



Woolliness and leatheriness in late peach cultivars submitted to both delayed storage and to cold storage

Leandro Camargo Neves^{1*}, Andre José de Campos², Marcos André de Souza Prill² and Sérgio Ruffo Roberto³

¹Departamento de Fitotecnia, Centro de Ciências Agrárias, Universidade Federal de Roraima, Km 12, BR-174, s/n, 69301-970, Boa Vista, Roraima, Brazil.

²Programa de Pós-graduação em Agronomia, Universidade Federal de Roraima, Boa Vista, Roraima, Brazil. ³Departamento de Agronomia, Centro de Ciências Agrárias, Universidade Estadual de Londrina, Londrina, Paraná, Brazil. *Author for correspondence. E-mail: rapelbtu@gmail.com

ABSTRACT. The study was performed to identify the effect of delayed storage on the control of woolliness and leatheriness during cold storage of the late peach cultivars grown in Brazil. The fruits were harvested at the mature-green stage. All of the cultivars were exposed to temperatures of $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ of R.H. in a cold room for 0, 24, or 48 hours. Afterwards, the fruits were kept at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H. for 28 days. The yellow pulp peaches, regardless of the length of delayed storage, did not present any symptoms of woolliness or leatheriness. The white pulp peaches not submitted to delayed storage developed either one or more of the other physiological disorders. Due to their lower level of pulp firmness, the control fruits of 'Chimarrita' and 'Marli' peaches were classified as woolly fruits. The control fruits of 'Chiripá' peaches, with pulp firmness of more than 30 N, presented leatheriness. High pectinmethylesterase (PE) activity was verified in the woolly fruits. The delayed storage for 48 hours in all the cultivars provided advanced ripening. The delayed storage by 24 hours was effective in the control of physiological disorders in the white pulp cultivars.

Keywords: *Prunus* sp., chilling injury, physiologic disturbances, quality, postharvest.

Lanosidade e retenção de firmeza em pêssegos de cultivares tardias, submetidos ao condicionamento térmico sob armazenamento refrigerado

RESUMO. Este estudo foi conduzido com o objetivo de identificar o efeito do condicionamento térmico no controle da lanosidade e da retenção de firmeza em pêssegos de cultivares tardias cultivadas no Brasil. Os frutos foram colhidos fisiologicamente maduros e expostos a temperatura de $20 \pm 0,5^\circ\text{C}$ and $75 \pm 3\%$ de U.R., em câmara frigorífica, durante 0, 24 ou 48 horas. Após, os frutos foram acondicionados em câmara frigorífica a $0 \pm 0,5^\circ\text{C}$ e $92 \pm 3\%$ de UR, por 28 dias. Os pêssegos de polpa amarela, independentemente do condicionamento térmico, não apresentaram sintoma de lanosidade ou retenção de firmeza. Os pêssegos de polpa branca, quando não submetidos ao condicionamento térmico, desenvolveram distúrbios fisiológicos. Devido aos baixos valores de firmeza de polpa, os pêssegos do grupo controle das cultivares Chimarrita e Marli, foram classificados como lanosos. Os frutos controle de pêssegos Chiripá, com firmeza de polpa acima de 30 N, apresentaram retenção de firmeza. A atividade da pectinametilesterase (PE) foi maior nos frutos lanosos. O condicionamento térmico por 48 horas acelerou o amadurecimento dos frutos de todas as cultivares. O condicionamento térmico por 24 horas foi eficiente no controle de distúrbios fisiológicos em pêssegos das cultivares de polpa branca.

Palavras-chave: *Prunus* sp., danos de frio, distúrbios fisiológicos, qualidade, pós-colheita.

Introduction

Peaches are seasonal fruits in the state of São Paulo, Brazil. The largest centers of peach production in this country are found in the southern states of Brazil. During the months of October and December, 79% of the peaches produced in Brazil come from 130 municipalities and nine Brazilian states. However, due to their high perishability, these peaches lose their quality during postharvest by decay, high dehydration, quick loss of pulp firmness, and physiological damages. (NEVES, 2009).

