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EFFECT OF ORGANIC AND INORGANIC PRODUCTS ON POSTHARVEST FRUIT HEALTH AND QUALITY OF MANGO CV. ATAULFO

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Abstract: Mango is a fruit that is highly consumed nationally and internationally; however, it is very susceptible to diseases during postharvest, such as anthracnose caused by the fungus *Colletortrichum gloeosporoides* Penz, which causes dark spots on the epidermis. Considering the above, an evaluation of the effectiveness of organic and inorganic products in the control of anthracnose and in the postharvest quality of Ataulfo mango fruits was carried out. Mango fruits at physiological maturity were harvested and treated for 1 min with products based on chitosan, potassium sorbate, hydrogen peroxide alone and combined in concentrations of 1 %, in addition to a commercial product: Exodusmax® and an absolute control. Some quality variables were evaluated during fruit ripening under a completely randomized design. The results indicated that the highest control effectiveness was with mango fruit treated with hydrogen peroxide, sodium bicarbonate, sodium sorbate, chitosan plus sodium bicarbonate, chitosan plus hydrogen peroxide and Exodusmax® (62.5, 62.5, 50.1, 62.5 and 74.9 %, respectively).
Keywords: severity, anthracnose, alternative products, quality.

INTRODUCTION

One of the most economically important diseases of mango is anthracnose, caused by the fungus *Colletotrichum gloeosporioides*. In postharvest, this disease appears as small rounded brown lesions with undefined edges and slightly sunken on the surface of the fruit, which increase in size with fruit maturity until they merge and in severe cases cover the entire surface (Gutiérrez-Martínez *et al*., 2017).

The control of anthracnose in postharvest mango fruits is done with synthetic fungicides; however, due to international market demands, this type of products have been discontinued because of the possible risks to health and the environment, as well as their toxic residues. As a consequence of the restriction of pesticide use, the market has currently proposed control alternatives such as hydrothermal treatment, use of inorganic salts, storage in controlled and modified atmospheres, biological control strategies, products of organic origin and plant extracts, among others (Gutiérrez-Martínez *et al*., 2017).

Within the products of organic origin, the use of chitosan has shown an inhibitory effect for disease development in postharvest mango fruit cv. Tommy Atkins (Gutiérrez-Martínez *et al*., 2017). However, there are reports that the effectiveness of some treatments is dependent on the pathogenic strain evaluated, the molecular weight of the product, the concentration evaluated, its degree of deacetylation and others (Bautista-Baños *et al*., 2006; Li *et al*., 2008). Other organic alternatives for anthracnose management is the use of sodium bicarbonate and potassium sorbate, since their use during postharvest of papaya (Ferreira *et al*., 2018) and tomato (Jabnoum-Khiareddine *et al*., 2016) have shown total control of the disease. As an inorganic alternative, the use of hydrogen peroxide is reported, as it has shown promising results in the laboratory for pathogen control (Apiradee, 2014).

The objective of this work was to evaluate the effectiveness of chitosan, potassium sorbate, sodium bicarbonate, hydrogen peroxide and chitosan combinations in the control of postharvest anthracnose of mango fruit cv. Ataulfo and fruit quality.

MATERIALS AND METHODS

Mango cv. Ataulfo fruits at physiological maturity were obtained from a commercial orchard in La Fonseca, Atoyac de Álvarez, Guerrero, Mexico, in August 2019, without the presence of anthracnose symptoms. These fruits were transported to the laboratory of research in management and integral production of product systems of the Escuela Superior de Ciencias Naturales at the Universidad Autónoma de Guerrero. The fruits were selected for similar size and degree of physiological maturity.

The fruits were then washed and disinfected with 1% sodium hypochlorite for 1 min, followed by triple rinsing with sterile water and dried with sanitas. The fruits were immersed for 1 min in nine treatments for anthracnose control: 1 % benomyl (BEN), 1 % chitosan (Q), 1 % hydrogen peroxide (PH), 1 % sodium bicarbonate (BS), 1 % potassium sorbate (SP), 1 % chitosan + 1 % sodium bicarbonate (Q+BS), chitosan 1 % + potassium sorbate 1 % (Q+SP), chitosan 1 % + hydrogen peroxide 1 % (Q+PH), Exodusmax® 1 % (EXO), plus a control with water immersion (control). Finally, the fruits were allowed to dry at room temperature and were stored at 25 °C for 10 days.

