POST-HARVEST FLESH FIRMNESS MAINTENANCE OF 'RED CHIRIPA' AND 'ERAGIL' PEACHES BY THE PRE-HARVEST SPRAYS OF GIBBERELLIC ACID

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ABSTRACT: Rio Grande do Sul is the largest Brazilian state of peach production, with an annual production of 120 thousand tons. Just under half of the production is destined for in natura consumption, which has as characteristic a short shelf life after harvested. The maturation of the fruits is regulated mainly by the respiratory rate and by the vegetable hormone ethylene, any practices that alter their behavior, the maturation of the fruits will be altered. The gibberellins are known to have an antagonistic effect on ethylene, thus, the pre-harvest application of gibberellic acid (GA_3) in peach trees may affect the maturation of peaches. The objective of this study was to verify the effects of pre-harvest GA_3 sprays on maturation characteristics of Eragil and Red Chiripa peaches cultivars grown in Southern Brazil. The pre-harvest application of GA_3 did not influence the soluble solids content of 'Eragil' peaches, on the other hand, it reduced the soluble solids content of 'Red Chiripa' peaches in the shelf life. The pre-harvest application of GA_3 is efficient to maintain flesh firmness for longer shelf life in both cultivars.

KEYWORDS: Gibberellin, soluble solids, Prunus, fruit ripening, Della Nonna peach.

MANUTENÇÃO DA FIRMEZA DE POLPA PÓS COLHEITA DE PÊSSEGOS 'CHIRIPÁVERMELHO' E 'ERAGIL' PELA APLICAÇÃO PRÉ COLHEITA DE ÁCIDO GIBERÉLICO

RESUMO: O Rio Grande do Sul é o estado de maior produção brasileira de pêssegos, com produção anual de 120 mil toneladas. Pouco menos da metade da produção destina-se ao consumo in natura, que possui como característica um curto período de prateleira após colhidos. A maturação dos frutos é regulada principalmente pela taxa respiratória e pelo hormônio vegetal etileno, quaisquer práticas que alterem o comportamento destes, a maturação dos frutos será alterada. As giberelinas são conhecidas por terem efeito antagônico ao etileno, com isso, a aplicação de ácido giberélico (GA_3) pré colheita em pessegueiros pode afetar a maturação de pêssegos. O objetivo deste trabalho foi verificar os efeitos da aplicação de GA_3 pré colheita nas características de maturação das cultivares de pêssegos Eragil e Chiripá Vermelho cultivados no Sul do Brasil. A aplicação de GA_3 pré colheita não influenciou a concentração de sólidos solúveis de pêssegos 'Eragil', por outro lado, reduziu a concentração de sólidos solúveis dos pêssegos 'Chiripá Vermelho' no período de prateleira. A aplicação de GA_3 pré colheita se mostra eficiente para manter a firmeza de polpa por mais tempo em período de prateleira em ambas cultivares.

PALAVRAS-CHAVE: Giberelina, sólidos solúveis, Prunus, maturação de frutos, pêssego Della Nonna.

INTRODUCTION

The peach trees [*Prunus persica* (L.) Batsch] belong to the Rosaceae family and are thought to have originated in China (Salunkhe and Desai, 1984). Chinese literature dates cultivation of the peach trees in China to 1000 b.c. and it was probably carried from China to Persia (current Iran). The peach tree name originated in Persia where it was identified as *Prunus persica* (Antunes et al., 1997), which is erroneously considered as the origin country (Sachs and Campos, 1998), and it was from this country that the peach tree spread by the world coming first in Europe and finally in the Americas. The peach tree was introduced in North America by the Spaniards in the early 16th century, and in Brazil in 1532 (Sachs, 1984).

The world production of peaches and nectarines exceeded 22 million tons in 2014, with the three main producing countries being China, Italy and United States in the northern hemisphere and Chile, South Africa and Australia in the southern hemisphere. Brazil is the 12th largest producer of peaches in the world, with 211 thousand tons of peaches grown on 18 thousand hectares (Fao 2017).

