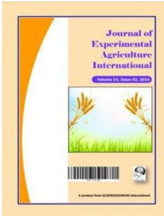

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Salicylic Acid Maintains Quality of 'Chimarrita' and 'Maciel' Peaches Under Cold Storage

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SBA and MBM designed the study and wrote the first draft of the manuscript. Author SBA performed the experiments. Author AVS participated in fieldwork and laboratory analysis. Authors AB and CG managed the analyses of the study. Author VBC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this work was to evaluate the efficiency of postharvest application of salicylic acid on Chimarrita and Maciel peach cultivars under cold storage.
Study Design: The experiment was conducted in a completely randomized design with four replications and 15 peaches per experimental unit, following a 4x3 factorial design for each cultivar, 4 treatments and 3 storage periods for both cultivars.
Place and Duration of Study: This work was executed at LabAgro/Fruticulture, Federal University of Pelotas, Rio Grande do Sul state, Brazil, between November 2013 and February 2014.

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Methodology: Postharvest application of salicylic acid was performed in both cultivars from the 2013/2014 crop by spraying the fruits with the solution (salicylic acid + distilled water + ethyl alcohol) and then letting them air-dry. The following treatments were used: T1- Peaches without the treatment solution (distilled water + ethyl alcohol (control); T2- Peaches treated with 0.5 $mmol.L^{-1}$; T3- Peaches treated with 1.0 $mmol.L^{-1}$; T4- Peaches treated with 1.5 $mmol.L^{-1}$. The fruits submitted to the treatments were cold-stored at 1.0 ± 0.5°C and 85-90% RH, during 30 days. Weight loss (%), DA index, flesh firmness (N), soluble solids content (°Brix), rot incidence (%) and soluble pectin ($g.100\ g^{-1}$), were evaluated after a storage period of 10, 20 and 30 days plus two days for commercial simulation.

Results: *Chimarrita cultivar:* The predict value for weight loss at the stationary point was 3.27%, obtained with 1.33 $mmol.L^{-1}$ of salicylic acid at day 12. Data regarding rot incidence showed to be adjusted to the regression model ($F = 3.90$; $p = 0.007$), with R^2 of 0.68 e R^2adj of 0.64. During the optimization process, the roots of the auxiliary equations were positive and negative in magnitude, indicating the saddle point as the stationary point. Under this condition, 35.4% of rotting was registered for 0.85 $mmol.L^{-1}$ of salicylic acid, after 23 days. *Maciel cultivar*: The predict value for weight loss at this stationary point was 5.18%, reached with 0.56 $mmol.L^{-1}$ of salicylic acid after 21.19 days. Flesh firmness findings adjusted to the regression model ($F = 61.87$; $p< 0.0001$), with R^2 of 0.89 and R^2adj of 0.87. During the optimization process, the roots of the auxiliary equations were positive and negative in magnitude, indicating the saddle point as stationary point, and the predict value was 35.7N for 0.75 $mmol.L^{-1}$ of salicylic acid in 20 days.

Conclusion: Postharvest application of Salicylic acid at 1.0 $mmol.L^{-1}$ was efficient in maintaining the quality of the Chimarrita cultivar at 20 plus two days for commercial simulation. As for the Maciel cultivar, a concentration of 0.5 $mmol.L^{-1}$ of salicylic acid was more efficient for the same storage period.

Keywords: Elicitor; Prunus persica (L.); storage period; quality.

1. INTRODUCTION

Peaches are highly perishable fruits and their quality can be affected if proper postharvest handling is not followed [1]. Reported studies have combined others techniques with cold storage in order to increase the shelf life of peaches. One of techniques can be postharvest application of salicylic acid combined with cooling.

