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Preharvest Applications of Aminoethoxivinylglycine in *Mangifera indica* L. "Ataulfo" Variety in Two Contrasting Environments

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Abstract: *Mangifera indica* var Ataulfo is the main variety grown in the Soconusco region of Chiapas, Mexico and faces a decrease in firmness and weight loss due to hydrothermal treatment, in addition to non-uniform ripening and consequently a decrease in price as the harvest period lengthens. In order to improve the postharvest quality of the "Ataulfo" mango fruit, preharvest applications of aminoethoxyvinylglycine (AVG; ReTain®, a.i. 15%) were carried out in "La Norteña" with Phaeozem soil, 1500 mm of annual precipitation, and applications of agrochemicals, and in "Santa Cecilia" with Acrisol soil, 2500 mm of annual precipitation, and without agrochemicals. The treatments were: (1) Control, (2) One application 7 days before harvest (0.1 g L^{-1}), (3) Two applications (14 days and 7 days before harvest, 0.2 g L^{-1}) and (4) Three applications (21, 14 and 7 days before harvest, in total 0.3 g L^{-1}), with completely randomized design in the laboratory. The results show contrasting differences between the evaluation sites, with lower weight loss (18.4%) and 3.1% more firmness in a drier climate and higher soil calcium content. The average firmness (N) on day 14 was 18.3 and with three applications of AVG it was 22.0. The °Brix at the end of the study in the control was 11.3 and on average with AVG applications it was 14.4. Three-time applications of AVG in preharvest delayed the weight loss with an increase in the maintenance of the firmness of the fruits. The weight of the fruit epidermis was lower with AVG applications, and increased with the number of applications.

Keywords: fruit quality; firmness; weight loss; total soluble solids

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1. Introduction

In Mexico, the cultivated area with different varieties and types of mango is 204,642 ha, distributed in the humid and sub-humid tropics [1], and represents an important source of income and job creation for the population. "Ataulfo" is the main variety established in the Soconusco region of Chiapas, the region where it was developed [2] and has a designation of origin [3].

This southeast region of Mexico is where the normal production and commercialization of the mango begins annually, generally in the month of January, and this situation favors its sale at a better price [2]. However, the ripening of the fruit is not uniform, and several harvests are required per season with a decrease in the sale price. In addition to the above, before leaving the consumption centers, inside or outside the country, the fruit is subjected to hydrothermal treatment and in this procedure the fruits lose more than 50% of their firmness [4]. Aminoethoxyvinylglycine (AVG) is an inhibitor of ethylene biosynthesis and

consequently the ripening and fall of fruit [5], and some producers apply it to improve quality and induce uniformity in the harvest.

Given this situation, the pre-harvest application of aminoethoxyvinylglycine (AVG) is considered as an alternative to improve the commercial potential of climacteric fruits by inhibiting the ethylene biosynthesis, which is necessary to carry out the fruit ripening process [6].

It also influences the reduction of fruit drop [7], the improvement of the total yield [8], and the maintenance of fruit quality in apricots [9], apples [10], sweet cherries [11], and pears [12]; the response of different cultivars can vary significantly [13] and also depends on the dose applied [14].

Aminoethoxyvinylglycine has been applied to "Braeburn" apples in concentrations of 100 to 300 mgL^{-1} 4 weeks before harvest, and the fruits showed an increase in firmness of 4.37% compared to the control fruit [15]. In some fruits it does not change the Hue angle, but the apple variety cv. Jersey Mac with an application of 250 mg L^{-1} maintained the luminosity (L*), chroma (C*), and Hue angle at 18 and 23% with respect to the control [16]. In *Coffea arabica* var. Castillo Paraguaicito the application of AVG increased the ripeness of the fruits by 12.8% and decreased the fall by 10% and 27% in the first and second harvest with respect to the control treatment [17]. AVG has not been applied to mangoes.

Therefore, in order to improve the postharvest quality of "Ataulfo" mango fruit, preharvest applications of aminoethoxyvinylglycine (AVG) were carried out under two contrasting environments and management in Soconusco, Chiapas, Mexico.