Rio Grande do Sul state is the main producer of peaches in Brazil, with an annual production of 123 thousand tons (IBGE, 2015). The state is characterized by 3 production poles, the South half region is made up of 103 municipalities where it concentrates more than 90% of the production of peaches for industrialization (Nakasu, 2003), especially in the municipalities of Pelotas, Canguçu and Morro Redondo (Scaloppi, 2006). The second producer pole is located on the upper northeast slope, called the Serra Gaúcha region. It is the main producing area of peaches for *in natura* consumption in Brazil, with emphasis on the municipalities of Pinto Bandeira and Farroupilha. The third pole is located in the metropolitan area of Porto Alegre, with most of its production destined also for *in natura* consumption (Protas and Madail, 2003).

A little less than half of the peaches produced in Brazil are destined for *in natura* consumption, which have a short shelf life, a factor that causes great losses. Because of this, it is normal to find low-quality fruit, usually soft and unattractive, at the marketing points. In addition, the evolution of peach maturation while in the plant occurs quickly, characterized mainly by the reduction of flesh firmness, a limiting factor for harvesting the peaches in a few days (Weksler et al. 2012).

The gibberellic acid (GA_3) is one of the most widely used plant growth regulators used to modify fruit development and maturation, is widespread in fruit growing, its results are seen in grapevines with stem lengthening, persimmon with harvest delay, plums and peaches to

increase shelf life. There are records of delay in the maturation of several fruits, including the stone fruits, by the application of GA_3 that has as characteristic the antagonism to ethylene (Ferri et al., 2004; Modesto et al., 2006). According to Steffens et al. (2010), the action mechanism of GA_3 seems to be related to the effect on the reduction of ethylene production, thus reducing the activity of cell wall hydrolytic enzymes, delaying the flesh firmness loss.

The purpose of the present study was to see if gibberellin applied close to harvest would affect the rate of the fruit softening of 'Eragil' and 'Red Chiripa' peaches after harvest.

MATERIAL AND METHODS

The study was conducted in 2015/16 season in commercial peach orchards of 'Eragil' and 'Red Chiripa' (also known as Della Nonna peach) cultivars grafted on the 'Capdebocsq', with 8 and 6 years old respectively, located in the municipalities of Farroupilha, RS, Brazil at the geographic coordinates 29° 09' 17'' S and 51° 24' 19'' W with an altitude of 730 meters, and Pinto Bandeira, located at the geographic coordinates 29° 09' 03'' S and 51° 26' 48'' W with an altitude of 650 meters, RS, Brazil.

The treatments were applied in increasing doses of gibberellic acid (0, 30, 60 and 90 mg L^{-1}), from the commercial product ProGibb 400, applied 24 or 15 days before harvest. A spray volume equivalent to 1000 liters per hectare was used, with 1 ml L^{-1} of Break-Thru® adhesive spreader.

At the harvest moment, samples of 40 fruits per plant were collected and stored at room temperature 24ºC ± 2 for evaluation of flesh firmness and soluble solids concentration at 0 (day of harvest), 2 and 4 days after harvest. The evaluations were made in the Laboratory of Food Technology of the Federal Institute of Rio Grande do Sul, Bento Gonçalves Campus.

The experimental design was completely randomized in a 4x2 factorial scheme, with 4 replications of one plant per plot. The data were submitted to analysis of variance and when significant to the regression analysis and to the comparison of means by Tukey test at 5% of error probability.

RESULTS

Table 1 shows the concentration of soluble solids in 'Eragil' peaches with pre-harvest application of gibberellic acid (GA_3). It was verified that there was no influence of the applications in the concentration of soluble solids and that there is no significant change with the advance of the peaches maturation in shelf life. These results corroborate with the results

reported by Stern and Ben-Arie (2009), who describes no changing in the soluble solids content in 'Giant Queen' nectarines treated with GA_3 in relation to the control fruits.