Salicylic acid, considered as an endogenous plant growth regulator, has been found to generate a wide range of metabolic and physiological responses in plants, affecting growth and development. Salicylic acid, known as a phenol natural and safe compound, exhibits a high potential in controlling postharvest losses [2], like rooting and physiological weight loss. The same has been observed by [3], with positive results. These same authors tested salicylic acid concentrations of 0.35 mmol, 0.7 mmol and 1.0 mmol, reporting good results for pulp firmness at 1.0 mmol of salicylic acid. According to Tareen et al. [4], the use of salicylic acid in peaches proved to be efficient in controlling fruit properties, such as epidermis color, mass loss, firmness and pH. The salicylic acid treated peaches exhibited significantly lower levels of total soluble solids, pH and weight loss and higher levels of firmness and total acidity than controls [5]. These results suggested that salicylic acid treatment might be a powerful strategy to enhance quality of peach fruits, especially because salicylic acid is one of natural and safe signaling molecule. Ali et al. [6] affirm that these growth elicitors, like salicylic acid, are considered safe chemicals and can be applied to enhance production and improve fruit quality of peach without compromising the food safety standards.

Many researchers have reported SA as a potential tool in inhibiting decay incidence and extending postharvest life of many fresh fruits [7]. The aim of this study was to evaluate the efficiency of postharvest application of different concentrations of salicylic acid in Chimarrita and Maciel peaches under cold storage.

2. MATERIALS AND METHODS

This study was carried out on Chimarrita and Maciel peaches obtained from the Palma Agricultural Center /Federal University of Pelotas, Capão do Leão, Rio Grande do Sul, Brazil, at latitude 31° 52 ' 00 "S, longitude

52° 21 ' 24" W and an altitude of 13.24 meters. The soil belongs to the Camaquã unit, being moderately deep with medium texture on the horizon A and clay in B, classified as ultisol [8]. The climate region is characterized as temperate and humid with hot summers, "Cfa" according to the Köppen classification. The region has an annual temperature and precipitation average of 17.9°C and 1500 mm, respectively.

Postharvest application of salicylic acid performed in both cultivars, 2013/2014, was done by spraying the solution (salicylic acid + distilled water + ethyl alcohol) at the fruits and then leaving them to air dry. Approximately 1.0 ml of the solution was sprayed on both sides of each fruit. In order to promote the solvency of salicylic acid, 5 $mL.L^{-1}$ of ethyl alcohol was used in the solution.

The following treatments were used: T1 (control) - Peaches without the treatment solution (distilled water + ethyl alcohol); T2- Peaches treated with 0.5 $mmol.L^{-1}$; T3- Peaches treated with 1.0 $mmol.L^{-1}$; T4- Peaches treated with 1.5 $mmol.L^{-1}$.

Treated fruits were cold-stored at 1.0 ± 0.5°C and 85-90% relative humidity (RH) during 30 days. Analyses were undertaken in the following periods: harvest day for lot characterization; after 10 days in cold storage plus 2 days at room temperature (20°C) for commercial simulation (10 + 2); after 20 days in cold storage plus 2 days at room temperature (20 + 2); and after 30 days in refrigerated storage plus 2 days of room temperature (30 + 2).

The experiment was conducted in a completely randomized design with four replications and 15 peaches per experimental unit, following a 4x3 factorial design for each cultivar, 4 treatments and 3 storage periods for both cultivars.

This study was executed at LabAgro/Fruticulture and the following variables were analyzed:

- Weight Loss (WL): Weight Loss (WL): WL was determined by the difference in percentage between the initial weight and final weight of the fruit through the equation: WL= (initial weight – final weight)/initial weight x 100;
- DA index: obtained through the DA-meter 53500, which gives the index of absorbance difference in wavelengths 670 and 720nm (peak of chlorophyll);
- Flesh Firmness: Flesh firmness was recorded using a penetrometer expressed in Newtons;
- Rot incidence: This was analyzed by counting the fruits that presented a lesion diameter greater than 0.5 cm, which is typical of fungus and bacteria. The results were expressed in percentage;
- Soluble solids: The soluble solids content in ºBrix was determined with a digital refractometer.
- Pectin soluble content: This was evaluated based on [9].

Data relating to normality were analyzed by Shapiro Wilk test; heteroscedasticity according to Hartley test and residues independence using graphic analysis.

