Ozone in postharvest conservation and anthracnose control in palmer mango

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ABSTRACT

The objective of this study was to evaluate the efficiency of water-solubilized ozone, combined or not with different types of fungicides, in the control of anthracnose over 25 days of cold storage in 'Palmer' mango, as well as to evaluate the effects of this process on the postharvest quality of the fruits. 'Palmer' mango fruits harvested by hand from commercial orchards in Jaíba were used. The statistical design was completely randomized, in a 4 x 2 factorial, with the first factor being the treatments (T1: Control; T2: Ozonated water; T3: Ozonated water + 2.5 ml/L of Tebuconazole; T4: Ozonated water + 1 ml/L of thiabendazole) and the second factor two times of evaluations (0 and 25 days after storage in a closed chamber). Three replicates were used, with each replication consisting of 2 fruits. After assembling the treatments, the fruits were sent to the Postharvest Physiology laboratory of UNIMONTES, packed in polystyrene trays and stored in a cold chamber at 13°C with a relative humidity of 85% and evaluated for the incidence and severity of anthracnose, soluble solids, pH, titratable acidity, color, firmness and loss of fresh mass. Treatments 3 and 4 are efficient in the control of anthracnose in the postharvest of 'Palmer' mango fruits. The combinations of ozonated water and fungicides used did not influence the ripening of the fruits, except for the loss of fresh mass, which was lower in the treatment 3. The storage conditions contributed to the obtaining of quality fruits at the end of the 25 days of storage.

Keywords: *Mangifera indica* L., *Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc, Storage, Alternative treatment.

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INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most important tropical fruits, and is highly appreciated for its characteristic flavor, aroma and color. It is a climacteric fruit that is usually harvested in the ripe green phase, has bioactive compounds such as vitamin C, β-carotene and polyphenols that contribute to the nutritional characteristics (SINGH et al., 2013). Despite its great economic importance, part of the production is lost due to problems that occur after the harvest. Brazil produced more than 1.5 million tons in 2020, in approximately 73 thousand hectares and has great growth potential for both export and the domestic market (IBGE, 2021).

One of the major causes of losses of this fruit is its susceptibility to fungal diseases, such as anthracnose, caused by the fungus *Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc. Anthracnose is one of the main diseases that affect fruits after harvest, and can infect a wide range of hosts from flowering, which decreases their post-harvest quality. The symptoms manifest themselves in the form of dark colored and circular-shaped punctuations on the skin of the fruits, which evolve and can go beyond the skin and reach the pulp. In the hottest months of the year, its incidence can reach 70 to 100% of the fruits in the absence of control measures, causing serious losses, as it compromises the physicochemical quality and commercialization of the product.

To curb the symptoms of this disease, the use of synthetic products is recommended. There are many fungicides recommended in preventive applications for the chemical control of this fungus, such as Thiabendazole and Tebuconazole, with application varying according to the climatic conditions of the place, stage and development of the fruits and their commercialization. This fact is especially important when the production is destined for the foreign market, since importing countries have specific legislation regarding the quality and residues of chemical products in food.

In this context, the study and development of alternative methods of postharvest disease control is of utmost importance. Among the new technologies in pest control, ozone (O3) is an alternative to maintain the quality of fruits consumed *in natura*, as it is a strong oxidant with low residual power, being an alternative disinfectant method, free of toxic residues, used for sanitizing food, such as fruits and vegetables in general (GLOWACZ et al., 2014).

In view of the above, the objective of this study was to evaluate the efficiency of water-solubilized ozone, combined or not with different types of fungicides, in the control of anthracnose over 25 days of cold storage in 'Palmer' mango, as well as to evaluate the effects of this process on the postharvest quality of the fruits.

