Effect of ethylene, intermittent warming and controlled atmosphere on postharvest quality and the occurrence of woolliness in peach (Prunus persica cv. Chiripá) during cold storage

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Abstract

The loss of quality in peach (Prunus persica) after harvest is associated with metabolic changes, mechanical damage, loss of pulp firmness, physiological disorders and decay. In the ‘Chiripá’ cultivar, woolliness is a major physiological process that affects the postharvest quality. For a better understanding of the development of woolliness in ‘Chiripá’ peach and to identify conditions that can prevent it, we devised several postharvest treatments consisting of cold storage (CS) either alone or in combination with the application of ethylene or 1-methycyclopropene (1-MCP), intermittent warming or controlled atmosphere (CA) storage. We evaluated the effects of these treatments on postharvest preservation, the occurrence of woolliness and the activities of endo-polygalacturonase (endo-PG), exo-polygalacturonase (exo-PG) and pectin methylesterase (PME). Our results indicated that these treatments could modify the activities of the three enzymes, and that the induction of endo-PG and exo-PG activity and/or the repression of PME activity reduced the occurrence of woolliness. CS alone had a major effect on endo-PG and exo-PG activity but less impact on PME activity. The application of 1-MCP exacerbated this difference. Either ethylene application or intermittent warming increased endo-PG and exo-PG activities without reducing PME activity, resulting in the loss of pulp firmness and decay. Under CA storage, PME activity was effectively reduced and the activities of endo-PG and exo-PG were low during the treatment, dramatically increased 5 days after the end of the treatment. The overall quality of
the peaches was better preserved under CA storage alone. With this treatment, the difference between PG and PME activity narrowed and the activity of both enzymatic groups decreased. As a result, the firmness of the pulp was better preserved and the incidence of decay and woolliness decreased.

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1. Introduction

Postharvest quality losses in stored peaches are caused predominantly by metabolic changes, mechanical damage, reduction in pulp firmness, physiological disorders and decay. These losses are influenced by varietal characteristics, ripening stage at harvest, handling, harvesting and storage conditions and by the storage system (Lill et al., 1989; Lelièvre et al., 1997; Crisosto et al., 1999; Rombaldi et al., 2002). In trying to reduce such losses, researchers have sought new genotypes and have examined pre-harvest conditions, harvesting procedures, cold storage (CS), controlled atmosphere (CA) storage and the use of systems that control the production and/or the action of ethylene (Zhou et al., 2000b; Dong et al., 2001).

For peaches of the ‘Chiripá’ cultivar, we have previously determined the fruit maturation stage that is most suitable for harvest and CS, and the appropriate conditions for CS. During these trials, we found that premature harvest resulted in a greater incidence of woolliness after CS. For this reason, harvest should be delayed until the fruit develops a light green colour, with a hue angle of 95–105° and pulp firmness between 45 and 65 N. Even so, woolliness occurs in approximately 30–40% of the fruit after 25–35 days of CS at 0°C and 90–95% relative humidity (RH) (Rombaldi et al., 2002). It is well known that cell wall pectolytic enzyme activities increase with the normal ripening of peach fruit. Pectin methylesterase (PME, EC 3.1.1.11) catalyzes the de-methylation of the C6 carboxylic acid group in galacturonosyl residues, whereas polygalacturonase (PG, EC 3.2.1.15) breaks down the pectin polysaccharides. Because PG needs de-esterified pectates as a substrate, PME could be necessary for optimal PG activity. Abnormal PG activity has been associated with aberrant pectin metabolism, including the accumulation of insoluble pectins in the cell wall and the occurrence of woolliness (Ben-Arie et al., 1989; Fernández-Trujillo et al., 1998; Zhou et al., 2000b). Recently, Obenland et al. (2003) demonstrated that expansin mRNA and protein are strongly suppressed in the mealy tissue of peach fruit. They hypothesized that inhibition of expansin accumulation could limit the ability of PGs to degrade pectin and therefore promote woolliness.

In order to decrease the woolliness in peaches, the use of CA conditions is recommended (Lurie, 1992; Zhou et al., 2000b). Our results (Rombaldi et al., 2002) and also those of Nava and Brackmann (2002), in each case working with ‘Chiripá’ peaches produced in commercial orchards in Southern Brazil, confirmed that the use of a CA, specifically 1.5 kPa O2 and 5 kPa CO2, was effective in the prevention of woolliness. In contrast, 100% of the fruit showed symptoms of woolliness when maintained under CS alone. Despite the successful preservation of ‘Chiripá’ peaches under CA conditions, this system is not yet widely used for commercial peach production in Brazil due to operational difficulties and economic limitations.

