

Original Research Article

Salicylic acid on maintenance of peaches 'Chimarrita' and 'Maciel' under cold storage

ABSTRACT

Aims: The objective of this work was to evaluate the efficiency of postharvest application of salicylic acid on peaches cultivar Chimarrita and Maciel 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 factorial arrangement (4X3) for each cultivar, 4 treatments and 3 storage periods for both cultivars.

Place and Duration of Study: This work was executed at LabAgro/Fruculture, Federal University of Pelotas, Rio Grande do Sul state, Brazil, between November 2013 and February 2014.

Methodology: 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 left to air dry. The following treatments were used: T1- Peaches without treatment (water distilled solution+ 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. Fruits submitted to treatment, were stored under cold at 1.0 ± 0.5 °C and 85-90% RH, during 30 days. Mass loss (%), DA index, firmness (N), soluble solids contents (°Brix), rot incidence (%), soluble pectin (g.100g⁻¹), were assessed at 10, 20 and 30 days, and two more days for commercial simulation.

Results: *Chimarrita cultivar:* The predict value for low mass at this stationary point was 3.27%, obtained with 1.33 mmol.L⁻¹ of salicylic acid in 12 days. Data regarding rot development showed to be adjusted to regression model (F = 3.90; p = 0.007), with R² of 0.68 e R²adj of 0.64. During the optimization process, roots of the auxiliary equations were positive and negative in its magnitudes, indicating the saddle point as the stationary point. At this condition was registered 35.4% of rotting for 0.85 mmol.L⁻¹ of salicylic acid, in 23 days.

Maciel cultivar: 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. Pulp firmness findings adjusted to the regression model (F = 61.87; p < 0.0001), with R² of 0.89 and R²adj of 0.87. 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.

Conclusion: Salicylic acid at 1.0 mmol.L⁻¹ was efficient in maintaining quality of Chimarrita cultivar at 20 days plus two days for commercial simulation. However, for Maciel cultivar 20 days plus two days of commercial simulation at 0.5 mmol.L⁻¹ of salicylic acid on postharvest was more efficient.

Keywords: Elicitor, *Prunus persica* (L.) Bats storage period, quality.

1. INTRODUCTION

Peach fruits are highly perishable and its quality can be affected if ~~there is not a~~ proper postharvest ^[1] Studies have been done associating others techniques with cold storage, in order to increase peaches shelf life. One of these techniques can be salicylic acid application on postharvest 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]. The same has been seen with positive results by [3]. These same authors tested salicylic acid concentrations at 0.35 mmol, 0.7 mmol and 1.0 mmol, finding good results for pulp firmness at 1.0 mmol of salicylic acid.

According to ^[4] the use of salicylic acid in peaches, showed to be efficient to control fruit quality, such as color of epidermis, mass loss, firmness and pH.

The aim of this study was to evaluate the efficiency of postharvest application of different concentrations of salicylic acid in peaches Chamarrita and Maciel under cold storage.

2. MATERIAL AND METHODS

This study was carried out on peaches Chamarrita and Maciel obtained from the Agricultural Center guided of Palm/Federal University of Pelotas, Capão do Leão, Rio Grande do Sul, Brazil, with latitude of 31° 52 ' 00 "S, longitude of 52° 21 ' 24" W and altitude of 13.24 meters. The soil belongs to Camaquã unit, being moderately deep with medium texture on the horizon A and clay in B, classified as ultisol [5]. Climate region is characterized by temperate and humid with hot summers, according to Köppen classification, "Cfa". 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 left to air dry. Approximately 1.0 ml of the solution was sprayed on both sides of each fruit. In order to promote salicylic acid dissolution, 5 mL.L⁻¹ of ethyl alcohol was used in the solution.

The following treatments were used: T1- Peaches without treatment (water distilled solution+ 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.

Fruits submitted to treatment, were stored under cold at 1.0 ± 0.5° C and 85-90% RH, during 30 days. Analyses were undertaken in the following periods: harvest day for lot characterization; at 10 days in cold storage and 2 more days at room temperature (20° C), for commercial simulation (10 + 2); at 20 days in cold storage plus 2 days at room temperature (20 + 2); and at 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 factorial arrangement (4X3) for each cultivar, 4 treatments and 3 storage periods for both cultivars.

