This study was carried out to evaluate the effect of different packaging systems on the shelf life of ‘Fuyu’ persimmon kept under refrigeration. ‘Fuyu’ persimmon fruits were harvested on the orange-yellow stage and wrapped in groups of three (≈900g) in different packaging systems: 12µm polyvinyl chloride film (PVC); 80µm low density polyethylene film (LDPE); 63µm PO plus 3% O\textsubscript{2}/8% CO\textsubscript{2}; 63µm PO plus 3% O\textsubscript{2}/8% CO\textsubscript{2}. Fruits stored in corrugated cardboard boxes were used as the control. The fruits were stored at 1°C ± 1°C/90 ± 5% RH for 40 days. Every 10 days, four replicates of each treatment were evaluated for headspace gas composition (O\textsubscript{2}, CO\textsubscript{2}) and then transferred to 25°C ± 1°C/80 ± 5% RH for three more days before being evaluated as to headspace gas composition (O\textsubscript{2}, CO\textsubscript{2}, acetaldehyde and ethanol), firmness, weight loss, skin and flesh color, total soluble solids, titratable acidity, pH, decay, discoloration and sensory attributes. The 63µm PO film permitted the maintenance of quality up to 40 days at 1°C plus 3 days at 25°C. This result differed (P=0.05) from that of the control fruits and of those in the PVC film which showed a shelf life of 20 days. Although the LDPE film permitted the maintenance of quality up to 40 days, it presented a risk of anaerobiosis, since CO\textsubscript{2}, acetaldehyde and ethanol accumulated inside the packages. Off-flavors were not detected in the sensory analysis.

 Este trabalho teve por objetivo avaliar os efeitos de diferentes sistemas de embalagem na conservação pós-colheita de caqui ‘Fuyu’. Caquis ‘Fuyu’ foram acondicionados, em grupos de três (≈900g), em diferentes sistemas de embalagem: PVC (policloreto de vinila), 12µm; PEBD (polietileno de baixa densidade), 80µm; PEBD (80µm) mais 3% O\textsubscript{2}/8% CO\textsubscript{2}; PO (multicamada coextrusado à base de poliolefinas), 63µm; PO (63µm) mais 3% O\textsubscript{2}/8% CO\textsubscript{2}. Frutos acondicionados em caixas de papelão foram utilizados como testemunha. Os caquis foram armazenados por 40 dias a 1°C ± 1°C/90 ± 5% UR. A cada 10 dias, quatro repetições de cada tratamento foram avaliadas quanto à composição gasosa do espaço livre e, então, transferidas para 25°C ± 1°C/80 ± 5% UR onde permaneceram por mais três dias, quando avaliaram-se: composição gasosa (O\textsubscript{2}, CO\textsubscript{2}, acetaldeído e etanol), resistência da polpa à penetração, perda de peso, cor de casca e de polpa, sólidos solúveis, acidez total, pH, incidência de podridões, escurecimento e análise sensorial. O filme PO 63µm manteve a qualidade dos frutos por até 40 dias a 1°C mais três dias a 25°C, diferindo (P=0.05) dos outros tratamentos e de aqueles armazenados nos PVC, os quais puderam ser armazenados por até 20 dias a 1°C mais três dias a 25°C. O filme PEBD 80µm, apesar de manter a qualidade dos frutos por até 40 dias a 1°C mais três dias a 25°C, apresentou risco de anaerobiose além de promover o acúmulo de CO\textsubscript{2}, acetaldeído e etanol no interior da embalagem. A avaliação sensorial não detectou sabor e odor indesejáveis nos frutos.
1. INTRODUCTION

The harvesting of persimmon in Brazil is largely concentrated, depending on the cultivar, between February and June. As a result of the large amount of fruit available on the market during this period, producers are obliged to sell their produce at fairly unfavorable prices. Although more satisfactory price levels are customarily attained after June, most producers do not have the technology to preserve the quality of their fruits up to that time. This is one of the main problems confronting persimmon producers in Brazil, in addition to fierce competition with more traditional horticultural crops (orange, banana and apple) and the lack of post-harvest technology, mainly with respect to storage and disease control.

