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CONTROL OF ANTHRACNOSE (*Colletotrichum* sp.) IN POSTHARVEST MANGO FRUIT CV. HADEN WITH CHITOSAN AND POTASSIUM SORBATE

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Abstract: The objective of the study was to evaluate the effectiveness of chitosan and potassium sorbate in the control of anthracnose in postharvest mango fruit cv. Haden. The treatments evaluated were Chitosan at 1 %, Potassium Sorbate at 1.5, 2.5 and 3.5 %, and the combination of Chitosan plus the three concentrations of Potassium Sorbate; distilled water was used as a control treatment. The incidence and diameter of anthracnose lesions were evaluated 3, 6, 9 and 12 days after application of the treatments. A completely randomized experimental design with three replicates was used, three fruits were considered as replicates. Data were analyzed using the Kruskal-Wallis nonparametric test and comparison with the mean rank test. The incidence at 12 days was higher in the control (94.47 %) while the lowest averages were recorded in 2.5 % potassium sorbate and in combination with chitosan. The lesion diameter was higher in the control (20.83 mm) and the lowest values in 2.5 % potassium sorbate (without necrotic lesion) and 1 % chitosan plus 3.5 % sorbate (1.21 mm). These two treatments showed an effectiveness of 100 and 94 % of disease control with respect to the control. However, fruits treated with 1% chitosan and 3.5% potassium sorbate did not ripen normally, since they presented green skin. Potassium sorbate 2.5% can be an ecological alternative for the control of anthracnose in postharvest of mango cv. Haden.

Keywords: inhibition, severity, anthracnose, mango, Haden.

INTRODUCTION

Anthracnose is one of the diseases that causes the greatest losses in mango fruits during postharvest, and can affect up to 60 % of the yield ((Li *et al.*, 2019). This disease is caused by the fungus *Colletotrichum gloeosporioides* (Penz.) (Sharma and Kulshrestha, 2015). The disease occurs in two sequential phases, pathogenic and saprophytic, causing blackish spots on the surface of the fruits, sometimes limited only on the peel or even invading and darkening the pulp as well (Siddiqui and Ali, 2014).

Post-harvest control of anthracnose in mango is carried out with synthetic fungicides such as Benomyl, Pacloraz and Thiabendazole, among others (Chillet *et al.*, 2019). However, growing concern in international markets about the adverse effects of these products on human health and the environment has prompted the search for more environmentally friendly alternatives for disease management. These include hydrothermal treatment (Alvindia and Acda, 2015), low temperature storage (Dofuor *et al.*, 2023), use of organic coatings (Mulkay, 2017), antagonistic microorganisms (Zapata-Narvaez *et al.*, 2021), organic and inorganic salts (Dessalegn *et al.*, 2013), plant extracts (Alemu *et al.*, 2014), either individually or combining two of these options.

Among the widely accepted postharvest control alternatives is the use of chitosan and potassium sorbate. Both products have demonstrated an inhibitory effect of the disease on papaya and mango cv. Tommy Atkins fruits (Gutiérrez-Martínez *et al.*, 2017; Ferreira *et al.*, 2018). Based on the above, in the present study, the effects of different concentrations and combinations of Chitosan and Potassium Sorbate on the control of mango fruit anthracnose were evaluated.

MATERIALS AND METHODS

Mango fruit of the Haden variety were harvested in May 2023 in the town of Río Grande, Villa de Tututepec, Oaxaca. Fruits were selected according to uniformity of physiological maturity and size, and without the presence of physical damage or disease spots.

The pathogenic strain (6523) of *Colletotrichum* sp. used in this study was obtained from mango inflorescences with anthracnose symptoms collected in the municipality of Huehuetán, Chiapas. This strain was chosen because of its previous evaluation of pathogenicity and aggressiveness (unpublished data).