Subsequently, the data were subjected to analysis of variance, F-test ($p \leq 0.05$). Response surface regression was used (PROC RSREG) SAS / STAT 9.1 for Windows (SAS Institute, Cary NC), with linear effects, quadratic and linear interaction of independents variables [10]. The model was chosen based on: (a) residue; (b) p value ($p \leq 0{,}05$); (c) standard derivation and (d) R^2 e R^2adj. Afterwards, the polynomial equation was adjusted to dependent variables data.

$y = \beta 0 + \Sigma \beta ixi + \Sigma \beta ii\ xi2 + \Sigma\ \beta ijxixj$, where y is the dependent variable; xi, xj are the independent variables that affect the dependent variable y; β0 is the intercept; βi is the linear effect; βii is the quadratic effect and βij is the interaction between xi e xj.

For optimization, the canonical rotational analysis added to surface response was used where standard variables (x1, dose; x2, time) – within the experimental probability – were established in order to obtain the response to each dependent variable studied. The response optimization function consisted in response function version (yk), from the origin toward the stationary points (x0). The response function was maximum when all roots achieved negative values and minimum when all roots achieved positive values. If some roots showed positive values and others negative it was characterized as a saddle point [11,12].

Harvest was undertaken in the first week of December, 2013 when fruit characterization was complete, obtaining an average of 1038.67 $g.15\ fruits^{-1}$, DA index of 0.82, soluble solids content of 11.8° Brix and flesh firmness of 18.7 N, for the Chimarrita cultivar.

For the Maciel cultivar, the harvest was also carried out in the first week of December 2013 when the fruit description was complete, reaching an average of 1613.33 $g.15\ fruits^{-1}$, DA index of 0.67, soluble solids content of 13.93 °Brix and flesh firmness of 39.5 N.

3. RESULTS AND DISCUSSION

3.1 Chimarrita Cultivar

As shown in Fig. 1A, weight loss data adjusted to the regression model (($F = 93.63$; $p< 0.0001$)) with R^2 0.92 and R^2adj of 0.91. For this variable during the optimization process, roots of the auxiliary equations were positive and negative in their magnitudes, indicating that the stationary point is a saddle point.

The predict value for weight loss at this stationary point was 3.27%, obtained with 1.33 $mmol.L^{-1}$ of salicylic acid after 12 days. [13] Suggest that for Chimarrita peaches, a mass loss limit of 5% can lead to shriveling symptoms, which was not observed in the present study.

The results in Fig. 1B showed that the DA rate adjusted to the regression model established ($F = 21.90$; $p< 0.0001$), with an R^2 of 0.72 and R^2adj of 0.69. For this variable during the optimization process, roots of the auxiliary equations were positive and negative in their magnitude, indicating that the stationary point is a saddle point, obtaining a predicted DA index value of 0.48 at 0.29 $mmol.L^{-1}$ of salicylic acid, combined with 13.4 days. If compared with lot characterization, DA index decreased considerably. This suggests a possible occurrence of chlorophyll degradation, since the closer it is to zero, the smaller the amount of chlorophyll in the fruit, [14] indicating probable fruit color and ripening evolution.

Firmness results adjusted to the regression model ($F = 11.55$; $p< 0.0001$), with R^2 of 0.77 and R^2adj of 0.74, as shown in Fig. 2A. During the optimization process, the roots of the auxiliary equations were positive and negative in their magnitude, indicating the saddle point as the stationary point. At this point, the predict point was 4.6 N in 1.09 $mmol.L^{-1}$ of salicylic acid in 18.7 days. Soluble pectin data adjusted satisfactorily to the regression model ($F = 6.40$; $p = 0.0004$), with R^2 of 0.62 and R^2adj of 0.59 (Fig. 2B). During the optimization process, the roots of the auxiliary equations were positive and negative in their magnitude, indicating the saddle point as the stationary point. At this point, 0.10 $g.100g^{-1}$ soluble pectin was obtained for 0.43 $mmol.L^{-1}$ of acid salicylic for 23.8 days.