Other investigators (Anderson and Penney, 1975; Anderson, 1982; Dawson et al., 1995; Artes et al., 1996; Obenland and Carroll, 2000) studied the use of intermittent warming during CS, with the aim of re-establishing the balance between PG and PME activities in order to prevent woolliness. On an experimental scale, the results were favourable, but there remain difficulties in the validation of this approach for commercial-scale applications.

The majority of postharvest physiological disorders in climacteric fruit are influenced, directly or indirectly, by ethylene. Several reports demonstrate that reducing ethylene production and/or action is sufficient to improve the postharvest quality of most climacteric fruit (Sisler et al., 1996; Lelièvre et al., 1997; Fan et al., 1999; Zhou et al., 2001). In some cases, however, a decrease in the production or action of ethylene induced by 1-methylcyclopropene (1-MCP), a potent inhibitor
of ethylene action (Sisler et al., 1996), can be inadequate for the improvement of postharvest quality (Dong et al., 2001; Zhou et al., 2001). Indeed, in fruit sensitive to wooliness, the loss of ethylene has a negative effect, promoting this condition (Dong et al., 2001).

In this context, we have evaluated the effects of ethylene, intermittent warming and CA on the quality of ‘Chiripá’ peaches after harvest, particularly focusing on the occurrence of wooliness and the activities of endo-PG, exo-PG and PME.

2. Materials and methods

2.1. Harvest

Peach fruit (Prunus persica cv. ‘Chiripá’) were harvested in Southern Brazil, in the city of Farroupilha, in January 2002. The fruit were harvested when the fruit colour was light green, the recommended stage in that region for cold storage (Rombaldi et al., 2002). Immediately after harvesting the fruit were transported to the storage unit in a truck equipped with an isothermal compartment, which had been acclimatized at 20 ± 2 °C and 75 ± 5% relative humidity. The time between harvest and the initiation of our experiment was approximately 12 h.

2.2. Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
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<tbody>
<tr>
<td>T1</td>
<td>CS at 0 ± 0.5 °C and 90 ± 3% RH</td>
</tr>
<tr>
<td>T2</td>
<td>CS with the application and continuous presence of 10–15 μL L⁻¹ ethylene during the entire CS period</td>
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<tr>
<td>T3</td>
<td>T2 with the application and continuous presence of 10–15 μL L⁻¹ ethylene, from the 15th day of CS</td>
</tr>
<tr>
<td>T4</td>
<td>T3 with the application of 0.9 μL L⁻¹ of 1-methylcyclopropene (1-MCP) for 24 h, at 20 ± 2 °C and 75 ± 5% RH</td>
</tr>
<tr>
<td>T5</td>
<td>15th day of storage</td>
</tr>
<tr>
<td>T6</td>
<td>CS with intermittent warming for 24 h at 20 ± 3 °C and 75 ± 5% RH, from the 15th day of storage</td>
</tr>
</tbody>
</table>

For the implementation of treatments T2 and T3, ethylene was injected into the cold room at a final concentration of approximately 12 μL L⁻¹ when established.

Thereafter, daily sampling of the cold room atmosphere was carried out to determine the concentration of ethylene, which was maintained between 10 and 15 μL L⁻¹ by absorption with potassium permanganate or by subsequent injections as appropriate. For treatment T3, the refrigeration system was turned off on the 15th day of CS and the room was heated until the temperature reached 20 ± 3 °C. This temperature was maintained for 24 h and then the CS was re-established. Ethylene application in T3 and intermittent warming in T5 were performed on the 15th day of storage, based on existing data for this cultivar which show that wooliness is induced from the 14th to the 18th day of CS (Rombaldi et al., 2001). For all treatments, the period of CS was 35 days, followed by 5 extra days at 22 ± 3 °C and 75 ± 5% RH (the latter aiming to evaluate shelf-life at room temperature).

