



Advances in biology through agronomy, aquaculture, coastal and environmental sciences

— Volume II —

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Editors

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**Advances in biology through
agronomy, aquaculture, coastal and
environmental sciences**
Volume II



Pantanal Editora

2026

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Catalog sheet

Cataloging in publication
Prepared by a Librarian Janaina Ramos – CRB-8/9166

A244

Advances in biology through agronomy, aquaculture, coastal and environmental sciences - Volume II /
Editors Leandris Argente-Martínez, Ofelda Peñuelas-Rubio, Joe Luis Arias-Moscato. – Nova
Xavantina-MT: Pantanal, 2026.
362p. ; il.

Book in PDF format

ISBN 978-65-85756-79-2

DOI <https://doi.org/10.46420/9786585756792>

1. Biology. 2. Agronomy. 3. Aquaculture. 4. Environmental sciences. I. Argente-Martínez, Leandris
(Editor). II. Peñuelas-Rubio, Ofelda (Editor). III. Arias-Moscato, Joe Luis (Editor). IV. Title.

CDD 570

Index to systematic catalog

I. Biology



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Advances in Biology through Agronomy, Aquaculture, Coastal and Environmental Sciences, Volume II, is an e-book that continues the work of the first version (<https://editorapantanal.com.br/ebooks/2023/advances-in-biology-through-agronomy-aquaculture-coastal-and-environmental-sciences/ebook.pdf>), published in 2023 by Leandris Argente!-Martínez and Ofelda Peñuelas-Rubio.

Our e-book compiles 25 manuscripts that present scientific results and reviews based on biological aspects. All of them contribute to explaining the responses of living organisms to agricultural, aquaculture, and coastal ecosystems, as well as those facing fragility or threat of climate change. This e-book was edited by Leandris Argente!-Martínez, Ofelda Peñuelas-Rubio, and Joe Luis Arias-Mosc!so, members of the Consolidated Academic Group ITVAYA-CA-3.

We appreciate the contribution of all authors for their careful attention to the editorial committee's recommendations. The review process was double-blind and conducted by internationally renowned researchers.

Special thanks to the members of the BioSecuraNet International Network for Biotechnology and Innovative Strategies for Global Food Security at the National Technological Institute of Mexico.

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Antifungal activity of edible chitosan coatings and *Coriandrum sativum* L. essential oil against *Colletotrichum gloeosporioides* and their application on mango fruits

Received: 18/03/2026

Accepted: 22/04/2026

doi 10.46420/9786585756792cap11

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ABSTRACT

Anthrachnose caused by *Colletotrichum gloeosporioides* is a major postharvest disease of mango, leading to significant economic losses. The use of synthetic fungicides has limitations because of resistance strains and safety concerns. In this study, the antifungal activity of edible chitosan coatings and *Coriandrum sativum* L. (coriander) leaf essential oil, alone and in combination, against *C. gloeosporioides* was evaluated through *in vitro* and *in situ* assays on mango fruits. The essential oil was obtained by hydrodistillation (yield of 0.2% w/w). *In vitro* tests revealed that the oil at 5 mg mL⁻¹ inhibited mycelial growth (71.5%), conidial germination (64.5%) and sporulation (64.9%) in a concentration-dependent manner. Chitosan coating (1%) alone achieved 42.6% mycelial inhibition. The combination of chitosan with 5 mg mL⁻¹ (QAE5) essential oil significantly improved antifungal activity, reaching 62.5% mycelial inhibition and 72.1% germination inhibition *in vitro*. In mango fruits (cv. manila), QAE5 reduced anthracnose severity to 42.7% after 18 days of storage at 13 °C, compared with 98.8% in the control and 70.9% with chitosan alone. The results demonstrate a synergistic effect between chitosan and coriander essential oil, providing an effective, safe and sustainable alternative for the postharvest management of mango anthracnose.

Keywords: antifungal; chitosan; edible coatings; *Coriandrum sativum*; anthracnose.