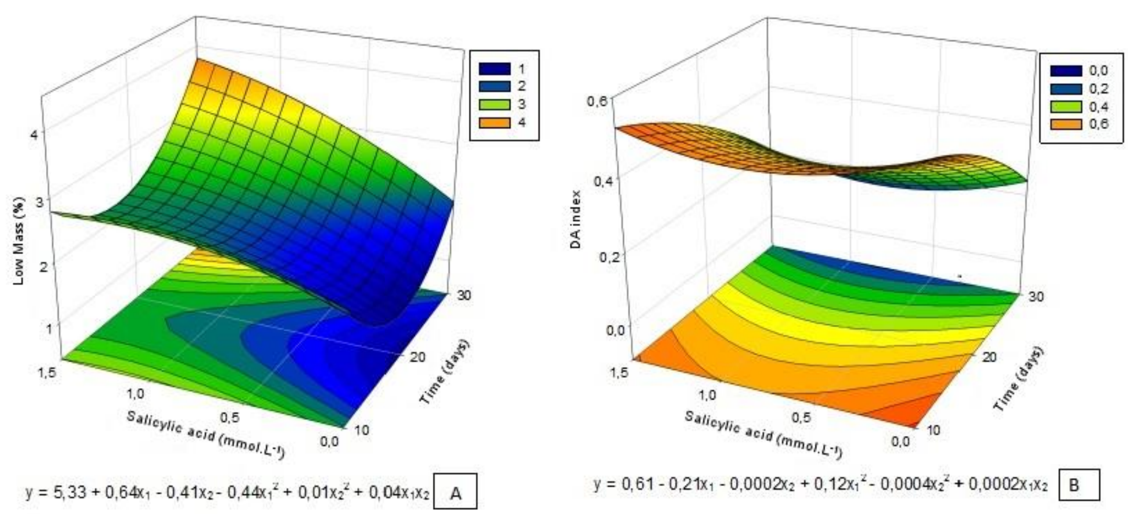

Fig. 1. Weight loss (A) and DA index (B) reported in Chimarrita peaches submitted to different concentrations of salicylic acid, after different periods under cold storage, plus 2 days at room temperature for commercial simulation. Pelotas - Brazil

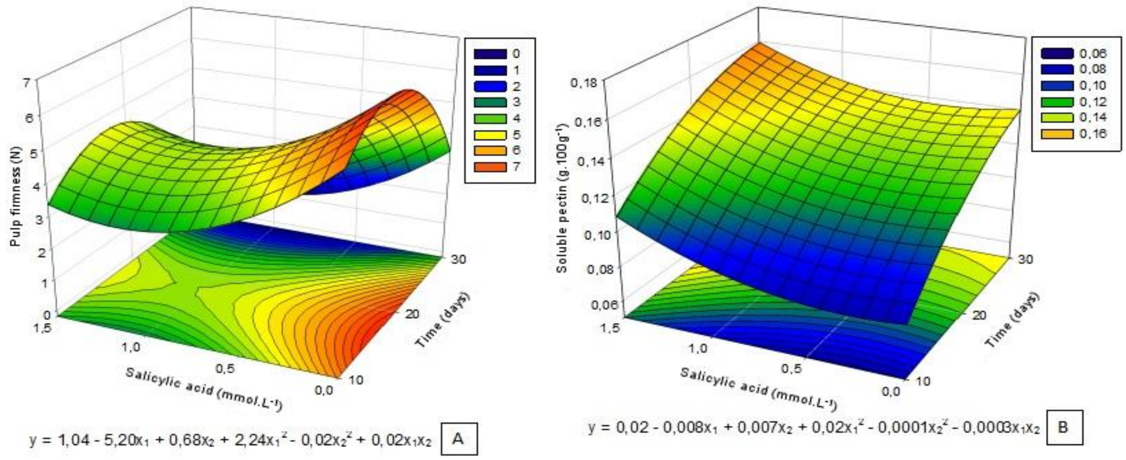

Fig. 2. Flesh firmness (A) and soluble pectin (B) reported in Chimarrita peaches submitted to different concentrations of salicylic acid, after different cold storage periods plus 2 days for commercial simulation. Pelotas – Brazil

This low firmness value could be explained by the increasing levels of soluble pectin. In a study with Laetitia plums, [15] reported that firmness reduction could be associated to higher soluble pectin as well higher soluble solids content (Fig. 3A). Soluble Solids content adjusted to the regression model (F = 12.94; p< 0.0001), with R^2 of 0.61 and R^2adj of 0.57. During the optimization process, the roots of the auxiliary equations achieved positive values stating that the stationary point is minimum. The predict value for SS at this stationary point was 12.03 °Brix reached with 0.72 mmol.L^{-1} of salicylic acid in 11.6 days.