This work was executed at LabAgro/Fructiculture and the following variables were analyzed:

59 • **Mass loss:** determined by the difference in percentage between the initial mass
60 through the equation: $(\text{initial weight} - \text{final weight} / \text{initial weight}) \times 100$;

61 • DA index: obtained through the DA-meter 53500, which gives the index of
62 absorbance difference in wavelengths 670 and 720nm (peak of chlorophyll);

63 • Pulp Firmness: Firmness was recorded using a penetrometer expressed in Newton;

64 • Rot incidence: was analyzed by counting the fruits that presented lesion diameter
65 greater than 0.5 cm, which is typical of fungus and bacteria. The results were expressed in
66 percentage;

67 • Soluble solids: the soluble solids content in °Brix was ascertained with a digital
68 refractometer.

69 • Pectin soluble content: was evaluated based on [6].

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

72 Subsequently data were subjected to analysis of variance, F-test ($p \leq 0.05$). Response
73 surface regression was used (PROC RSREG) SAS / STAT 9.1 for Windows (SAS Institute,
74 Cary NC), with linear effects, quadratic and linear interaction of independent variables [7].
75 Model was chosen based on: (a) residue; (b) p value ($p \leq 0.05$); (c) standard derivation and
76 (d) R^2 e R^2 adj. Afterwards polynomial equation was adjusted to dependent variables data.

77 $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_{ij} x_i x_j$, where y is the dependent variable; x_i , x_j are the
78 independent variables, that affect the dependent variable y; β_0 is the intercept; β_i is the
79 linear effect; β_{ii} is the quadratic effect and β_{ij} is the interaction between x_i e x_j .

80 For optimization, the canonical rotational analysis added to surface response was used
81 where variables standard (x_1 , dose; x_2 , time) – within the experimental probability – were
82 established in order to obtain the answer to each dependent variable studied. Function
83 response optimization consisted in function response version (y_k), from the origin toward the
84 stationary points (x_0). Response function was maximum when all roots achieved negative
85 values and minimum when all roots achieved positive values. If some roots showed positive
86 values and others negative it was characterized as a saddle point [8] [9].

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89 3. RESULTS AND DISCUSSION

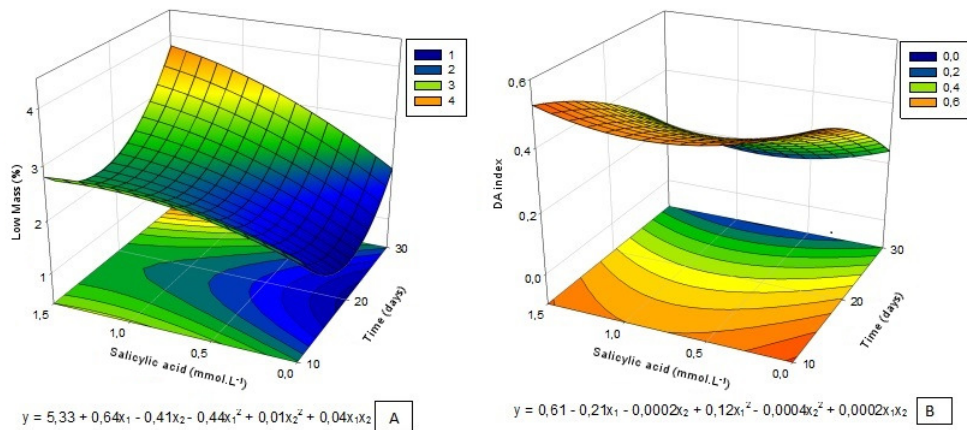
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91 3.1 Chimarrita Cultivar

92 Harvest was undertaken in the first week of December, 2013 when fruit characterization was
93 complete, which showed average of 1038.67 g.15 fruits⁻¹, index of 0.82, soluble solids
94 content of 11.8° Brix and pulp firmness of 18.7 N.

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

99 The predict value for low mass at this stationary point was 3.27%, obtained with 1.33
 100 mmol.L⁻¹ of salicylic acid in 12 days. [10] Suggest that for peaches Chimarrita a mass loss
 101 limit of 5% can lead to shriveling symptoms, which was not reported in the present study.