There were differences on the flesh firmness of the 'Eragil' peaches due to the period of GA_3 application, where at doses of 60 and 90 mg L^{-1}, when applied 15 days before harvest (DBH), presented greater flesh firmness on the day of harvest (January 6) when compared to the fruits submitted to application 24 DBH. On the two shelf days, only the peach trees treated with 30 mg L^{-1} of GA_3 presented statistical differences, and the previous application provided greater flesh firmness in the fruits. From the four shelf days, there were no differences in the flesh firmness of the fruits comparing the treatments performed at 24 DBH and 15 DBH (Table 2).

The flesh firmness behavior of the 'Eragil' peaches submitted to the GA_3 treatments was altered as the fruits matured in the shelf life. On the day of harvest (January 6) fruits from trees treated with 90 mg L^{-1} at 24 DBH obtained flesh firmness lower than the fruits of the trees submitted to the other treatments. From the second shelf day, the fruits of the peach trees treated with 60 and 90 mg L^{-1} of GA_3 began to present greater flesh firmness compared to the fruits of the control trees. On the fourth day of the shelf, the differences were further accentuated, with the fruits of the control trees presenting flesh firmness much lower than the fruits treated with GA3, regardless of the dose or time of application. In general, on the fourth day of shelf the fruits of treated plants presented twice the flesh firmness than the fruits of untreated trees (Table 2).

Dagar et al. (2012) describes in their article the effect of the GA_3 application on the maturing delay of peaches and nectarines. As well as the results found for the 'Eragil' peach in this work, the above authors describe that there was no difference in the solid soluble contents between the two harvests. Zilka et al. (1997) reported greater flesh firmness of 'Flamekist' nectarines treated with GA_3 in relation to the control, without any effect on soluble solids content, emphasizing that most of the work done with peaches and nectarines shows a higher effect of GA_3 application on flesh firmness without changing the soluble solids content.

The 'Red Chiripa' peaches, in general, had soluble solids reduction by the GA_3 application, presenting different results between evaluations, doses and times of application. With regard to the effect of the time of application of GA_3 on the concentration of soluble solids in the peaches at the time of harvest, only the fruits of the plants submitted to application of 90 mg L^{-1} at 24 DBH had lower soluble solids concentration when compared to the fruits of the plants with application of the same dose at 15 DBH. At two days shelf life, the reduction of

soluble solids occurred at a dose of 60 mg L^{-1} at 24 DBH. From the fourth day of shelf there was no difference influenced by the time of GA_3 application (Table 3).

At the time of harvest, the concentration of soluble solids in the fruits submitted to 90 mg L^{-1} at 24 DBH and 60 mg L^{-1} at 15 DBH was reduced, the latter treatment presented the same behavior after two days of shelf. In the other evaluations, including the four shelf days, which resembled the peaches consumers consumption moment, all treatments reduced on average of 1,5 ºBrix of the soluble solids concentration of 'Red Chiripa' peaches (Table 3). Contradicting the results found by Pegoraro et al. (2011), who reported no effect of GA_3 on the soluble solids content of 'Chiripa' peaches.

The flesh firmness of the 'Red Chiripa' peaches was not influenced by the moment of application. At the time of harvest, this variable was the same for all treatments, as well as for the two shelf days of fruits submitted to treatments at 24 DBH. On the other hand, at two days shelf life, the application of 90 mg L^{-1} at 15 DBH maintained the flesh firmness 12 N upper than untreated fruits. The other treatments did not differ from each other at two shelf days. After the four days of shelf, the flesh firmness of the untreated fruits reduced drastically while the fruits submitted to the application of GA_3 reduced the flesh firmness of slower form. The application of 60 mg L^{-1} at 24 DBH maintained flesh firmness 22.2 N higher than untreated fruits, with the other treatments not differing at this date of application. At 15 DBH, the fruits submitted to the 30 and 90 mg L^{-1} doses had the highest flesh firmness, 20 and 19 N more than the untreated fruits, respectively.

