect activity. *Agronomy* 12 (3): 735. <https://doi.org/10.3390/agronomy12030735>
- Gaytán IF, Veloz CS, Franci SHC, León MTC, Espinoza JS. 2012. Efectividad del encerado y metil jasmonato en el control de daños por frío asociados al tratamiento de cuarentena por fríos en pomelos “Rio Red”. *Revista Iberoamericana de Tecnología Postcosecha* 13 (2): 146–152.
- Goldschmidt EE. 1997. Ripening of citrus and other non-climateric fruits: A role for ethylene. *Acta Horticulturae* 463: 333–340. <https://doi.org/10.17660/actahortic.1998.463.42>
- Gottwald TR, Graca JVD, Bassanezi RB. 2007. Citrus huanglongbing: The pathogen and its impact. *Plant Health Progress* 8 (1): 31. <https://doi.org/10.1094/php-2007-0906-01-rv>
- Halbert SE, Manjunath K. 2004. Asian citrus psyllids (*Sternorrhyncha: Psyllidae*) and greening disease of citrus: A literature review and assessment of risk in Florida. *Florida Entomologist* 87 (3): 330–353.
- Hernández-Rivera A, Arellano-Ostoa G, Robles-González MM, Jaén-Contreras D, Contreras-Oliva A, Saucedo-Veloz C. 2018. Calidad y vida postcosecha de frutos de limones mexicanos provenientes de árboles con síntomas de HLB y asintomáticos. *Revista Mexicana de Ciencias Agrícolas* 9 (8): 1801–1807. <https://doi.org/10.29312/remexca.v9i8.1724>
- Indriyani NN, Anshori JA, Permadi N, Nurjanah S, Julaeha E. 2023. Bioactive components and their activities from different parts of *Citrus aurantifolia* (Christm.) Swingle for food development. *Foods* 12 (10): 2036. <https://doi.org/10.3390/foods12102036>
- Jagoueix S, Bove JM, Garnier M. 1994. The phloem-limited bacterium of greening disease of citrus is a member of the α subdivision of the Proteobacteria. *International Journal of Systematic and Evolutionary Microbiology* 44 (3): 379–386. <https://doi.org/10.1099/00207713-44-3-379>
- Jeffrey J, Sudigdoadi S, Kurnia D, Satari MH. 2020. A monoterpene isolated from *Citrus aurantifolia* peel and its potential as an antibacterial for the inhibition and eradication of *Streptococcus mutans* biofilm. *Systematic Reviews in Pharmacy* (11): 1205–1210. <https://doi.org/10.31838/srp.2020.6.175>

- Jiménez-Cuesta M, Cuquerella J, Martínez-Jávega JM. 1981. Determination of color index for fruit degreening. *Proceedings of the International Society of Citriculture* 2 (3): 750–753.
- Julaeha E, Nurzaman M, Wahyudi T, Nurjanah S, Permadi N, Anshori JA. 2022. The development of the antibacterial microcapsules of citrus essential oil for the cosmetotextile application: A review. *Molecules* 27 (22): 8090. <https://doi.org/10.3390/molecules27228090>
- Kazeem MI, Bancole HA, Oladokun TI, Bello AO, Maliki, MA. 2020. *Citrus aurantifolia* (Christm.) Swingle (lime) fruit extract inhibits the activities of polyol pathway enzymes. *Efood* 1 (4): 310–315. <https://doi.org/10.2991/efood.k.200824.001>
- Lee SK, Kader AA. 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biology and Technology* 20 (3): 207–220. [https://doi.org/10.1016/S0925-5214\(00\)00133-2](https://doi.org/10.1016/S0925-5214(00)00133-2)
- Magomere TO, Obukosia SD, Mutitu E, Ngichabe C, Olubayo F, Shibairo S. 2009. Molecular characterization of 'Candidatus Liberibacter' species/strains causing huanglongbing disease of citrus in Kenya. *Electronic Journal of Biotechnology* 12 (2): 5–6.
- Mohammed RMO, Ayoub SMH. 2016. Study of phytochemical screening and antimicrobial activity of *Citrus aurantifolia* seed extracts. *American Journal of Analytical Chemistry* 7 (3): 254. <https://doi.org/10.4236/ajac.2016.73022>
- Muñoz-Lazcano AC, Saucedo-Veloz C, García-Osorio, Robles-González M. 2011. Evaluación de la calidad y tiempo de almacenamiento del fruto en tres variedades de limón mexicano. *Revista Iberoamericana de Tecnología Postcosecha* 12 (2): 156–163.
- Robles-González MM, Velázquez-Monreal J, Manzanilla-Ramírez MÁ, Orozco-Santos M, Medina-Urrutia VM, López-Arroyo JI, Flores-Virgen R. 2013. Síntomas del huanglongbing (HLB) en árboles de limón mexicano [*Citrus aurantifolia* (Christm.) Swingle] y su dispersión en el estado de colima, México. *Revista Chapingo Serie Horticultura* 19 (1): 15–31. <https://doi.org/10.5154/r.rchsh.2012.01.005>
- Sagaram US, de Angelis KM, Trivedi P, Andersen GL, Lu SE, Wang N. 2009. Bacterial diversity analysis of huanglongbing pathogen-infected citrus, using PhyloChip arrays and 16S rRNA gene clone library sequencing. *Applied and Environmental Microbiology* 75 (6): 1566–1574. <https://doi.org/10.1128/aem.02404-08>
- Shchérazade OSF, Pétronille AZ, Joseph FKY, Georges A. 2021. Study of the analgesic effect of the aqueous extract of the leaves of *Citrus aurantifolia* (Rutaceae) in mice. *GSC Biological and Pharmaceutical Sciences* 14 (3): 207–214. <https://doi.org/10.30574/gscbps.2021.14.3.0072>
- Swandiny GF, Nafisa S, Gangga E, Fauzi M. 2021. Standardization of 70 % ethanol extract and 96 % lime leaves as antioxidants with DPPH and FRAP. *Journal of Pharmacognosy and Phytochemistry* 10 (4): 47–52.
- Teixeira DC, Danet JL, Eveillard S, Martins EC, de Jesus WCJR, Yamamoto PT, Bové JM. 2005. Citrus huanglongbing in Sao Paulo State, Brazil: PCR detection of the *Candidatus Liberibacter* species associated with the disease. *Molecular and Cellular Probes* 19 (3): 173–179. <https://doi.org/10.1016/j.mcp.2004.11.002>
- Vitor HB, Gabriel RR, Marcos RF, Alexandre DCU, Luiz FG, Wesley ACG, Pedro TY. 2013. Population Dynamics of *Diaphorina citri* Kuwayama (Hemiptera: Livididae) in orchards of Valencia orange, Ponkan mandarin and Murcott tangor trees. *Florida Entomologist* 96 (1): 173–179. <https://doi.org/10.1653/024.096.0123>