For this reason, cold storage of seasonal fruits is widely recommended as an adequate storage method, expanding the fruits' postharvest life (APEZZATTO-DA-GLORIA et al., 2004). However, low temperatures during cold storage may cause disturbances and/or physiological disorders, which are also known as chilling injuries. In peaches and nectarines, the symptoms caused by these damages are mainly pulp browning, woolliness, and/or leatheriness (LURIE; CRISOSTO, 2005).

The identification of woolliness is quite difficult because there are no clear differences between

healthy and woolly fruits. The symptoms are only visible when the fruit is open, at which point it is already in the consumer's hand (LUCHSINGER; WALSH, 1998). According to Zhou et al. (2000), woolliness results from an imbalance of peptic enzyme activity during the ripening stage, with increased pectinmethylesterase enzyme activity, inhibition of polygalacturonase activity and an accumulation of peptic substances with low degrees of esterification, which prevent these substances from being soluble. These substances can bind water outside of the cells, forming a gel and leading to the absence of juice.

Nevertheless, according to Ju et al. (2001), the effect of cold on the polygalacturonase enzyme activity is still controversial. In some studies, the exposure of peaches to low temperatures inhibits the polygalacturonase activity and reduces pectin degradation. However, in other studies, fruits with abundant juice and woolly fruits had similar levels of polygalacturonase. These authors also verified that in 'Snow Giant' and 'Elegant Lady' peaches, the fruits with leatheriness had a lower polygalacturonase activity and higher pulp firmness when compared to the woolly and healthy fruits. Thus, Ju et al. (2001) attest that woolliness causes softening of the fruit with pulp firmness values below 10 N while retaining a normal polygalacturonase activity level. With regards to leatheriness, the fruit would manifest problems in the ripening stage but retain pulp firmness higher than 30 N and a low polygalacturonase activity during cold storage.

For the control of physiological damages in peaches, Lurie et al. (2003) and Lurie and Crisosto (2005) indicated that in addition to the delayed storage and controlled temperature, other techniques such as intermittent heating and the use of plastic containers are also employed. However, according Lurie and Crisosto (2005), the effects of such techniques in the case of physiological disorders of cold-stored peaches are still unclear and demand further studies, most notably in the case of Brazilian peach cultivars.

Therefore, the purpose of this research was to study the control of physiological damages such as woolliness and leatheriness during the storage of late-grown peaches in delayed cold storage.

Material and methods

The experiments were performed using the yellow pulp peaches 'Maciel,' 'Flordagrande,' and 'Peach' and the white pulp peaches 'Chimarrita,' 'Marli,' and 'Chiripá.'

The trials were conducted during two harvesting seasons. The fruits, harvested at the mature-green stage, were obtained from a farm located in Arroio do Ratos, Rio Grande do Sul State, Brazil (Lat 30°08'53"S, Long 51°32'25"W). Before being placed into delayed storage, the fruits were selected by their skin color (less than 25% green) and cleaned in 100 mg L⁻¹ of previously acidulated sodium hypochlorite (NaClO) solution for 10 minutes.

The experimental design was completely randomized, with a factorial scheme of 3 x 8 (periods of delayed storage x sample times), with 3 replicates and experimental plots composed of 15 fruits. The fruits were exposed to delayed storage temperatures of 20 ± 0.5°C and 75 ± 3% R.H. in a cold room for 0, 24, or 48 hours. Next, they were placed in a cold room at 0 ± 0.5°C and 92 ± 3% RH for 28 days. The analyses were made at harvest and at 1, 7, 14, and 21 days after storage. An additional sample was also checked for two days at room temperature (25 ± 3°C and 72 ± 3% R.H.) after storage. All the analyses were performed between four and six hours after the fruits were removed from the cold storage.

