



Inhibition of pulp browning and quality maintenance of late peach cultivars

Leandro Camargo Neves^{1*}, Jessica Milanez Tosin², Samuel da Silva², Leonara Lima de Vasconcelos² and Sérgio Ruffo Roberto³

¹Departamento de Fitotecnia, Centro de Ciências Agrárias, Universidade Federal de Roraima, BR-174, Km 12, s/n, 69301-970, Boa Vista, Roraima, Brazil. ²Departamento de 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@hotmail.com

ABSTRACT. The purpose of this study was to identify the effect of delayed storage on the maintenance of the quality and on the control of pulp browning during cold storage of late peach cultivars. The fruit was harvested at the mature-green stage. All cultivars were exposed to temperatures of $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ of moisture in a cold room for 0.24, or 48 hours. Afterwards, the peaches were kept at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H. for 28 days. In the end, the yellow pulp cultivars, regardless of temperature and length of delayed storage, did not present signs of internal browning and were of adequate quality for commercialization. When they were not subjected to delayed storage, the white pulp peaches presented pulp browning after 14 days of cold storage plus two days out of the cold room. From the results observed in the analysis of soluble solids, titratable acidity and decay development, these peaches showed an increased level of ripening. In both cultivars, delayed storage for 48 hours resulted in increased ripening and decay. Delayed storage for 24 hours was effective in controlling pulp browning and in maintaining the quality of the white pulp peach cultivars.

Keywords: postharvest, *Prunus persica*, chilling injury, storage.

Inibição do escurecimento da polpa e manutenção da qualidade de pêsegos de cultivares tardias, submetidas ao condicionamento térmico

RESUMO. Este estudo tem por objetivo identificar o efeito do armazenamento térmico na manutenção da qualidade, bem como, no controle do escurecimento da polpa durante o armazenamento refrigerado de cultivares de pêsegos tardios. Os frutos foram colhidos fisiologicamente maduros. Os frutos foram submetidos às temperaturas de $20 \pm 0,5^\circ\text{C}$ e $75 \pm 3\%$ de UR, em câmara frigorífica, durante 0, 24 ou 48. Após, os frutos foram mantidos a $0 \pm 0,5^\circ\text{C}$ e $92 \pm 3\%$ de UR, por 28 dias. Ao final do experimento, os frutos das cultivares de polpa amarela, independentemente de armazenamento refrigerado, não apresentaram sinais de escurecimento interno, apresentaram qualidade adequada para comercialização. Quando não submetidos ao armazenamento refrigerado, após 14 dia de armazenamento, mais dois sem refrigeração, os frutos de polpa branca apresentaram escurecimento da polpa. A partir dos resultados observados na análise de sólidos solúveis, acidez titulável e desenvolvimento de podridões, esses frutos apresentaram um maior nível de amadurecimento. O condicionamento térmico de 48 horas, nas duas cultivares, resultou em um amadurecimento maior e apodrecimento dos frutos. Armazenamento refrigerado por 24 horas foi eficiente no controle de escurecimento da polpa e na manutenção da qualidade das cultivares de pêsego de polpa branca.

Palavras-chave: pós-colheita, *Prunus pérsica*, distúrbios fisiológicos, armazenamento.

Introduction

Several defects such as woolliness, browning and a leathery texture, are associated with damage in peaches caused by cold storage (BRACKMANN et al., 2003). The symptoms of these physiological disorders are the inability to ripen, loss or increase in hardness, high loss of moisture, complete lack of juice, and accelerated senescence (CRISOSTO; LABAVITCH, 2002).

According to Kluge et al. (2002) internal browning of the pulp occurs because of changes in the integrity and permeability of the membrane; these changes modify the normal metabolism of the fruit and reduce the normal activity of enzymes, mainly oxidases, in the membrane. The alteration of pulp color is due to damage in the cells caused by intermediary toxic products accumulated during cold storage (CRISOSTO et al., 1997). The onset of

this disorder varies according to the time and temperature of storage and the sensitivity of each cultivar.

Fruit color is one of the main factors determining the quality of the fruit *in natura* and in pulps, juices and canned peaches (ROBERTSON et al., 1993). Color alterations in the epidermis and pulp are due to enzymatic or non-enzymatic reactions (GARZA et al., 2000). Polyphenol oxidase is considered to be responsible for enzymatic browning in peaches and has long been acknowledged as such (GIRNER et al., 2002). However, little has been reported in relation to Brazilian cultivars.

Research has indicated that countless enzymes are responsible for the defense response of vegetal tissues to pathogenic attacks and/or physiological injuries caused by mechanical processing. Among these enzymes, polyphenol oxidase is the one responsible for browning during handling, cold storage and stone fruit processing (BOWER; CUTTING, 1988). Polyphenol oxidase is also responsible for oxidation reactions associated with browning and discoloration of pulp in injured vegetables (SIDDIQ et al., 1992). Thus, pulp browning in peaches can be understood as a visual manifestation of the fruit's defensive system, possibly due to its physical and/or physiological composition.

For the control of pulp browning in peaches, Lurie et al. (2003) and Lurie and Crisosto (2005) indicate that besides delayed storage and controlled temperature, other techniques such as intermittent heating and the use of plastic containers are employed.

Thus, this present work aimed to characterize the effect of delayed storage in the preservation of quality and the control of pulp browning during cold storage of the yellow pulp peach cultivars 'Maciel' and 'Flordagrande' and the white pulp peach cultivars 'Chimarrita,' 'Marli' and 'Chiripá.'

Material and methods

These experiments were carried out with the yellow pulp peaches Maciel and Flordagrande and with the white pulp peaches 'Chimarrita,' 'Marli,' and 'Chiripá'.