2. Materials and Methods

2.1. Study Area Locations

The research was carried out in two "Ataulfo" mango orchards in the Soconusco region of Chiapas, Mexico—the first in "La Norteña" of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), located at 14°45′36.8″ NL and 92°23′4.61″ WL at 22 m a.s.l.; and the second in "Santa Cecilia" commercial orchard, located at 15°03′12.4″ NL, 92°20′60″ WL and 311 m a.s.l.

2.2. Edaphoclimatic Conditions and Agricultural Management

"La Norteña" has an Aw_2 (w") ig climate, with 1200 to 1500 mm of annual precipitation distributed from June to November, minimum, average, and maximum temperatures of 20, 28, and 39 °C, and relative humidity 68% [18]. Phaeozem soil analysis revealed the following characteristics: loamy-clay texture (Bayoucus) with O.M. 1.9%, (Walkley–Black), E.C. 0.07 (Dsm^{-1} a 25 °C), pH 6.53 (1:2 H_2O), NO_3^- 12.0 (mg kg^{-1}), NH_4^+ 14 (mg kg^{-1}), P 13 (mg kg^{-1} Olsen), Fe^{2+} 21.9 (mg kg^{-1}), Mn^{2+} 19.8 (mg kg^{-1}), Zn^{2+} 9.1 (mg kg^{-1}), B 6.1 (mg kg^{-1}), K^+ int. 289 (mg kg^{-1}), Ca^{2+} 2863 (mg kg^{-1}), and Mg^{2+} 185 (mg kg^{-1}). The "Ataulfo" mango plantation was 18 years old at the time of the study with a planting distance of 15 × 15 m. The plantation management is based on the application of agricultural inputs such as synthetic chemical fertilizers (Urea 46% N) applied to the soil and Potassium Nitrate (KNO_3) (22.5_N-0_P-52_K) as a flowering inducer applied to the foliage in mid-October. In addition, fungicide (Trifloxystrobin) is applied at the beginning of flowering. Weed control is carried out with agricultural machinery and tree pruning is performed after harvest between March and April.

In "Santa Cecilia" the climate is Am (w") ig with 2000 to 3000 mm of annual precipitation, and minimum, average, and maximum temperatures of 22, 28, and 35 °C and relative humidity 76% [18]. The Acrisol soil analysis presented the following characteristics: loamy-clay texture (Bayoucus), O.M: 3.4% (Walkley–Black), E. C. 0.07 (Dsm^{-1} a 25 °C), pH 6.12 (1:2 water), NO_3^- 3.16 (mg kg^{-1}), P 1.72 (mg kg^{-1} Bray), Fe^{2+} 22.9 (mg kg^{-1}), Mn^{2+} 13.4 (mg kg^{-1}), Zn^{2+} 0.1 (mg kg^{-1}), B 0.1 (mg kg^{-1}), K^+ int. 58.7 (mg kg^{-1}), Ca^{2+} 397 (mg kg^{-1}), and Mg^{2+} 98.3 (mg kg^{-1}) and an apparent density of 1.03 (g cm^3).

The plantation is 21 years old and has a distance between plants of 20 × 20 m plus one in the center in "cinco de oros". The plant cover is planted with *Pueraria phaseoloides* (Roxb.)

Benth. and *Calathea lutea* (Aubl.) E.Mey. ex Schult., and intercropped with *Theobroma cacao* L., *Ananas comosus* L. Merr., and *Cedrela odorata* L. The cultivation is temporary, chemical fertilizers or herbicides are not applied, and agricultural practices are with a machete and by hand after harvest.

2.3. Experiment Setup and Aminoethoxyvinylglycine Application

On both sites, for the establishment of the experiment and application of aminoethoxyvinylglycine, eight trees were selected (two per treatment) according to the previous year's yield record, which was 5.4 tons or 105 kg.tree^{-1}.