The following variables were analyzed: A) Pulp firmness: measured by Effe-GI penetrometer, 5/16 inch diameter, after collection of a small portion of epidermis, with two readings in each hemisphere (right and left), with results expressed in Newtons (N); B) Loss of fresh mass: samples were weighed on a Toledo-computagram scale, and the results were expressed as a percentage of fresh mass loss in relation to the initial mass of the fruits at harvest time; C) Juice content (incidence of woolliness or leatheriness): determined subjectively by pressing fruits between fingers and direct visualization, presence or lack of juice, and/or farinaceous juice. The degree of damage was expressed according to a hedonic scale of values where: 1 = high (normal fruit), 2 = moderate (50% juice content of the normal fruits), 3 = low (25% juice content of the normal fruits) and 4 = null (no juice); D) Pectinmethylesterase enzyme activity (PE): determined according to Jen and Robinson (1984) with results expressed in UE min.⁻¹ g of tissue⁻¹; and E) Polygalacturonase enzyme activity (PG): determined according to Pressey and Avants (1973) with the results expressed in UE min.⁻¹ g of tissue⁻¹. All data were submitted to analysis of variance by F test, and the comparison of means was made by the Tukey DMS test at 5% probability.

Results and discussion

Pulp firmness

With the exception of the control fruits of 'Chiripá' peaches, which showed higher values of firmness at the end of the experiment, all the others, regardless of delayed storage, lost their pulp firmness throughout the experiment (Figure 1 through Figure 3). The same finding was observed by Bron et al. (2002) who worked with the peaches Aurora-1 and Dourado-2, noting that the peaches also showed a reduction in pulp firmness during and after cold storage. This reduction may have occurred due to changes in the peptic substances present in the cell walls of the vegetal tissues called protopectins or calcium pectates, turning them into solubles after fruit harvest. Thus, during the ripening of the peaches, the calcium bonds between the pectins would be broken due to the polygalacturonase and pectinmethylesterase activity on their depolymerization, which would make them more soluble.

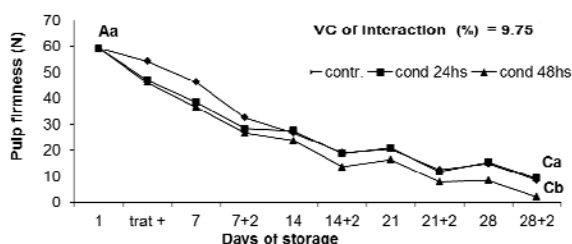


Figure 1. Mean variation of pulp firmness, in delayed storage of yellow pulp peaches, conditioned or not at $20 \pm 0,5^{\circ}\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0,5^{\circ}\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

As for the control 'Chiripá' peaches (Figure 3), the cold damage known as leatheriness could be characterized by the maintenance of the values of pulp firmness above 30 N, excessive loss of fresh mass, and the inability to ripen. However, the other white pulp fruits not submitted to delayed storage also presented a certain resistance to the manual penetrometer, mainly after being removed from the cold room. Their values were always below 10 N, characterizing them as woolly. These results should be considered carefully because a closer analysis of juice content and the loss of fresh mass results in the perception that the quality of those fruits was not satisfactory for commerce and/or consumption.

As cited above, the resistance to penetrometer was also detected in the pulp of the control 'Chimarrita' and 'Marli' peaches (Figure 2). However, the firmness of these fruits was lower (below 10 N) when compared

to the control 'Chiripá' peaches, which presented leatheriness (above 30 N) and were also characterized as having a dry and arenaceous quality.