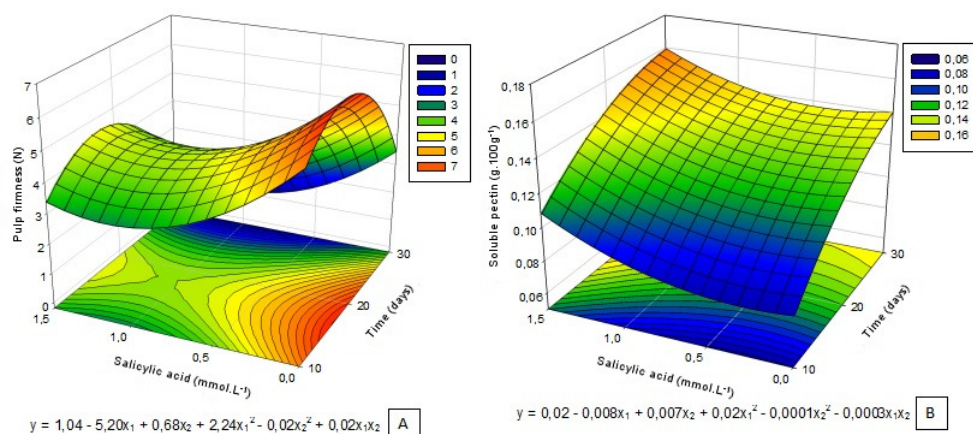


102
 103 **Figure 1: Low mass percentage (A) and DA index (B) reported in peaches Chimarrita,**
 104 **through different periods in cold storage, after 2 days of commercial simulation,**
 105 **submitted to different concentrations of salicylic acid. Pelotas - Brazil.**
 106

107 At Figure 1B, results showed that DA rate adjusted to the regression model established ($F =$
 108 21.90 ; $p < 0.0001$), with R^2 of 0.72 and R^2_{adj} of 0.69 . For this variable during the optimization
 109 process, roots of the auxiliary equations were positive and negative in its magnitudes,
 110 indicating that the stationary point is a saddle point, obtaining as predicted value DA index of
 111 0.48 at 0.29 mmol.L⁻¹ of salicylic acid, combined with 13.4 days. If compared with lot
 112 characterization, DA index decreased considerably. This suggest that possibly occurred
 113 chlorophyll degradation, since as closer to zero, smaller is the amount of chlorophyll in the
 114 fruit, [11] indicating probably fruit color and ripening evolution.

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

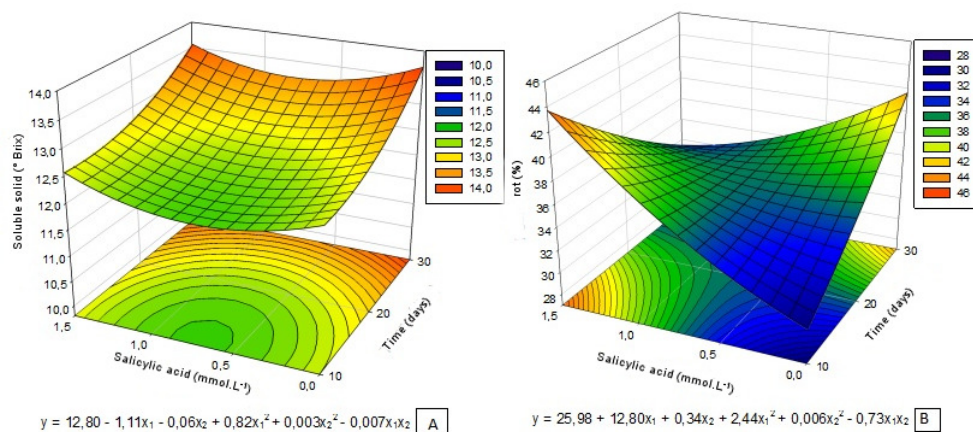
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126 **Figure 2: Pulp firmness (A) and soluble pectin (B) reported in peaches Chimarrita,**
 127 **through different periods in cold storage, after 2 days of commercial simulation,**
 128 **submitted to different concentrations of salicylic acid. Pelotas – Brazil.**
 129

130 This low value regarding firmness could be explained by the increasing levels of soluble
 131 pectin. [12] Reported in a study with plums Laetitia, that firmness reduction could be
 132 associated to higher soluble pectin as well higher soluble solids contents (Figure 3A). Solid
 133 soluble contents adjusted to the regression model ($F = 12.94$; $p < 0.0001$), with R^2 of 0.61
 134 and R^2_{adj} of 0.57. During the optimization process roots of the auxiliary equations achieved
 135 positive values stating that the stationary point is minimum. The predict value for SS at this
 136 stationary point was 12.03 °Brix reached with 0.72 mmol.L⁻¹ of salicylic acid in 11.6 days.



