

Impact of exogenous pre and postharvest salicylic acid applications on MD2 pineapple quality

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All relevant data are within the paper and its Supporting Information files.

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The authors declare no competing interests.

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Abstract: Salicylic acid (SA) is a natural plant compound that has been proven to enhance the quality of fruits; therefore, its impact on pineapple should be further studied, especially in the most marketable hybrids. This study aimed to evaluate the effect of SA treatments on MD2 pineapple quality. The experiment consisted of two parts with applications pre and postharvest following the next treatments, control: No use of SA, and 5, 7 and 9 mM of SA. The total soluble solids, total acidity, ascorbic acid content, respiration rate, together with the severity and incidence of internal browning and flesh translucency were determined, after 40 days of cold storage. The treatment using 9 mM of SA in pre and postharvest delivered the best results, having the most elevated ascorbic acid (526.75 mg kg⁻¹) and total acidity (0.8%), the lowest severity and incidence outcomes of internal browning and flesh translucency (0% in both cases), with the most reduced respiration rate values during postharvest. In conclusion, SA treatments with concentrations of 9 mM applied in pre and postharvest on MD2 pineapple can improve its quality after 40 days of cold storage.

1. Introduction

Pineapple is a fruit characterized by its rich source of sugars, organic acids, fibers, minerals, vitamins, flavonoids, and carotenoids (De Ancos *et al.*, 2017). These are essential food properties for healthy human nutrition. Nowadays, low acid hybrids like MD2 are the most exported by the industry worldwide (Hossain, 2016; Cano-Reinoso *et al.*, 2022 a). This hybrid is known for its bright-gold colour, sweeter taste, high ascorbic acid (AsA) content, and uniform size (Bin Thalip *et al.*, 2015; Cano-Reinoso *et al.*, 2022 a). Nevertheless, MD2 is susceptible to physiological disorders like flesh translucency and internal browning, which are major problems that negatively impact its quality (Chen and Paull, 2017; Paull and Chen, 2018).

Currently, the use of natural compounds to deal with these disorders has become a trend (Lu *et al.*, 2011; Goñi *et al.*, 2017). Because of the reduced negative impact these compounds cause to the environment and human health, multiple studies have been implemented by producers and growers (Ponce *et al.*, 2011; Goñi *et al.*, 2017). In this context, salicylic acid (SA) has been investigated as a potential treatment to decrease physiological disorders due to its positive impact on fruit metabolism (Hayat *et al.*, 2010; Goñi *et al.*, 2017). This secondary metabolite has been proved to enhance ion uptake and transport, disease resistance, ripening delay, and control postharvest quality and shelflife of horticultural products (Asghari and Aghdam, 2010; Goñi *et al.*, 2017). For instance, SA has demonstrated outstanding results in reducing the fruit softening rates and the degrading of the sugar and acid content during postharvest (Asghari and Aghdam, 2010; Goñi *et al.*, 2017). Also, SA can mitigate the cell wall degrading and polygalacturonase (PG) enzyme activity, phenomena highly associated with translucency and internal browning in pineapple (Goñi *et al.*, 2017; Paull and Chen, 2018; Cano-Reinoso *et al.*, 2021).

Previous studies in pineapple fruit demonstrated that postharvest SA treatments (in solutions with concentrations between 5 and 9 mM), reduced the internal browning severity and translucency occurrence without affecting the total soluble solids (TSS) and total acidity (TA) negatively (Lu *et al.*, 2010, 2011; Cano-Reinoso *et al.*, 2022 b). Besides, it was determined that in pineapple SA could cause a positive effect on the antioxidant content with a reduction of the peroxidase (POD), polyphenol oxidase (PPO) and phenylalanine ammonia-lyase (PAL) enzyme activities, concomitantly with a low respiration rate (Lu *et al.*, 2010, 2011; Cano-Reinoso *et al.*, 2022 b).