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INTRODUCTION

Fungal diseases represent a significant cause of economic losses in high-value horticultural products (Ramírez-Salcedo et al., 2019). Among the most prevalent phytopathogens are *Colletotrichum gloeosporioides*, the causal agent of anthracnose, a disease affecting leaves, young branches, inflorescences and fruits. In the particular case of mango (*Mangifera indica* L.), anthracnose is among the main postharvest diseases, with yield losses that can reach 100% in plantations without proper management (Dofuor et al., 2023). Infection of the fruits induces their premature drop, and during ripening, irregular dark brown to black lesions develops that compromise both the sensory quality and the commercial value of the product, generating substantial economic losses for producers.

The control of this disease has traditionally been based on the application of synthetic fungicides such as benomyl, thiabendazole and imazalil. However, the intensive use of these compounds has led to the emergence of resistant strains of the pathogen, which has resulted in increased application concentrations and frequency (Zhang et al., 2025). This practice not only increases production costs but also carries the risk of exceeding the maximum permitted residue limits, thus compromising fruit safety and consumer health. In this context, natural products, such as essential oils, organic acids and polyphenolic compounds, are promising alternatives for the control of postharvest diseases because of their biodegradability and efficacy against various fungal species (Tubay-Bermúdez et al., 2024).

Chitosan coatings are promising because they possess broad-spectrum antimicrobial activity. López-Mora et al. (2013) reported that 1% chitosan inhibited the germination of *Alternaria alternata* and reduced sporulation. Similarly, Correa-Pacheco et al. (2017) reported that nanostructured chitosan films inhibited the mycelial growth (0.2%) and spore germination (96%) of *C. gloeosporioides*. Rayón-Díaz et al. (2021) also demonstrated that treatment with chitosan (0.1–1.5%) resulted in up to 99% inhibition of the mycelial development of *C. gloeosporioides*. Therefore, the incorporation of essential oils into chitosan coatings could enhance the control of this pathogen on fruits.

Essential oils are complex mixtures of polar and nonpolar compounds of plant origin that exert synergistic antifungal activity and play a relevant role in protecting crops against biotic enemies. They therefore constitute a viable alternative for extending the shelf life of horticultural products (Alonso-Gato et al., 2021). Coriander (*Coriandrum sativum* L.), an annual herbaceous plant of the Apiaceae family, is widely cultivated in regions such as Morocco, France, Spain, India and Mexico (Leal-Torres et al., 2013). Its essential oil has been recognized as safe (GRAS, generally recognized as safe) by the United States Food and Drug Administration (FDA). The major volatile compounds in seed oil are linalool and γ -terpinene, while in fresh leaves, decanal and trans-2-decenal predominate (Mandal & Mandal, 2015). This oil exhibits a wide range of biological activities, such as antioxidant, antidiabetic, anxiolytic, anti-inflammatory, antihypertensive, antidiabetic, diuretic and antimicrobial activities (Bogavac et al., 2015; Al-Khayri et al., 2023). Bogavac et al. (2015) reported that a minimum inhibitory concentration (MIC) of 0.4 $\mu\text{L mL}^{-1}$ of coriander leaf essential oil was effective against *Escherichia coli*. Moreover, Yildiz

(2016) evaluated the antifungal activity of this oil against *Candida albicans* and *Aspergillus niger* and reported inhibition zones of 18 mm (MIC of 7.8 µg mL⁻¹) and 14 mm (MIC of 250 µg mL⁻¹), respectively. Despite this background, most studies have focused on coriander seeds (Darughe et al., 2012; Mandal; Mandal, 2015), and research on the antifungal activity of leaf oil against phytopathogenic fungi is scarce (Sobhani et al., 2022).

Considering the need to develop sustainable alternatives for the management of anthracnose in mango and given the lack of information on the combined effect of *C. sativum* L. (leaf) essential oil with chitosan coatings on *C. gloeosporioides*, the present study aimed to evaluate the antifungal activity of edible chitosan coatings and *Coriandrum sativum* L. essential oil, as well as their combination, on the development of *C. gloeosporioides* through in vitro and in situ assays on mango fruits.