AVG (ReTain®, i.a. 15%) (Valent BioSciences® Corporation, Libertyville, IL, USA) 0.1378 mM dose (0.1 g.L^{-1} de ReTain®) was applied at a 0.1378 mM dose (0.1 g.L^{-1} de ReTain®). The treatments for both sites were:

(1) Control
(2) One application 7 days before harvest (0.1 g L^{-1})
(3) Two applications (14 days and 7 days before harvest, in a total of 0.2 g L^{-1})
(4) Three applications (21, 14, and 7 days before harvest, in a total of 0.3 g L^{-1}).

In La Norteña, the first application was on 29 January and in Santa Cecilia on 8 March, both in 2020. Four treatments were applied considering one tree as an experimental unit. Each tree was divided in four equal parts according to the cardinal points and each quadrant received the corresponding treatment clockwise. To make the applications, fruits of 9 ± 1 cm in length were taken as reference. Treatments were applied in the morning from 7:00 to 9:00 a.m. with a 20 L. motor sprayer (Stihl, SR200, Waiblingen, Germany) until the trees were soaked to dripping point. The sprayed area was protected with plastic film to avoid spraying other parts of the tree.

2.4. Biological Material and Variables

Nine fruits per treatment were harvested per site, and treatment was given on each of the four sampling dates (36 fruits per treatment) in a state of physiological maturity when they showed changes in the color of the epidermis from dark green to light green and yellow. This change occurred 99 days after flowering in La Norteña and 112 days in Santa Cecilia. They were then washed with distilled water. Weight loss (g) was performed at 0 (harvest), 2, 6, 10, and 14 days of postharvest storage and was calculated as the percentage of the initial weight loss on a digital scale (Ohaus® Adventurer™ Pro, Parsippany, NJ, USA) at 25 ± 3 °C.

Sixty-three fruits were used for the evaluation of the epicarp firmness with a texturometer (Chatillon Model FDV-30, Greenwich, CT, USA) expressed in Newtons (N), pH (potentiometer, Thermo Orion, Model 230A, Beverly, MA, USA), °Brix (ATAGO, Model Pallete PR-32αUSA, Bellevue, WA, USA: 0–32%), titratable acidity (expressed as % citric acid). With the previous data, the °Brix/acidity relationship was calculated, which represents the maturity index in fruits and the °Brix/acidity ratio, an index of maturity. Additionally, the mass of the epidermis, pulp, and seed was determined after 2 and 14 days of storage.

2.5. Statistical Analysis

The data were analyzed with the SAS software ver. 9.0 [19], and a factor analysis of variance 2 × 4 (ANOVA) was carried out for all the parameters evaluated. When the ANOVA was significant, the parameters were compared by a Tukey test ($p < 0.05$). The data, expressed in percentages, were transformed by the formula arc.sin, before the ANOVA.

3. Results

3.1. Weight Loss

The contrasting climate and soil conditions between the study sites induced differences in fruit weight loss (Table 1). In La Norteña there was less weight loss in relation to the fruits produced in Santa Cecilia. In general, the control lost more weight compared to

AVG applications and between applications was the treatment with a single application of 0.1 g L^{-1}.

Table 1. Effect of aminoethoxyvinylglycine on weight loss (%) of *Mangifera indica* L. cv. Ataulfo grown in two contrasting environments and agronomic management in Soconusco, Chiapas, Mexico.

Sites			Treatments (g L^{-1})				
Days *	**La Norteña**	**Santa Cecilia**	**Control**	**0.1**	**0.2**	**0.3**	***** CV (%)**
2	98.5 ± 0.2 a **	97.6 ± 0.4 a	98.1 ± 0.4 a	95.7 ± 1.3 a	98.5 ± 0.1 a	98.3 ± 0.4 a	4.8
6	92.6 ± 0.3 a	91.6 ± 0.8 a	90.9 ± 0.8 b	91.6 ± 1.7 a	92.2 ± 1.4 a	92.5 ± 0.5 a	6.3
10	87.8 ± 0.5 a	84.8 ± 0.9 b	85.1 ± 0.5 a	85.3 ± 1.0 a	86.2 ± 1.0 a	87.9 ± 0.3 a	6.8
14	81.0 ± 0.6 a	80.9.1 ± 0.7 a	81.0 ± 1.1 b	85.6 ± 1.7 ab	78.8 ± 1.7 ab	86.1 ± 1.8 a	5.3

* Storage days at 25 ± 3 °C. ** Values with a different letter within each factor and lines are statistically different (Tukey $p \leq 0.05$). *** CV = Coefficient of variation (%).