In the laboratory, the fruits were washed with running water and then disinfected with 1.0% sodium hypochlorite for 1 min. Subsequently, three rinses were performed with sterile distilled water and the fruits were dried with sterile sanitas. A pair of 2 mm deep wounds was made on the peel in the central part of each fruit with a sterile needle, with a distance of 4 cm between each point (Zapata-Narváez *et al*., 2021). A mycelial disc of 5 mm in diameter was placed over each wound. The inoculated fruits were placed inside plastic trays (50 x 35 x 35 x 15 cm) and incubated under humid chamber conditions (wet absorbent paper at the base) for 24 h. After incubation, the fruits were immersed for 1 min in a solution of the following treatments: Chitosan at 1 % concentration (Q1.0), Potassium Sorbate at concentrations of 1.5, 2.5 and 3.5 % (SP1.5, SP2.5 and SP3.5) and the combination of Chitosan with the concentrations of Potassium Sorbate (QSP1.5, QSP2.5 and QSP3.5). As a positive control treatment, wounded fruits inoculated with the fungus were used. Treated fruits were allowed to dry at room temperature for 2 h and stored at 25 °C for 12 days. The experimental design was completely randomized with three replicates, three fruits were considered as one replicate. After the storage period in each of the treatments, the incidence and severity of anthracnose was evaluated in each of the fruits. Incidence was determined at 3, 6, 9 and 12 days after the application of the treatments based on the number of fruits with development of anthracnose symptoms (at inoculation points) within each treatment, and then transformed into percentage values of incidence. Severity was determined by measuring the diameter of the lesion caused by anthracnose with a digital vernier.

The incidence and severity results were analyzed using the Kruskal-Wallis test and a comparison of average ranges ($P = 0.05$), because the errors were not normally distributed.

RESULTS AND DISCUSSION

The incidence of anthracnose on mango cv. Haden treated with the organic products was statistically different during the study period ($p<0.05$). At 3 days after the application of the treatments (ddat), the highest average range of incidence was recorded in the control treatment, while the lowest was recorded in 2.5% potassium sorbate (Table 1). After the sixth day, there were no changes in disease incidence. The positive control again showed the highest average range of incidence, while 2.5% potassium sorbate and chitosan plus 3.5% potassium sorbate showed the lowest values.

The lesion diameter caused by *Colletotrichum* sp. on mango fruit cv. Haden was different during the study period ($p<0.05$). The control treatment presented the largest lesion diameter at 3, 6 and 9 days, reaching 2.08 cm on day 12 of the study, while the lowest values were obtained with 2.5 % potassium sorbate and 1 % chitosan plus 2.5 and 3.5 % potassium sorbate (Table 2 and Figure 1). These three treatments showed an effectiveness of 100, 89 and 94 % of disease control with respect to the positive control. Coronado and Partida (2021) reported similar effects of the combined treatment of chitosan (1%) and potassium sor-

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Treatment	3 ddat		6-12 ddat	
	Media	RX	Media	RX
SP1.5	44.43	16.83 bc	72.20	18.33 bc
SP2.5	0	5.0 a	0	4.5 a
SP3.5	22.20	10.67 ab	22.20	9.83 b
Q1.0	50.00	17.67 bc	77.77	18.00 bc
QSP1.5	27.77	12.33 ac	50.03	13.83 ac
QSP2.5	11.10	7.83 ab	11.10	7.17 ab
QSP3.5	5.57	6.67 ab	5.57	6.17 a
Witness	91.67	23 c	94.47	22.17 c

Table 1. Incidence of anthracnose (%) on mango fruit cv. Haden treated with Chitosan, Potassium Sorbate alone and in combination, during twelve days of storage at 25 °C.

Ddat=days after application of treatments; RX=Range average; SP1.5, SP2.5 and SP3.5=Potassium Sorbate at 1.5, 2.5 and 3.5 %; Q1.0=Chitosan at 1.0 %; QSP1.5, QSP2.5 and QSP3.5= Chitosan at 1 % plus Potassium Sorbate at 1.5, 2.5 and 3.5 %; *Equal letters indicate that the means do not differ significantly at the 5 % level, according to non-parametric multiple comparisons.