The work was conducted during two harvesting seasons. The peaches, harvested at the mature-green stage, were obtained from a farm located in the municipality of Arroio dos Ratos, Rio Grande do Sul State, Brazil. Before placement in delayed storage, peaches were selected by skin color (less than 25%

green) and cleaned in sodium hypochlorite (NaClO) solution at 100 mg L⁻¹, previously acidulated, 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 an experimental plot composed of 15 peaches. To prepare for treatment, the peaches were exposed to delayed storage temperatures of 20 ± 0.5°C and 75 ± 3% R.H. in a cold room during 0, 24, or 48 hours. The peaches were then placed in the cold room at 0 ± 0.5°C and 92 ± 3% R.H. (monitored every half hour by a control panel located outside the cold room) for 28 days. The analyses were made at harvest and 1, 7, 14 and 21 days after storage; an additional sample was kept at room temperature (°C) two days after storage. All analyses were performed between 4 and 6 hours after the peaches were removed from cold storage.

The following variables were analyzed: A) Incidence of Pulp Browning: analyzed by cutting all the peaches of each replicate in half, visually observing the symptoms found, and relating them to the following hedonic scale: 1 – healthy (normal pulp), 2 – start of alteration (section with translucent browning), 3 – slightly brown pulp (slightly darkened section), 4 – moderately brown pulp (moderately darkened section), 5 – marked characteristics of browning (remarkably darkened section). The results were expressed as the mean of each replicate; B) Phenol content: determined according to Hyodo et al. (1978). The results were expressed in mg of phenols g⁻¹ fresh mass; C) Polyphenol Oxidase Enzyme (PPO): determined according to the methodologies of Siriphanich and Kader (1985) and Flukey and Jen (1978). The activity was expressed as units of PPO min.⁻¹ g⁻¹ of fresh mass; D) Decay: measured as the percentage of pulp with typical symptoms of decay, relating these symptoms to the following subjective scale of value: 1 – light (no decay), 2 – low (25 to 50% compromised fruit), 3 – average (50 to 75% compromised fruit) and 4 – high (above 75% compromised fruit). The results were expressed by the mean percentage of decay in each replicate. The peaches that displayed symptoms of internal browning, regardless of the damage level, were submitted to microbiological analyses to determine the causal agent and later exposed through photographs of the colonies (VANDERZANT; SPLITTSTOESSER, 1992); E) Soluble Solids Content: determined by Shimadzu[®] refractometer, using a drop of pure juice from each repetition, and results expressed

in °Brix; F) Titratable Acidity: determined by dilution of 10 mL pure juice in 30 mL distilled water and titration with NaOH 0.1 N, up to pH 8.2, expressed the results in mg citric acid 100 g⁻¹ pulp. 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 browning – According to the results presented here, and confirming the studies obtained by Martins et al. (2004), pulp browning (Figures 1 and 2) was directly related to polyphenol oxidase activity and phenol contents

(Figures 3 to 6). The yellow pulp peaches, regardless of the heat treatment, did not display other evidence of physiological damage caused by cold storage, such as woolliness and leathery texture (Figure 1). In this sense, according to Lurie and Crisosto (2005), temperature plays an important role in the symptoms of damage caused by cold temperatures, but genetic load, maturation stage and environmental factors also contribute to this damage.

The yellow pulp peaches presented values no higher than 0.0624 units PPO min.⁻¹ g⁻¹ of fresh mass, while the controls of white pulp cultivars presented values up to 0.2688 units PPO min.⁻¹ g⁻¹ of fresh mass (Figures 3 and 5).

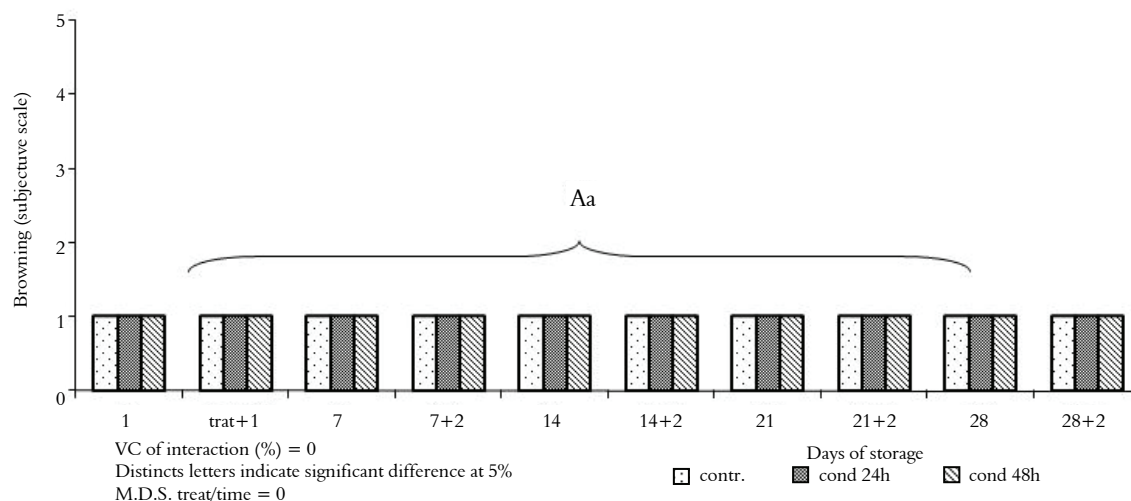


Figure 1. Mean variation of pulp browning, in delayed storage of yellow pulp and white pulp peaches conditioned at 20 ± 0.5°C and 75 ± 3% de R.H. and stored at 0 ± 0.5°C and 92 ± 3% of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

