# PACKAGING FORMATS FOR STONE AND POME FRUIT

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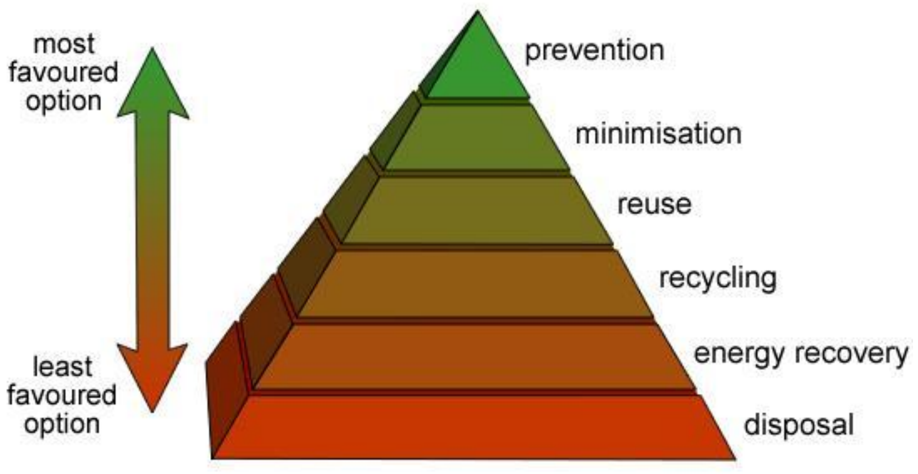
**Research financed by the Post Harvest Innovation (PHI) programme and Fruitgro[Science]**

## The importance of effective packaging and responsible packaging practices

Packaging is a necessity in the modern economy. In addition to the regular demands by trade and society upon packaging to satisfy convenience, identification, marketing, safety and efficiency requirements, packaging plays a crucial role in the maintenance of quality of perishable products, during storage and distribution. When fresh fruit is packed for long distance shipping and for the extended storage periods associated with export, the optimisation of packaging for each fruit type and cultivar becomes important. Components of packaging must be combined to achieve sufficient ventilation, favourable relative humidity, effective temperature control and in some cases, achievement of modified atmosphere conditions to maintain fruit quality through the export chain. Producers and exporters are confronted with numerous commercially available packaging options. In addition, the packaging arena is now becoming more complicated due to the need for environmentally friendly alternatives and responsible packaging practices, as indicated in the hierarchy for responsible packaging (Figure 1).




Source : Wikipedia after University of Toronto

**Figure 1 :** Hierarchy for responsible packaging

The current environmental concerns emphasise the need to reduce the carbon footprint and energy requirements of all products. Plastic film manufactured from renewable sources (Biofilm) has recently become available, and shows potential to lower the carbon footprint compared to packaging material made from polymers. An approach to address this environmental protection challenge is to ensure that the "four R" principles of responsible packaging, namely: reducing, re-using, recycling and replacing with lower carbon footprint material, are applied in the selection of the appropriate packaging. To be effective under commercial conditions, packaging should have sufficient ventilation to allow temperature pull-down during forced-air cooling and to enable good temperature management during storage. Insufficient ventilation increases the duration of cooling cycles and energy consumption. Therefore, proper incorporation of the ventilation requirement is seen as complimentary to the "four R" principles in the endeavour to reduce the fruit packaging carbon footprint. This paper communicates results of research conducted from 2008 to 2010 on several populations of Golden Delicious and Pink Lady apples, Bon Chretien and Forelle pears, and Sapphire and Larry Anne plums. The research was conducted on behalf of dti (PHI programme) and Fruitgro$^{science,}$, the latter representing SASPA and SAAPPA, and was undertaken to provide growers and packers with information required to make informed decisions regarding optimal packaging choices.

**The effect of transport packaging with distinctly different levels of ventilation was studied in combination with various inner packaging formats, to evaluate the effect on forced-air cooling rates and post-storage fruit quality.**

"Low vented" and "high vented" transport packaging formats (Figure 2A and 2B, respectively) were packed with combinations of primary (inner) packaging (Table 1). The inner treatments were selected from 60 µm PE, 37 µm PE, 20 µm PE bags, the 20 µm "plum wrapper" and 40 µm "Biobags". A no liner control treatment was employed.