However, despite the previous information described currently, there are no sufficient studies on pineapple fruit that document the impact of SA, especially complementing postharvest with preharvest applications. For example, concerning the preharvest stage only two experiments have reported the use of SA, obtaining contradictory results, and mostly implementing just low concentrations (around 2 mM), like in Lu *et al.* (2011) and Cano-Reinoso *et al.* (2022 b). On top of that, some of these former researches have mainly focused on acid hybrids. Therefore, this issue open questions concerning the determination of the exact impact of SA on low acid

hybrids like MD2, primordially with a complementary administration, including pre and postharvest. As a result, this study aims to evaluate the impact of exogenous pre and postharvest SA applications on MD2 pineapple quality.

2. Materials and Methods

Preparation of the experiment

This research was implemented in pineapple fields in Lampung, a place located in south Sumatra Indonesia, from January to March 2020, employing the MD2 pineapple hybrid. In order to fulfil the objective of the research, the experiment was divided into two parts. The first part regarding preharvest applications of SA, while the second part concerned the postharvest administration of this natural compound.

Preharvest treatments implementation

Regarding the first part of the experiment, a completed randomized block design was used with four replications, having 20 fruits each of the replications. The fruits were harvested between 144-147 days after flowering, when it has been determined that MD2 can expose the most optimal quality characteristics for commercial consumption (Bin Thalip *et al.*, 2015; Ding and Syazwani, 2016). Besides, for this part of the research, four rows in each block were prepared with a width and length of 0.4 and 3.75 m, respectively. Pineapple plants were organized in two lines of ten plants with a separation of 0.25 m. For this stage the treatments implemented were; control: No use of SA, 5, 7 and 9 mM of SA.

Furthermore, the administration of SA was done using sprayings with their respective solutions until the fruits were wet to runoff. SA solutions were mixed with 1% (v/v) of ethanol and 0.01% (v/v) of tween 20 (emulsifier) before their application. The sprayings were performed at eight, six, four and two weeks before harvest at night, in the fruit shell and crown. Previous experiment of Cano-Reinoso *et al.* (2022 b) demonstrated that two applications prior to harvest (six and three weeks) can cause a positive effect on pineapple quality. Therefore, this research aimed to increase the frequency of application preharvest in order to enhance the influence on the fruit quality. Moreover, the fruit shell and crown were selected as adequate spots to be used based on the findings about mineral mobility in pineapple plants

described by Vásquez-Jiménez and Bartholomew (2018) and Murai *et al.* (2021). They demonstrated that through these plant structures there was mineral assimilation when foliar fertilizations were carried out after flowering.

The soil, where the pineapple plant was cultivated, was fertilized previously with 200 kg ha⁻¹ Diammonium Phosphate, 1000 kg ha⁻¹ of K₂SO₄ and 200 kg ha⁻¹ Kieserite crystal. Three months after plating 700 kg ha⁻¹ of Urea were administered by sprayings; also, 700 kg ha⁻¹ of (NH₄)₂SO₄, 1000 kg ha⁻¹ of K₂SO₄, 170 kg ha⁻¹ of MgSO₄, 60 kg ha⁻¹ FeSO₄, 60 kg ha⁻¹ ZnSO₄, were applied in intervals of 30 days. Besides, borax was sprayed in doses of 30 kg ha⁻¹ at flower induction. Climatological conditions were determined where the plants were cultivated with a weather station (LSI Lastem; equipped with a CR6 data logger from Campbell Scientific; Italy). An average of 70.60% of relative humidity (RH), 22.43°C, 10.18 w m⁻¹ of solar radiation, and rainfall of 353.10 mm were detected. The physical and mineral composition of the soil of the first part of the experiment is presented in Table 1.