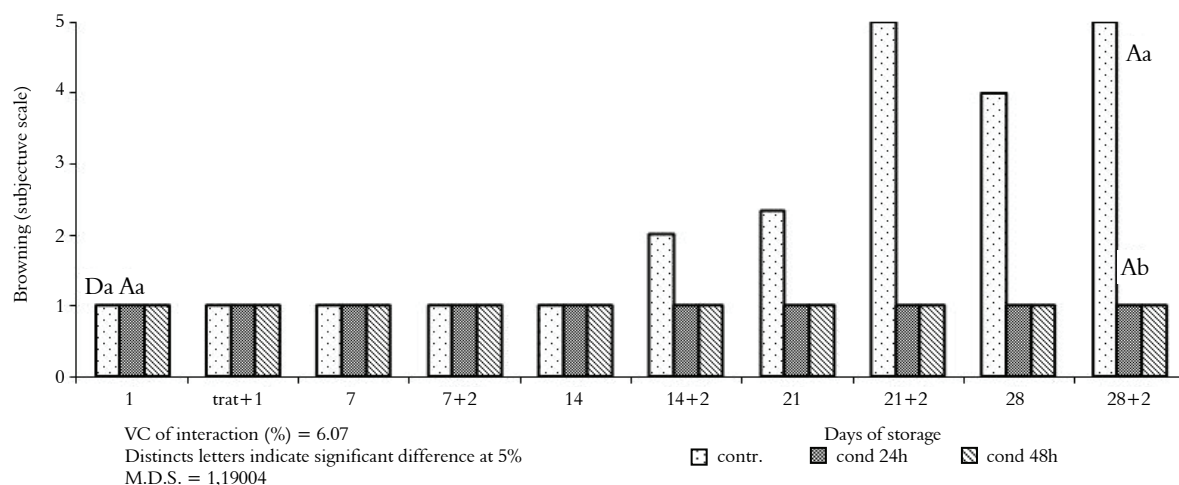


Figure 2. Mean variation of pulp browning, in delayed storage of white pulp peaches, conditioned or not conditioned at 20 ± 0.5°C and 75 ± 3% de R.H. and stored at 0 ± 0.5°C and 92 ± 3% of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

Figures 1 to 2 – T1: control; T2: fruits conditioned at 20 ± 0.5°C and 75 ± 3% de R.H., for 24 hours; T3: fruits conditioned at 20 ± 0.5°C and 75 ± 3% de R.H., for 48 hours. Means followed by same letter between treatment (small letters), and between storage times (capital letters), do not differ one from the other by the Tukey test at 5% probability.

Likewise, the yellow pulp peaches had values no higher than $0.0616 \text{ mg phenol g}^{-1}$ of fresh mass, and the control of white pulp cultivars had up to 1.7745 mg of phenol g^{-1} of fresh mass (Figures 4 and 6). These values, for both white and yellow pulp peaches, were similar to those described by Martins et al. (2004), but differed for the physiologically injured white pulp cultivars, whose pulp had browned and had 3 or 4 times higher levels of polyphenol oxidase and 25 to 28 times higher phenol content. Thus, it is possible that polyphenol oxidase activity and phenol content during and after cold storage are related to the browning of white pulp peaches, generally occurring after two weeks of cold storage. According to Siddiq et al. (1992), the conclusion is that the potential for this

disorder depends on the amount of phenolic compounds and level of polyphenol oxidase enzyme activity.

In this present experiment, after up to 14 days of cold storage, when polyphenol oxidase activity did not surpass $0.0861 \text{ unit PPO min}^{-1} \text{ g}^{-1}$ of fresh mass and $0.8525 \text{ mg phenol g}^{-1}$ of fresh mass, the peaches did not present any signs of pulp browning. However, after 14 days of cold storage plus 2 days of commercial simulation, when the values of polyphenol oxidase activity and phenol content increased, the white pulp cultivar controls already demonstrated pulp browning (Figure 2). Girardi et al. (2002) also observed that the Chiripá peaches demonstrated pulp browning after more than 14 days in cold storage.

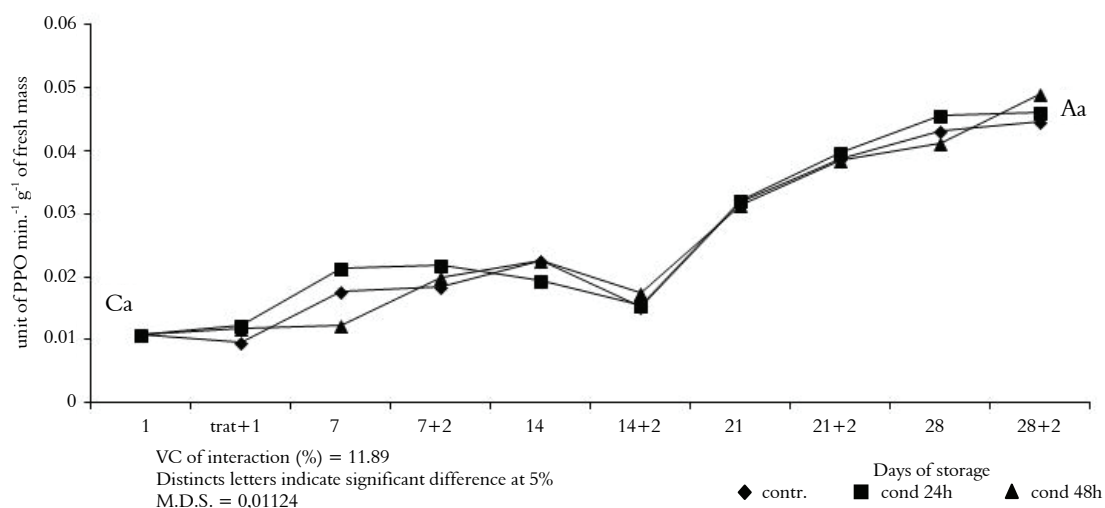


Figure 3. Mean variation of polyphenol oxidase activity, in delayed storage of yellow pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