The experimental design was completely randomized with three replications. Health variables and some postharvest fruit quality parameters were evaluated.

Fruit health was measured at 10 days (d) with the scale proposed by Rebolledo et al. (2008): 0) no damage, 1) damage less than 15 %, 2) light damage, between 16 and 30 % of the peel affected; 3) medium damage, between 31 and 45 %, 4) heavy damage, between 46-60 % and 5) very heavy damage, with more than 61 % of the peel affected.

Likewise, some physicochemical variables were evaluated during fruit ripening (10 d), such as weight loss, which was obtained by weighing the fruit at the beginning and end of the study (10 d after the application of treatments) with an Ohaus® (Triple Beam TJ26II) granatary balance, and the results were expressed in grams.

The color of the epidermis was determined at three points located on the left side of the mango with a spectrophotometer (X-rite, Mod. SP60 series). The values obtained were lightness (L*) and the change in a* and b* parameters; the measurement was performed only once on each fruit.

Firmness was determined in the mesocarp or pulp with a penetrometer (Mod. FHT-803), adapted with a cylindrical punch of 8 mm diameter. The results were recorded in Newton ($N\ cm^{-2}$), the measurement was made in triplicate.

Total soluble solids were evaluated with a digital refractometer (HANNA INSTRUMENTS® model HI96801) by placing two drops of juice extracted from the fruit pulp; the results were expressed as brix degrees (°Brix). The measurements were made in triplicate.

To determine the pH, 10 g of pulp tissue were taken and liquefied with 50 mL of distilled water, then filtered and the pH was determined with a potentiometer (HANNA HI 207). With the same filtrate the titratable acidity was determined using an aliquot of 5 mL. The acid-base titration was carried out using 0.1 normal (N) sodium hydroxide (NaOH) as titrating solution and 0.5 of phenolphthalein as indicator, the following formula was used to express the variable: % Titratable acidity $=((G \times N \times \text{meq of acid})/M)\times 100$, where: G: volume in mL spent by the base; N: normality of the base; Meq: milliequivalents of the predominant acid in the acid sample (0.067); and M: grams or milliliters of sample in the aliquot.

Physical-chemical data were analyzed by analysis of variance and means comparison with Tukey's test, 0.05. Fruit health was analyzed with the Kruskall-Wallis test and the means comparison with the average range test, because the data did not present a normal distribution.

RESULTS AND DISCUSSION

The severity of anthracnose in fruits treated with organic and inorganic products alone or combined, was statistically different after 10 days of storage ($p<0.05$) (Table 1). The fruits of the control treatment (control) showed the highest anthracnose damage, while fruits treated with hydrogen peroxide, sodium bicarbonate, sodium sorbate, chitosan plus sodium bicarbonate, chitosan plus hydrogen peroxide and Exodusmax® showed the lowest severity values (effectiveness higher than 50 %).

The control activity of hydrogen peroxide behaves as an antimicrobial agent and activates the disease resistance reaction to pathogen infection, as reported in tomato (Malolepsza and Rózalska, 2005) . Whereas, sodium bicarbonate acts by modifying the pH of the pathogen growth environment, resulting in the inactivation of extracellular enzymes of the phytopathogen, an increase in osmotic stress and a reduction in cell turgor pressure; resulting in a collapse and shrinkage of hyphae (Gonzalez-Estrada *et al*., 2020). Potassium sorbate action is attributed in decreasing intracellular pH and ionization of acid molecules, thus affecting the development of the fungus (Gregori *et al*., 2008; Stanojevic *et al*., 2009). Whereas, chitosan presents free amino groups, which produce changes in cell permeability, cellular imbalances of ionic homeostasis K^+ and Ca^{2+} (Peña *et al*., 2013), leading to stunting, deformation and collapse of hyphae.