137

138 **Figure 3: Soluble solid contents (A) and rot percentage (B) reported in peaches**
 139 **Chimarrita, under different periods in cold storage, after 2 days of commercial**
 140 **simulation, submitted to different concentrations of salicylic acid. Pelotas -Brazil.**
 141

142 Data regarding rot development showed to be adjusted to regression model ($F = 3.90$; $p =$
 143 0.007), with R^2 of 0.68 e R^2_{adj} o 0.64, as seen in Figure 3B. During the optimization process,
 144 roots of the auxiliary equations were positive and negative in its magnitudes, indicating the
 145 saddle point as the stationary point. At this condition was registered 35.4% of rotting for 0.85

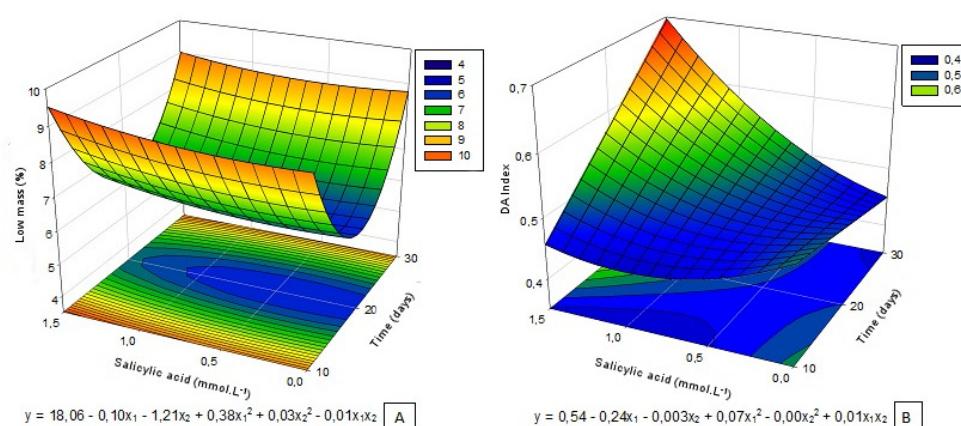
mmol.L⁻¹ of salicylic acid, in 23 days. Phytopathological testing was not performed to identify the causal agent of rot but by its symptomatology it referred to brown rot. According to [10], *Monilinia fructicola* is set up in the field, being then difficult to separate infected fruits from healthy fruits, which can explain the large percentage and ranges in rot mean values founded in this study.

151

152 3.2 Maciel Cultivar

153 Harvest was carried out in the first week of December 2013 when fruit description was
154 complete, which showed average of 1613.33 g.15 fruits⁻¹, DA index of 0.67, soluble solids
155 content of 13.93 °Brix and firmness 39.5 N.

156 Mass loss adjusted to the regression model ($F = 6.07$; $p = 0.0003$), with R^2 of 0.61 and R^2_{adj}
157 of 0.57 (Figure 4A). During the optimization process roots of the auxiliary equations achieved
158 positive values stating that the stationary point is minimum. The predict value for low mass at
159 this stationary point was 5.18%, reached with 0.56 mmol.L⁻¹ of salicylic acid in 21.19 days.
160 Mass loss can be considered low if compared with an experiment carried out with peaches
161 Maciel [13] where fruits without treatment stored under similar conditions (21 days in cold
162 storage plus 3 days of commercial simulation) showed mean values of 8.1% for peaches
163 harvested. [4] Have also reported that salicylic acid application showed to be effective in
164 reducing mass loss in peaches Flordaking.