Data regarding rot development showed to be adjusted to regression model (F = 3.90; p = 0.007), with R^2 of 0.68 e R^2adj o 0.64, as seen in Fig. 3B. During the optimization process, roots of the auxiliary equations were positive and negative in their magnitude, indicating the saddle point as the stationary point. Under this condition, 35.4% of rotting was registered for 0.85 mmol.L^{-1} of salicylic acid, in 23 days. Phytopatological testing was not performed to identify the causal agent of rot, but by its symptomatology, it referred to brown rot. According to [13], *Monilinia fructicola* is set up in the field, thus it is difficult to separate infected fruits from healthy ones, which can explain the large percentage and ranges in rot mean values found in this study.

3.2 Maciel Cultivar

Weight loss adjusted to the regression model (F = 6.07; p = 0.0003), with R^2 of 0.61 and R^2adj of 0.57 (Fig. 4A). During the optimization process, the roots of the auxiliary equations achieved positive values stating that the stationary point is minimum. The predict value for low mass at this stationary point was 5.18%, reached with 0.56 mmol.L^{-1} of salicylic acid in 21.19 days. Weight loss can be considered low if compared to an experiment carried out with Maciel peaches by [16], where fruits without treatment stored under similar conditions (21 days in cold storage plus 3 days of commercial simulation) showed mean values of 8.1% for harvested peaches. [4] Have also reported that salicylic acid application showed to be effective in reducing mass loss in peaches Flordaking.

DA index behavior was analyzed in Fig. 4B, wherein the index decreases during cold storage period; however, the parameter range was low in comparison with harvest day indicating fruit maturity process. DA findings adjusted to the regression model (F = 7.85; p = 0.0004), with R^2 of 0.68 and R^2adj of 0.65. During the optimization process roots of the auxiliary equations were positive and negative in its magnitudes, indicating the stationary point is a saddle point, and predict value of DA index 0.44 for 0.62 mmol.L^{-1} of salicylic acid in 14.7 days.

Pulp firmness findings adjusted to the regression model (F = 61.87; p< 0.0001), with R^2 of 0.89 and R^2adj of 0.87 (Fig. 5A). During the optimization process, roots of the auxiliary equations were positive and negative in its magnitudes, indicating the saddle point as stationary point, and predict value was 35.7N for

0.75 mmol.L^{-1} of salicylic acid in 20 days. The results are in agreement with [4] salicylic acid showed to be efficient for maintaining firmness, if compared to lot at the harvest period.

Soluble pectin adjusted to the regression model (F = 37.67; p< 0.0001), with R^2 of 0.86 and R^2adj of 0.84 (Fig. 5B). During the optimization process, the roots of the auxiliary equations achieved positive values indicating that the stationary point is minimum. The predict value for soluble pectin at this stationary point was 0.19 g.100g^{-1} reached with 0.94 mmol.L^{-1} of salicylic acid in 22.9 days. According to [14], there is a natural ripening process, during which pectin solubility occurs, and is deposited in the cell wall, being responsible for fruit firmness.

In a study with Aurora-1 peaches, [17] observed that increase in soluble solids content may be due to changes in accumulated resources, especially starch, during storage, as shown in Fig. 6A. Soluble content data adjusted to the regression model (F = 9.95; p< 0.0001), with R^2 of 0.64 and R^2adj of 0.61. During the optimization process, the roots of the auxiliary equations were positive and negative in their magnitude, indicating the saddle point as the stationary point. Soluble contents of 13.3 °Brix for 1.3 mmol.L^{-1} of salicylic acid in 11.7 days were reported.