Persimmon is very susceptible to physiological damage, particularly skin and flesh discoloration during storage. These injuries may be related to field factors and low storage temperatures (LEE et al., 1993). Cold storage for storage. These injuries may be related to field factors and low damage, particularly skin and flesh discoloration during disease control.

Post-harvest technology, mainly with respect to storage and horticultural crops (orange, banana and apple) and the lack of addition to fierce competition with more traditional problems confronting persimmon producers in Brazil, in quality of their fruits up to that time. This is one of the main most producers do not have the technology to preserve the satisfactory price levels are customarily attained after June, although more favorable prices. Although more satisfactory price levels are customarily attained after June, most producers do not have the technology to preserve the quality of their fruits up to that time. This is one of the main problems confronting persimmon producers in Brazil, in addition to fierce competition with more traditional horticultural crops (orange, banana and apple) and the lack of post-harvest technology, mainly with respect to storage and disease control.

Of the various physical methods commonly employed for the post-harvest control of Alternaria alternata in stored persimmons, the use of modified atmospheres (MA) stands out as the most important. This may be the result of the combined effect of CO₂ and acetaldehyde, which accumulate inside the package during storage and have a direct inhibitory effect on fungal development (BEN-ARIE et al., 1992). PRUSKY et al. (1997), observed that high CO₂ concentrations suppressed the development of several pathogens by inhibiting various metabolic functions, and that the atmosphere inside the packages increased in terms of the natural volatiles produced by the fruit, such as CO₂, acetaldehyde and ethanol.

In the current work, the effects of active and passive modified atmosphere storage on the quality maintenance of 'Fuyu' persimmon and the reduction of post-harvest decay were evaluated, aiming at extending the post-harvest period.

2. MATERIALS AND METHODS

‘Fuyu’ persimmon fruit were harvested from orchards in Pilar do Sul, São Paulo State, Brazil. The fruits were harvested in the orange-yellow stage with minor traces of green around the calyx and immediately transported to the FRUTHOTEC/ITAL laboratory (=150km), where they were graded for ripening uniformity, size, phytosanitary conditions and freedom from mechanical damage and visual blemishes. Next, the fruits were submitted to a phytosanitary pre-treatment with a 500μL.L⁻¹ Imazalil solution.

In a constant temperature room (16-17°C), the fruits were weighed and repacked, each consisting of 3 fruits each (average weight of each replicate: 900g) were wrapped in different packaging systems: 1 – Control (corrugated paperboard boxes; industrial standard); 2 – 12μm PVC film (polyvinyl chloride); 3 – 80μm LDPE film [low-density polyethylene]; 4 – 80μm LDPE film plus 3% O₂/8% CO₂; 5 – 63μm PO film (multilayer co-extruded polyolefine-based), PD – 900, manufactured by Cryovac®; 6 – 63μm PO film plus 3% O₂/8% CO₂. The properties of these packaging systems are shown in Table 1.

### TABLE 1. Properties of the packaging systems, as related to the modified atmosphere.

| Treatments                | Thickness (μm) | Initial gas composition (% v/v): | Average area of gas permeation (cm²) | Gas transmission rate (cm² [STP]/m²/day at 25°C and 1 atm): 
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>O₂ / CO₂</td>
<td></td>
<td>O₂ / CO₂</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>- / -</td>
<td>-</td>
<td>- / -</td>
</tr>
<tr>
<td>PVC</td>
<td>12</td>
<td>Air</td>
<td>591</td>
<td>10555/20033</td>
</tr>
<tr>
<td>LDPE</td>
<td>80</td>
<td>Air</td>
<td>641</td>
<td>1287/6386</td>
</tr>
<tr>
<td>LDPE (8% CO₂ + 3% O₂)</td>
<td>80</td>
<td>3.14 / 5.24</td>
<td>578</td>
<td>1287/6386</td>
</tr>
<tr>
<td>PO</td>
<td>63</td>
<td>Air</td>
<td>612</td>
<td>3940/22360</td>
</tr>
<tr>
<td>PO (8% CO₂ + 3% O₂)</td>
<td>63</td>
<td>3.01 / 6.64</td>
<td>576</td>
<td>3940/22360</td>
</tr>
</tbody>
</table>
The packed fruits were placed in a storage room \(1^\circ\pm 1^\circ\mathrm{C}/90\pm 5\% \mathrm{RH}\) in corrugated cardboard boxes for a total storage period of 40 days. Every 10 days, four replicates of each treatment were evaluated as to the gas concentration inside the packages \((\mathrm{O}_2, \mathrm{CO}_2)\). Next, these replicates were transferred to room conditions \(25^\circ\pm 1^\circ\mathrm{C}/80\pm 5\% \mathrm{RH}\) for three days and then analyzed for the gas composition inside the package \((\mathrm{O}_2, \mathrm{CO}_2, \text{acetaldehyde}, \text{ethanol})\), and the sensory, physical-chemical and phytopathological conditions.