For each treatment, 10 replicates were performed, each corresponding to a box containing approximately 10 kg of fruit. The evaluations were performed immediately before the treatments started (P1), at the end of 35 days (P2), and on the fifth day at room temperature (22 ± 3 °C and 75 ± 5%) after the treatments (P3). Before evaluating the fruit at P2, they were stored at 22 ± 3 °C and 75 ± 5% for 6 h in order to bring the fruit temperature to approximately 20 °C.

2.3. Evaluations

For the analysis of pulp firmness, total soluble solids (TSS), titratable acidity (TA), ethylene production, skin colour, wooliness, presence of decay and endo-PG, exo-PG and PME enzymatic activities, the following procedures were used. Pulp firmness was determined using a hand penetrometer (TR Fruit Test 327, Italy) with an 8-mm tip, and results expressed in Newtons (N). For each fruit, two readings were taken in the equatorial region of the fruit after the skin was removed. The readings were taken on opposite sides of the fruit. TSS was determined using a hand refractometer (ATAgro PR-100 Palette, Japan). The results were expressed in % (w/w). TA was determined by titration with NaOH (0.1N) to pH 8.1, using 10 mL of juice from 10 fruit samples. The results were expressed in cmol L⁻¹ of juice.

Ethylene production was determined by gas phase chromatography using a Varian® model 3300 gas chromatograph (Shimadzu GC-2010, Japan) equipped with a 1/8 in. steel column, prepared with Porapak® and a flame ionization detector. Samples consisting...
of approximately 10 peaches were placed in a 600-
l.m hermetically closed container and maintained at
22 ± 3 °C and 75 ± 5% RH. After 1 h, 1 mL of the
atmosphere in the container was sampled to determine
the ethylene concentration. The results were expressed
in nL g⁻¹ h⁻¹.

Skin colour was measured with a Minolta CR-300
colorimeter and expressed in hue values. Woolliness
was evaluated visually. Fruit that did not release juice
when pressed by the fingers were considered to have
the condition. The results were expressed as a percent-
age. Decay was also evaluated visually and expressed
as a percentage. After the 35-day evaluation, decayed
fruit were eliminated from the samples and the second
evaluation was made by calculating the percentage of
decayed fruit in relation to the total number of fruit
in the samples at that time. Exo-PG, endo-PG and
PME activities were determined exactly as described
by Zhou et al. (2000a).

2.4. Experimental design and statistical analysis

Experiments were performed in a completely ran-
nomized manner, with 10 replicates. The experimen-
tial unit was a box containing approximately 10 kg of
peaches. The percentage data for the variables woolli-
ness and decay were normalized according to the equa-
tion \( f(x) = \arcsin(\sqrt{x}) \). ANOVA was performed using
the F test with a 5% significance level. Means of treat-
ments were compared using the Duncan test with a 5%
significance level.

3. Results and discussion

Peaches were harvested at the pre-climacteric stage,
with a light green colour (b value of 98.45–99.25)
(Fig. 1a) and a pulp firmness between 54.12 and
55.02 N (Fig. 1b), which is characterized by minimal
ethylene production (0.11–0.25 nL h⁻¹ g⁻¹). Ethylene
production, colour and pulp firmness are relatively con-
stant from year to year, showing only small variations
between harvests in southern Brazil (Rombaldi et al.,
2002). However, the other measurements we analyzed
to monitor the fruit quality – TSS, TA, decay, woolli-
ness, exo-PG, endo-PG and PME activities – undergo
significant variation between harvests, and are espe-
cially influenced by climatic–edaphic conditions. In
the present study, the fruit were harvested at the stage
recommended for 2–3-week CS of the ‘Chiripa’ culti-
var (Rombaldi et al., 2002). If harvested at an earlier
stage, the period of storage can be extended with-
out significant increases in decay, but the incidence
of woolliness approaches 100% and the sensory qual-
ity decreases drastically. Conversely, if the harvest is
delayed, the period of storage has to be shortened to
less than 15 days, otherwise significant losses in the
overall quality of the fruit will occur. In addition, due
to the reduction in pulp firmness to <20 N, it becomes
difficult to avoid mechanical damage to the fruit during
handling.

After 35 days of CS, we observed a reduction in
pulp firmness (Fig. 1b) under all treatments, with the
most significant decrease under T5 (intermittent warm-
ing). Despite the well-characterized effect of ethylene
in reducing pulp firmness, there was no significant
effect on the pulp firmness of ‘Chiripa’ peaches after
35 days of CS under T2, T3 or T4, which included
the application of 1-MCP. This demonstrates that the
effects of ethylene on pulp firmness are not detectable
during cold storage (T1–T4). In contrast, intermittent
warming (T5) reduced pulp firmness.