MATERIALS AND METHODS

Plant material

Coriander leaves (*Coriandrum sativum* L.) were collected during September 2023 from an orchard located in Ixil, Yucatán, Mexico (21° 9.8' N, 89° 28.56' W; 5 m a.s.l.). Healthy, well-developed plants at 90 days after sowing were selected. Leaves were taken at random and immediately transported to the Fruit and Vegetable Workshop of the Instituto Tecnológico de Chiná, where they were processed on the same day.

Extraction of essential oil from C. sativum L.

The essential oil was obtained from fresh leaves and cut into fragments of approximately 0.5 cm. Samples of 50 g of leaves were subjected to hydrodistillation in 200 mL of distilled water for 4 hours using a Clevenger-type apparatus. The process was repeated several times until a sufficient amount of oil was obtained (1500 g of leaves in total). The hydrodistilled extract was dried over anhydrous sodium sulfate (Na₂SO₄; J. T. Baker®, Mexico) and stored in amber glass vials at 4 °C until analysis. The average yield of the essential oil was 0.2% w/w (wet basis).

Obtaining the C. gloeosporioides strain.

Monosporic isolates of *Colletotrichum gloeosporioides* from the Microbiology Laboratory Collection of the Universidad de la Sierra Sur were used. The strains, previously identified on the basis of their morphological and molecular characteristics, were reactivated on potato dextrose agar (PDA; Bioxon®, Mexico) and incubated at 25 ± 2 °C for five days.

Antifungal effect of C. sativum L. essential oil.

The assay was performed according to the methods of Chen et al. (2013) with modifications. Finally, essential oils were prepared at concentrations of 0.5, 1, 3 and 5 mg mL⁻¹ in PDA medium. For

this purpose, the oil was mixed with Tween® 20 (0.1% v/v; Hycl, Mexico) and added to 100 mL of molten PDA (45 °C). The mixture was poured (20 mL per plate) into 90 mm diameter Petri dishes (five replicates per treatment) and allowed to solidify at room temperature (25 ± 2 °C). On the surface of each plate, a 5 mm diameter agar disc with active mycelium (5- day-old culture) was placed. PDA without essential oil was used as a negative control, and PDA with Tween® 20 (0.1%) was used as a solvent control. The plates were incubated at 25 ± 2 °C, and the mycelial growth diameter was measured daily (in two perpendicular directions) using a Vernier caliper. The experiment ended when the mycelium of the control completely covered the plate.

The percentage of mycelial growth inhibition for each treatment was calculated using the following formula:

$$\text{MGI (\%)} = (\text{DMCc} - \text{DMCt}) / \text{DMCc} \times 100$$

where MGI = mycelial growth inhibition; DMCc = diameter of mycelial growth of the control; and DMCt = diameter of mycelial growth of the treatment.

At the end of the incubation period, the spores produced on each plate were collected by adding 10 mL of sterile distilled water and gently scraping the surface with a sterile glass rod. The suspension was filtered through sterile gauze, and the number of conidia was quantified in a Neubauer chamber (BRAND®, Mexico) under an optical microscope (ZEISS® Axio Lab. A1, Oberkochen, Germany). The percentage of sporulation inhibition (SI) was calculated as follows:

$$\text{SI (\%)} = (\text{NCc} - \text{NCt}) / \text{NCc} \times 100$$

where SI = sporulation inhibition; NCc = number of conidia of the control; and NCt = number of conidia of the treatment.

From a 5--day--old sporulated culture, a suspension of 10^6 conidia mL^{-1} in sterile distilled water was prepared. Fifty microliters of this suspension were placed on the surface of PDA plates containing different essential oil concentrations (0.5–5 mg mL^{-1}). The plates were incubated for 8 h at 25 ± 2 °C. One hundred conidia per treatment were examined under a microscope; a conidium was considered to have germinated when the length of the germ tube was at least twice the major diameter of the conidium. The percentage of germination inhibition (GI) was determined using the following equation:

$$\text{GI (\%)} = (\text{NGc} - \text{NGt}) / \text{NGc} \times 100$$

where GI = germination inhibition; NGc = number of germinated conidia of the control; and NGt = number of germinated conidia of the treatment.