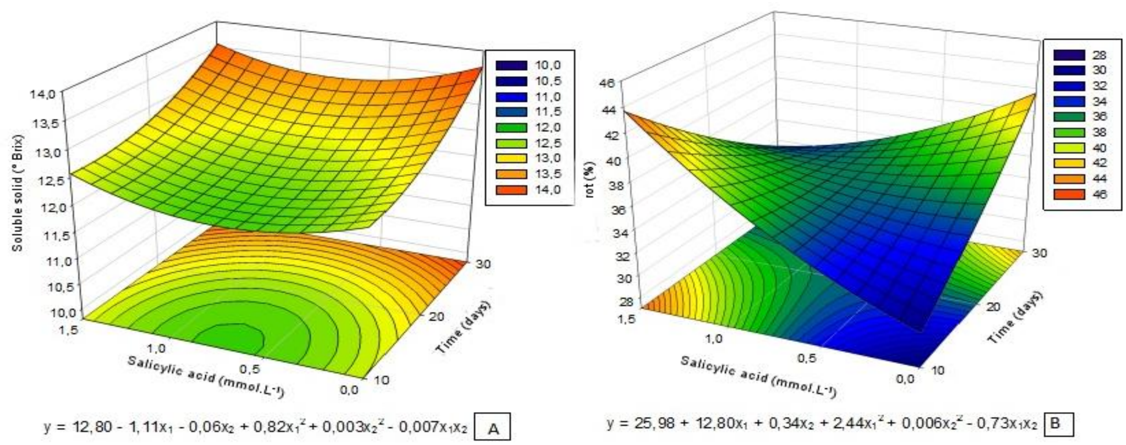

Fig. 3. Soluble solids content (A) and rot percentage (B) reported in Chimarrita peaches submitted to different concentrations of salicylic acid, after different cold storage periods, plus 2 days for commercial simulation. Pelotas -Brazil

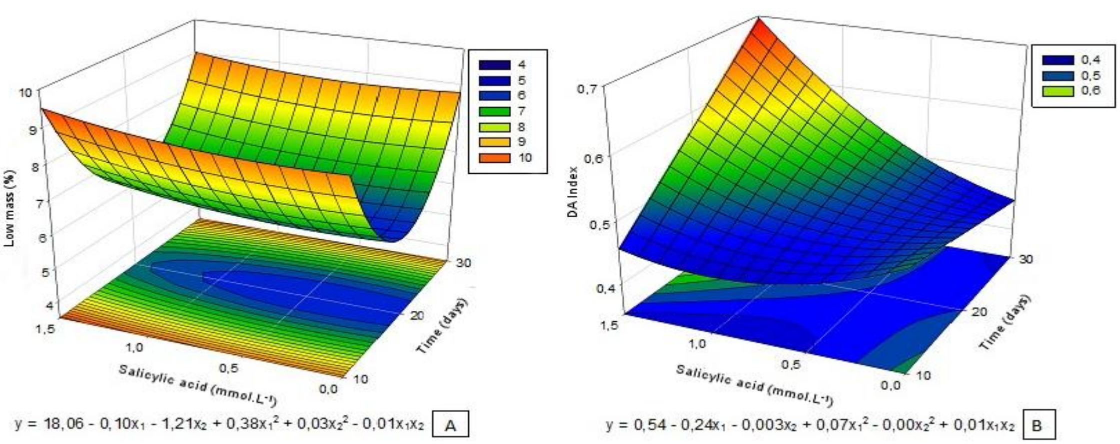

Fig. 4. Weight loss (A) and DA index (B) reported in Maciel peaches submitted to different concentrations of salicylic acid, during different cold storage periods, plus 2 days of commercial simulation. Pelotas –Brazil