The persimmon fruit samples were weighed before and after storage to calculate weight loss \(\%\) during storage. Skin and flesh color at six points (skin) and two points (flesh) of each fruit was determined objectively with a Minolta Chroma Skin and flesh color at six points (skin) and two points (flesh) and after storage to calculate weight loss \(\%\) during storage.

2=25-50%; 3=50-75%; 4=75-100%, whereas discoloration severity of decay were rated on a scale of 0-5 where: 0=none; 1<25% of the fruit surface area exhibiting signs of decay; 2=25-50%; 3=50-75%; 4=75-100%, whereas discoloration was evaluated based on the incidence of skin browning as described by PARK (1999). A sensory evaluation was carried out by a panel consisting of 12 non-trained individuals using structured scales. The intensity of off-odors and off-flavors was based on a scale divided into 5 grades, where grade 1 corresponded to no off-flavor or off-odor and grade 5 to very intense.

The concentrations of \(\mathrm{O}_2\) and \(\mathrm{CO}_2\) were determined by injecting 300\,µL of gas, taken directly from the headspace of the packages, into a Varian [model 3400] gas chromatograph, with a thermal conductivity detector \((\mathrm{TCD})\) at 140°C, after passage through a 13X Molecular Sieve and using Poropak N columns at 50°C and an injection temperature of 70°C. The gas chromatography results were analyzed with an Intralab (model 4290) integrator based on standard curves produced by calibration gases. The results were expressed as percentage of the total gas volume.

Ethanol and acetaldehyde concentrations were determined by injecting a sample of 1mL taken from the headspace into a gas chromatograph, CG 37370, using a flame ionization detector \((\mathrm{FID})\) at 250°C, and a 10% Carbowax on Chromosorb W column at 80°C, vaporizer at 150°C, argon flow rate \((\text{carrier gas})\) of 20mL\,min\(^{-1}\) and detector gas flow \((\text{H}_2/\text{O}_2)\) 20/40mL\,min\(^{-1}\) with 10X attenuation.

The experimental design adopted was completely randomized with 4 replications \(3\) fruits per set). Statistical significance was determined by submitting the mean values to an analysis of variance and was subsequently comparing the results using the Tukey test at the 5\% probability level.

### 3. RESULTS AND DISCUSSION

The factors that most affected the composition of the atmosphere inside the packages were the gas permeability rate to \(\mathrm{O}_2\) and \(\mathrm{CO}_2\) of the films and the storage temperature [Figure 1]. There were no appreciable differences between the equilibrium atmosphere established inside the packaging systems with injection of gaseous mixture and without it. As expected, in the packaging systems with gas injection, equilibrium was obtained earlier. At room temperature the lower \(\mathrm{O}_2\) and the higher \(\mathrm{CO}_2\) levels established within the LDPE film, when compared to the \(\mathrm{O}_2\) and \(\mathrm{CO}_2\) levels of the PO film, were related to the lower gas transmission rate of the former [Table 1].