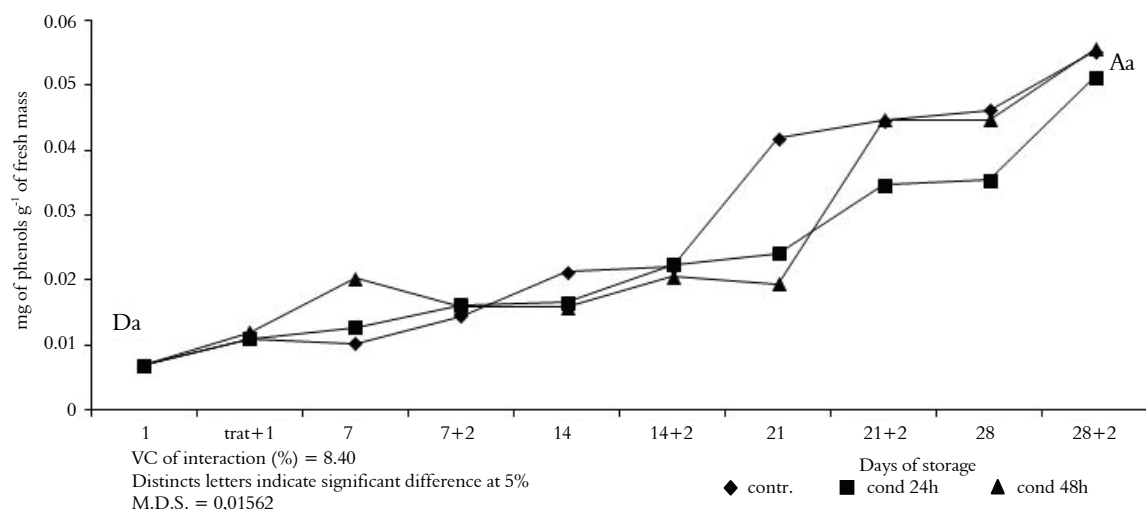


Figure 4. Mean variation of phenol contents, in delayed storage of yellow pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

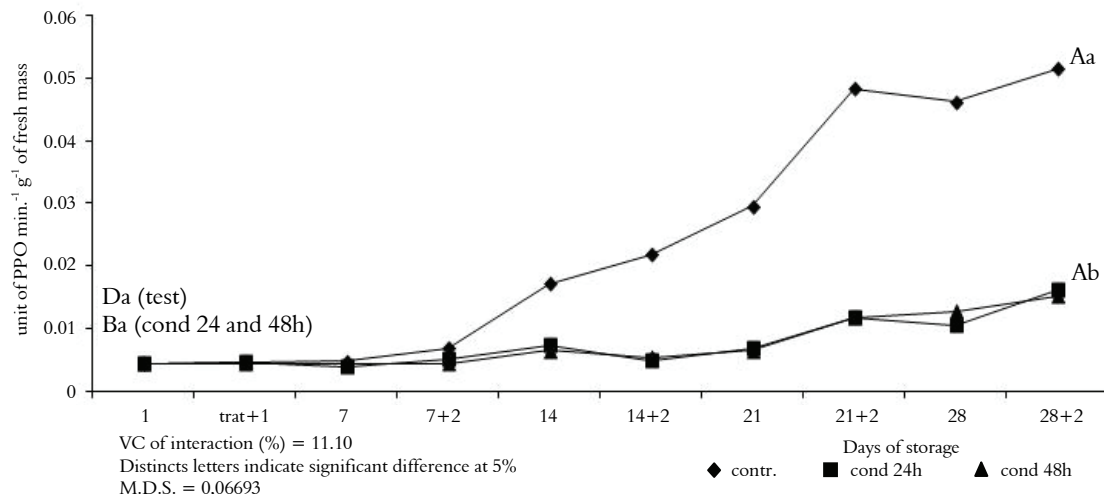


Figure 5. Mean variation of polyphenol oxidase activity, in delayed storage of white pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

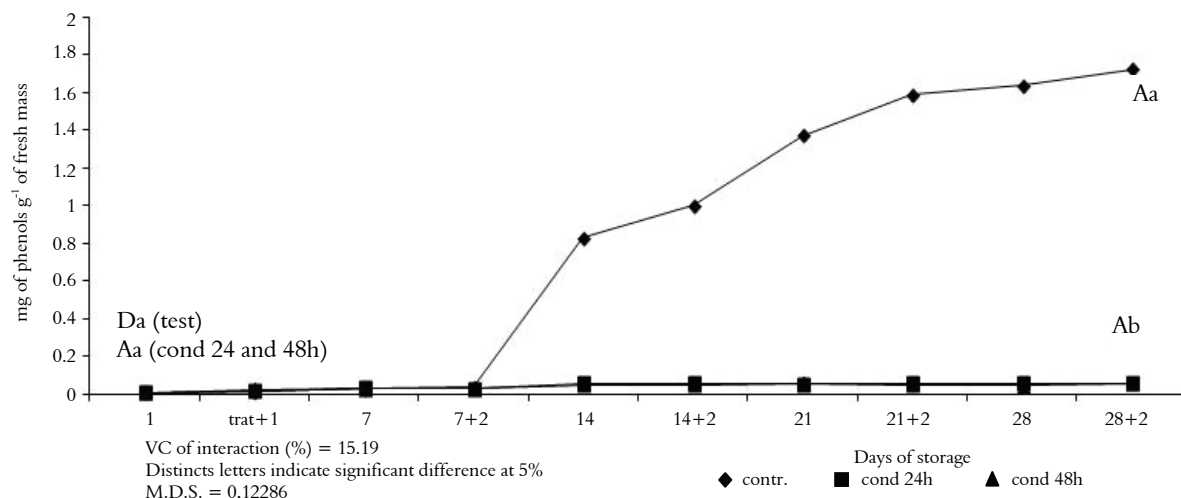


Figure 6. Mean variation of phenol content, in delayed storage of white pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

*Figures 3 to 6 – T1: control; T2: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 24 hours; T3: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 48 hours. Means followed by same letter between treatment (small letters), and between storage times (capital letters), do not differ one from the other by the Tukey test at 5% probability.

However, as with the control of other damage caused by cold, delayed storage for 24 hours prevented browning in peach pulp, mainly in white pulp cultivars, which are considered susceptible to this physiological disorder, according to the results obtained here. Nevertheless, the peaches subjected to delayed storage for 48 hours, as observed with the chemical analyses (Figures 8 to 11) and evaluation of decay (Figure 7), did not present satisfactory quality, even with efficient control of physiological disorders.

Polyphenol oxidase enzyme and phenol contents – It was observed that both polyphenol oxidase activity and phenol content increased as the peaches ripened (Figures 3 to 6). As previously

indicated, polyphenol oxidase activity and phenol content are also related to the incidence of pulp browning. Nevertheless, only in the white pulp cultivar controls, due to the high values of polyphenol oxidase activity and phenol content, did these increments contribute to browning.