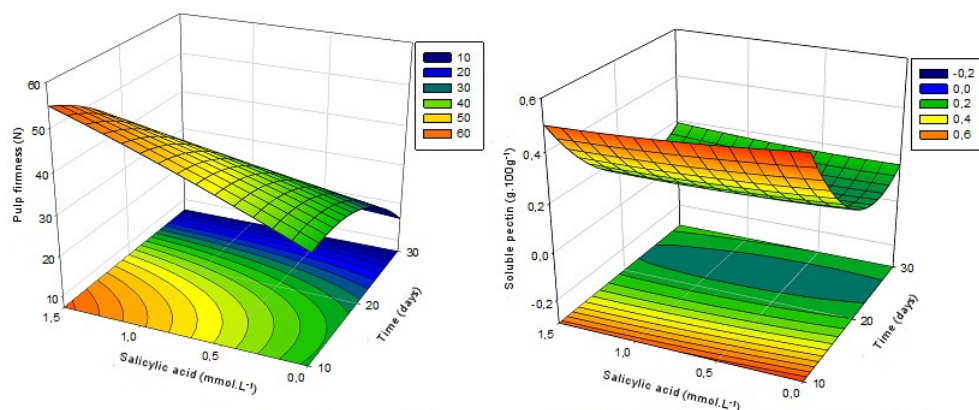
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166 **Figure 4: Mass low percentage (A) and DA index (B) reported in peaches Maciel,**
167 **during different periods in cold storage, after 2 days of commercial simulation,**
168 **submitted to different concentrations of salicylic acid. Pelotas –Brazil.**

169

170 DA index behavior was analyzed in Figure 4B, which the index decreases during cold
171 storage period; however the parameter range was low in comparison with harvest day
172 indicating fruit maturity process. DA findings adjusted to the regression model ($F = 7.85$; $p =$
173 0.0004), with R^2 of 0.68 and R^2_{adj} of 0.65. During the optimization process roots of the
174 auxiliary equations were positive and negative in its magnitudes, indicating the stationary
175 point is a saddle point, and predict value of DA index 0.44 for 0.62 mmol.L⁻¹ of salicylic acid
176 in 14.7 days.

177 Pulp firmness findings adjusted to the regression model ($F = 61.87$; $p < 0.0001$), with R^2 of
 178 0.89 and R^2_{adj} of 0.87 (Figure 5A). During the optimization process, roots of the auxiliary
 179 equations were positive and negative in its magnitudes, indicating the saddle point as
 180 stationary point, and predict value was 35.7N for 0.75 mmol.L⁻¹ of salicylic acid in 20 days.
 181 The results are in agreement with [4] salicylic acid showed to be efficient for maintaining
 182 firmness, if compared to lot at the harvest period.



183

$$y = 24,03 + 23,50x_1 + 1,53x_2 - 1,46x_1^2 - 0,06x_2^2 - 0,69x_1x_2 \quad \text{A}$$

$$y = 1,36 - 0,10x_1 - 0,10x_2 + 0,02x_1^2 + 0,002x_2^2 + 0,003x_1x_2 \quad \text{B}$$

184 **Figure 5: Pulp firmness (A) and soluble pectin (B) reported in peaches Maciel., during**
 185 **different periods in cold storage, after 2 days of commercial simulation, submitted to**
 186 **different concentrations of salicylic acid. Pelotas - Brazil.**

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

193 [14] In a study with peaches Aurora-1 assigned that soluble solid contents increase may be
 194 due to changes in accumulated resources, especially starch, during storage, as shown in
 195 Figure 6A. Soluble contents data adjusted to the regression model ($F = 9.95$; $p < 0.0001$),
 196 with R^2 of 0.64 and R^2_{adj} of 0.61. During the optimization process roots of the auxiliary
 197 equations were positive and negative in its magnitudes, indicating the saddle point as
 198 stationary point. Soluble contents of 13.3 °Brix for 1.3 mmol.L⁻¹ of salicylic acid in 11.7 days
 199 were reported.