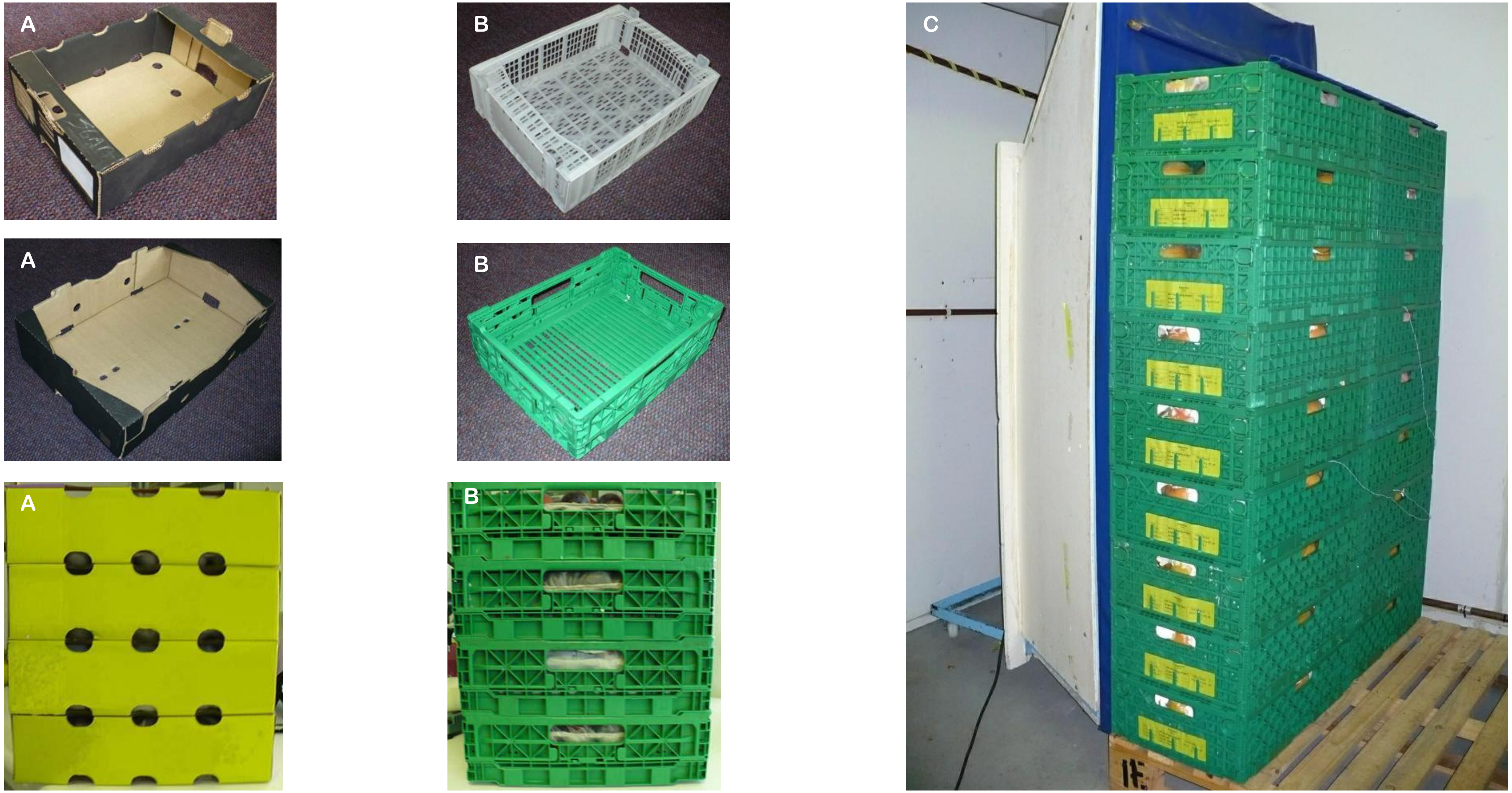



**Figure 2:** Transport packaging used for testing the effect of low vent (A) and high vent (B) packaging during forced – air cooling in an experimental stack (C) and simulated sea-freight storage of apples, pears and plums

The cultivars and packaging details of the combinations tested are presented in Table 1. Plums were packed in transport (outer) packaging with a 400 x 300 mm footprint. All apple and pear fruit were packed in transport packaging with a 600 x 400 mm footprint. Six packaging units of each treatment combination were used to establish forced-air cooling rates of the different packaging combinations and for measurement of post-storage fruit quality parameters. Each unit comprised a single replicate.

### Forced-air cooling was done in single column stacks to ensure uniform air-flow and heat exchange

To eliminate the variability in air-flow usually encountered in the “10-down” or “5-down” commercial pallet stacks, forced-air cooling was done in experimental cooling stacks with adjustable fan speed and commenced directly after packing. Prior to cooling, the suction force created by the electrical fans was standardised for the various cooling tunnels. Thereafter, the packaging treatments were stacked as columns (Figure 2C) of single-unit width, to ensure that heat exchange was consistent between replicates. The direction of the delivery air flow was across the 400 mm section of the transport packaging for both the 400 x 300 mm and 600 x 400 mm configurations. Fruit pulp temperatures were recorded during forced-air cooling at hourly intervals, by means of type T thermocouples connected to data loggers.