MATERIAL AND METHODS

The fruits were harvested manually from commercial orchards in Jaíba, Minas Gerais. All fruits were at stage 2 of maturation, which is characterized by having a yellow cream pulp color. The

fruits were washed with a neutral detergent at 2 mL/L, rinsed in drinking water and air-dried. The statistical design was completely randomized, in a 4 x 2 factorial, with the first factor being the treatments (T1: Control; T2: Ozonated water; T3: Ozonated water + 2.5 ml/L of Tebuconazole; T4: Ozonated water + 1 ml/L of thiabendazole) and the second factor two times of evaluations (0 and 25 days after storage in a closed chamber). Three replicates were used, with each replication consisting of 2 fruits.

Immediately after drying, all fruits, except those of the control treatment, were subjected to ozonated water bathing for about 10 minutes. The ozone gas was obtained through the ozone generator of the company Ozonfresh® and is generated by the passage of O_2 in an electrical discharge environment. The concentration used was 40g of O3/m3 of water. After the fruits were air-dried again, they were divided into batches corresponding to each treatment. Then, the doses of different fungicides were applied by immersion for 10 minutes. After assembling the treatments, the fruits were sent to the Postharvest Fruit Physiology Laboratory of the State University of Montes Claros, packed in polystyrene trays and stored in a cold chamber at 13°C with a relative humidity of 85%.

The fruits were evaluated for the incidence and severity of anthracnose. The incidence was obtained by the number of symptomatic fruits per repetition, and these values were expressed as percentages per treatment. Severity refers to the proportion of colonized tissue area, and its determination was performed with the aid of a specific diagrammatic scale for anthracnose in mangoes (CORKIDI et al., 2006), with disease severity ranging from 0 - 1% (no disease); 1 - 5% (mild disease); 6 - 9% (moderate disease); 10 - 49% (severe disease), and 50 - 100% (very severe disease) of the injured area/fruit.

The chemical characteristics evaluated were: a) soluble solids (°Brix): obtained by means of refractometry, using a digital refractometer Model N-3000E, Atago; b) pH: measured in PG1800 digital pH meter; c) titratable acidity (g Ac citric .100g of pulp-1): determined by the titration method with 0.1 M NaOH, with 1% phenolphthalein, where 10g of pulp was homogenized in 90 ml of distilled water and added three drops of phenolphthalein (1%) used as an indicator.

The analysis of the pulp color was performed using a Color Flex colorimeter model nº 45/0, with direct reflectance reading of the coordinates L* (luminosity), a* (red or green hue) and b* (yellow or blue hue), from the Hunterlab Universal Software system, measured in the median region of the fruit. From the values of a* and b*, the hue angle (°h*) and the chroma saturation index (C*) were calculated.

The firmness of the unpeeled fruits was evaluated using a penetrometer, measured in Newton (N). The loss of fresh mass (PMF) was determined by the difference between the initial mass of the

fruits and the mass obtained from the same fruits in each subsequent sampling period. The results were expressed as percentage (%) of fresh mass loss.

In addition to the above-mentioned evaluations, the fruits were weighed on a precision scale to determine the percentage of mass loss, which was determined by means of the difference in mass on the day of harvest and on the 25th day of storage, using the formula: PM (%) = ((Pi-Pj)/Pi) x 100, where: PM = mass loss (%); Pi = Initial weight of the fruit (g); Pj = Mass of the fruit in the period following Mi (g). The data obtained were submitted to analysis of variance, verifying the significance of the tested factors with subsequent developments for the significant interactions. For the treatments tested, Tukey's test was performed at 5% probability, using the SISVAR software (FERREIRA, 2015).

RESULTS AND DISCUSSION

A significant interaction was observed between the treatments tested and the two evaluation periods ($p>0.05$) for the variables severity and loss of fresh mass. For the other characteristics evaluated, a difference was found only for the factor time of evaluation ($p<0.05$).

At 25 days of storage, the treatments T3 (ozonated water + 2.5 ml/L of Tebuconazole) and T4 (ozonated water + 1 ml/L of thiabendazole) had the lowest rate of disease severity, 7 and 8%, respectively (Table 1). These treatments differed from the control treatment and the treatment with only ozonated water, which had an average of more than 60% of disease severity. The efficiency of the treatments in relation to the control indicated that the treatments using Tebuconazole and Thiabendazole proved to be more efficient in controlling the severity of anthracnose.