Treatment	3 ddat		6 ddat		9 ddat		12 ddat	
	Media	RX	Media	RX	Media	RX	Media	RX
SP1.5	2.36	18.33 bc	6.42	18.33 cd	10.94	19.33 c	16.87	19.33 c
SP2.5	0	5.0 a	0	4.5 a	0	4.50 a	0	4.5 a
SP3.5	0.97	10.33 ab	1.99	9.5 ac	3.13	9.50 ac	4.75	9.83 ab
Q1.0	1.76	15.0 ac	5.01	17.0 bd	8.07	17.5 bc	12.90	17.50 bc
QSP1.5	0.98	11.0 ab	3.03	13.67 ad	4.88	13.33 ac	6.81	13.33 bc
QSP2.5	0.54	8.67 ab	0.99	7.0 ab	1.54	7.0 ab	2.09	6.67ab
QSP3.5	0.16	6.67 a	0.51	6.33 ab	0.82	6.33 ab	1.21	6.33 ab
Witness	4.69	22.00 c	8.36	21.33 d	11.83	20.33 c	20.83	20.33 c

Table 2. Anthracnose lesion diameter (mm) in mango cv.Haden fruit treated with Chitosan, Potassium Sorbate alone and in combination, during twelve days of storage at 25 °C.

Ddat=days after application of treatments; RX=Range average; SP1.5, SP2.5 and SP3.5=Potassium Sorbate at 1.5, 2.5 and 3.5 %; Q1.0=Chitosan at 1.0 %; QSP1.5, QSP2.5 and QSP3.5= Chitosan at 1 % plus Potassium Sorbate at 1.5, 2.5 and 3.5 %; *Equal letters indicate that the means do not differ significantly at the 5 % level, according to non-parametric multiple comparisons.

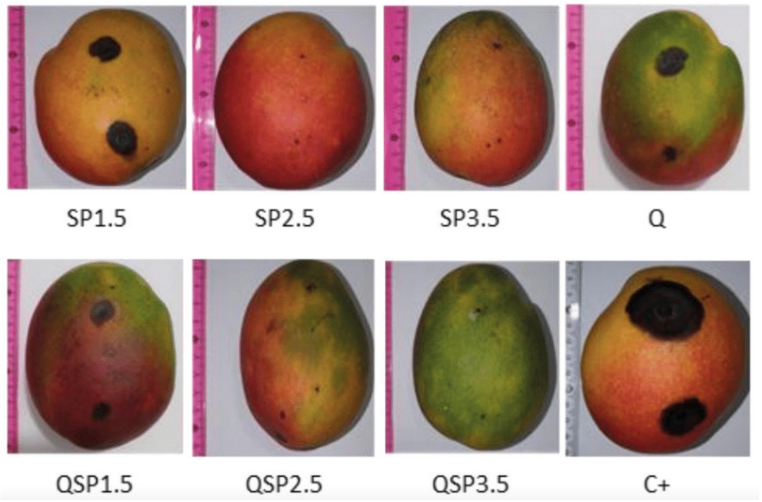

Figure 1. Anthracnose severity in mango fruit cv. Haden treated with chitosan and potassium sorbate alone and in combination, after 12 days of storage at 25 °C. SP1.5, SP2.5 and SP3.5=potassium sorbate at 1.5, 2.5 and 3.5 %; Q1.0=Chitosan at 1.0 %; QSP1.5, QSP2.5 and QSP3.5=Chitosan at 1 % plus potassium sorbate at 1.5, 2.5 and 3.5 %; and C+=Witness.

bate (1%), by inhibiting the germination of *Rhizopus stolonifer* spores and significantly reducing soft rot in jackfruit (*Artocarpus heterophyllus* L.) without damaging fruit quality.

At the end of the study, fruits treated with chitosan and chitosan with potassium sorbate did not show the characteristic coloration of commercial maturity, since their skin remained green (Figure 1); this effect of chitosan on mango fruit maturity was previously reported in fruits of the cultivar Nam Dok Mai treated with chitosan at 1.5 and 2.0 % (Pongphen *et al.*, 2007).