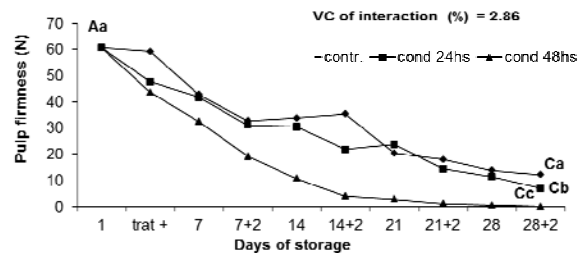


Figure 2. Mean variation of pulp firmness, in delayed storage 'Chimarrita' and 'Marli' peaches, conditioned or not at $20 \pm 0,5^{\circ}\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0,5^{\circ}\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

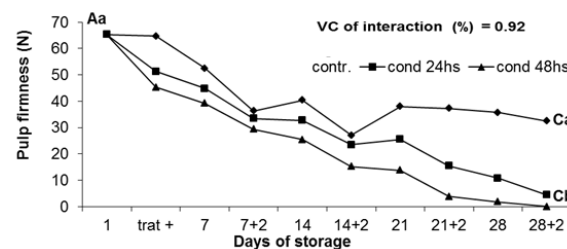


Figure 3. Mean variation of pulp firmness, in delayed storage of 'Chiripá' peaches, conditioned or not at $20 \pm 0,5^{\circ}\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0,5^{\circ}\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

This fact, considered along with the enzymatic analyses and juice content, may be clearly characterized as a behavior of wooliness fruits. According to our results, this disorder was commonly more frequent in the white pulp cultivars than in the yellow ones. Thus, the yellow pulp fruits, regardless of submission to the delayed storage, presented higher values of pulp firmness (Figure 1) than the white pulp peaches, although these fruits did not present any symptoms correlated with cold damages.

It was also observed at the end of the experiment that delayed storage by 24 hours, in all the cultivars tested, resulted in an excessive acceleration of ripening, characterized by a high loss of pulp firmness and fresh mass. Nevertheless, the delayed storage by 24 hours avoided the onset of physiological disorders in the white pulp cultivars. These fruits had a mean pulp firmness of 7 N, which was considered adequate for commerce according Rombaldi et al. (2001).

Therefore, it is concluded that woolliness and leatheriness, two disorders that relate directly to pulp firmness in peaches, present distinct behaviors and are characteristic of the white pulp fruits. Woolly fruits had a pulp firmness below 10 N and a dry texture, and those fruits with leatheriness, along with the farinaceous aspect of their pulps, also presented a pulp firmness of more than 30 N and a high loss of moisture. According to Ju et al. (2001), two disorders can cause dry and leathery texture in fruits. In one of these disorders, the fruits remain firm, and in the other disorder, there is loss of firmness after ripening at higher temperature than that used in cold storage.

Loss of fresh mass

The loss of fresh mass in the peach cultivars, in both harvests, presented two distinct patterns (Figures 4 and 5). First, the control group of 'Chiripá' peaches, which presented leatheriness, had losses of fresh mass up to 25.3% (Figure 4). These results were considered greatly superior to those found for the other peach cultivars, whose fresh mass averaged 16.9%. In this sense, the peaches of cv. Chiripá that experienced the condition of 48 hours of delayed storage showed a loss of fresh mass up to 15.87%, approximately 10% less than the fruits from the control group.

Supposing that those fruits submitted to delayed storage could have an initial acceleration of metabolism (LUCHSINGER; WALSH, 1998), it would be expected that an increase of respiratory activity and greater losses of moisture would occur during cold storage. However, the white pulp fruits that had not been submitted to delayed storage showed high values of pulp firmness and presented farinaceous qualities, lack of juice, and the greatest losses of moisture at the end of the experiment. Such characteristic symptoms of leatheriness lead to the conclusion that these fruits experienced deep alterations in their normal metabolism.