Kechinscki et al. (2012) used ozonated water at concentrations of 2 and 4 mg/L for the postharvest treatment of papayas, combining it with hydrothermal treatment and application of carnauba wax. They concluded that the isolated use of ozonated water at these concentrations and for periods of 1 to 2 minutes was not effective in controlling anthracnose. However, they observed that the effectiveness in disinfecting the fruits was achieved only in combined treatments, such as the combination of ozonated water with hydrothermal treatment. These results corroborate the present study, since the control of anthracnose was only achieved in the combined treatments between ozonated water and fungicides.

Table 1. Severity of anthracnose in 'Palmer' mango fruits submitted to different treatments to control the disease.

Treatments	Days of Storage	
	0	25
Witness	0 bA	66 b.a.
Ozonated water	0 bA	60 b.a.
Ozonated water + 2.5 ml/L Tebuconazole	0 aA	7 aB
Ozonated water + 1 ml/L of Thiabendazole	0 aA	8 aB
CV (%)		50,9

Note: Means followed by the same letter, lowercase in the row, and uppercase in the column, do not differ from each other by Tukey's test at 5% significance

Source: authors

When analyzing the incidence of the disease, we observed that there was no significant difference between the treatments tested, only for the evaluation periods (Table 2). This is due to the generalization of this analysis, since only the presence or absence of symptoms is identified, instead of their intensity being assessed. The quantification of diseases (incidence and/or severity) is necessary both to describe the progress of the epidemic and to design management strategies that allow the rational use of available resources (SILVA; JESUS JUNIOR, 2000).

Table 2. Incidence of anthracnose in 'Palmer' mango fruits submitted to different treatments for anthracnose control.

Evaluated Characteristics	Days of Storage	
	0	25
Incidence (%)	0 b	66 to
CV (%)	43,3	

Note: Means followed by the same letter, lowercase in the line, do not differ from each other by the F test at 5% significance

Source: authors

There was an increase in the solids content during the storage period and there was no effect of the treatments under this variable. Initially, the fruits had a content of 6.88 °Brix and when they left cold storage, at 25 days, they presented an average content of 12.41 °Brix (Table 3). This increase may be related to the accumulation of reserve carbohydrates in the fruits during plant development, which undergo hydrolysis with ripening and result in the formation of soluble sugars (LIZADA, 2012).

Regarding pH, an increase of 0.21 was observed in the pH value from day 0 to day 25 (Table 3). Consequently, the storage period reduced the titratable acidity on the 25th day, which was also significant only for the storage days (Table 3). During the ripening of the mango, there is a reduction in acidity, this occurs due to the reduction in the content of citric acid, which corresponds to the most abundant organic acid in this fruit (NOGUEIRA et al., 2015). Titratable acidity can be used as a

reference point for the degree of ripeness of the fruits, which is mainly attributed to the organic acids that are dissolved in the vacuoles of the cells (CHITARRA; CHITARRA, 2005).

Table 3. Chemical characteristics of 'Palmer' mango fruits submitted to different treatments in the control of anthracnose.

Evaluated Characteristics	**Days of Storage**		CV (%)
	0	25	
Soluble Solids (°Brix)	6,88 b	12,41a	11,49
Ph	3,30 b	3,51a	4,73
Titratable acidity (g ac. Citrus/100g pulp-1)	0,92 a	0,80 b	13,6

Note: Means followed by the same letter, lowercase in the line, do not differ from each other by the f-test at 5% significance

Source: authors

A decrease in luminosity and color angle (°Hue) and an increase in chromaticity (Table 4) were observed during the storage period. Changes in pulp color variables are the most evident indicators of ripening. The luminosity represents the brightness of the sample, that is, whether the yellow color of the pulp of the fruit studied is lighter or darker (CRUZ, 2010). The decrease in the values of luminosity (L*) and °Hue observed in the fruits in relation to the first day (day 0) and the last day (day 25) of storage, regardless of the technique used, indicated that there was a development from cream to yellow-orange color (Table 4).