The white pulp cultivar controls presented values between 0.1024 and 0.1155 units PPO $\text{min}^{-1} \text{g}^{-1}$ of fresh mass at 14 days of cold storage and 2 days out of cold storage when the first symptoms of pulp browning were first detected. At the end of the experimental time, these values ranged from 0.2526 to 0.2688 units PPO $\text{min}^{-1} \text{g}^{-1}$ of fresh mass. At 14 days of cold storage and 2 days out of cold storage, the phenol contents of white

pulp cultivar controls varied from 0.9765 to 1.1130 mg of phenol g⁻¹ of fresh mass. In the final period of the experiment, the phenol content was between 1.5540 and 1.7745 mg of phenol g⁻¹ of fresh mass. These results are consistent with the standard established by Robertson et al. (1993), in which peaches considered to be of low quality have phenol content equal to or less than 1.2 mg of phenol g⁻¹ of fresh mass. The development of pulp browning is indicated by external signs on the fruit, which is simply visible damage in response to tissue injury such as cuts and/or exposure to low temperatures. In this case, it is likely that an interaction between polyphenol oxidase enzymes and the phenolic compounds triggers tissue browning. Espin et al. (1997) also reported that the onset of pulp browning is due to the increased content of phenolic compounds and polyphenol oxidase enzyme activity.

In white pulp cultivars, delayed storage for 24 hours was efficient in inhibiting browning. In this treatment, in addition to the inhibition of physiological disorders, there was no damage to the ripening of the fruit, and no negative influence on fruit quality was found. The values of polyphenol oxidase activity and phenol content in these peaches after 28 days of cold storage and 2 days under simulated market conditions did not exceed 0.0888 units PPO min.⁻¹ g⁻¹ of fresh mass and 0.0692 mg of phenol g⁻¹ of fresh mass, respectively; that is, these values were much lower than those observed in the Chimarrita, Marli and Chiripá peach controls (Figures 5 and 6). These results agree with those of Lurie and Crisosto (2005), who proposed that delayed storage may promote the stability of cell tissues and decrease the activity of oxidizing enzymes, such as polyphenol oxidase, allowing the fruit to withstand low temperatures for a longer period of time during cold storage and remain free of physiological disorders. However, despite adequate control of cold injuries, white pulp fruits subjected to delayed storage for 48 hours were not suitable for market and/or consumption.

The yellow pulp fruit, regardless of delayed storage and duration of each treatment, did not present any physiological symptoms of pulp browning (Figure 1), even when taking into consideration the polyphenol oxidase activity and phenol content (Figures 3 and 4).

Decay – The decay of the peaches, in relation to their quality and storage potential, is shown in Figure 7. Of all the cultivars tested, the controls and those peaches subjected to delayed storage for 48 hours presented some incidence of decay after 14 days of cold storage plus 2 days out of cold storage. These symptoms decisively influenced their quality.

Taking this results into consideration, marketing such peaches would certainly be unfeasible. These results are consistent with those of Martins et al. (2004), who describe the main causes of postharvest losses in peaches as the occurrence of physiological disorders and the development of decay. Lurie and Crisosto (2005) also mentioned that during cold storage, peaches may display both physiological disorders and decay (GOTTINARI et al., 1998), which contribute decisively to their qualitative devaluation during and after market placement. Therefore, high dehydration and the rapid loss of pulp firmness associated with an increased percentage of physiological disorders and decay would indicate that peaches are going through senescence and that they have passed their ideal market time.

Therefore, taking into account that delayed storage may stimulate biochemical events associated with maturation (LUCHSINGER; WALSH, 1998), the accelerated development of decay can clearly be used as an example of such behavior throughout this work. However, if the time x temperature binomial for delayed storage is well regulated, it is possible to increase thermal tolerance to cold without accelerating peach senescence, while adequately maintaining quality. This was the case for all peaches subjected to delayed storage for 24 hours; at no time was the presence of decay detected in fruit thus treated. It can therefore be concluded that delayed storage for 24 hours was enough not only to control cold damage but also to provide disinfection in case of possible microbial agents in the peaches, even without additional chemical treatment. Indeed, Sasaki et al. (2010) mentioned that although delayed storage may eventually cause oxidative stress, it may be used as a disinfecting agent. Thus, delayed storage not only reduces the damage caused by low temperatures in species not tolerant to cold storage but also prevents the development of decay (RODOV et al., 2000).

As for the characterization of microorganisms in the controls and in peaches subjected to delayed storage for 48 hours, only the genus *Monilinia* was associated with the detected symptoms. Among the damage in these peaches, brown decay affected 80% of the conventional production in this region (FACHINELLO et al., 2003).

Soluble solids contents and titratable acidity – During cold storage, the peaches with normal maturation (without any physiological disorders) underwent small and constant increases in soluble solids content (Figures 8 and 9). This behavior may be considered normal for climacteric fruits such as peaches and is also very important for fruit integrity once these substances are utilized as a respiratory substrate (KLUGE et al., 2002; SASAKI et al., 2010).

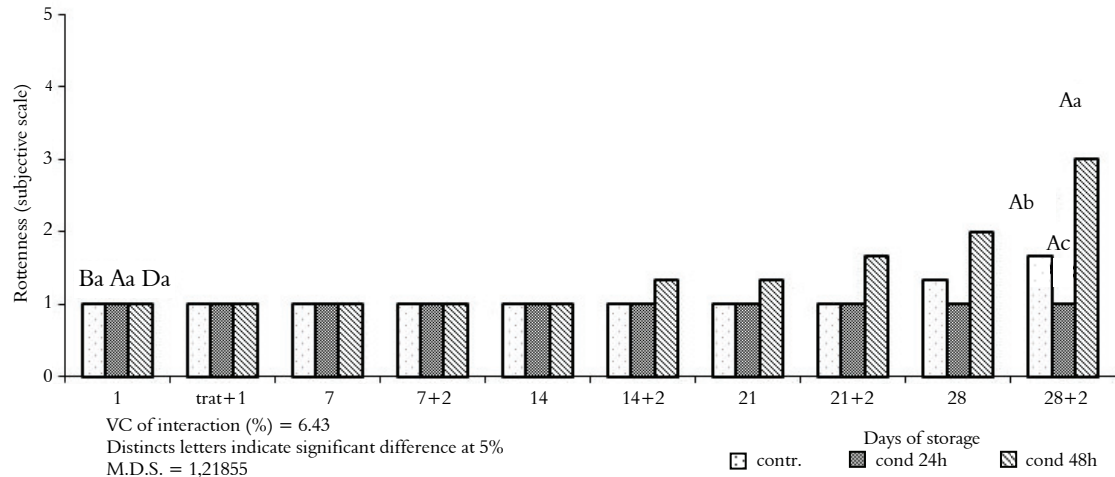


Figure 7. Mean variation of decay, in delayed storage of yellow and white pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