## FORCED-AIR COOLING AND FRUIT QUALITY RESULTS

Selected results are reported to illustrate the main findings of this study.

### Pear cooling and post storage quality:

The fastest reduction in Bon Chretien pulp temperature was achieved when no inner liners were used, in both high and low vent transport packaging (Figure 3). The forced-air cooling target was reached within 2.6h and 5.9h in the high venting and low venting transport packaging without any liners, respectively. In comparison, inclusion of liner bags increased cooling time by factors of 7.4 times and 6.8 times, for high vent and low vent packaging, respectively. The combination of high vent outer packaging and liner bags resulted in approximately half the cooling time compared to the combination of low vent packaging and liners. This difference is attributed to the combination of the higher venting and greater headspace in the high vent packaging. The relative contribution of the different inner bag types on the cooling time was proportionally small. The highest percentage mass loss occurred in treatments without polymer liners (Table 2). All the inner packaging polymer liner types reduced the mass loss significantly and eliminated shrivel development. The mass loss in the Bon Chretien pears was not significantly influenced by the level of venting in the outer packaging. Yellow skin colour development was more advanced in the lower vented outer packaging and in the of 20µm PE liner. This can possibly be ascribed to the combined effect of the relatively slower forced-air cooling rates in the less ventilated box and insufficient levels of carbon dioxide build-up in the thinner gauge PE to retard yellow colour development and/or counter the ripening effect of ethylene build-up in the bags (no data shown). No significant differences occurred in DA readings, although the trends for lower DA readings in the lower vent outer packaging and in the 20µm PE liner indicated more advanced ripening in these treatments, in agreement with the URS skin colour chart results. No significant differences in DA readings, flesh firmness, or decay incidence were observed. Internal breakdown occurred at low levels in the 20µm PE liner. This flesh breakdown was likely due to senescence. The Bon Chretien pear quality data showed that both the type of internal packaging and transport packaging and likely, the indirect effect of the cooling rates, influenced post storage fruit ripening of Bon Chretien pears. The faster cooling high vent external packaging resulted in greener skin colour and the 20µm inner bag resulted in yellower fruit. Moisture barriers are required to control shrivel. With Forelle pears (no data shown), the internal packaging (MAP vs no liner) had a greater influence on fruit quality maintenance than the external packaging.

### Apple cooling and post-storage quality (no data shown) :

The trends in the apple cooling rates were similar to that discussed for pears, although the difference in cooling rates between high vent and low vent transport packaging was smaller for apples, as a result of less headspace above the folded liner bags. The most consistent significant quality results for apples were differences in moisture loss and shrivel, where all liners gave superior quality compared to un-bagged fruit. With Pink Lady, the inner packaging affected moisture loss but this did not manifest as fruit shrivel. The higher vented transport packaging, and therefore the indirect effect of a more rapid cooling rate did not improve quality in terms of the important ripening parameters such as skin colour and flesh firmness.

### Plum cooling and post storage quality results

In one plum experiment, the high vent transport packaging cooled approximately 32% faster in combination with bags, than the lower vent packaging in combination with bags (no data shown). In another plum experiment (Figure 4), the difference in cooling rate between the high vent and lower vent packaging in combination with bags was less at 9%. This was likely due to the reduced headspace (free space) in the case of the latter, as is the commercial situation in the fruit counts which optimise payload. The most consistent significant quality results for plums were the differences in moisture loss and shrivel, when using the higher vent packaging (Table 3). Overall, the internal packaging had a greater influence on fruit quality than the ventilation of the external packaging or the indirect effect of forced-air cooling rate. Moisture barriers are required to control shrivel on the plum cultivars tested in these trials. The 20µm 54 x 2 mm perforated PE liner bags maintained quality better than the plum wrapper, but it must be cautioned that these bags may result in higher levels of decay than the perforated wrapper in certain instances (data not shown).

## GENERAL FINDINGS

**Fruit shrivel as a result of moisture loss was a persistent problem on apples, pears and plums, which limits the opportunities for the complete removal of moisture barriers such as liners for export fruit.**

Moisture loss and associated fruit shrivel was the most dominant and persistent quality disorder across the 18 populations of deciduous fruit studied. In some experiments, moisture loss and shrivel were higher in the high vented transport packaging than the low vented packaging.