Preparation of coatings based on chitosan and coriander (*C. sativum* L.) essential oil.

Medium-molecular-weight chitosan (75–85% degree of deacetylation, viscosity 200–800 cps; Sigma Aldrich®, Missouri, USA) was used. On the basis of the mycelial growth inhibition results, three concentrations of coriander leaf essential oil were selected: 1, 3 and 5 mg mL⁻¹. A 1% (w/v) chitosan solution was prepared by dissolving the polymer in 1% (v/v) acetic acid with constant stirring for 24 hours at room temperature. The solution was adjusted to pH 5.6 with 1 N NaOH and homogenized for 15 minutes until a stable emulsion was obtained. The emulsion was subsequently degassed under vacuum to remove air bubbles and divided into three equal portions. To each portion, the corresponding concentration of essential oil was added, and the mixture was homogenized for 10 minutes and allowed to rest for 24 hours before use (Sebti et al., 2005; Ramos et al., 2012).

Antifungal effect of the coatings

Molten PDA (45 °C) was mixed with each of the chitosan- essential oil emulsions (final oil concentrations: 1, 3 and 5 mg mL⁻¹) in a 1:1 (v/v) ratio, and 20 mL was poured into Petri dishes. PDA with 1% chitosan solution (without essential oil) was used as a positive control, and PDA alone was used as an absolute control. On each plate, a 5 mm disc of fungal mycelium (5 days old) was placed. The plates were incubated at 25 ± 2 °C for 7 days. The mycelial diameter was measured daily, and the percentage of growth inhibition was calculated using the same formula as in the previous section. To evaluate conidial germination in the presence of the coatings, a suspension of 10⁶ conidia mL⁻¹ was prepared, and 50 µL was inoculated onto the surface of the PDA plates. After 20 minutes in a laminar flow cabinet (to absorb excess moisture), 5 mL of each coating emulsion was poured over the inoculum and allowed to dry for 90 minutes at room temperature. The plates were incubated for 7 hours at 25 ± 2 °C, after which the germination of 100 conidia per treatment was determined. The percentage of germination inhibition (GI) was calculated as previously described.

In vivo evaluation of the coatings

Mango fruits (*Mangifera indica* L.) cv. Manila, harvested in May 2024 from a commercial orchard in Chiná, Campeche, Mexico, were used. Fruits were selected for their homogeneous mass (272 ± 11 g), physiological maturity and absence of physical damage or pathological symptoms. After the samples were washed and disinfected with 2% (v/v) sodium hypochlorite, three wounds were made in the equatorial zone of each fruit (2 mm diameter × 2 mm depth) with a sterile dissecting needle. Each wound was inoculated with 10 µL of a suspension of 10⁶ conidia mL⁻¹ of *C. gloeosporioides*. The inoculated fruits were kept for 24 hours at room temperature (25 ± 2 °C) to allow infection and then immersed for 20 seconds in the corresponding coating emulsions (chitosan with 1, 3 or 5 mg mL⁻¹ of essential oil). Inoculated

fruits without a coating were used as a negative control. The fruits were subsequently stored at 13 °C for 18 days.