3.2. Physiological Components of the Fruit

Between sites there is a contrasting difference between the days of storage. The mango epidermis at 14 days in La Norteña presented the highest value and was statistically different from that of the Santa Cecilia mangoes. Between treatments, the epidermis presented an increase of 37% on average when AVG was applied in relation to the control after two days of storage, and after 14 days, the value was 25% (Table 2).

Table 2. Comparison of means of epidermis, seed, pulp, and pulp/seed ratio of "Ataulfo" mango treated in preharvest with different applications of AVG on two sites with contrasting environments and agronomic management in Soconusco, Chiapas, Mexico.

Variables (%)	Sites			Treatments (g L^{-1})				*** CV(%)
	Days *	**La Norteña**	**Santa Cecilia**	**Control**	**0.1 g**	**0.2 g**	**0.3 g**	
Epidermis	2	6.0 ± 0.2 a **	6.1 ± 0.3 a	4.7 ± 0.1 c	6.1 ± 0.2 b	6.1 ± 0.3 b	7.4 ± 0.4 a	11.9
	14	17.9 ± 0.6 a	11.7 ± 0.6 b	11.7 ± 1.1 c	13.6 ± 1.3 bc	16.1 ± 0.5 a	14.6 ± 1.9 ab	11.8
Seed	2	8.2 ± 0.3 a	8.9 ± 0.1 a	8.5 ± 0.4 a	8.1 ± 0.2 a	9.1 ± 0.4 a	8.7 ± 0.2 a	12.0
	14	10.0 ± 0.6 a	9.4 ± 0.4 a	9.9 ± 0.8 a	9.2 ± 0.6 a	9.4 ± 0.5 a	10.1 ± 0.7 a	21.4
Pulp	2	85.6 ± 0.4 a	84.8 ± 0.3 a	86.8 ± 0.4 a	85.7 ± 0.3 ab	84.7 ± 0.6 bc	83.8 ± 0.4 c	2.5
	14	72.0 ± 0.6 b	78.7 ± 0.6 a	78.2 ± 1.5 a	77.1 ± 1.4 ab	74.4 ± 0.8 b	75.1 ± 1.9 ab	4.2
Pulp/seed ratio	2	10.6 ± 0.4 a	9.4 ± 0.2 a	10.5 ± 0.6 a	9.8 ± 0.3 a	8.7 ± 0.6 b	10.7 ± 0.2 a	14.1
	14	7.5 ± 0.6 b	8.7 ± 0.5 a	9.3 ± 1.3 a	11.1 ± 0.8 a	8.1 ± 0.5 b	7.5 ± 0.7 b	32.3

* Storage at 25 ± 3 °C. ** Values with a different letter within each factor in a row are statistically different (Tukey $p \leq 0.05$). *** CV = Coefficient of variation (%). AVG aminoethoxyvinylglycine.

In the case of the mango seed in the evaluation sites, there was no statistical difference between evaluation sites, treatments, or days of storage.

The pulp of the fruits was higher in Santa Cecilia ($p \leq 0.05$) in comparation with La Norteña. Between treatments the highest value after two days of storage was in the control and with an application of 0.1 g L^{-1} of AVG and was statistically different from the other treatments ($p \leq 0.05$). The lowest value was presented with the treatments of 0.2 and 0.3 g L^{-1} of AVG.

3.3. Firmness

The firmness of the "Ataulfo" fruits between localities presented statistical differences, ($p \leq 0.05$) on days 2, 10, and 14 of evaluation, and the greatest increase in firmness occurred in La Norteña. On this site, treatments with three AVG applications maintained 12% and 30% higher firmness at 10 and 14 d compared to the control fruits (Figure 1). In La Norteña, more firmness was found in the control fruits from days 6, 10, and 14 with a statistically significant difference ($p \leq 0.05$). In the treatment where 0.1 and 0.2 g L^{-1} of AVG were applied, greater firmness was found in the Santa Cecilia mangoes during the initial days, that is, at 2 and 6 days. On the other hand, with the treatment with the highest application

of AVG (0.3 g L^{-1}), the mangoes of La Norteña presented greater firmness during the evaluation periods and were statistically different from the fruits of Santa Cecilia. These results suggest different applications of AVG in both environments.