**With the exception of Bon Chretien pears, higher venting and the resultant faster cooling rates did not provide significant quality improvement in parameters such as flesh firmness or green skin colour.**

In fifteen other fruit populations including Forelle pears, Golden Delicious apples, Sapphire plums and Larry Ann plums, faster rates of cooling due to type of transport packaging did not significantly improve fruit quality. For these cultivars, the higher vented transport packaging is expected to impact more on logistical throughput, including shorter forced-air cooling cycles and the associated energy savings. Therefore, no evidence was found for a fruit quality driven requirement for faster forced-air cooling rates than those currently used for these cultivars. In general, the forced – air cooling rates currently achieved in deciduous fruit pack houses (up to 20 h for plums and 40 h for pome fruit, as tested in in these experiments), seem to adequately meet cold chain requirements.

**Biobags showed potential for fruit packaging but optimisation is required**

During the first storage trial with Golden Delicious apples, anaerobic off-tastes were detected in the Biobag by some panellists. This demonstrated that Bioplastic film has the potential to be optimised for improved retention of fruit quality, but requires dedicated attention to be customised for specific fruit-kinds and cultivars. This aspect is being further addressed in the GREENPAC programme, financed by TIA.

**Conventional green pome bags may not be sufficiently optimised for the 600 x 400 mm footprint MK 9 packaging**

The absence of major quality differences between PE bags of different thickness in some of the pear and apple populations provides opportunity for reduction of material with optimum quality fruit. However, it also raises the concern that the transition of the original MAP technology from mainly MK 6 packaging to MK 9 packaging has not occurred optimally or that the specifications of the currently used bags have been compromised. Although $O_2$ and $CO_2$ levels were not specifically studied in this programme, these gas levels were occasionally monitored towards the end of the cold storage period. In all the 600 x 400 mm pome fruit packaging, the $CO_2$ levels were frequently below 1%. This indicated that the PE liners currently employed, are likely to have minimal impact on maintenance of green skin colour by atmosphere modification, even if the moisture barrier properties of the film are beneficial. It was also evident that the $CO_2$ levels in packaging with more free headspace, were lower than the fuller packed formats. This indicated that the tighter "folds" of the liners in fuller packs influence gas exchange. Since the requirements for some form of moisture barrier was clearly evident for most of the fruit populations studied, the sacrificing of the atmosphere modifying ability appears to be a waste of potential benefit. Therefore, the consistency of quality and dimensions of PE liners and means of application require further study.

## Summary of test results and the impact for the industry

- The use of plastic liners had a prominent effect on cooling rates and increased cooling time by factors of 4 to 8 times. Under the test conditions, the difference in cooling rates between liner types was relatively small.
- As expected, forced-air cooling rates were consistently faster in the high vent than in the low transport packaging. However, the difference in cooling rates between the two packaging types varied by as much as 50% for pear and 9% in some plum formats. This was attributed to the volume of free headspace which varies according to packaging format and fruit count. In commercial pallet stacks, it can be expected that packaging formats designed for maximal utilisation of the packaging cube (payload), have less free headspace and smaller or lesser inadvertent micro-channels between the liners and outer packaging. Therefore slower cooling rates would be expected. In these instances, the impact of perforations in the inner bag liners is likely to play a more dominant role in determining cooling rates.
- In the case of two Bon Chretien populations, higher venting and the resultant faster cooling improved flesh firmness and retention of greener skin colour significantly. In fifteen other fruit populations the transport packaging and associated rates of cooling did not result in significant improvement in quality. There was therefore no evidence of a broad, quality driven requirement for extremely fast, or faster forced-air cooling rates than those tested on Forelle pears, Golden Delicious apples and Sapphire and Larry Ann plums. For these cultivars, when cooling fruit to target temperature within a "commercially realistic" time-span (which was within 3 – 20 hours for plums and 3 – 40 hours for pome fruit), the cooling rate did not influence post storage parameters such as firmness and green colour. It remains important that cold chain requirements are met throughout the fruit handling chain.
- For the fore-mentioned cultivars, the higher vented transport packaging is expected to impact more on logistical throughput, including shorter forced-air cooling cycles and the associated energy savings, rather than on direct fruit quality benefits.
- After simulated fruit export conditions, shriveling occurred in most deciduous fruit populations as a result of moisture loss, with a higher incidence in high vent transport packaging. This confirmed that packaging liners are essential in most instances and that the opportunities to remove moisture barriers completely, are limited. Plastic liners can only be removed from current packaging combinations if fruit is stored for a short pre-packaging period, delivered to the export market in the shortest possible time and if good relative humidity control is maintained until the fruit is sold.