Anthracnose control using chitosan works in an inhibitory manner, since this product prevents mycelial growth of *C. gloeosporioides* (Berumen-Varela *et al.*, 2015). In papaya fruits, a 1.5 % concentration of Chitosan reduced sporulation by up to 70 % and completely inhibited conidial germination (López-Mora *et al.*, 2013). The inhibition is due to the free amino groups of Chitosan producing changes in cell permeability, ionic homeostatic cellular imbalances of K^+ and Ca^{2+} , causing hyphae to atrophy, deform and collapse (Peña *et al.*, 2013). Chitosan has also been shown to induce the production of Peroxidase enzymes, which through oxidation-reduction reactions involved in the process of defense and hypersensitivity against fungal attack (Zhu and Ma, 2007).

It is currently known that different potassium-based products, such as sorbate, reduce the turgor pressure of the fungi, causing collapse and contraction of the hyphae, thus inhibiting the growth and sporulation of *C. gloeosporioides* (Palmer *et al.*, 1997). The use of different salts together with edible coatings on different postharvest fruits has been one of the most useful methods for the control of anthracnose; however, the physicochemical and sensory attributes of the fruits are affected, the latter also depending on the specific characteristics of the postharvest products (Martínez-Blay *et al.*, 2020).

CONCLUSIONS

The 2.5% potassium sorbate treatment significantly reduces anthracnose without affecting the external appearance of mango cv. Haden fruit. This product can be an ecological alternative for the control of this anthracnose in postharvest.

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REFERENCES

Alemu, K., Ayalew, A., and Woldetsadik, K. (2014). Antifungal activity of plant extracts and their applicability in extending the shelf-life of mango fruits. *Food Sci. Qual. Manag.,* 33, 47-53.

Alvindia, D.G. and Acda, M. A. (2015). Revisiting the efficacy of hot water treatment in managing anthracnose and stem-end rot diseases of mango cv. 'Carabao. *Crop protection*, 67, 96-101. https://doi.org/10.1016/j.cropro.2014.09.016

Berumen-Varela, G., Coronado-Partida, L.D., Ochoa-Jiménez, V.A., Chacón-López, M.A., y Gutiérrez-Martínez, P. (2015). Efecto del quitosano en la inducción de resistencia contra *Colletotrichum* sp. en mango (*Mangifera indica* L.) cv. Tommy Atkins. *Investigación y Ciencia,* 23, 16-21. https://doi.org/10.33064/iycuaa2015663565

Chillet, M., Minier, J., Hoarau, M. and Meile, J.C. (2019). Potential use of thymol to control anthracnose development in mango. *Eur J Plant Pathol,* 155, 943–952. https://doi.org/10.1007/s10658-019-01825-9

Coronado-Partida, L. D., Gianfranco-Romanazzi, M.S., González-Estrada, R. R., and Gutiérrez-Martínez, P. (2021). Application of GRAS compounds to control soft rot in jackfruit (*Artocarpus heterophyllus* L.) caused by *Rhizopus stolonifera*. *TIP Revista Especializada en Ciencias Químico-Biológicas*, 24, 1-7. https://doi.org/10.22201/fesz.23958723e.2021.327

Dessalegn, Y., Ayalew, A., and Woldetsadik, K. (2013). Integratin plant defense inducing chemical, inorganic salt and hot water treatments for the management of postharvest mango anthracnose. *Posharvest Biology and Technology*, 85, 83-88. https://doi.org/10.1016/j.postharvbio.2013.05.003

Dofuor, A.K., Quartey, N.K-A., Osabutey, A.F., Antwi-Agyakwa, A.K., Asante, K., Boateng, B.O., Ablormeti, F.K., Lutuf, H., Osei-Owusu, J., Osei, J.H.N., Ekloh, W., Loh, S.K., Honger. J.O., Aidoo, O.F. and Ninsin, K.D. (2023). Mango anthracnose disease: the current situation and direction for future research. *Front. Microbiol*. 14, 1168203. doi: 10.3389/fmicb.2023.1168203.