In all the treatments, the end of the CS period (P2)
was followed by maintenance at 22 ± 3 °C and 75 ± 5%
RH for 5 days (P3), in order to simulate storage on
shelves under realistic commercial conditions. By the
end of this 5-day period, the effect of ethylene was obvi-
ous, since the pulp firmness was dramatically reduced
to 10 N (T2). Similarly, but even more noticeably, the
effect of intermittent warming reduced pulp firmness to
1.26 N (T5). Under the other treatments, the pulp firm-
ness remained >25 N. It was clear that the controlled
atmosphere (T6) as well as the reduction of ethylene
action through the application of 1-MCP (T4), led to a
better preservation of the pulp firmness (Fig. 1b).

There was no significant difference in the content
of total soluble solids (TSS) across all the treatments
(Fig. 1c). On average, fruit with 11.30% of TSS at the
time of harvest showed an increase to 13.0% after 35
days of CS. After a further 5 days at room tempera-
ture (22 ± 3 °C and 75 ± 5% RH) the TSS content
significantly increased in the fruit under T1, T4–T6
reaching 13.5%. In fruit treated with ethylene (T2 and
T3), no significant further increases were observed after
5 days at room temperature. Increasing TSS content in
peaches harvested at the pre-climacteric stage is normal
Fig. 1. Colour, pulp firmness, total soluble solids and titrable acidity in ‘Chiripa’ peaches under six different cold storage treatments (T1–T6), analysed over three different periods (P1–P3). The results, means of 10 replicates, were compared by Duncan’s test ($p > 0.05$). Results for the same treatment and different periods do not differ from each other if the capital letter on top of the columns is the same. Results for the same period and different treatments do not differ from each other if the lower case letter on top of the column is the same. (■) Period 1 (P1): immediately before treatment started; (□) period (P2): at the end of 35 days of treatment; (□) period 3 (P3): on the fifth day at room temperature ($22 \pm 3^\circ C$ and $75 \pm 5\%$ RH) after the treatment. T1: cold storage (CS) at $0 \pm 0.5^\circ C$ and $90 \pm 3\%$ of relative humidity (RH); T2: CS with the application and the maintenance of $10–15$ µL L$^{-3}$ of ethylene; T3: CS following the application and the maintenance of $10–15$ µL L$^{-3}$ of ethylene from 15th day of storage; T4: CS following the application of $0.9$ µL L$^{-3}$ of 1-MCP at $25 \pm 3^\circ C$ and $75 \pm 5\%$ RH, for 24 h; T5: CS with intermittent warming of 24 h at $20 \pm 3^\circ C$ and $75 \pm 5\%$ RH, on the 15th day of storage; T6: CS with controlled atmosphere (CA) at 1.5 kPa of O$_2$ and 5 kPa of CO$_2$.

and reflects the solubilization and synthesis of carbohydrates (Lelièvre et al., 1997).

The titratable acidity (Fig 1d) of the peaches decreased during the storage period, but the magnitude of the effect depended on the treatment. The largest reductions were observed in peaches treated with exogenous ethylene (T2 and T3) and in peaches subjected to intermittent warming (T5). For most of the fruit, a reduction in the level of TA is normal and the rate of reduction is directly proportional to the temperature, which first affects ethylene production and then respiratory activity. This explains the more significant reductions in TA in peaches treated with ethylene (T2 and T3) and in those exposed to increased temperature (T5). This also explains the higher TA of peaches stored in the presence of 1-MCP (T4) in comparison to those under CS alone (T1). The protective effect of 1-MCP, inhibiting the action of ethylene, reduces the respiratory activity and, consequently, reduces the catabolism of organic acids.
Ethylene production (Fig. 2a), which was about 0.22 nL g\(^{-1}\) h\(^{-1}\) at the beginning of the experiment (P1), increased under all the treatments during the 35 days of CS. The largest increases were observed in treatments that stimulated ethylene biosynthesis, i.e., the application of exogenous ethylene (T2 and T3), which induces a positive feedback loop in which more ethylene is produced, and thermal stimulation (T5). Low temperatures are more effective in controlling ACC oxidase than ACC synthase activity (Lelièvre et al., 1997). The lowest increases were observed in peaches treated with 1-MCP, where this positive feedback loop was interrupted.