Determination of severity by digital image analysis

Anthracoze severity was quantified as the percentage of necrotic area on the fruit surface. Three digital images per fruit (one per wound) were captured using a FUJIFILM® FinePix S1000fd camera (JPG format, 2736 × 3648 pixels, RGB color space, 24 bits per pixel, 300 dpi resolution). The images were calibrated such that 175.09 pixels corresponded to 1 cm². Analysis was performed with ImageJ software v1.51e (National Institutes of Health, Bethesda, MD, USA). The determination of the severity percentage was carried out in two stages: In the first stage, image binarization (Process > Make binary), selection of the mango region using the “Wand” tool (Tolerance = 0 and Legacy mode) and determination of the total mango area (TMA) using the “Analyze particle” function were performed. In the second stage, the “color threshold” tool was used to segment the images on the basis of thresholds for channels of a color space. The RGB color space was converted to the HSB (hue, saturation, and brightness) color space to obtain an adequate representation of the pixels and thereby facilitate the analysis. To segment each image, the following values were used: Hue = 0–255, Saturation = 0–255 and Brightness = 0–140. The value of the damaged area of each mango (DAM) was obtained using the sequence of commands “Analyze/Analyze particle”. The severity percentage (S) was calculated using the following equation:

$$S (\%) = \text{DAM}/\text{TMA} \times 100$$

where DAM = damaged area of the mango in cm² and TMA = total mango area in cm². Digital image processing was performed with ImageJ version 1.51e (National Institute of Health, Bethesda, MD, USA; this software is available at <https://imagej.nih.gov/ij/download.html>)

Experimental design and statistical analysis

For all *in vitro* and *in vivo* assays, treatments were distributed in a completely randomized design. Each experiment was performed twice independently. In the *in vitro* assays, the experimental unit was a Petri dish, with five replicates per treatment in each repetition of the experiment (total n = 10 per treatment). In the *in vivo* assay, 10 fruits per treatment (three wounds per fruit) were used in each of the two repetitions.

The percentages of growth inhibition, sporulation and germination were transformed using arcsine $\sqrt{(\text{percentage}/100)}$ to meet the assumptions of normality and homoscedasticity. The transformed data were subjected to two-way analysis of variance (ANOVA) (experiment × treatment), and as no significant effect of the experiment was found, the data were combined. Differences between means were

evaluated with Tukey's test ($p \leq 0.05$) using Statgraphics Centurion XVI software (Statistical Graphics Corp., USA).

RESULTS AND DISCUSSION

Antifungal effect of Coriandrum sativum L. essential oil in vitro.

Coriander essential oil had a concentration-dependent inhibitory effect on the mycelial growth, conidial germination and sporulation of *C. gloeosporioides* (Table 1). The concentration of 5 mg mL⁻¹ resulted in the greatest mycelial growth inhibition (71.5%), followed by 3 mg mL⁻¹ (61.2%), with significant differences between all the treatments ($p \leq 0.05$). The inhibition of mycelial growth can be attributed to the ability of the major terpenic compounds (decanal and trans-2-decenal) to interact with the fungal cell membrane. Recent work has shown that essential oils can damage the integrity and permeability of the plasma membrane, decrease intracellular ATP levels and increase the production of reactive oxygen species (Xia et al., 2025).

Table 1. Effects of *Coriandrum sativum* L. essential oil concentration on the percentage of mycelial growth inhibition (MGI), germination inhibition (GI) and sporulation inhibition (SI) of *C. gloeosporioides*.

Essential Oil Concentrations (mg mL ⁻¹)	MGI ^z	GI ^z	SI ^z
0.5	41.2d	15.3c	9.7c
1	56.7c	15.8c	5.3d
3	61.2b	55.1b	33.6b
5	71.5a	64.5a	64.9a
Testigo	0 e	0 d	0 e

^zDifferent letters in the same column indicate a significant difference according to Tukey's test ($n = 10$, $p \leq 0.05$).

Similarly, germination inhibition reached its maximum value (64.5%) at 5 mg mL⁻¹, whereas concentrations of 0.5 and 1 mg mL⁻¹ were ineffective (15.3 and 15.8%, respectively). Sporulation was inhibited by 64.9% at the highest concentration but was practically zero (5.3%) at 1 mg mL⁻¹ (Table 1). The progressive reduction in mycelial growth as a function of the essential oil concentration is shown in Figure 1. This response pattern is consistent with that reported in the literature for various essential oils against phytopathogenic fungi (Atnafu et al., 2024). For example, Mutlu Ingök et al. (2020) reported in an updated review that the antifungal efficacy of essential oils is directly related to their concentration, attributing this behavior to the lipophilic nature of their bioactive compounds, which require them to reach a critical threshold to interact effectively with fungal membranes. Similarly, Raveau et al. (2020) reported that the inhibitory activity of essential oils on phytopathogens is clearly concentration-dependent, showing that sublethal concentrations can induce fungistatic effects, while higher concentrations achieve complete fungicidal control. This dose-response relationship is fundamental for the development of practical formulations, as it allows identification of the optimal

concentration that maximizes efficacy without compromising economic viability or the quality of the treated product.