The PVC film was found to be inefficient at establishing acceptable MA due to the high gas permeability of the film with regard to the respiration rate of the fruits. Transferring fruits to room temperature \(25^\circ\mathrm{C}\) caused a decrease in the \(\mathrm{O}_2\) levels and a slight accumulation of \(\mathrm{CO}_2\) inside the package. This change may indicate that the respiration rate of the fruits was more affected by the temperature than by the permeability of the film to both gases.

There was a continuous accumulation of acetaldehyde and ethanol inside the packages. The maximum levels found were for the 80\,µm LDPE film without injection of gas mixture, reaching 34\,µg\,L\(^{-1}\) and 958\,µg\,L\(^{-1}\) of acetaldehyde and ethanol, respectively. This result may be attributed to the high gas barrier of this film. The low \(\mathrm{O}_2\) level may have led to anaerobic respiration of the fruits. However, according to the sensory evaluation, no off-odors or off-flavors were detected for any treatment [data not show].

BEN-ARIE, ZUTKHI (1992) obtained similar results with ‘Fuyu’ persimmon in 80\,µm LDPE film. In their experiment, the fruits presented satisfactory quality for four months at 0°C plus seven more days at 20°C. However, there was greater accumulation of ethanol inside this package when compared to the 60\,µm LDPE film. This may cause off-flavors in the fruits during storage.

Figure 2 shows that all packaging systems were effective in limiting weight loss of the fruits throughout storage. The lower the water vapor transmission rate, the lower the water vapor pressure deficit and the higher the relative humidity within the package thus reducing the rate of transpiration of the fruits is reduced. The PVC film was found to be less effective than the other packaging systems. However, it was shown to be more effective than the unpacked control fruits. With respect to this, MOURA et al. (1997) found that ‘Taubate’ persimmon fruit in PVC film presented limited weight loss after 72 days storage at 0°C.
FIGURE 1. Evolution of $O_2$ (-----) and $CO_2$ (●—●) levels in the headspace of the packages 12µm PVC (A), 80µm LDPE (B), 80µm LDPE plus 3% $O_2$/8% $CO_2$ (C), 63µm PO (D), 63µm PO plus 3% $O_2$/8% $CO_2$ (E), containing 'Fuyu' persimmon fruit after different periods at 1°C / 90% RH (-----) plus 3 more days at 25°C / 80% RH (——). Each value is the mean of 4 replicates.
PO and LDPE films retarded softening of the fruits during storage (Figure 3). The firmness evaluation showed that the control fruits and those in PVC film softened much more rapidly, from the tenth and twentieth days of storage onwards, respectively. Furthermore, these fruits were already excessively soft (unmarketable) on the thirtieth day of storage. The ability of modified atmosphere to reduce the respiratory activity of the fruits represents not only controlling the respiration rate, but also decreases the intensity of catabolic activity and the degradation process (LOUGHEED, 1987). Similar results were obtained by BRACKMANN et al. (1997) who reported that ‘Fuyu’ persimmon in 40 µm LDPE film maintained greater firmness after 30 days of storage at 0°C plus four days at 13.5°C.

The packaging showed a favorable effect on the retention of the external color of the fruits (Figure 4). The control fruits and those in PVC film showed a more rapid change in color than those in PO and LDPE films. On the 10th day of storage, the objective evaluation showed that the control fruits had lost luminosity (decrease in L*), and after 20 days of storage similar results were obtained for the fruits in PVC film (Figure 4A). These fruits also exhibited higher values for a* (red) up to the point when they reached their limit of marketability (20 days storage). Furthermore, these fruits exhibited lower values for b* (yellow) throughout storage (Figures 4B and 4C). This pattern is characteristic of more advanced stages of ripening.
Similar results were obtained for flesh color (Figure 5). The greater loss of luminosity in the control fruits and those in PVC film became evident after 20 and 30 days, respectively (Figure 5A). However, significant differences amongst the treatments in terms of $a^*$ and $b^*$ were only observed when the control fruits and those in PVC film had already reached the overripe stage (Figures 5B and 5C).

A significant benefit of modified atmosphere is its ability to prevent loss or degradation of chlorophyll (BRECHT, 1980). Loss of chlorophyll and biosynthesis of carotenoids are avoided in fruits kept in modified or controlled atmospheres (KADER, 1986).