Ferrerira et al. (2018), reports total growth inhibition of the fungus *C. gloeosporioides* on papaya fruits when treated with 1 % sodium bicarbonate. In the present study, 1 % sodium bicarbonate contributed to reduce anthracnose severity by 63 %, which can be attributed to the pathogenic strain.

Coronado-Partida et al. (2021) reported the control of soft rot caused by *Rhizopus stolonifer* in yaka (*Artocarpus heterophyllus*) fruits with the use of 1% chitosan plus 1% potassium sorbate (without disease development). These positive results are similar to those obtained in the present work, with fruits of mango cv. Ataulfo, with degrees of severity lower than 15 % of the fruit surface.

Treatment	Severity	Average Range		Effectiveness (%)
Benomyl 1%.	1.33	32.17	ab	50.18
1% chitosan	1.67	35.17	ab	37.45
1% hydrogen peroxide	1.00	24.50	b	62.54
Sodium bicarbonate 1%.	1.00	24.50	b	62.54
Potassium sorbate 1%.	1.33	28.17	b	50.18
Chitosan 1% + Sodium bicarbonate 1%.	1.67	39.83	ab	37.45
Chitosan 1% + Potassium sorbate 1%.	1.00	24.50	b	62.54
Chitosan 1% + Hydrogen peroxide 1%.	0.67	17.50	b	74.90
Exodusmax 1%.	1.00	25.17	b	62.54
Control	2.67	53.50	a	-

Table 1. Anthracnose severity in mango fruit cv. Ataulfo treated with organic and inorganic products at 10 days after storage at 25 °C.

*Values with the same letter are not statistically different between treatments with the mean ranks test ($P<0.05$).

The treatments of the study influenced the weight loss of the fruits of mango cv. Ataulfo at 10 d of storage ($p<0.05$) (Figure 1a). Fruits treated with chitosan plus potassium sorbate had the lowest weight loss (9.1%), while control fruits (control) had the highest weight loss (10.9%).

With respect to brightness in Ataúlfo cv. fruits, there were no significant effects due to the effect of treatments (Table 1b).