Mohanapriya et al. (2024) evaluated essential oils of citronella, clove, ginger, basil, lemongrass, garlic, cinnamon, black cumin, black pepper and onion against *C. gloeosporioides* and reported complete mycelial growth inhibition at concentrations as low as 0.050% for citronella and cinnamon and 0.075% for lemongrass and clove. That study emphasized that such inhibition follows a concentration-dependent pattern, attributable to the presence of specific bioactive compounds such as citronellal, eugenol, cinnamaldehyde and geranial, which act on fungal membranes and enzymatic functions.

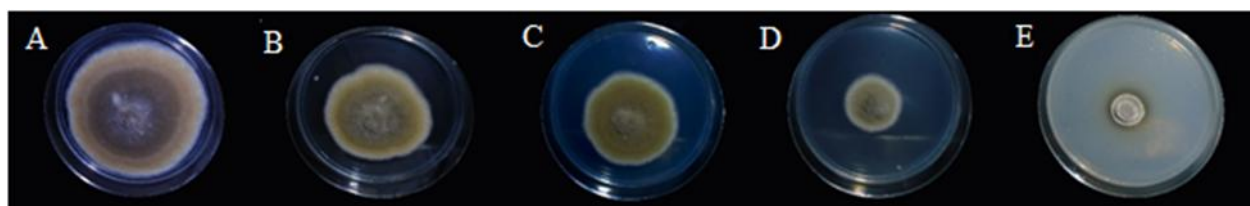


Figure 1. *In vitro* effectiveness of the essential oils on the mycelial growth of *C. gloeosporioides*: A) Control, B) 0.5 mg mL⁻¹, C) 1 mg mL⁻¹, D) 3 mg mL⁻¹ and E) 5 mg mL⁻¹.

In vitro antifungal effect of chitosan essential oil coatings

Chitosan coatings at 1% (C) showed moderate activity (42.6% mycelial inhibition) (Table 2). Recent studies have confirmed that 0.8% (w/v) chitosan can inhibit up to 78% of the mycelial growth of *C. gloeosporioides* (Gumede et al., 2025). The antifungal mechanism of chitosan is related to its polycationic character at acidic pH (5.6), which favors electrostatic interactions with anionic groups on the fungal surface, causing structural disorganization and leakage of ions and nutrients (Yang et al., 2005; Aloui et al., 2014). Current research has shown that chitosan nanocomposites induce severe damage to hyphae and spore collapse, which is attributed to the synergistic generation of reactive oxygen species and chitosan-mediated membrane disruption (Hassan et al., 2026).

The incorporation of essential oil significantly improved the antifungal activity of the coatings, especially in terms of the inhibition of germination (72.1% in C-EO5 vs. 36.5% in C). This synergistic effect can be explained by the complementary action of both compounds: while chitosan alters the cell wall, the hydrophobic compounds of the essential oil easily penetrate the destabilized membrane, enhancing cell integrity loss (Aloui et al., 2014; Minova et al., 2015). Moreover, the chitosan matrix can act as a protective vehicle that gradually releases volatile compounds, prolonging their antifungal activity (Ramos et al., 2012). Recently, chitosan coatings with cinnamon or lemongrass essential oil completely inhibited mycelial growth of *C. gloeosporioides* in *in vitro* assays and significantly reduced anthracnose severity in mangoes (Hassam et al., 2026).

Table 2. Effect of chitosan essential oil on the percentage of *C. gloeosporioides* mycelial growth inhibition (MGI) and germination inhibition (GI).