Postharvest treatments implementation

Concerning the second part of the experiment, randomly ten fruits per replication were selected at harvest, organized according to their respective treatments and replications inside a cold storage during 40 days (8°C and 90% RH), and analyzed in inter-

Table 1 - Physical and mineral composition of the soil in the first part of the experiment

Properties	Content
<i>Texture</i>	
Clay (%)	9.00
Loam (%)	36.56
Sand (%)	50.42
<i>Chemical properties</i>	
pH (H ₂ O)	7.62
C (%)	4.60
N (mg kg ⁻¹)	853.00
P (mg kg ⁻¹)	5.29
K (mg kg ⁻¹)	9.68
Ca (mg kg ⁻¹)	76.39
Mg (mg kg ⁻¹)	109.00
Na (mg kg ⁻¹)	12.84

The N, P, K, Ca, Mg and Na represent the available mineral content in the soil.

vals of eight days. The treatments implemented in this stage of the research were; control: No use of SA, 5, 7 and 9 mM of SA. All the treatments, including the control, received fungicide and waxing applications in postharvest; those materials, following that order, were administrated in dipping applications for ten seconds, just after the dipping on SA. The fungicide product used was Prochloraz in doses of 2 cc l⁻¹, while the waxing material employed was Sta-Fresh 2952 in doses of 74 g l⁻¹. Furthermore, the SA concentrations were dissolved in a water container of 25 L; Besides, in this case SA was also mixed with 1% (v/v) of ethanol and 0.01% (v/v) of tween 20 (emulsifier). The dipping in SA was done for five minutes. This dipping time and the concentrations implemented were selected based on Lu *et al.* (2011) and Cano-Reinoso *et al.* (2022 b). They proved that postharvest dipping applications around five minutes should have a minimum concentration of 2 mM to cause a positive impact on pineapple fruit. Finally, the summary of the treatments implemented pre and postharvest in this research are presented in Table 2.

Table 2 - Summary of the treatments implemented in pre and postharvest stage of the experiment

Treatment	Description
A	Control: No use of SA
B	5 mM SA pre/postharvest
C	7 mM SA pre/postharvest
D	9 mM SA pre/postharvest

* Preharvest salicylic acid (SA) was sprayed at 8, 6, 4 and 2 weeks before harvest until fruits were wet to runoff. Postharvest SA was administrated with dipping of 5 minutes, and complemented with fungicide and waxing applications. Pre and postharvest SA solutions were mixed with: 1% (v/v) ethanol, and 0.01% (v/v) tween 20 (emulsifier).

Fruit quality evaluation

Total soluble solids (TSS) and total acidity (TA) in the fruit

The total TSS and TA content was calculated in every fruit selected of every treatment from each replication, employing the method described in Shamsudin *et al.* (2020). TSS was measured using a hand-held refractometer (MASTER-53 α; Atago; Japan), while TA was determined by titration to pH 8.1 with 0.1 M NaOH employing phenolphthalein indicator and expressed as a percentage of citric acid.

Fruit respiration rate

The respiration rate was calculated in a fruit selected from eight until 40 days of cold storage in each replication of every treatment implemented. A similar method previously reported in Bhande *et al.* (2008) and Cano-Reinoso *et al.* (2022 b) was implemented. For this case, changes in the CO₂ concentration were measured in a sealed glass container having 31 cm height x 24 cm wide with 9 l of capacity. The device used for this procedure was a portable AZ7788A carbon dioxide detector (CO₂ range: 0-5000 mg kg⁻¹, 10-95 % RH, 0-50°C; AZ Instrument Corp; Taiwan). Moreover, before beginning the procedure, the fruit weight was calculated using a weighing scale, as described in Shamsudin *et al.* (2007). Once finished this process, the CO₂ detector and the fruit were arranged inside the container, avoiding any air introduction or scape. The changes in the CO₂ concentration were measured during one hour in every fruit, and after that, the respiration rate was determined using the following expression:

$$RF = \left[\frac{(FCO_2)_h - (FCO_2)_{h+1}}{\Delta t} \right] \frac{V}{FW} \quad (1)$$