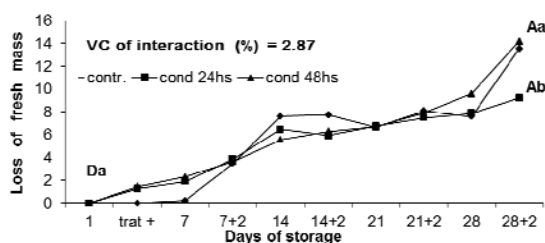


Figure 4. Mean variation of loss of fresh mass, in delayed storage of 'Maciel', 'Flordagrande', 'Peach', 'Chimarrita' and 'Marli' peaches, conditioned or not at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

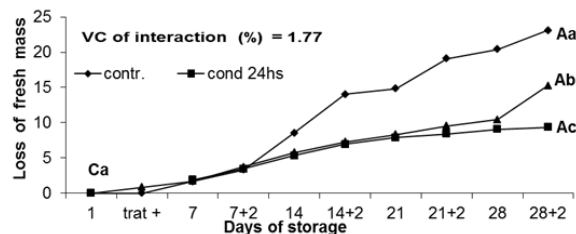


Figure 5. Mean variation of loss of fresh mass, in delayed storage of 'Chiripá' peaches, conditioned or not at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

The second pattern verified was the constant fresh mass losses of peaches regardless of submission to delayed storage (Figure 5). In contrast to the fruits with leatheriness, those submitted to delayed storage for 48 hours had significant losses when compared to the yellow pulp cultivars from the control group and to the 'Chimarrita' and 'Marli' peaches. Nevertheless, these losses were not higher than 16.9%, which is approximately 66% of that in the control group of 'Chiripá' peaches (25.3%). Furthermore, they were, on average, 17.35% superior to the control group 'Chimarrita' and 'Marli' peaches. Thus, it can be concluded that leatheriness has a direct connection to excessive loss of fresh mass and that the woolliness found in the white pulp cultivars cannot be related to loss of moisture but can be related to a lack of juice that is kept in the formation of pectic gels. This leads to a certain resistance in the pulp and complete absence of juice.

It was also observed that delayed storage did not accelerate the metabolism, increasing the fruit oxidation stress and leading to great losses of humidity, as described by Sasaki et al. (2010). However, when these peaches were submitted to delayed storage for 48 hours, it can be observed that losses of firmness and fresh mass occurred similar to that found in the control fruits. According to Lurie and Crisosto (2005), the cultivars adjusted well to delayed storage, which did not cause deterioration and could increase the shelf-life of the peaches by up to two weeks. In this experiment, some symptoms such as loss of moisture and firmness were identified, but these did not affect the quality of the fruits.

The peaches that were submitted to delayed storage for 24 hours, regardless of pulp color, had losses no higher than 9.45% at the end of the experiment, thus reflecting a good quality for commerce (ROMBALDI et al., 2001). Lurie and Crisosto (2005) mentioned that the symptom of rugosity in peaches can only be

verified when the losses of fresh mass exceed 10%. In this experiment, the yellow pulp peaches and the cultivars of white pulp submitted to delayed storage for 24 hours did not present problems of appearance such as rugosity. Therefore, the correct time x temperature binomial on delayed storage increased the thermotolerance to cold without accelerating ripening (SASAKI et al., 2010).

Juice content

Juice content is related to normal development of the fruits, regardless of cultivar or pulp color (Figures 6 and 7). According to Martins et al. (2004), in both woolliness and leatheriness fruit disorders, the loss of juice contents was a remarkable characteristic associated with low temperature intolerance.

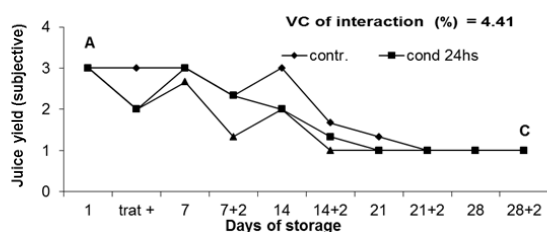


Figure 6. Mean variation of juice yield, in delayed storage of yellow pulp peaches, conditioned or not at $20 \pm 0,5^{\circ}\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0,5^{\circ}\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. The degree of damage was expressed according to a hedonic scale of values, where 1= high (normal fruit), 2= moderate (50% of juice content of the normal fruits), 3= low (25% of juice content of the normal fruits) and 4 = null (no juice). Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