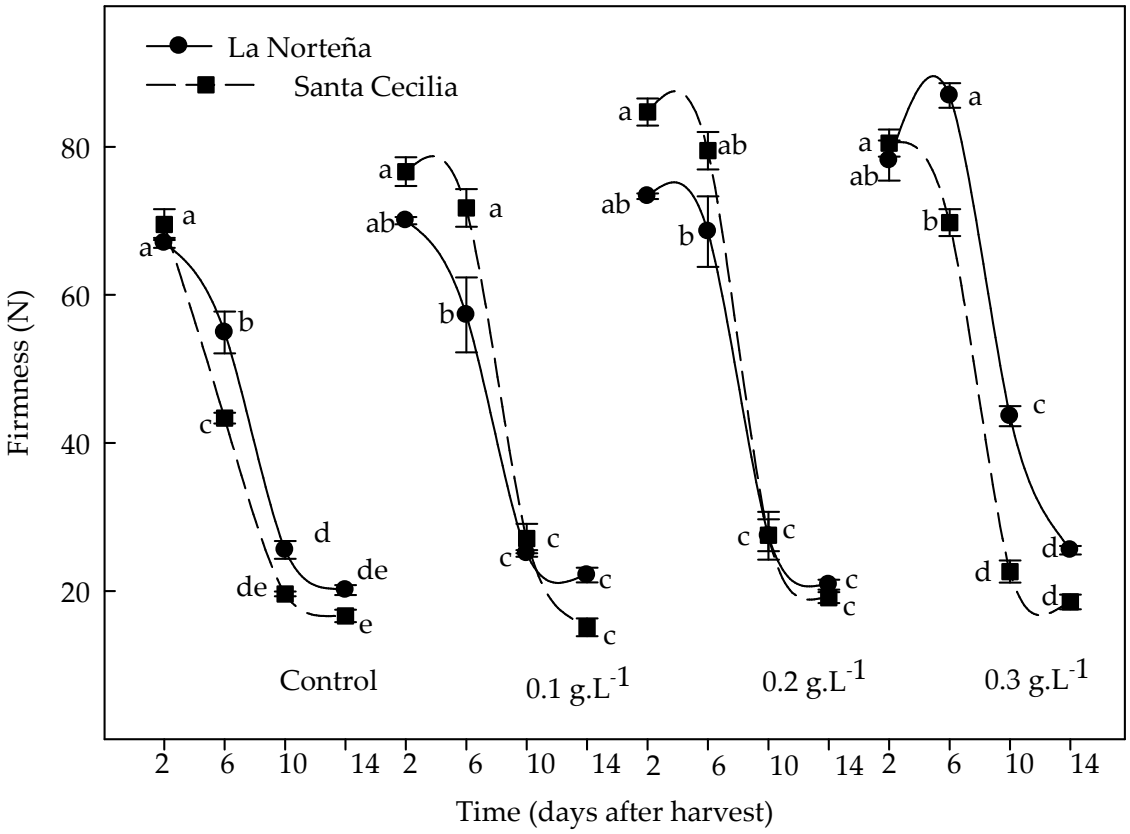

Figure 1. The changes of fruit firmness (N) of "Ataulfo" mangoes treated with AVG in preharvest on two sites with contrasting environments in Soconusco, Chiapas, Mexico and storage for 14 days after harvest at 25 ± 3 °C. The different letters in each line are statistically different ($p \leq 0.05$). The vertical line indicates ± the standard error of five repetitions.

3.4. Biochemical Variables

Between evaluation sites, the pH of the fruits in La Norteña were less acidic at 2, 6, and 10 days of storage compared to the fruits in Santa Cecilia, and were statistically different ($p \leq 0.05$) except for at 14 days (Table 3).