Weksler et al. (2012) verified the maintenance of flesh firmness of 'Swelling' and 'Oded' peaches subjected to the application of GA_3 in the dose of 25 and 50 mg L^{-1} at 24 days before harvest when compared to untreated fruits. These authors attributed this result to the increase of cellulose in the cell wall of the fruits submitted to the treatments with GA_3.

Another benefit of the GA_3 application is the significant reduction of damages caused by cold during storage. Lurie and Crisosto (2005) verified this benefit in studies carried out in Israel and in the state of California, USA, through the pre-harvest application of GA_3 in the dose of 50 to 100 mg L^{-1}. The authors attributed the damage reduction caused by cold storage, the greater flesh firmness conferred by GA_3.

Table 1 - Soluble solids concentration of 'Eragil' peaches submitted to pre-harvest application of gibberellic acid, Pinto Bandeira, RS, Brazil, 2016.

Gibberellic Acid	Soluble Solids (ºBrix)											
	6 Jan (harvest day)				8 Jan (2 shelf days)				10 Jan (4 shelf days)			
	24 DBH		15 DBH		24 DBH		15 DBH		24 DBH		15 DBH	
0 mg L^{-1}	10.7	ns	10.7	ns	10.3	ns	10.3	ns	9.8	ns	9.8	ns
30 mg L^{-1}	10.6		10.5		10.5		10.7		10.0		10.0	
60 mg L^{-1}	10.5		10.8		10.5		10.4		9.9		9.9	
90 mg L^{-1}	10.9		11.1		10.1		10.8		9.8		10.0	
C.V. (%)	4.6				6.9				1.5			

* DBH – Days before harvest.
**ns – not significant

Table 2 - Flesh firmness of 'Eragil' peaches submitted to pre-harvest application of gibberellic acid, Pinto Bandeira, RS, Brazil, 2016.

Gibberellic Acid	Flesh Firmness (N)											
	6 Jan (harvest day)				8 Jan (2 shelf days)				10 Jan (4 shelf days)			
	24 DBH		15 DBH		24 DBH		15 DBH		24 DBH		15 DBH	
0 mg L^{-1}	54.3	aA	54.3	aA	38.3	bA	38.3	bA	22.7	bA	22.7	cA
30 mg L^{-1}	56.9	aA	57.8	aA	58.7	aA	42.3	bB	41.4	aA	40.0	bA
60 mg L^{-1}	52.9	aA	59.6	aB	60.0	aA	58.7	aA	45.3	aA	48.9	aA
90 mg L^{-1}	46.3	bA	53.8	aB	59.5	aA	61.8	aA	41.3	aA	50.7	aA
C.V. (%)	6.2				12.7				38.5			

* DBH – Days before harvest.
** Means followed by the same lowercase letter in the columns and upper case in the lines, for each evaluation, do not differ by Tukey test (p>0,05).

Tabela 3 - Soluble solids concentration of 'Red Chiripa' peaches submitted to pre-harvest application of gibberellic acid, Farroupilha, RS, Brazil, 2016.

Gibberellic Acid	Soluble Solids (ºBrix)											
	6 Jan (harvest day)				8 Jan (2 shelf days)				10 Jan (4 shelf days)			
	24 DBH		15 DBH		24 DBH		15 DBH		24 DBH		15 DBH	
0 mg L^{-1}	12.4	aA	12.4	aA	13.2	aA	13.2	aA	13.3	aA	13.3	aA
30 mg L^{-1}	11.8	abA	11.3	bA	11.8	bA	11.7	bA	11.9	bA	11.6	bA
60 mg L^{-1}	12.1	abA	12.4	aA	11.4	bB	12.4	abA	11.6	bA	11.9	bA
90 mg L^{-1}	11.2	bB	12.2	abA	12.0	bA	12.1	abA	11.6	bA	11.9	bA
C.V. (%)	4.5				3.8				2.6			

* DBH – Days before harvest.