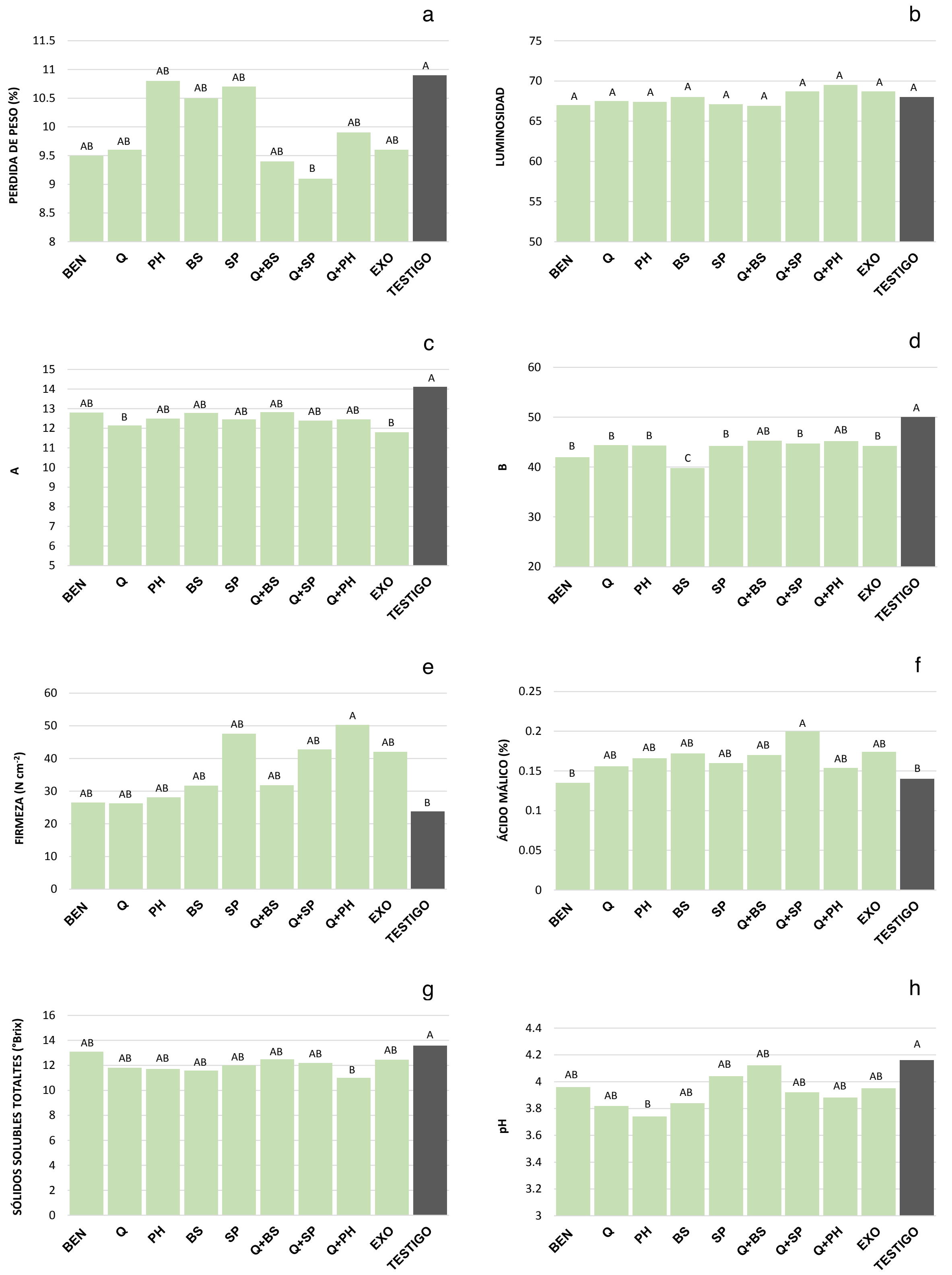

Figure 1. Effect of organic and inorganic products on some physicochemical characteristics of mango fruit cv. Ataulfo stored for 10 days at 25°C.

As for green to red (a*), fruits treated with Exodusmax® and chitosan showed slightly green coloration, which was different from the control (control), with orange-yellow coloration (Figure 1c). While, in blue to yellow (b*), fruits from benomyl, chitosan, hydrogen peroxide, potassium sorbate, chitosan + potassium sorbate, Exodusmax® and sodium bicarbonate treatments were different from the control treatment (control), showing less yellow color (Figure 1d).

Organic and inorganic coatings influenced fruit firmness ($p<0.05$) and showed statistical differences between treatments (Figure 1e). Fruit with chitosan and hydrogen peroxide showed higher firmness (50 N cm^{-2}), followed by potassium sorbate (48 N cm^{-2}), Exodusmax® (42 N cm^{-2}) and chitosan + potassium sorbate (43 N cm^{-2}); fruit with lower firmness were with benomyl (26 N cm^{-2}), chitosan (26 N cm^{-2}) and the control (23.8 N cm^{-2}).

The malic acid content was statistically different according to the treatments ($p<0.05$) (Figure 1f). Chitosan + potassium sorbate (0.2%) had the highest malic acid content, while the lowest percentages were determined in the benomyl treatment and the control (control).

According to the °Brix content, there were statistical differences between the averages of the treatments for the Ataulfo mango fruit (Figure 1g). The lowest Brix value was in fruits treated with chitosan + hydrogen peroxide (11%) and ripening was stopped, while the highest content was in the control fruits (control).

Fruit pH was higher in the control (4.18) and lower in the fruits treated with hydrogen peroxide (3.78); therefore, the rest of the treatments were similar to the control (Figure 1h).

CONCLUSIONS

Hydrogen peroxide, sodium bicarbonate, sodium sorbate, chitosan plus sodium bicarbonate, chitosan plus hydrogen peroxide and Exodusmax® contributed to lower postharvest anthracnose severity in mango cv. Ataulfo. These organic and inorganic products do not significantly affect postharvest quality compared to the control treatment. These organic and inorganic products can be added to other mango fruit postharvest practices for more efficient control.

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