Between treatments, the pH of the fruits treated with AVG decreased more compared to the control at 2, 6, and 10 days of storage. Between applications, the decrease was higher as the dose of AVG was increased with statistical differences between them ($p \leq 0.05$).

The °Brix of the fruits increased at 2 and 6 days of storage in Santa Cecilia and in La Norteña at 10 and 14 days with significant statistical differences ($p \leq 0.05$). Between treatments, the °Brix presented contrasting values during the days of storage. On day 2, the values increased as AVG applications were increased, but in the other samplings, they decreased when increasing the dose of AVG.

The titratable acidity (TA) of the fruits between the evaluation sites was higher, and statistically different ($p \leq 0.05$), in Santa Cecilia at 2, 6, and 10 days of storage compared to La Norteña. On day 14 the opposite occurred and the increase was recorded with the increase in AVG applications. Between treatments it increased when applying AVG compared to the control during days 2, 6, and 10 of storage. At day 14, it increased in the control and decreased in the AVG treatments.

Table 3. Comparisons of means of the organoleptic characteristics of "Ataulfo" mangoes treated with AVG in two sites with contrasting environments and agronomic management in Soconusco, Chiapas, Mexico.

Variable (%)	* Days	Sites		Treatments (g L^{-1})				*** CV %
		La Norteña	Santa Cecilia	Control	0.1 g	0.2 g	0.3 g	
pH	2	3.0 ± 0.05 a **	2.5 ± 0.01 b	2.9 ± 0.1 a	2.7 ± 0.09 b	2.7 ± 0.06 b	2.7 ± 0.04 b	2.8
	6	3.3 ± 0.6 a	2.8 ± 0.03 b	3.2 ± 0.08 b	3.1 ± 0.5 b	3.0 ± 0.1 bc	2.9 ± 0.02 c	4.3
	10	4.0 ± 0.9 a	3.7 ± 0.1 b	4.6 ± 0.6 a	4.0 ± 0.2 b	3.8 ± 0.2 b	3.1 ± 0.1 c	10.2
	14	4.6 ± 0.05 a	4.7 ± 0.1 a	4.6 ± 0.1 a	4.7 ± 0.1 a	4.6 ± 0.07 a	4.6 ± 0.1 a	6.96
°Brix	2	3.9 ± 0.2 b	4.9 ± 2.1 a	4.2 ± 0.3 a	4.2 ± 0.3 a	4.5 ± 0.3 a	4.7 ± 0.1 a	15.4
	6	7.6 ± 0.6 a	8.5 ± 0.4 a	9.7 ± 0.4 a	8.2 ± 0.6 ab	8.1 ± 0.8 ab	6.5 ± 0.6 b	23.0
	10	14.2 ± 0.5 a	11.4 ± 0.3 b	13.6 ± 0.6 a	12.5 ± 0.1 a	14.6 ± 0.8 a	10.6 ± 0.1 b	9.57
	14	18.6 ± 0.4 a	13.6 ± 0.5 b	15.9 ± 1.7 bc	17.5 ± 0.9 a	14.6 ± 0.8 c	16.5 ± 0.6 ab	6.6
TA	2	2.8 ± 0.1 b	3.1 ± 0.05 a	2.7 ± 0.1 a	2.9 ± 0.1 a	3.1 ± 0.08 a	3.0 ± 0.1 a	10.4
	6	2.0 ± 0.1 b	2.6 ± 0.1 a	1.6 ± 0.09 c	2.3 ± 0.3 b	2.4 ± 0.2 b	3.0 ± 0.1 a	18.3
	10	0.75 ± 0.1 b	1.14 ± 0.1 a	0.32 ± 0.07 c	0.64 ± 0.1 bc	0.93 ± 0.5 b	1.91 ± 0.1 a	30.9
	14	0.34 ± 0.02 a	0.26 ± 0.01 b	0.41 ± 0.04 a	0.27 ± 0.01 b	0.26 ± 0.01 b	0.26 ± 0.02 b	16.0
°Brix/TA	2	1.4 ± 0.07 a	1.5 ± 0.04 a	1.5 ± 0.1 a	1.4 ± 0.09 a	1.4 ± 0.1 a	1.5 ± 0.3 a	17.1
	6	4.6 ± 0.8 a	3.5 ± 0.4 a	5.9 ± 0.5 a	4.3 ± 1.1 ab	3.9 ± 1.0 ab	2.1 ± 0.2 b	25.8
	10	34.7 ± 5.3 a	15.0 ± 3.2 b	40.9 ± 2.1 a	31.1 ± 8.3 ab	21.7 ± 7.0 b	5.7 ± 0.4 c	37.1
	14	57.3 ± 2.8 a	54.5 ± 4.1 a	39.1 ± 3.2 c	63.8 ± 1.9 ab	55.6 ± 4.8 b	65.2 ± 3.4 a	12.3