Treatment ^y	MGI ^z	GI ^z
Q	42.6c	36.5d
QAE1	53.7b	44.8c
QAE3	61.0a	59.5b
QAE5	62.5a	72.1a
Control (PDA)	0 d	0 e

^yQ: 1% chitosan coating; QAE1: 1% chitosan coating + 1 mg mL⁻¹ essential oil; QAE3: 1% chitosan coating + 3 mg mL⁻¹ essential oil; QAE5: 1% chitosan coating + 5 mg mL⁻¹ essential oil.

^zDifferent letters in the same column indicate a significant difference according to Tukey's test (n = 10, p ≤ 0.05).

In vivo effects of the coatings on anthracnose severity in mango

There were significant differences in the severity percentage of *C. gloeosporioides* on fruits among the treatments (p ≤ 0.05) (Figure 2). The control had the highest severity percentage (98.8%), followed by the C treatment (70.9%). The most effective treatment was C-EO5 (chitosan + essential oil at 5 mg mL⁻¹), with 42.7% severity, followed by C-EO3 (3 mg mL⁻¹), with 53.9%. The reduction in the number of necrotic lesions on fruits treated with C-EO5 compared with that on the control and C.

These results are comparable to those of recent research. For example, an active chitosan coating with ZnO nanoparticles and Eucalyptus radiata essential oil reduced postharvest rot severity in mangos by 64.3% (Oliveira et al., 2025). Similarly, a thyme essential oil nanoemulsions encapsulated in chitosan reduced anthracnose incidence in tomatoes by 50% (Gumede et al., 2025). The lower severity observed in fruits treated with C-EO5 can be attributed not only to direct inhibition of fungal growth and germination (as demonstrated in vitro) but also to the induction of defense mechanisms in the fruit, such as the activation of cell-wall-related enzymes (chitinases, glucanases) or the accumulation of phytoalexins, as suggested by Bautista et al. (2003) and more recent studies (Parente et al., 2025). Although the assay conditions differ, these results underscore the potential of essential oils as effective tools for anthracnose management.

Despite the efficacy demonstrated by the C-EO5 treatment, the residual severity of 42.7% indicates that there is still room for improvement. High doses of essential oils could increase control, but the possible effects on the sensory properties of mangos must be carefully evaluated, since high concentrations of essential oils may result in the transfer of unwanted odors or flavors. Furthermore, the stability of the coating during prolonged storage periods and its behavior under real commercial conditions require additional investigation.