Where, respiration of the fruit (*RF*) is the respiration rate in ml CO₂ kg⁻¹ · h⁻¹, *FCO₂* is the CO₂ gas concentration in ml l⁻¹, *h* is the storage time in hours, Δt the time difference between two CO₂ gas measurements, *V* is the free volume of the container in l and *FW* is the weight of the fruit in kg. The free volume of the container was obtained as the total volume of the container minus the volume occupied by its content at the moment of the measuring, using a water displacement method as described in Bhande *et al.* (2008). Figure 1 shows a picture of the arrangements carried out to implement the respiration rate method of this experiment already described.

Ascorbic acid (AsA), translucency and internal browning incidence determination

These variables were measured in each of the fruits per replication of every treatment. The AsA content was calculated using dye, 2,6-dichlorophenol-indophenol titration method described in Ding and Syazwani (2016) and Ojukwu and Nwobi (2017). First, diluted pineapple juice was pipetted into a conical flask and mixed with glacial acetic acid, titrating the solution until faint permanent pink colour. Next, the titrated value was recorded; then, the titration was repeated, boiling and cooling with distilled water for a blank and a standard ascorbic acid solution. The

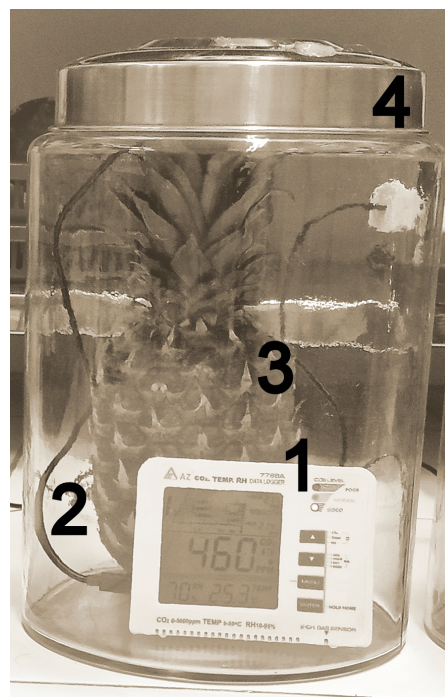


Fig. 1 - Picture showing the respiration rate method employed. 1) CO₂ detector used, 2) Cable of electricity to activate the detector introduced by the top of the container, 3) Fruit and 4) Sealed container.

titrations obtained were repeated twice, and the average value was calculated and expressed as mg kg⁻¹ fruit fresh weight.

On the other hand, the translucency internal browning incidence was obtained accounting number of fruits affected from the total examined, since harvest until 40 days of cold storage. The results are expressed in percentage.

Statistical analysis

The statistical analyses were performed using SPSS Version 22.0 software (SPSS Inc., Chicago, IL, USA). All data were analysed by an analysis of variance of one-way (ANOVA). Mean significant differences at *p*<0.05 were determined by Duncan's multiple range tests.

3. Results

Fruit physicochemical quality

The TSS, TA and TSS/TA ratio did not show significant differences after 40 days of cold storage in the implemented treatments. The TSS and TA content was on average 15 and 0.70%, respectively; mean-

while, for the TSS/TA the mean values ranged around 21 (Table 3). For these variables, high SA concentrations were not clearly associated with more elevated mean results. On the other hand, the AsA results did not demonstrate significant differences in this experiment after 40 days of cold storage. Nevertheless, it is important to notice that the treatment using 9 mM of SA in pre and postharvest obtained the highest mean value (526.75 mg kg⁻¹), which was linked to the more superior content of TA (0.80%) (Table 3). Moreover, in figure 2 it is possible to observe the trend of AsA through the postharvest time of the experiment. AsA continually elevated and reduced its level, with the treatment employing 9 mM of SA in pre and postharvest having the most inferior peak change, especially between 32 and 40 days of cold storage.