Total soluble solids concentrations tended to increase during the storage period for all the treatments investigated.
(Figure 6). There were no significant differences amongst the treatments. However, the control fruits presented higher levels than the other treatments during storage. This result may indicate that the modified atmosphere generated inside the packages was effective in delaying fruit ripening. With respect to this aspect, Clark, MacFall (1996) reported that the levels of total soluble solids of ‘Fuyu’ persimmon fruit stored at 7°C for six weeks in 60-µm LDPE film presented only marginal variation.

**Figure 5.** Flesh color of ‘Fuyu’ persimmon wrapped in different packaging materials, after different periods at 1°C/90% RH plus 3 more days at 25°C/80% RH, where \( L^* \) (A) stands for luminosity (0=black to 100=white), \( a^* \) (B) and \( b^* \) (C) chroma (\( a^* \)=green to \( a^* \)=red and \( b^* \)=blue to \( b^* \)=yellow). Control (---), 12µm PVC (--.--), 80µm LDPE (-----), 80µm LDPE plus 3% \( O_2/8% CO_2 \) (----), 63µm PO (-----), 63µm PO plus 3% \( O_2/8% CO_2 \) (---). Each value is the mean of 4 replicates, three fruits per set. Vertical bars indicate the least significant difference at \( P=0.05 \).
**FIGURE 6.** Total soluble solids of ‘Fuyu’ persimmon wrapped in different packaging materials, after different periods at 1°C/90% RH plus 3 more days at 25°C/80% RH. Control (●), 12µm PVC (○ , ○), 80µm LDPE (--), 80µm LDPE plus 3% O₂/8% CO₂ (——), 63µm PO (●), 63µm PO plus 3% O₂/8% CO₂ (××). Each value is the mean of 4 replicates, three fruits per set. Vertical bars indicate the least significant difference at P=0.05.

**FIGURE 7.** Titratable acidity of ‘Fuyu’ persimmon wrapped in different packaging materials, after different periods at 1°C/90% RH plus 3 more days at 25°C/80% RH. Control (●), 12µm PVC (○, ○), 80µm LDPE (--), 80µm LDPE plus 3% O₂/8% CO₂ (——), 63µm PO (●), 63µm PO plus 3% O₂/8% CO₂ (××). Each value is the mean of 4 replicates, three fruits per set. Vertical bars indicate the least significant difference at P=0.05.
FIGURE 8. The pH values of ‘Fuyu’ persimmon wrapped in different packaging materials, after different periods at 1°C/90% RH plus 3 more days at 25°C/80% RH. Control (---), 12µm PVC (···), 80µm LDPE (—-), 80µm LDPE plus 3% O₂/8% CO₂ (——), 63µm PO (-----), 63µm PO plus 3% O₂/8% CO₂ (—×—). Each value is the mean of 4 replicates, three fruits per set. Vertical bars indicate the least significant difference at P=0.05.

4. CONCLUSIONS

According to the results, the 63µm PO film, with or without the injection of gas mixture, maintains the quality of ‘Fuyu’ persimmon up to 40 days. The 80µm LDPE film is effective in delaying fruit ripening. However, this packaging system presents the risk of anaerobiosis and excessive CO₂ accumulation inside the packages. The 12µm PVC film is found to be ineffective in delaying ripening of the fruits, since this material does not efficiently modify the atmosphere inside the packages.

ACKNOWLEDGEMENTS

The authors would like to thank “Fundação de Apoio à Pesquisa do Estado de São Paulo-FAPESP” for the financial support of this research. This work is part of the Master of Science thesis of P. Cia who was granted a fellowship by FAPESP. We also thank Dr. Silvia Valentini (Instituto de Tecnologia de Alimentos / Campinas) for correction of the English text, as well as the “Associação Paulista dos Produtores de Caqui” and White Martins Company, who supplied the industrial gases.

REFERENCES


CIA P. et al.  Effect of Modified-Atmosphere Packaging on the Quality of ‘Fuyu’ Persimmon