Following CS, during the 5-day period at room temperature (P3), ethylene levels in the different experimental treatments either remained the same, decreased or increased (Fig. 2a). We found that the senescence phase began under the T2 and T5 treatments, characterized by a decrease in ethylene production. For the other treatments, ethylene production was stable (T1, T4 and T6) or increased (T3), indicating that the fruit had a greater biological integrity. The application of 1-MCP, blocking the action of ethylene, inhibited synthesis after CS. Similar behaviour was reported by Dong et al. (2001) in ‘Flavortop’ nectarines.

As was the case for ethylene production, fruit colour was also influenced by the storage conditions (Fig. 1a). The greatest change in colour occurred in peaches treated with ethylene throughout the CS period (T2) and in those subjected to intermittent warming (T5), since variation in the background colour of the ‘Chiripá’ cultivar is due mainly to chlorophyll degradation. In fruit with lower ethylene production, the colour changed to a lesser degree, i.e., under treatments T4 (1-MCP) and T6 (CA). Similar results have been reported for other fruit and vegetables in which the greenish colour was preserved with the increase in CO\(_2\) concentration and/or a reduction in O\(_2\) levels sometimes associated with the application 1-MCP (Lill et al., 1989; Lelièvre et al., 1997; Fan et al., 1999).

Woolliness, which is the main physiological symptom of poor postharvest quality in ‘Chiripá’ peaches during CS, was also affected by the treatments (Fig. 2b). For the fruit maintained under CS alone (T1), 19% woolliness was observed after 35 days (P2) and 100% woolliness was observed after the 5-day period at room temperature that followed the CS (P3). When 1-MCP was applied prior to CS (T4), the disorder was more severe, reaching 48% when the CS period ended (P2) and 100% after the 5-day period at room temperature (P3). However, under treatments that included ethylene (T2 and T3), intermittent warming (T5) and CA with changes in O\(_2\) and CO\(_2\) levels (T6), woolliness was either avoided (T2, T5 and T6) or reduced (T3).

Although for the majority of fruit, the control of ethylene production and/or action increases the period of conservation and avoids physiological disorders during refrigerated storage (Lelièvre et al., 1997), in ‘Chiripá’ peaches this is not entirely true. Although, on one hand, the application of ethylene (T2) induced a greater loss of pulp firmness (Fig. 1b) and change in colour (Fig. 1a), on the other hand it prevented the occurrence of woolliness, the main physiological disorder of this cultivar (Fig. 2b). Several authors studying woolliness in peaches, plums and nectarines, found that this condition became apparent by the time the fruit were removed from CS and kept at 20–25°C (Anderson and Penney, 1975; Zhou et al., 2000b; Dong et al., 2001, 2002; Rombaldi et al., 2001). Crisosto et al. (1999) noted that the induction of woolliness is dependent on cultivar, stage of maturation at harvest and storage temperature.

The use of intermittent warming during CS (T5) prevented the occurrence of woolliness (Fig. 2b). According to Anderson and Penney (1975), Dawson et al. (1995) and Artes et al. (1996), increased temperature during CS accelerates the fruit’s metabolism, restoring the balance between the metabolic pathways and avoiding woolliness. However, this strategy has its limitations in commercial production, since temperature equalization and temperature monitoring is more challenging in large storage rooms. Furthermore, we observed that increases in temperature promoted decay (Fig. 2c), which affected 32% of the fruit at the end of the CS period (P2) and 53% of the remaining fruit at the end of the additional 5-day period at room temperature (P3). This alone makes the strategy economically unfeasible. However, from a technical and scientific point of view, this demonstrates that the reactivation of metabolism during CS can prevent woolliness. Further studies at the molecular level, employing ‘Chiripá’ peach as a model, and using the same treatments as described in this article, could provide important data in terms of the activities of genes and enzymes involved in the occurrence of this condition.
Fig. 2. Ethylene, woolliness, decay, exo-PG activity, endo-PG activity and PME activity in 'Chiripa' peaches under six different cold storage treatments (T1–T6), analysed over three different periods (P1–P3). The results, means of 10 replicates, were compared by Duncan's test (*p* > 0.05).