Furthermore, in the case of the respiration rate, this variable exposed significant differences after 40 days of cold storage. The control treatment (no use of SA) provided the highest value, while the treatment utilizing 9 mM of SA in pre and postharvest had the most reduced one (8.24 and 6.32 ml CO₂ kg⁻¹·h⁻¹, respectively). Figure 3 shows the respiration rate trend during postharvest. In this figure, it is evidenced that the treatments employing a higher SA concentration, like the treatments with 7 and 9 mM of SA in pre and postharvest, had a steadier trend and lower change during cold storage. On the other hand, the control treatment and the one using 5 mM of SA in pre and postharvest suffered a remarkable increase, primordially in 16 days, suggesting a representative metabolic change at that moment in the fruit. On top of that, high concentrations of SA were associated with a lower respiration rate and more elevated AsA content at harvest.

Internal browning and flesh translucency in the fruit

The internal browning and flesh translucency provided significant differences in the results obtained.

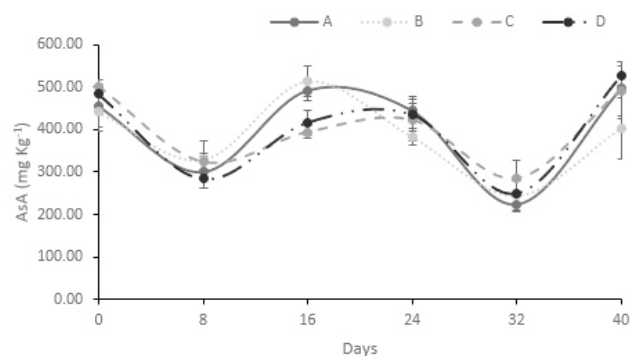


Fig. 2 - Effect of the treatments implemented on the ascorbic acid (AsA) content during 40 days of cold storage. A) control [No use of salicylic acid (SA)], B) 5 mM SA pre/postharvest, C) 7 mM SA pre/postharvest, and D) 9 mM SA pre/postharvest. Values are the mean four replicates, and vertical bars represent \pm SE.

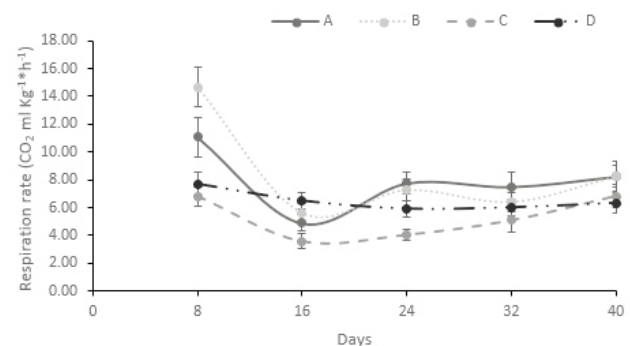


Fig. 3 - Effect of the treatments implemented on the fruit respiration rate during 40 days of cold storage. A) control [No use of salicylic acid (SA)], B) 5 mM SA pre/postharvest, C) 7 mM SA pre/postharvest, and D) 9 mM SA pre/postharvest. Values are the mean four replicates, and vertical bars represent \pm SE.

Regarding the internal browning, this had its most elevated severity and incidence in the treatments using 5 and 7 mM of SA in pre and postharvest (3.75 and 6.25%, respectively), while the control treatment

Table 3 - Impact of the treatments implemented on the fruit quality characteristics after 40 days of storage