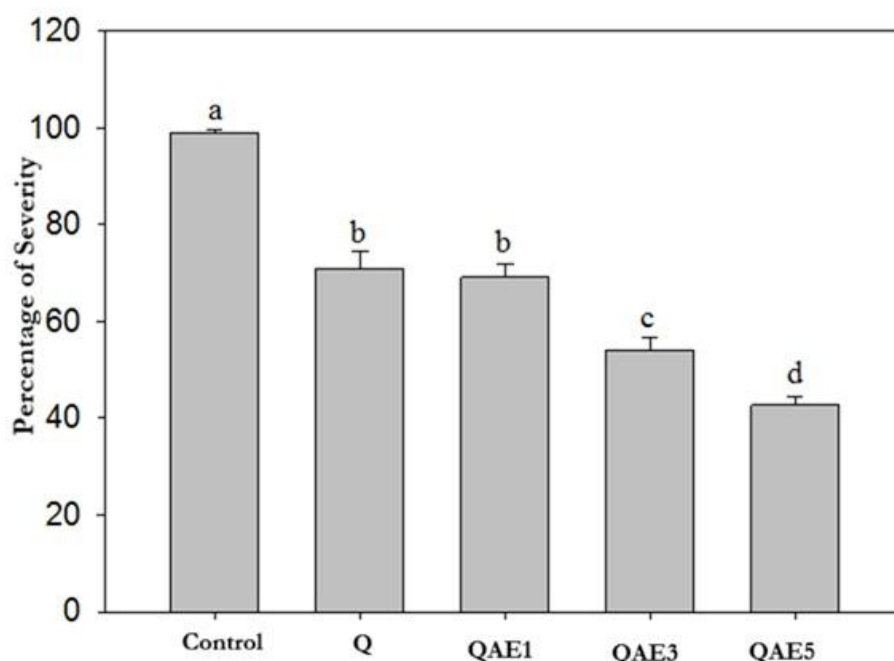


Figure 2. Percentage of anthracnose severity on mango fruits with chitosan and essential oil coatings. Data represent the mean $\pm$ standard deviation. Bars with the same letters are not significantly different ($n = 10$, $p \geq 0.05$). Q: 1% chitosan coating; QAE1: 1% chitosan coating + 1 mg mL⁻¹ essential oil; QAE3: 1% chitosan coating + 3 mg mL⁻¹ essential oil; QAE5: 1% chitosan coating + 5 mg mL⁻¹ essential oil.

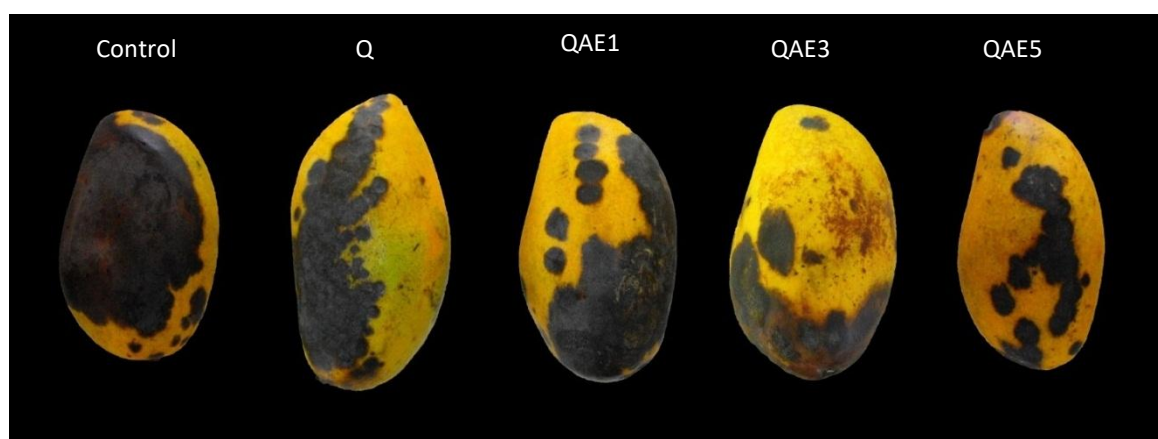


Figure 3. Expression and severity of anthracnose symptoms 18 days after inoculation in mangoes with chitosan and essential oil coatings, as determined by digital image analysis. Q: 1% chitosan coating; QAE1: 1% chitosan coating + 1 mg mL⁻¹ essential oil; QAE3: 1% chitosan coating + 3 mg mL⁻¹ essential oil; QAE5: 1% chitosan coating + 5 mg mL⁻¹ essential oil.

CONCLUSIONS

The essential oil of *Coriandrum sativum* L. leaves presents concentration dependent antifungal activity against *Colletotrichum gloeosporioides*, inhibiting mycelial growth, conidial germination and sporulation. Edible chitosan coatings at 1% enriched with 5 mg mL⁻¹ of this essential oil (C-EO5) significantly improved antifungal efficacy compared with chitosan alone, reducing anthracnose severity in mango by 56.8%. The correlation between in vitro germination inhibition and in vivo severity emphasizes the importance of evaluating early infection processes. This study provides a solid foundation for the development of a sustainable, safe and effective postharvest coating, with the potential to reduce the use of synthetic fungicides in the management of mango anthracnose.

ACKNOWLEDGEMENTS

The authors thank the International Network of Biotechnology and Innovative Strategies for Global Food Security for its institutional support and its contribution to the strengthening of scientific capabilities in this research.

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