* Storage at 25 ± 3 °C. ** Values with a different letter within each factor in a row are statistically different (Tukey $p \leq 0.05$). *** CV = Coefficient of variation (%).

The °Brix/AT ratio was similar in La Norteña and Santa Cecilia during days 2 and 6 of storage. On the other hand, the relationship increased during days 10 and 14 in La Norteña. On days 6 and 10 of storage, the relationship decreased according to the frequency of AVG applications and the lowest values were with the treatment where three applications were made. At day 14, the relationship was inverse, increased in the AVG treatments and decreased in the control.

3.5. Color

The luminosity of the fruits did not present statistical differences ($p \leq 0.05$) between the treatments applied during the 14 days of evaluation. In general, the fruits that conserved the greatest luminosity were those from La Norteña, while the Hue angle (°h), that is, the difference found in the radiation wave between the fruits, was presented with a statistical difference only on day 2 of storage ($p \leq 0.05$).

4. Discussion

Fruit weight loss decreased from 4.6 to 5.1% with the application of AVG compared to the control during the 14 days of evaluation. Contrasting climate and soil conditions between study sites also induced differences in fruit weight loss. The lower weight decrease in the fruits of La Norteña may be associated in part to the high concentration of calcium in the soil. Even when this nutrient favors the opening of the stoma, in the presence of some stress, such as the water stress that occurs in La Norteña, the plants synthesize abscisic acid and a pronounced antiperspirant effect is induced in the leaf [20], and as a consequence, water loss decreases [21].

AVG treatments exhibited less tendency to reduce weight loss on the evaluation dates compared to the control, even though in the fruit ripening process, various biochemical and physiological changes occur, derived from enzymatic reactions, in addition to the production of autocatalytic ethylene that induces water loss and affects the speed of ripening [22] and weight loss of the fruits [7]. This process is not reversible but the exogenous application of ethylene inhibitors can delay the rate of ripening significantly compared to the control fruits.

In *Malus domestica* Borkh apple "Braeburn" [15], a decrease in weight loss was observed when increasing AVG doses to 150, 225, and 300 mg L^{-1} 4 weeks before harvest and the result is attributed to the decrease in ethylene biosynthesis, delayed in the enzyme activity and the consequent degradation of hemicellulose and pectin, essential components of the cell wall. On the other hand, in persimmon fruits (*Diospyros kaki* Thunb) "Tone wase" stored at −1 °C and treated with AVG and 1-MCP, they did not show differences in weight loss and ethylene production in relation to the control fruits [23].

Its effect on ethylene biosynthesis, which decreases the degradation of cell wall components, can also be considered [24,25]. In *M. domestica* "Braeburn" apples [15], 500 mg L^{-1} of AVG were applied 4 weeks before harvest, without significant effects on the thickness of the epidermis. The action of AVG as an ethylene inhibitor could delay the cascade of events that lead to the enzymes biosynthesis related to cell wall degradation, such as polygalacturonase and pectinmethylesterase [26], with the consequent decrease in loss of weight [16]. This same effect has been recorded in other crops treated with AVG, such as *M. domestica* "Baigent" apple, which presented a greater breaking force of the epidermis of 12.3 N compared to 11.6 N of the control when 125 mg L^{-1} of AVG were applied, in Rio Grande do Sul, Brazil [27].