Results for the same treatment and different periods do not differ from each other if the capital letter on top of the columns is the same. Results for the same period and different treatments do not differ from each other if the lower case letter on top of the column is the same. ([■]) Period 1 (P1): immediately before treatment started; ([ ]) period (P2): at the end of 35 days of treatment; ([□]) period 3 (P3): on the fifth day at room temperature (22 ± 3 °C and 75 ± 5% RH) after the treatment. T1: cold storage (CS) at 0 ± 0.5 °C and 90 ± 3% of relative humidity (RH); T2: CS with the application and the maintenance of 10–15 μL·L⁻¹ of ethylene; T3: CS following the application and the maintenance of 10–15 μL·L⁻¹ of ethylene from the 15th day of storage; T4: CS following the application of 0.9 μL·L⁻¹ of 1-MCP at 25 ± 3 °C and 75 ± 5% RH, for 24 h; T5: CS with intermitting warming of 24 h at 20 ± 3 °C and 75 ± 5% RH, on the 15th day of storage; T6: CS with controlled atmosphere (CA) at 1.5 kPa of O₂ and 5 kPa of CO₂.
For the other treatments (T1–T4 and T6), the percentage of fruit with decay at the end of CS did not vary significantly. However, after 5 days at room temperature (P3), there was a higher incidence of decay in peaches treated with 10–15 μL·L⁻¹ of ethylene during the whole CS (T2). These fruit were more mature, characterized by reduced pulp firmness, making them susceptible to microbial infection and activity, resulting in a higher proportion of rotten fruit.

In terms of enzymatic activity (Fig. 2d–f), we observed that CS alone (T1) has a more pronounced effect controlling exo-PG and endo-PG activity than PME activity. Under the influence of 1-MCP (T4), this effect was intensified, i.e. the exo-PG and endo-PG activities were reduced further but PME activity was not affected. Ethylene application (T2 and T3) induced exo-PG and endo-PG activities but not PME activity. With respect to endo-PG and exo-PG, the highest increase was detected in fruit in which ethylene was maintained during the whole period of storage (T2). Under CA conditions (T6), there was a reduction in all three enzyme activities. These data indicate that reductions in temperature and ethylene levels have a stronger effect on endo-PG and exo-PG than on PME. However, reduction of the partial O₂ pressure and the increase in CO₂ pressure, associated with CS, decreased not only the endo-PG and exo-PG activities but also PME activity. When the enzyme assays were performed 5 days after the fruit were removed from CS, the largest increments in endo-PG and exo-PG activity occurred in fruit under T6 (CA), preventing woolliness.

‘Chiripá’ peaches are very sensitive to woolliness (Rombaldi et al., 2002), and this condition is related to an imbalance between the PG and PME activities (Zhou et al., 2000b). More specifically, it was found that woolliness in ‘Chiripá’ peaches is related to the very low endo-PG and continuous PME activities in agreement with results in other peach varieties (Artes et al., 1996). Therefore, two approaches can be used to reduce the occurrence of woolliness in this cultivar: (1) induce the activity of enzymes that are repressed in woolly peaches, i.e. endo-PG and exo-PG and/or (2) inhibit the activity of enzymes that are induced in woolly peaches, in this case PME. For the first strategy, we showed that the application of ethylene (T2 and T3) or intermittent warming (T5) stimulated endo-PG and exo-PG activity. For the second strategy, we showed that altering the balance of O₂ and CO₂ (T6) helped to control the activity of endo-PG and exo-PG, as well as reducing PME activity. Both strategies reduced the occurrence of woolliness. However, when either ethylene or intermittent warming was applied, the prevention of woolliness was accompanied by a significant loss in the pulp firmness and more decay. For these reasons, the use of a controlled atmosphere is the more suitable strategy—this restores the balance between the two competing enzymatic groups and decreases their activity, avoiding woolliness and decay but also maintaining higher pulp firmness.

4. Conclusion

Woolliness can be avoided by the induction of endo-PG and exo-PG activities and/or by the reduction of PME activity. Treatment with ethylene, 1-MCP and intermittent warming have the greatest impact on the activities of endo-PG and exo-PG, but little effect on PME activity. In contrast, the CA treatment reduces the activities of all three enzymes and is the most suitable treatment for improving the postharvest quality of ‘Chiripá’ peaches. Neither the supply of ethylene nor intermittent warming is recommended because these encourage fruit decay and a significant loss of pulp firmness.

References