The Hue angle represents the shade of the sample evaluated. According to the CIE L* a* b* system, graphically, the angle 0º is considered red, 90º yellow, 180º green and 270º blue (FERREIRA; SPRICIGO, 2017). In the study of mango pulp, the focus was on the variation of the intense yellow color (90°). The values of the color angle (°Hue) obtained were close to 90° until the 20th day, indicating that the color of the fruit pulp varied from cream to yellow during this period for all the preservation techniques employed.

An increase in chromaticity values was also observed during the days of storage, which characterizes an increase in the intensity of the yellow color. According to Ferreira and Spricigo (2017), as chroma increases, the saturation of colors perceived by humans also increases. This is probably due to the change in the color of the pulp, caused by the process of chlorophyll degradation and carotenoid synthesis in the fruit, as pointed out by Ebrahimi and Rastegar (2020).

Table 4. Luminosity, Chromaticity and Hue Angle of 'Palmer' mango fruit pulp submitted to different treatments to control Anthracnose.

Evaluated Characteristics	Days of Storage		CV (%)
	0	25	
Luminosity	84,58 a	80,83 b	1,61
Chromaticity	39,56 b	49,86 a	7,22
Hue	95,21 a	90,96 b	1,67

Note: Means followed by the same letter, lowercase in the line, do not differ from each other by the f-test at 5% significance

Source: authors

The firmness of the mangoes decreased with the storage period (Table 5). The firmness of the fruits at the time of the experiment was 90.16 N, while after 25 days of storage, this value decreased to 48.81 N, representing a decrease of about 40%. This reduction is comparatively lower than that observed by Guimarães et al. (2017), who, under refrigeration conditions at 12 ºC for 12 days, followed by three days at 25 ºC, found an average firmness below 30 N on the 15th day. These results indicate that the storage conditions adopted ensured a lower loss of firmness in the pulp of 'Palmer' mango fruits.

Table 5. Firmness of 'Palmer' mango fruits submitted to different treatments in the control of Anthracnose.

Evaluated Trait	Days of Storage	
	0	25
Firmness (N)	90,16 a	48,81b
CV (%)	19,53	

Note: Means followed by the same letter, lowercase in the line, do not differ from each other by the F test at 5% significance

Source: authors

For the variable fresh mass loss, it was observed that at 25 days of storage, treatment 3 (ozonated water + 2.5 ml/L of Tebuconazole) presented the lowest percentage of mass loss when compared to the other treatments (Table 3). Lima et al. (2007) found in mangoes cv. An average loss of fresh mass of 15% at the end of 12 days was observed under cold storage, a result higher than that found in the present study. According to Chitarra and Chitarra (2005), mass loss is directly linked to water reduction. The loss of water from fruits during the storage period is mainly due to transpiration (MAGUIRE et al, 2000).

Table 6. Loss of Fresh Mass of 'Palmer' mangoes submitted to different treatments in the control of Anthracnose.

Treatments	Days of Storage	
	0	25
Witness	0 bA	3,64 aA
Ozonated water	0 bA	3,62 aA
Ozonated water + 2.5 ml/L Tebuconazole	0 bA	2.94 aB
Ozonated water + 1 ml/L of Thiabendazole	0 bA	3.34 aA
CV (%)		8,22

Note: Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ from each other by Tukey's test at 5% significance.

Source: authors

CONCLUSIONS

The combinations of ozonated water + 2.5 ml/L of Tebuconazole and ozonated water + 1 ml/L of Thiabendazole are efficient in the control of anthracnose in the postharvest of 'Palmer' mango fruits. The combinations of ozonated water and fungicides used did not influence the ripening of the fruits, except for the loss of fresh mass, which was lower in the use of ozonated water + 2.5 ml/L of Tebuconazole. The storage conditions contributed to the obtaining of quality fruits at the end of the 25 days of storage

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