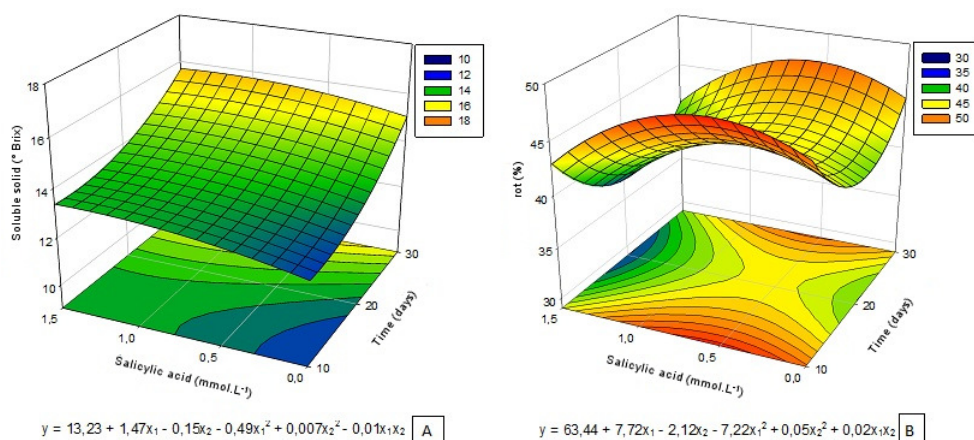


Figure 6: Soluble solid contents (A) and rot percentage (B) reported in peaches Maciel, during different periods in cold storage, after 2 days of commercial simulation, submitted to different concentrations of salicylic acid. Pelotas - Brazil.

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

4. CONCLUSION

Salicylic acid at 1.0 mmol.L⁻¹ was efficient in maintaining quality of Chimarrita cultivar at 20 days plus two days for commercial simulation. However, for Maciel cultivar 20 days plus two days of commercial simulation at 0.5 mmol.L⁻¹ of salicylic acid on postharvest was more efficient.

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. 2010. 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.

- 236 5. Reisser Junior, C, Timm, LC, Tavares, VEM. Characteristics of peach cultivation in the
237 region of Pelotas-RS, related to the availability of water to the plants. Documents 240,
238 Embrapa Clima Temperado-Pelotas, RS ISSN 1806-9193, Brazil; 2008. English.
239
- 240 6. Sasaki, FF. Thermal treatments, calcium chloride and modified atmosphere in peaches
241 'IAC Douradão': physiological, biochemical and quality aspects. 177f. Thesis (Doctorate).
242 University of São Paulo (School of Agriculture "Luiz de Queiroz", São Paulo, Brazil; 2009.
243 Portuguese.
244
- 245 7. Freund, RJ, Littell, RC. SAS System for Regression. SAS Institute Inc., North Carolina,
246 USA, pp. 127-150; 1991.
247
- 248 8. Myers, RH. Response Surface Methodology, Allyn and Bacon, Boston. 1971.
249
- 250 9. Khuri, AI, Cornell, J. A. Response Surfaces: Designs and Analyses, Marcel Dekker, New
251 York; 1989.
- 252 10. Seibert, E, Casali, MI, Leo, ML, Pezzi, E, Corrent, AR, Bender, RJ. Cold damages and
253 qualitative changes during refrigerated storage of peaches harvested at two maturation
254 stages Bragantia, Campinas, Brazil. 2008; 67: 1021-1029. English.
255
- 256 11. Betemps, DL, Fachinello, JC, Galarça, SP. Visible and Near Infrared Spectroscopy (Vis /
257 Nir) in the Tommy Atkins Sleeve Quality Assessment. Revista Brasileira de Fruticultura,
258 Jaboticabal - SP. 2011; [E] .306-313. English.
259
- 260 12. Steffens, CA, Amarante, CVT, Chechi, R, Silveira, JPG., Corrêa, TR. Maturation and
261 postharvest quality of 'Laetitia' plums with the pre-harvest application of AVG and GA3.
262 Revista Brasileira de Fruticultura, Jaboticabal - SP, 2011; 33: 021-031. English.
263
- 264 13. Seibert, E, Leão, ML, Rieth, S, Bender, RJ. Effects of conditioning on the quality of
265 peaches Maciel. Acta Scientiarum Agronomy. Maringá. 2010; 32: 477-483. English.
266
- 267 14. Martins, RN, Mattiuz, B, Santos, LO, Hojo, ETD., Mattiuz, CFM. 2013. Aurora-1 peach
268 maturation stages for minimum processing. Revista Brasileira de Fruticultura, Jaboticabal -
269 SP, Brazil. 2013; 35: 391-397. English.