Ferreira, E. M. S, Malta, C. M., Bicalho, J. O., and Pimenta, R. S. 2018. A safe method to control the anthracnose in papaya. *Revista Brasileira de Fruticultura,* 40(3), e-683. https://doi.org/10.1590/0100-29452018683

Gutiérrez-Martínez, P., Bautista-Baños, S., Berúmen-Varela, B., Ramos-Guerrero, A. and Hernández-Ibañez, A. B. (2017). *In vitro* response of *Colletotrichum* to chitosan. Effect on incidence and quality on tropical fruit. Enzymatic expression in mango. *Acta Agronómica*, 66(2), 282-289. https://doi.org/10.15446/acag.v66n2.53770

Landero-Valenzuela, N., Lara-Viveros, F.M., Andrade-Hoyos, P., Aguilar-Pérez, L.A., and Aguado, G.J. (2016). Alternativas para el control de *Colletotrichum* spp. *Revista Mexicana de Ciencias Agrícolas*, 75(5), 1189-1198. https://doi.org/10.29312/remexca.v7i5.245

Li, Q., Bu, J., Shu, J., Yu, Z., Tang, L., Huang, S., Guo, T., Mo, J., Luo, S., Solangi, G. S. & Hsiang T. (2019). Colletotrichum species associated with mango in southern China. *Sci. Rep.* 9, 18891. https://doi.org/10.1038/s41598-019-54809-4

López-Mora, L.I., Gutiérrez-Martínez, P., Bautista-Baños, S., Jiménez-García, L.F., and Zavaleta-Mancera, H.A. (2013). Evaluación de la actividad antifúngica del quitosano en *Alternaria alternata* y en la calidad del mango 'Tomy Atkins' durante el almacenamiento. *Revista Chapingo, Serie Horticultura*, 19, 315-331. https://doi.org/10.5154/r.rchsh.2012.07.038

Martínez-Blay V., Pérez-Gago, M.B., Fuente, B., Carbó, R., and Palou, L. (2020). Edible coatings formulated with antifungal GRAS salts to control citrus anthracnose caused by *Colletotrichum gloeosporioides* and preserve postharvest fruit quality. *Coatings*, 10, 1-19. https://doi.org/10.3390/coatings10080730

Mulkay, V.T. (2017). Effect of chitosan salts in post-harvest quality of mango 'Tommy Atkins'. *Cultivos Tropicales*, 38, 135-141.

Palmer, C.L., Horst, R.K., and Langhans, R.W. (1997). Use of bicarbonates to inhibit *in vitro* colony growth of *Botrytis cinerea*. *Plant Disease*, 81, 1432-1438.

Peña, A., Sánchez, N. S., and Calahorra, M. (2013). Effects of chitosan on *Candida albicans*: conditions for its antifungal activity. *BioMed Research International*, 1-15. DOI: 10.1155/2013/527549

Pongphen, J., Sudkanueng, P.Y., and Sirichai, K. (2007). Effect of chitosan on ripening enzymatic activity and disease development in mango (*Mangifera indica* L.) fruit, New Zealand. *Journal of Crop and Horticultural Science*, 35, 211-18. https://doi.org/10.1080/01140670709510187

Sharma, M., and Kulshrestha, S. (2015). *Colletotrichum gloeosporioides*: An anthracnose causing pathogen of fruits and vegetables. *Biosciences Biotechnology Research Asia*, 12(2), 1233-1246.

Siddiqui, Y., and Ali, A. (2014). *Colletotrichum gloeosporioides* (Ahthracnose). En S. Bautista-Baños, (Ed.), Postharvest Decay. Control strategies (pp. 337-371). Elsevier. https://doi.org/10.1016/B978-0-12-411552-1.00011-9

Zapata-Narváez, Y.A., Izquierdo-García, L.F., Botina-Azaín, B.L., y Beltrán-Acosta, C.R. (2021). Eficacia de antagonistas microbianos y quitina en el control de *Colletotrichum gloeosporioides* en poscosecha de mango cv. Azúcar. *Revista Mexicana de Fitopatología*, 39(2), 1-18. https://doi.org/10.18781/r.mex.fit.2102-1

Zhu, S.J., and Ma, B.C. (2007). Benzothiadiazole or methyl jasmonate induced resistance to *Colletotrichum musae* in harvested banana fruit is related to elevated defense enzyme activities. *Journal Horticultural Science and Biotecnology,* 82, 500-506. https://doi.org/10.1080/14620316.2007.11512265