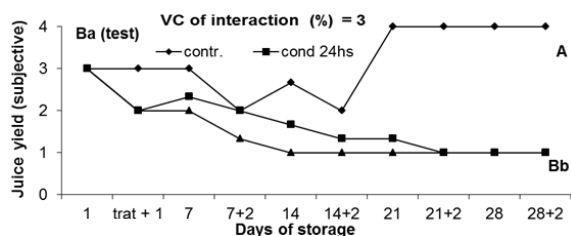


Figure 7. Mean variation of juice yield, in delayed storage of white pulp peaches, conditioned or not at $20 \pm 0,5^{\circ}\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0,5^{\circ}\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability.

Therefore, the peaches that presented woolliness or leatheriness that are the white pulp cultivars from the control group presented a low yield of juice at the end of the experiment (Figure 7). Ju et al. (2001) noted that a lack of juice in peaches may occur due to a high degree of pulp firmness associated with

leatheriness or woolliness, and in this case, always present pulp firmness no higher than 10 N. According to Bron et al. (2002), the reason for this apparent lack of juice is the presence of de-esterified pectin substances of high molecular weight that are able to transform the juiciness into gel. However, all the yellow pulp peaches and those white pulp cultivars submitted to delayed storage presented maximum availability of juiciness at 28 days of cold storage plus 2 days out of the cold storage (Figure 3).

The white pulp controls with leatheriness ('Chiripá') and woolliness ('Chimarrita' and 'Marli'), as mentioned, presented problems with a lack of juice after two weeks. However, this symptom was only definitive after three weeks of cold storage. These fruits, upon the onset of damage during the second week, showed a discontinuous pattern in their lack of juice when they were removed from cold storage and kept two days out of refrigeration. In this case, they resumed their normal metabolism and juiciness. These results are concordant to those of Luchsinger and Walsh (1998), where the symptoms of woolliness were not observed in cold storage but only at the time when the fruits were removed from refrigeration and the temperature increases.

As for the process of regaining juice content in these fruits, it is possibly understood that upon the onset of physiological damages, some harmful changes take place in the tissues. These negative effects are cumulative, but they may be reversed by the transfer of the fruits to temperatures higher than those of cold storage, thus allowing the peaches to ripen at a normal rate. However, the benefits of such reversibility of woolliness or leatheriness, according to Zhou et al. (2000) and what is presented here, may be compromised according to the duration of exposure to critical temperatures during cold storage, and most importantly, the damage could be definitely irreversible. Here, in this experiment, the irreversibility was detected after three weeks of cold storage.

Therefore, the lack of juice may be considered an important reflex of cold damage in peaches, as shown for the fruits that presented woolliness and leatheriness, but may differ according to cultivar and storage conditions. Thus, it may be concluded that leatheriness and woolliness always affect juice availability, and as delayed storage inhibits the onset of physiological disorders, it also has a direct effect on the yield of juice.

Polygalacturonase and Pectinmethylesterase Enzymes

From the results observed, it is possible to understand that the incidence of leatheriness is related to the imbalance of the enzymatic complex formed by

polygalacturonase and pectinmethylesterase (Figures 8, 9 and 10). The same may not be said for the woolliness, as the polygalacturonase behavior in this experiment is similar in both woolly and healthy fruits. Zhou et al. (2000) evidenced different enzymatic behavior from the one observed in this experiment, where the pectinmethylesterase activity was high and constant, and the polygalacturonase activity was inhibited over the passage of time.

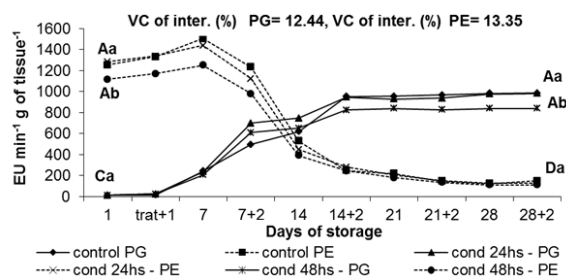


Figure 8. Mean variation of polygalacturonase enzyme and pectinmethylesterase activity, in delayed storage of yellow pulp peaches, conditioned or not at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability; and, Bold letters represent comparison of means of polygalacturonase activity regarding duration of storage and simple letters refer to comparisons between pectinmethylesterase activities regarding duration of storage.