*Figure 7- T1: control; T2: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 24 hours; T3: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 48 hours. Means followed by same letter between treatment (small letters), and between storage times (capital letters), do not differ one from the other by the Tukey test at 5% probability.

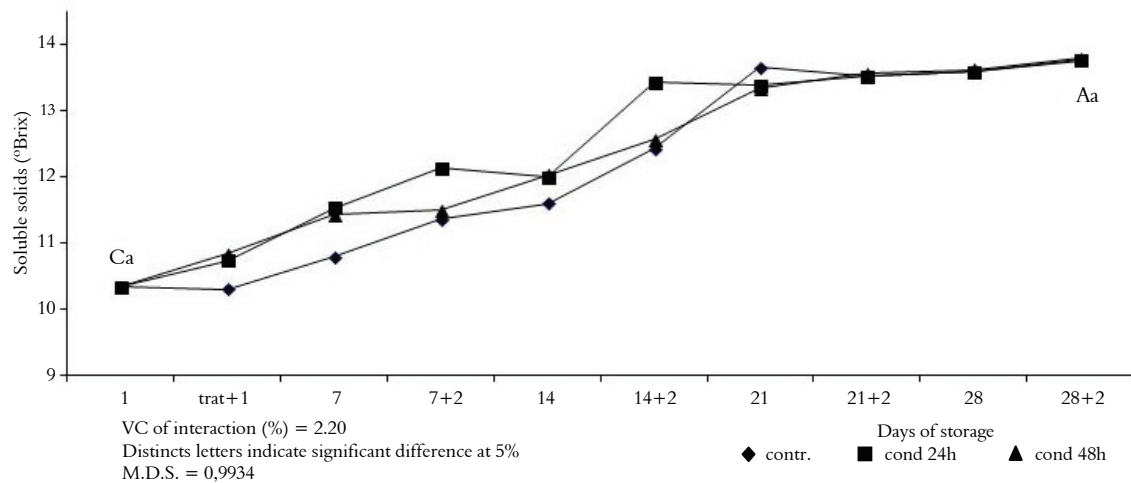


Figure 8. Mean variation of soluble solids contents, in delayed storage of yellow pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

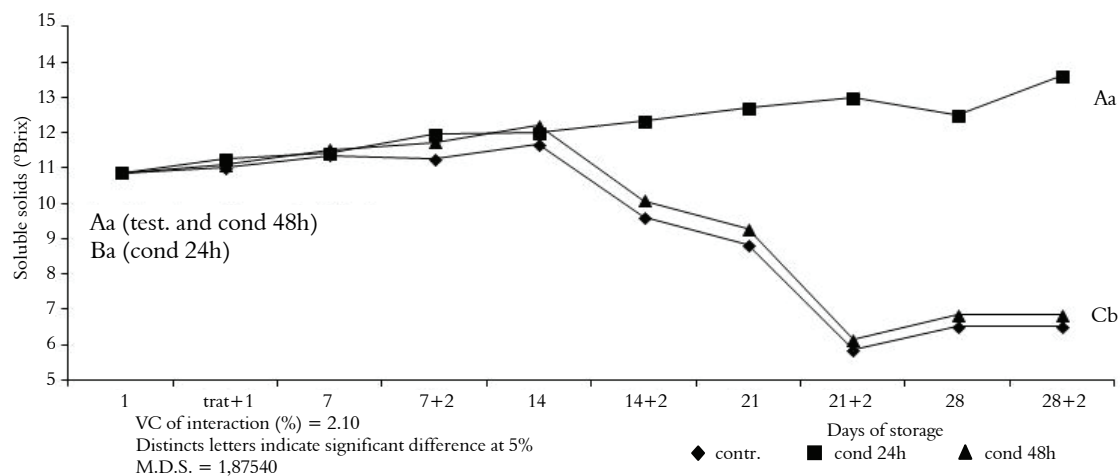


Figure 9. Mean variation of soluble solids contents, in delayed storage of white pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

*Figures 8 to 9 - T1: control; T2: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 24 hours; T3: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 48 hours. Means followed by same letter between treatment (small letters), and between storage times (capital letters), do not differ one from the other by the Tukey test at 5% probability.

All yellow pulp and white pulp peaches subjected to delayed storage for 24 hours were still in the fully maturing stage at the end of the experiment, showing the best quality and potential for conservation compared to other treatments. Thus, the soluble solids content in yellow pulp peaches ranged from 9.2 at harvest time to 14.2°Brix at 28 days of cold storage plus 2 days out of cold storage. Similarly, the white pulp cultivars subjected to delayed storage for 24 hours experienced increases in soluble solids content from harvest time (10°Brix) to the end of the experiment (14.6°Brix). In both cases, these peaches exhibited sufficiently good quality for market and consumption at the end of this work. These values are satisfactory, as the minimum soluble solids content required for harvested peaches not to be considered immature, as established by the Technical Regulations of Identity and Quality of Peaches and Nectarines (MARTINS et al., 2004), is 8°Brix. Therefore, yellow and white pulp peaches subjected to delayed storage for 24 hours met quality requirements from the moment they were harvested up to 28 days of cold storage and 2 days out of cold storage.