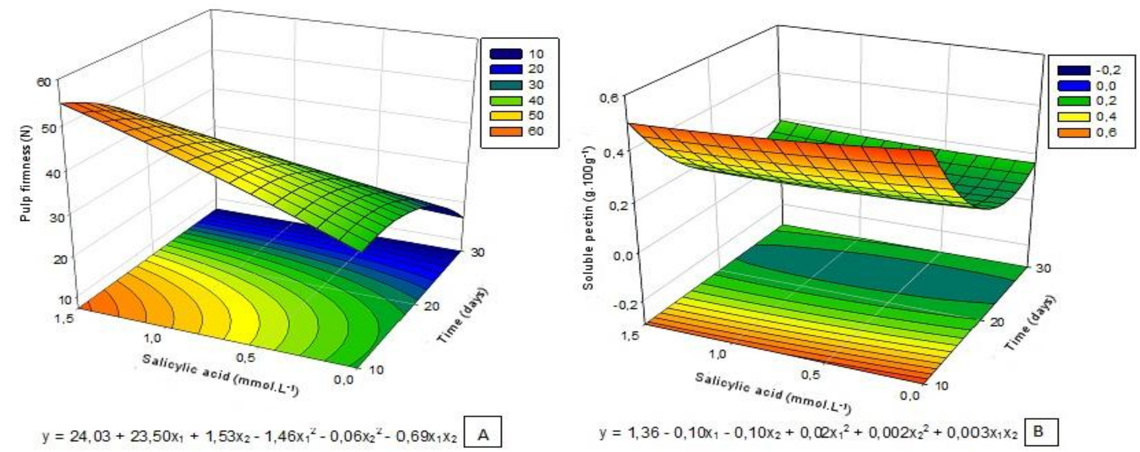

Fig. 5. Flesh firmness (A) and soluble pectin (B), reported in Maciel peaches submitted to different salicylic acid concentrations during different cold-storage periods, plus 2 days for commercial simulation. Pelotas - Brazil

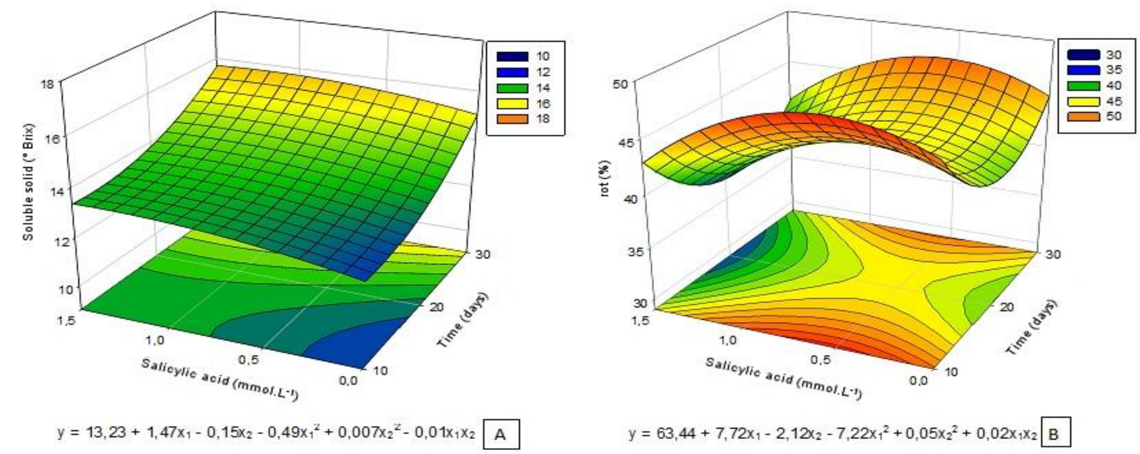

Fig. 6. Soluble solids content (A) and rot percentage (B) reported in Maciel peaches submitted to different concentrations of salicylic acid, during different cold-storage periods plus 2 days, for commercial simulation. Pelotas - Brazil

Rot percentage findings adjusted to the regression model (F = 14.60; p< 0.0001), with R^2 of 0.62 and R^2adj of 0.59. During the optimization process, the roots of the auxiliary equations were positive and negative in their magnitude, indicating the saddle point as stationary point. At this condition, 42.3% rotting was registered for 0.56 mmol.L^{-1} of salicylic acid in 22 days. This high percentage of brown rot could be attributed to salicylic acid postharvest application, increasing fruit humidity, promoting rot progress during storage [1].