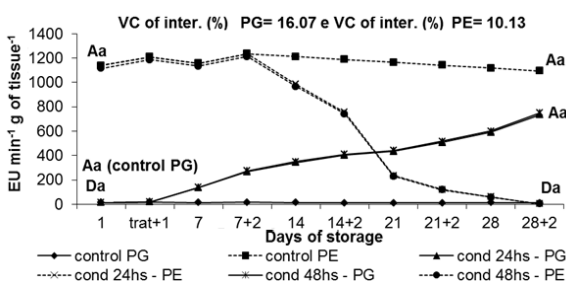


Figure 9. Mean variation of polygalacturonase enzyme and pectinmethylesterase activity, in delayed storage 'Chimarrita' and 'Marli' peaches, conditioned or not at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability; and, Bold letters represent comparison of means of polygalacturonase activity regarding duration of storage and simple letters refer to comparisons between pectinmethylesterase activities regarding duration of storage.

Therefore, the controls from cvs. Chimarrita and Marli, which showed woolliness after three weeks of cold storage, presented high pectinmethylesterase activity. As for polygalacturonase activity, these same woolly fruits presented an activity similar to the healthy fruits. These results are in agreement with Ju et al. (2001), who reported that the influence of

polygalacturonase should not be considered, but only pectinmethylesterase activity should be taken into account for an evaluation of woolliness. However, studies performed by Ben-Arie and Sonego (1980) associated the reduced polygalacturonase activity with temperatures that lead to cold damage.

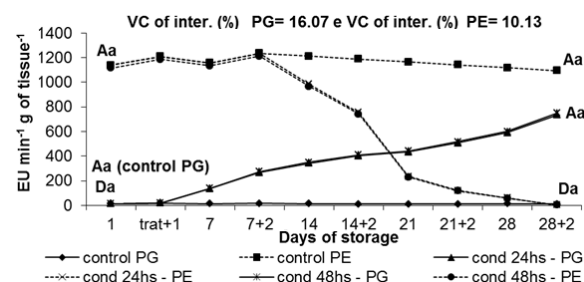


Figure 10. Mean variation of polygalacturonase enzyme and pectinmethylesterase enzyme activity, in delayed storage 'Chiripá' peaches, conditioned or not at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State. Means followed by the same letter in treatments (small letters), and between durations of storage (capital letters) do not differ one from the other by the Tukey test at 5% probability; and, Bold letters represent comparison of means of polygalacturonase activity regarding duration of storage and simple letters refer to comparisons between pectinmethylesterase activities regarding duration of storage.

In the 'Chiripá' peaches from the control group, which presented leatheriness, the polygalacturonase activity was reduced and constant during the experimental period (Figure 10). Ju et al. (2001) also observed in 'Snow Giant' and 'Elegant Lady' peaches that fruits with leatheriness had lower polygalacturonase activity and a high degree of leatheriness when compared to healthy or woolly fruits. Therefore, it is possible to consider woolliness and leatheriness as two distinct physiological disorders and conclude that woolliness involves fruit softening to firmness values below 10 N, with constant polygalacturonase activity. On the other hand, fruits with leatheriness showed ripening deficiency with firmness above 30 N, high losses of moisture, and low polygalacturonase activity.

The yellow pulp cultivars and the white pulp fruits under delayed storage, regardless of the time of treatment, did not present any symptoms of physiological damage, such as woolliness or leatheriness. These fruits had a high pectinmethylesterase initial activity, following a decreased and gradual increased polygalacturonase activity that enabled maximum juice yield and fruit quality (Figure 8).