** Means followed by the same lowercase letter in the columns and upper case in the lines, for each evaluation, do not differ by Tukey test (p>0,05).

Table 4 - Flesh firmness of 'Red Chiripa' peaches submitted to pre-harvest application of gibberellic acid, Farroupilha, RS, Brazil, 2016.

Gibberellic Acid	Flesh Firmness (N)											
	6 Jan (harvest day)				8 Jan (2 shelf days)				10 Jan (4 shelf days)			
	24 DBH		15DBH		24 DBH		15DBH		24 DBH		15DBH	
0 mg L^{-1}	52.0	aA	52.0	aA	41.8	aA	41.8	bA	26.6	bA	26.6	bA
30 mg L^{-1}	53.8	aA	53.8	aA	48.4	aA	49.8	abA	42.2	abA	46.7	aA
60 mg L^{-1}	56.9	aA	55.1	aA	51.5	aA	50.2	abA	48.4	aA	39.1	abA
90 mg L^{-1}	53.8	aA	56.4	aA	50.7	aA	53.8	aA	44.4	abA	45.8	aA
C.V. (%)	6.1				9.1				21.4			

* DBH – Days before harvest.

** Means followed by the same lowercase letter in the columns and upper case in the lines, for each evaluation, do not differ by Tukey test (p>0,05).

In studies with increasing concentrations of products, it is important to perform regression analysis to better interpret the data, when significant. For the soluble solids concentration at four days of shelf life (24ºC ± 2), it was significant only for the 'Red Chiripa', and in the application at 24 DBH the regression behavior was polynomial of third degree, while at 15 DBH The behavior was of the second degree (Figure 1). This indicates that, although there is a reduction in the concentration of soluble solids with the application of gibberellic acid, it is not an increasing reduction with increasing dose, and may increase the concentration of solids soluble in higher doses of gibberellic acid, which does not could occur if the behavior were linear.

The regression analysis was also significant for flesh firmness at four days of shelf (24ºC ± 2) only for the 'Red Chiripa' peach, where the fruits treated at 24 DBH presented a linear behavior, which estimates that the higher the dose of GA_3 acid higher would be the flesh firmness of the fruit. At 15 DBH, showed a third degree behavior, that is, there was flesh firmness increases in the fruits treated with 30 mg L^{-1} of GA_3, then reduction of flesh firmness of fruits treated with 60 mg L^{-1} and again another increase in the fruit treated with 90 mg L^{-1} (Figure 2).