Treatment	TSS (%)	TA (%)	TSS/TA	AsA (mg Kg ⁻¹)	Respiration rate (ml CO ₂ Kg ⁻¹ h ⁻¹)	Browning (%)		Translucency (%)	
						Severity	Incidence	Severity	Incidence
A	14.80 \pm 0.22 a	0.70 \pm 0.07 a	21.73 \pm 1.85 a	496.25 \pm 62.86 a	8.24 \pm 0.40 a	0.00 b	0.00 b	1.85 ab	16.67 a
B	15.40 \pm 0.50 a	0.67 \pm 0.07 a	24.10 \pm 3.65 a	402.50 \pm 71.81 a	8.23 \pm 0.92 a	3.75 a	6.25 a	0.64 b	8.33 b
C	15.80 \pm 0.29 a	0.75 \pm 0.05 a	21.43 \pm 1.53 a	492.50 \pm 65.97 a	6.83 \pm 0.65 ab	3.75 a	6.25 a	0.35 b	4.17 b
D	15.15 \pm 0.31 a	0.80 \pm 0.06 a	19.13 \pm 1.23 a	526.75 \pm 23.47 a	6.32 \pm 0.53 b	0.00 b	0.00 b	0.00 b	0.00 c

* Mean values \pm SE in each column followed by the same lower-case letters are not statistically different by Duncan's multiple range test, and Kruskal-Wallis test (for the internal browning and translucency data) ($p < 0.05$).

and the one employing 9 mM of SA in pre and postharvest did not expose representative symptoms after 40 days of cold storage (0% for the severity and incidence in both cases) (Table 3). Moreover, this lowest browning severity and incidence outcome was related to the most inferior respiration rate and the highest AsA content at harvest, primordially in the treatment utilizing 9 mM of SA in pre and postharvest. Concerning the flesh translucency, the outcomes of this experiment also revealed that this previous treatment is the one causing the lowest severity and incidence (0% in both cases), while the control treatment was the least efficient in this aspect (1.85 and 16.67%, respectively) (Table 3). Similar to the internal browning results, the most elevated AsA content and lowest respiration rate at harvest in the treatment employing 9 mM of SA in pre and postharvest were linked to the most inferior translucency incidence and severity.

4. Discussion and Conclusions

Typically, MD2 pineapple displays 12% or higher values for TSS during cold storage (Paull and Chen, 2018; Cano-Reinoso *et al.*, 2021). The values obtained in this research were higher than 14%, especially for those using SA applications. TSS represents the sucrose content in pineapple fruit primordially; also, a change in its content commonly is associated with modifications in the cell wall invertase (CWI) activity (Saradhulhat and Paull, 2007; Paull and Chen, 2018). The results of this experiment infer that the pre and postharvest treatments employed did not cause a representative impact on the sucrose content and the sugar metabolizing enzymes, essentially a negative impact, to cause a change in the TSS level at the end of the cold storage.

In the case of the TA, due to its low acid properties, MD2 has evidenced TA values among 0.4-0.7% at harvest, which is much lower than acid hybrids like smooth cayenne (Ding and Syazwani, 2016; Paull and Chen, 2018). Nevertheless, a small increase in this range has been reported during cold storage of pineapple due to the rise of the citric acid content (Mandal *et al.*, 2015; Ding and Syazwani, 2016). Citric acid is considered a source for several metabolizing process in fruits, like antioxidant scavenging and respiration; also, it is the main acid influencing the TA measuring in pineapple (Paull and Chen, 2018; Yang *et al.*, 2019). Therefore, in concomitance with the

fruit decay, this acid could have speed up its accumulation as a reflect of this physiological deterioration, influenced by the need of a scavenger agent to cope with this condition. This fact can explain why despite the lack of significant differences, in mostly all the treatments, TA had higher values than the minimal recommended for MD2, after 40 days of cold storage. On top of that, as also the control treatment (no use of SA) had an ideal TA outcome, it could be suggested that the waxing formula used was ideal to decrease the fruit metabolism in order to avoid a high consumption of citric acid as a substratum of several physiological process, generating the respective TA content.