Conclusion

Delayed storage at 20°C for 24 hours is enough for the control of woolliness and leatheriness in both cultivars of white pulp. This treatment also maintains

the fruit firmness and preserves the juice content at an acceptable level for commerce and consumption.

References

- APEZZATTO-DA-GLORIA, B.; BRON, I. U.; MACHADO, S. R. Lanosidade em cultivares de pêssego (*Prunus persica* (L.) Batsch): estudos anatômicos e ultra-estruturais. **Revista Brasileira de Botânica**, v. 27, n. 1, p. 55-61, 2004.
- BEN-ARIE, R.; SONEGO, L. Pectolytic enzyme activity involved in woolly breakdown of stored peaches. **Phytochemistry**, v. 19, n. 12, p. 2553-2555, 1980.
- BRON, I. U.; JACOMINO, A. P.; APEZZATO-DA-GLÓRIA, B. Alterações anatômicas e físico-químicas associadas ao armazenamento refrigerado de pêssegos 'Aurora-1' e 'Dourado-2'. **Pesquisa Agropecuária Brasileira**, v. 37, n. 10, p. 1349-1358, 2002.
- JEN, J. J.; ROBINSON, M. L. P. Pectolytic enzymes in sweet bell peppers (*Capsicum annum* L.). **Journal of Food Science**, v. 49, n. 4, p. 1085-1087, 1984.
- JU, Z.; DUAN, Y.; JU, Z.; GUO, A. Different responses of 'Snow Giant' and 'Elegant Lady' peaches to fruit maturity and storage temperature. **Journal of Horticultural Science e Biotechnology**, v. 76, n. 5, p. 575-580, 2001.
- LUCHSINGER, L.; WALSH, C. S. Chilling injury of peach fruit during storage. **Acta Horticultura**, n. 464, p. 473-477, 1998.
- LURIE, S.; CRISOSTO, C. H. Chilling injury in peach and nectarine. **Postharvest Biology and Technology**, v. 37, n. 3, p. 195-208, 2005.
- LURIE, S.; ZHOU, H. W.; LERS, A.; SONEGO, L.; ALEXANDROV, S.; SHOMER, I. Study of pectin esterase and changes in pectin methylation during normal and abnormal peach ripening. **Physiologia Plantarum**, v. 119, n. 2, p. 287-294, 2003.
- MARTINS, C. R.; CANTILLANO, R. F. F.; FARIAS, R. M.; ROMBALDI, C. V. Atividade polifenoloxidase em pós-colheita de pêssegos de pomares de produção integrada e convencional. **Ciência Rural**, v. 34, n. 3, p. 749-754, 2004.
- NEVES, L. C. **Manual pós-colheita da fruticultura brasileira**. Londrina: Eduel, 2009.
- PRESSEY, R.; AVANTS, J. K. Separation and characterization of exopolygalacturonase and endopolygalacturonase from peaches. **Plant Physiology**, v. 52, n. 3, p. 252-256, 1973.
- ROMBALDI, C. V.; SILVA, J. A.; MACHADO, L. B.; PARUSSOLO, A.; GIRARDI, C. L.; DANIELLI, R. Ponto de colheita e período de armazenamento refrigerado na qualidade de pêssegos de mesa, cv. Chiripá. **Ciência Rural**, v. 31, n. 1, p. 19-25, 2001.
- SASAKI, F. F.; CERQUEIRA, T. S.; SESTARI, I.; KLUGE, R. A. Woolliness control and pectin solubilization of 'douradão' peach after heat shock treatment. **Acta Horticulturae**, v. 877, p. 539-542, 2010.
- ZHOU, H. W.; LURIE, S.; LERS, A.; KHATCHITSKI, A.; SONEGO, L.; BEN-ARIE, R. Delayed storage and controlled atmosphere storage of nectarines: two strategies to prevent woolliness. **Postharvest Biology and Technology**, v. 18, p. 133-141, 2000.

Received on May 6, 2011.

Accepted on November 21, 2011.

License information: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.