4. CONCLUSION

Salicylic acid at 1.0 mmol.L^{-1} was efficient in maintaining the quality of the Chimarrita cultivar at 20 days plus two for commercial simulation. However, for the Maciel cultivar, 0.5 mmol.L^{-1} of salicylic acid was more efficient for the same period.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cantillano RFF. Post-harvest management and conservation: Physiology and technology. In: Ramp MCB; Pereira JFM, Carvalho FLC. (Org.) Peach. Embrapa, Brazil; 2014. English.

2. Asghari M, Aghdam MS. Impact of salicylic acid on postharvest physiology of horticultural crops. Trends in Food Science & Technology. 2010;21:502-509.
3. Wang L, Chen S, Kong W, Li S, Archbold DD. Salicylic acid pretreatment alleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. Postharvest Biology and Technology. 2006;41:244–251.
4. Tareen MJ, Abbasi NA, Hafiz IA. Effect of salicylic acid treatments on storage life of peach fruits cv. 'Flordaking'. Pakistan Journal of Botany. 2012;44(1):119-124.
5. Razavi F, Hajilou J, Dehgan G, Hassani RNB, Turchi M. Enhancement of postharvest quality of peach fruit by salicylic acid treatment. International Journal of Biosciences. 2014;4(1):177-184.
6. Ali I, Abbasi NA, Hafiz IA. Physiological response and quality attributes of peach fruit cv. Florida king as affected by different treatments of calcium chloride, putrescine and salicylic acid. Pak. J. Agri. Sci. 2014; 51(1):33-39.
7. Yang Z, Cao S, Cai Y, Zheng Y. Combination of salicylic acid and ultrasound to control postharvest blue mold caused by *Penicillium expansum* in peach fruit. Innovative Food Science & Emerging Technologies. 2011;12(3):310-314.
8. Reisser Junior C, Timm LC, Tavares VEM. Characteristics of peach cultivation in the region of Pelotas-RS, related to the availability of water to the plants. Documents 240, Embrapa Clima Temperado-Pelotas, RS, Brazil; 2008. English.
   ISSN: 1806-9193
9. Sasaki FF. Thermal treatments, calcium chloride and modified atmosphere in peaches 'IAC Douradão': Physiological, biochemical and quality aspects. 177f. Thesis (Doctorate). University of São Paulo (School of Agriculture "Luiz de Queiroz", São Paulo, Brazil; 2009. Portuguese.
10. Freund RJ, Littell RC. SAS system for regression. SAS Institute Inc., North Carolina, USA. 1991;127-150.
11. Myers RH. Response surface methodology. Allyn and Bacon, Boston; 1971.
12. Khuri AI, Cornell JA. Response surfaces: designs and analyses. Marcel Dekker, New York; 1989.
13. Seibert E, Casali MI, Leo ML, Pezzi E, Corrent AR, Bender RJ. Cold damages and qualitative changes during refrigerated storage of peaches harvested at two maturation stages Bragantia, Campinas, Brazil. 2008;67:1021-1029. English
14. Betemps DL, Fachinello JC, Galarça SP. Visible and near infrared spectroscopy (Vis / Nir) in the tommy atkins sleeve quality assessment. Revista Brasileira de Fruticultura, Jaboticabal - SP. 2011;[E] 306-313. English.
15. Steffens CA, Amarante CVT, Chechi R, Silveira JPG, Corrêa TR. Maturation and postharvest quality of 'Laetitia' plums with the pre-harvest application of AVG and GA3. Revista Brasileira de Fruticultura, Jaboticabal – SP. 2011;33:021-031. English.
16. Seibert E, Leão ML, Rieth S, Bender RJ. Effects of conditioning on the quality of peaches Maciel. Acta Scientiarium Agrononomy. Maringá. 2010;32:477-483. English.
17. Martins RN, Mattiuz B, Santos LO, Hojo ETD, Mattiuz CFM. Aurora-1 peach maturation stages for minimum processing. Revista Brasileira de Fruticultura, Jaboticabal - SP, Brazil. 2013;35:391-397. English.

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