As for the white pulp cultivars, their controls and those subjected to delayed storage for 48 hours presented mixed results with regard to levels of soluble solids content. These peaches demonstrated increased values of soluble solids at 14 days of cold storage and then had a linear decrease to values even lower than those at harvest time. Furthermore, from the results presented, the timing of this decrease in soluble solids content can be related to the beginning of symptoms of cold damage and decay.

However, peaches subjected to delayed storage for 48 hours did not present any symptoms related to cold damage

Titrateable acidity (Figures 10 and 11) generally decreased, confirming the studies by Neves et al. (2008), who claimed that the decrease of titrateable acidity in fruits occurs naturally, and as part of the soluble solids content, these acids can be used in the oxidative process during climacteric respiration. However, the speed at which these metabolic processes occur may increase the ripening stage of the fruits. Thus, fruits that preserve their acidity and soluble solids content for a longer period of time may be considered to be in a less advanced stage of ripening, as in the case of the yellow pulp peaches and the white pulp cultivars subjected to delayed storage for 24 hours.

Differences in titrateable acidity at the end of the experiment were not significant in yellow pulp peaches, but reached statistical significance in white pulp cultivars. In the yellow pulp peaches, titrateable acidity varied from 4.08 to 4.28 mg of citric acid 100 g⁻¹ of pulp. In white pulp cultivars subjected to delayed storage for 24 hours, the values of titrateable acidity ranged from 4.56 to 4.79 mg of citric acid 100 g⁻¹ of pulp, while on average these peaches had 5% more acidity than both the controls and peaches subjected to delayed storage for 48 hours. Therefore, white pulp peaches subjected to delayed storage for 24 hours may be considered to be in a less advanced stage of ripening. Consequently, there was a delayed ripening evolution of these peaches, evidenced by their high levels of titrateable acidity and soluble solids content.

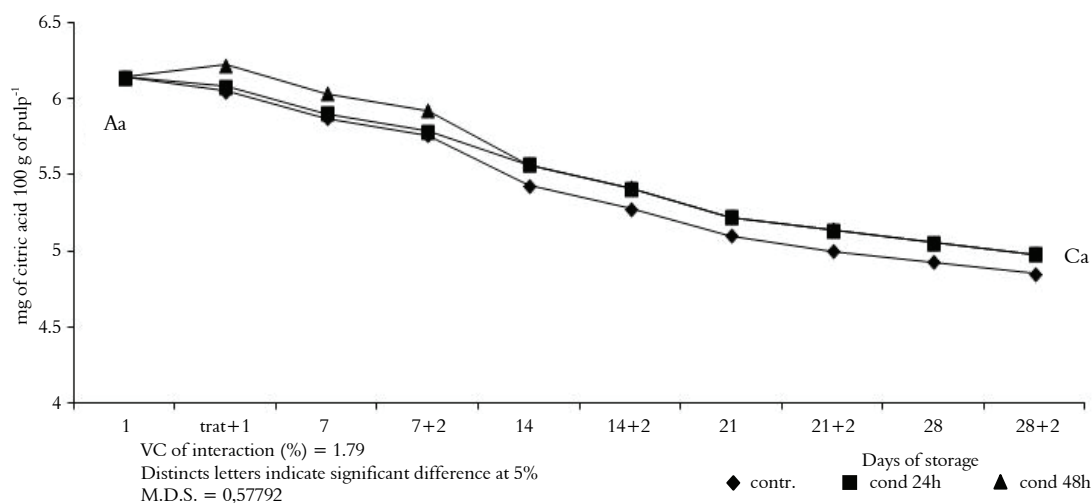


Figure 10. Mean variation of titrateable acidity, in delayed storage of yellow pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ of R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

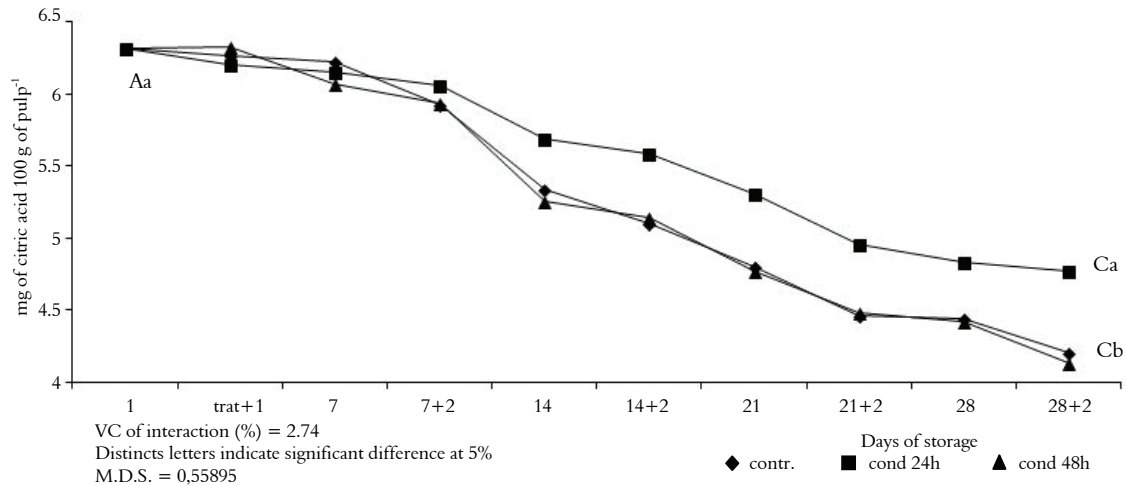


Figure 11. Mean variation of titratable acidity, in delayed storage of white pulp peaches, conditioned or not conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H. and stored at $0 \pm 0.5^\circ\text{C}$ and $92 \pm 3\%$ de R.H., for 28 days. Arroio dos Ratos, Rio Grande do Sul State.

*Figures 10 to 11 – T1: control; T2: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 24 hours; T3: fruits conditioned at $20 \pm 0.5^\circ\text{C}$ and $75 \pm 3\%$ de R.H., for 48 hours. Means followed by same letter between treatment (small letters), and between storage times (capital letters), do not differ one from the other by the Tukey test at 5% probability.