Furthermore, a small increase in the TSS and TA content has been observed by SA applications in pineapple (Lu *et al.*, 2011; Mandal *et al.*, 2015). Moreover, some studies have demonstrated that pre and postharvest implementations of SA tend to suppress the TSS and TA degrading, especially during postharvest, like in mango and grape (Champa *et al.*, 2014; Hong *et al.*, 2014). This information could explain why the TSS and TA values were in the optimal content for consumption or slightly superior in almost all the treatments employing SA. Besides, MD2 has more elevated TSS/TA ratios than other hybrids, especially because of its lower acid content, ranging between 20-30 in mostly all cases. (Chen *et al.*, 2009; Ding and Syazwani, 2016). Overall, values between this range were observed in the results of this experiment (Table 3).

On the other hand, regarding AsA, this is considered a powerful plant antioxidant and one of the most representative in pineapple fruit (Kongsuwan *et al.*, 2009; Noichinda *et al.*, 2017). This information infers that the treatment utilizing 9 mM of SA in pre and postharvest can provide a more elevated antioxidant production, as it impacts the AsA level positively and the previous described TA content associated with citric acid. MD2 delivers AsA values as minimal as 300 mg kg⁻¹ at harvest, much higher than pineapple acid hybrids (Lu *et al.*, 2014; Paull and Chen, 2018). This value tends to increase during postharvest to maintain optimal physiological conditions, essentially when a stress factor affects the fruit (Lu *et al.*, 2011; Mandal *et al.*, 2015). The variability of the AsA exposed in figure 2 could be associated with the activity of the ascorbic peroxidase (APX) and monodehydroascorbate reductase (MDHAR) enzymes. For example, APX is an optimal scavenger of H₂O₂, which is generated with the progress of the fruit

senescent. However, this enzyme can cause the oxidation of AsA into monodehydroascorbate (MDHA). Therefore, MDHA have to be recycled into AsA by the glutamic acid pathway employing MDHAR as cofactor, in order to maintain an ideal level of AsA to cope with impact of the fruit decay. As a result, these two enzymes can be used as an indicator of the AsA content and metabolization (Gallie, 2013; Akram *et al.*, 2017). Based on that, the treatment working with 9 mM of SA in pre and postharvest could be considered the one causing more influence on these enzymes, catalyzing their activities during cold storage. Similar patterns in the AsA production during postharvest has been reported in pineapple by Lu *et al.* (2010) and Cano-Reinoso *et al.*, (2022 b), where higher SA concentrations were associated with a more superior AsA content.

In the case of the respiration rate, values between 5 and 20 ml CO₂ kg⁻¹·h⁻¹ have been reported for pineapple in previous studies (Lu *et al.*, 2011; Hu *et al.*, 2012; Cano-Reinoso *et al.*, 2022 b). The outcomes obtained in this experiment provided results among that recommended range. On the other hand, SA has been associated with an increase in antioxidant scavenger enzymes like catalyze (CAT) and superoxide dismutase (SOD), which, together with the APX, reduced the impact of the fruit decay symptoms during postharvest, eliminating singlet of oxygen-derived from reactive oxygen species (ROS), essentially the already mentioned H₂O₂ (Goñi *et al.*, 2017; Noichinda *et al.*, 2017). On top of that, Lu *et al.* (2011) and Cano-Reinoso *et al.* (2022 b) demonstrated that SA solutions with concentrations higher than 5 mM, essentially with postharvest implementations, can generated a low respiration rate, with a similar trend pattern of this experiment. Besides, they determined that this low respiration rate was associated with a more superior activity of the CAT, SOD and APX, especially between 16 and 24 days of cold storage. That period of time was regarded as the moment when more ROS were produced in the fruit; therefore, the higher activity of these enzymes to cope with the damage caused. According to that, in this experiment the treatments using 7 and 9 mM of SA in pre and postharvest could be suggested as the ones causing a more elevated scavenger activity of CAT, SOD, APX, generating less ROS, decreasing the respiration rate, and promoting an ideal fruit physiological condition.