In the case of pulp it is probable that the AVG in a higher frequency of application can inhibit ethylene and thus contribute to the weight reduction of the fruits. In the case of the fruits' pulp/seed ratio, initial values are presented with no apparent relationship with the AVG application frequencies. At the end of storage, there is a decrease according to the increase in AVG application frequencies. In *P. avium* L. "North Wonder" with applications of 250 mg L^{-1} of AVG, a decrease in the pulp/seed ratio was also induced, although this effect is attributed to the effects of variety, fruit load, and environmental conditions [28].

In addition, the greater firmness of the fruits in La Norteña may be related to the high content of calcium (Ca) in the soil. There is evidence of the beneficial effect in mangoes of the exogenous application of calcium on the delay of senescence through the maintenance of cell walls and fruit softening is associated with decreased calcium levels as fruit ripens [29]. The previous answer is attributed to the effect of AVG in delaying the decrease in firmness, and its influence in delaying the loss of weight of the epidermis when the fruits ripen.

The fruits' firmness is also related to lower rainfall, as cited in Kenya with "Tommy Atkins" fruits [30] and in the case of La Norteña, the rainfall represents 50% of the average amount in Santa Cecilia. It is important to note that between days 6 and 10 of storage there is a considerable loss of firmness, so storage at low temperatures is important to delay this process.

In relation to color, the lack of response on both sites and in the different treatments suggests a stable genetic characteristic in "Ataulfo" mangoes. Other crops, such as *Prunus armeniaca* L. "Canino" apricot fruits treated with 150 mg L^{-1} of AVG, [6] cite high values of °H compared to the control, and they associate the low content of carotenoids with a delay in ripening.

The saturation or C* chroma of the color presented differences between treatments on days 10 and 14 of evaluation, but with no evident trend due to the effect of applications of AVG. Instead, different results are cited in *Prunus avium* L. "North Wonder" cherry, where the value of C* increased with the application of AVG to 250 mgL^{-1} [28]. The lack of consistency in the color results suggests the possibility of exploring other frequencies and doses of AVG application.

The pH decreases more when increasing the AVG dose. Similar results were presented in "Braeburn" apples (*M. domestica* Borkh) when applying 100, 300, and 500 mg L^{-1} of AVG 4 weeks before harvest, with a decrease in pH when increasing the dose [15]. The previous result is possibly influenced by agronomic practices such as chemical fertilization. In this regard, [31] an increase in °Brix of mangoes is cited when applying urea and potassium nitrate before flowering. A similar result is recorded on the Chiapas Coast, with the application of urea in "Ataulfo" mangoes [32]. The contrasting response of Brix degrees between experimental sites, treatments, and its relationship with storage days is similar to

the results obtained in "Red Chief" and "Braeburn" apples, where °Brix decreased when AVG doses were increased [33]. This could be attributed to the accumulation of starch in the fruits treated with AVG and the decrease in °Brix, since starch is converted into monosaccharides during ripening [34].

The high levels of TA present in Santa Cecilia are related to a decrease in the respiration rate due to the consumption of organic acids in the tricarboxylic acid cycle [35]. Instead the different AVG applications induced similar results. The effects that the AVG can induce are changes in the concentration of AT depending on the concentration, the applied period, and the variety of the fruit [25]. However, this effect may not always occur in the second year of AVG application, as in the case of the "Baigent" apple [27].

This °Brix/AT ratio constitutes the balance between acids and sugars, influenced by the balance between the flavor and aroma of the fruits [36].

Of the variables recorded, weight loss, epidermis weight, firmness, and °Brix in fruits increased with AVG applications. These attributes favor the quality and marketing of fruits at greater distances from the place of origin. However, it is necessary to define the effects at different concentrations and application opportunities.

5. Conclusions

The greater frequency of exogenous applications of AVG in preharvest delayed the weight loss and the ripening process with an increase in the maintenance of the firmness of the fruits. The weight of the fruit epidermis was lower with AVG applications, and increased with the number of applications. This response favors the quality of the fruit and allows its transport to consumption or export centers.

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