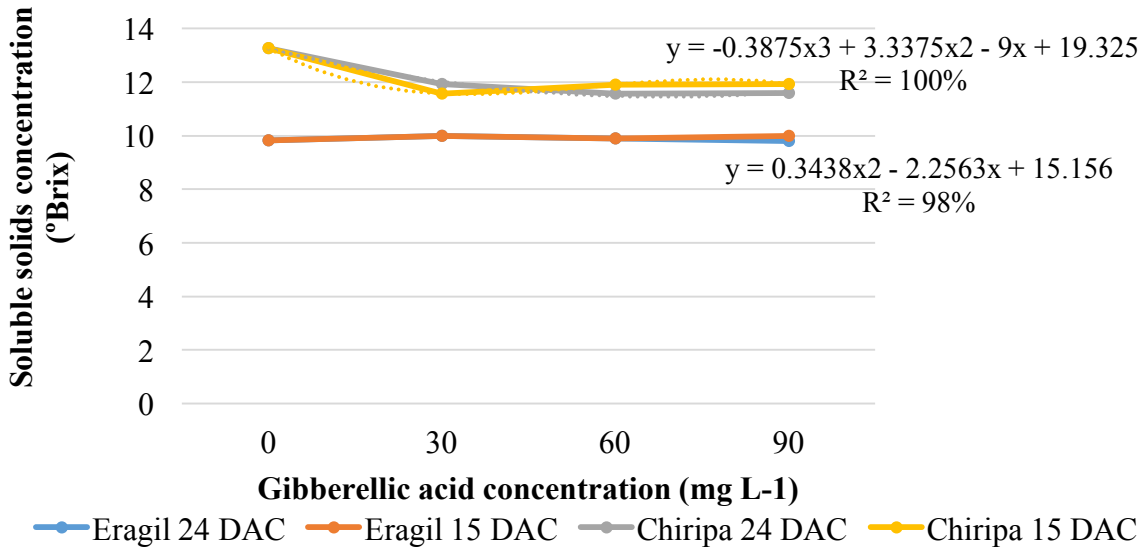

Figure 1 - Soluble solids concentration of 'Eragil' and 'Red Chiripa' peaches at fourth days shelf (24ºC±2) submitted to pre-harvest application of gibberellic acid.

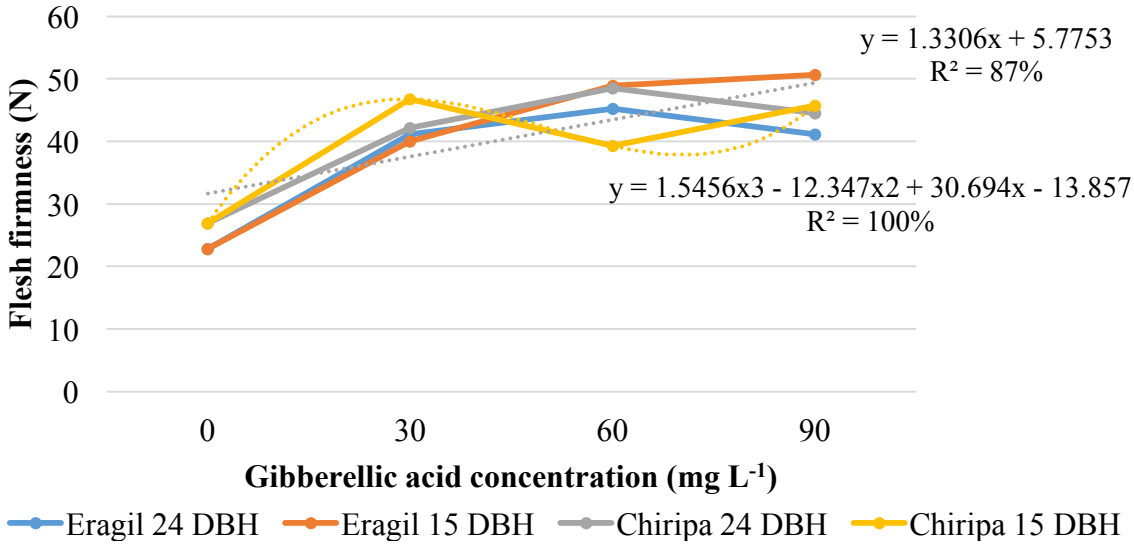

Figure 2 - Flesh firmness of 'Eragil' and 'Red Chiripa' peaches at fourth days shelf (24ºC±2) submitted to pre-harvest application of gibberellic acid.

Most studies with GA_3 pre-harvest application on peach and nectarine demonstrate effect in increasing firmness, an important factor to extend the shelf life period of the fruit while maintaining quality and reducing losses in marketing. However, it is important to test doses and application times for the different cultivars grown in Southern Brazilian soil and climate conditions to ensure maximum efficiency of this technology already used in others peach producing countries.

CONCLUSIONS

The pre-harvest application of gibberellic acid does not influence the concentration of soluble solids of 'Eragil' peaches.

The pre-harvest application of gibberellic acid reduces the concentration of soluble solids in the 'Red Chiripa' peach shelf period.

The pre-harvest application of gibberellic acid is efficient to maintain flesh firmness for longer shelf life of the 'Red Chiripa' and 'Eragil' peaches.

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