Regarding the internal browning, this physiologi-

cal condition in fruits is associated with a high activity of phenylalanine ammonia-lyase (PAL) and polyphenol oxidase (PPO) enzymes during postharvest, concomitant with an elevated level of ROS and low antioxidant content (Youryon *et al.*, 2018; Paull and Chen, 2019). This finding suggests that SA solutions with concentrations of 5 and 7 mM applied pre and postharvest can catalyze PAL and PPO activity, increasing the ROS content, creating higher browning symptoms in the flesh. In the case of the treatment employing 9 mM of SA in pre and postharvest, its lowest internal browning severity and incidence was linked to the lowest respiration rate and the most elevated antioxidant content. This fact infers that those high concentrations of SA (9 mM), on the contrary, can inhibit the PAL and PPO activity, reduce the ROS level, generating positive effect on the fruit metabolism.

On the other hand, these results contradict the outcomes of Lu *et al.* (2011) and Mandal *et al.* (2015), where concentrations of 5 mM or higher applied pre and postharvest caused the lowest internal browning incidence and severity, as in this experiment the control treatment, produced positive results in this matter. Furthermore, despite having a high respiration rate, the control treatment delivered an ideal AsA and TA content. This situation exposes that the fruits of this treatment were harvested with optimal physiological characteristics, necessary to delay any internal browning symptoms until the last day of cold storage. Besides, some authors have suggested that MD2 pineapple, due to its higher antioxidant content, could extend its postharvest shelflife up to 45-50 days, depending on the fruit quality condition collected from the field (Paull and Chen, 2018, 2019).

Conversely, translucency is a physiological disorder of pineapple fruit characterized by water soaking symptoms, being MD2 a susceptible hybrid (Chen and Paull, 2017; Paull and Chen, 2018). Furthermore, the low calcium content in the fruit and possible low assimilation of Ca²⁺ into the cell wall matrix have been linked to this physiological disorder's exhibition (Paull and Chen, 2015, 2018). These facts suggest that SA applications employed in pre and postharvest, essentially at high concentrations like in the treatment working with 9 mM of SA in pre and postharvest, could enhance the calcium ion assimilation and concentration in flesh tissues, reducing the exhibition of translucency. These results agree with

the findings of Mandal *et al.* (2015), where implementing SA with concentrations of 5 mM after 15 days of cold storage got to reduce translucency incidence, compared to treatments without SA. On top of that, similar with the internal browning, the lowest translucency severity and incidence was associated with the most inferior respiration rate and highest AsA content. As a result, after analyzing all the variables measured in this experiment, it is possible to suggest that this treatment could be considered as the more appropriate to obtain an ideal pineapple quality after the 40 days of cold storage.

Finally, the current available information about the SA effect on pineapple exposes that low preharvest concentrations, between 2 and 5 mM, mixed with more elevated ones in postharvest, provide the best results regarding the fruit quality (Lu *et al.*, 2010, 2011; Cano-Reinoso *et al.*, 2022 b). Nevertheless, this experiment got to demonstrated that elevated concentrations of SA employed preharvest could also benefit the fruit. For example, a more superior calcium uptake, and AsA level and recycling can be encourage with those high SA concentrations (primordially between 7 and 9 mM). Because of that, future experiments in pineapple should be focus on these concentrations, prioritizing the impact on the fruit mineral status and antioxidant content. Also, deeper researches concerning the determination of the ideal pre harvest frequency of SA application should be done, as former studies still lack on this matter. These preliminary results demonstrated that four preharvest applications can be more beneficial than two, complementing former experiments.

In conclusion, SA treatments applied pre and postharvest affected the MD2 pineapple quality. The treatment employing SA solutions with a concentration of 9 mM pre and postharvest provided the best results, essentially because it had the lowest and regular postharvest trend and outcome of respiration rate, and the highest value of AsA and TA content. Also, this treatment obtained the most reduced severity and incidence of internal browning and flesh translucency after 40 days of cold storage.

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