The variability in soluble solids content and titratable acidity is very large within orchards and even in the same plant. Therefore, soluble solids and titratable acidity content may not be used as precise indicators of fruit maturation stage, but only as indicators of fruit quality.

Conclusion

Delayed storage for inhibition of pulp browning of yellow pulp cultivars was not significant, showed no difference between the tested treatments. In white pulp cultivars, the onset of symptoms of browning was linked to high concentrations of phenolic compounds and phenol content. However, when delayed storage was performed for 24 hours, at $20 \pm 0.5^\circ\text{C}$, this heat treatment was effective for avoiding pulp browning and controlling quality in white pulp peaches. However, delayed storage for 48 hours, accelerated the ripening stage excessively in all the fruit, regardless of pulp color.

References

- BOWER, J. P.; CUTTING, J. G. M. Avocado fruit development and ripening physiology. **Horticultural Reviews**, v. 10, n. 1982, p. 229-271, 1988.
- BRACKMANN, A.; FREITAS, S. T.; MELLO, A. M.; STEFFENS, C. A. Aplicação de 1-MCP em caqui 'Quioto' armazenado sob refrigeração e atmosfera controlada. **Revista Brasileira de Fruticultura**, v. 25, n. 1, p. 42-44, 2003.
- CRISOSTO, C. H.; LABAVITCH, J. M. Developing a quantitative method to evaluate peach (*Prunus persica*) flesh mealiness. **Postharvest Biology and Technology**, v. 25, n. 2, p. 151-158, 2002.

CRISOSTO, C. H.; JOHNSON, R. S.; DeJONG, T.; DAY, K. R. Orchard factors affecting postharvest stone fruit quality. **HortScience**, v. 32, n. 5, p. 820-823, 1997.

ESPIN, J. C.; MORALES, M.; VÁRON, R.; TUDELA, J.; GARCIA, C. F. Monophenolase activity of polyphenol oxidase from Blanquilla pear. **Phytochemistry**, v. 44, n. 1, p. 17-22, 1997.

FACHINELLO, J. C.; TIBOLA, C. S.; VICENZI, M.; PARISOTTO, E.; PICOLOTTO, L.; MATTOS, M. L. T. Produção integrada de pêssegos: três anos de experiência na região de Pelotas – RS. **Revista Brasileira de Fruticultura**, v. 25, n. 2, p. 256-258, 2003.

FLUKEY, W.; JEN, J. Peroxidase and polyphenol oxidase actives in developing peaches. **Journal of Food Science**, v. 43, n. 6, p. 1826-1831, 1978.

GARZA, S.; IBARAZ, A.; PAGAN, J.; GINER, J. Non-enzymatic in peach pure during heating. **Food Research International**, v. 32, n. 5, p. 335-343, 2000.

GIRARDI, C. L.; PARUSSOLO, A.; DANIELI, R.; CORRENT, A.; ROMBALDI, C. V. Armazenamento de pêssegos [*Prunus persica* (L) Batsch] cv. Chiripá em atmosfera modificada. **Revista Iberoamericana de Tecnologia Postcosecha**, v. 4, n. 2, p. 128-133, 2002.

GIRNER, J.; ORTEGA, M.; MESEGUÉ, M.; GIMENO, V.; BARBOSA-CANOVAS, G. V.; GOTTINARI, R.; ROMBALDI, C. V.; ARAÚJO, P. J. Inactivation of peach polyphenoloxidase by exposure to pulsed electric fields. **Journal of Food Science**, v. 37, n. 4, p. 264-267, 2002.

GOTTINARI, R.; ROMBALDI, C. V.; ARAÚJO, P. J. Frigoconservação de pêssegos da cultivar BR1. **Revista Brasileira de Agrociência**, Pelotas, v.4, n.1, p.47-54, 1998.

HYODO, H.; KURODA, H.; YANG, S. F. Induction of phenylalanine ammonialyase and increase in phenolics in lettuce leaves in relation to the development of russet spotting caused by ethylene. **Plant Physiology**, v. 62, n. 1, p. 31-35, 1978.

- KLUGE, R. A.; NACHTIGAL, J. C.; FACHINELLO, J. C.; BILHALVA, A. B. **Fisiologia e manejo pós-colheita de frutas de clima temperado**. Campinas: Livraria e Editora Rural, 2002.
- LUCHSINGER, L.; WALSH, C. S. Chilling injury of peach fruit during storage. **Acta Horticulturae**, 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.; BENEDETTE, R. M.; SILVA, V. X.; PRILL, M. A.; ROBERTO, S. R.; VIEITES, R. L. Qualidade pós-colheita de mangas, não refrigeradas, e submetidas ao controle da ação do etileno. **Revista Brasileira de Fruticultura**, v. 30, n. 1, p. 94-100, 2008.
- ROBERTSON, J. A.; MEREDITH, F. I.; FORBUS, W. R. Changes in quality characteristics during peach (cv. Majestic) maturation. **Journal of Food Quality**, v. 14, n. 3, p. 197-207, 1993.
- RODOV, V.; AGAR, T.; PERETZ, J.; NAFUSSI, B.; KIM, J. J.; BEN-YEHOSHUA, S. Effect of combined application of heat treatments and plastic packaging on keeping quality of "Oroblanco" fruit (*Citrus grandis* L. x *C. paradisi* Macf.). **Postharvest Biology and Technology**, v. 20, n. 3, p. 287-294, 2000.
- 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**, n. 877, p. 539-542, 2010.
- SIDDIQ, M.; SINHA, N. K.; CASH, J. N. Characterization of polyphenol oxidase from "Stanley" plums. **Journal of Food Science**, v. 57, n. 5, p. 1177-1179, 1992.
- SIRIPHANICH, J.; KADER, A. A. Effects of CO₂ on total phenolics, phenylalanine ammonia lyase and polyphenol oxidase in lettuce, **Journal of the American Society Horticultural Science**, v. 110, n. 2 p. 249-253, 1985.
- VANDERZANT, C.; SPLITTSTOESSER, D. F. **Compendium of methods for the microbiological examination of foods**. Washington, D.C.: American Public Health Association, 1992.

Received on May 5, 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.