- Bioplastic film can potentially replace petroleum-based film in deciduous fruit packaging, but the modification of atmospheric gases around the fruit requires further investigation.
- Based on this study, a one-page matrix (Table 4) was compiled taking the responsible packaging philosophy into account. This is to assist growers, exporters and pack houses in selecting the most suitable responsible packaging options for plums and pome fruit, or to consider strategic possibilities for the future.

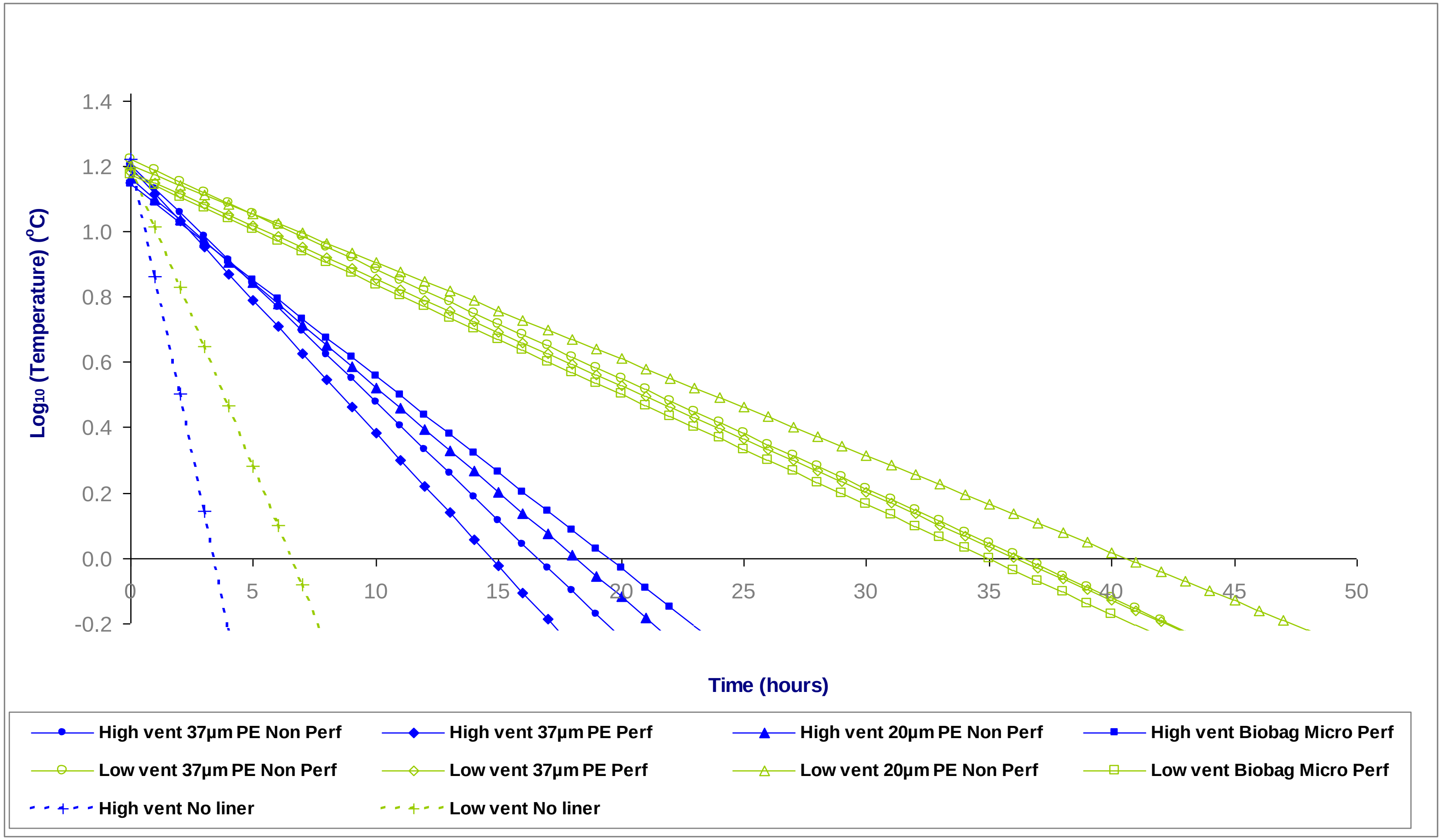



**Figure 3:** $Log_{10}$ fruit pulp temperature of Bon Chretien pears during forced-air cooling in high vent and low vent transport packaging with and without different inner packaging liners (Perf = Perforated; Non Perf = Non Perforated)

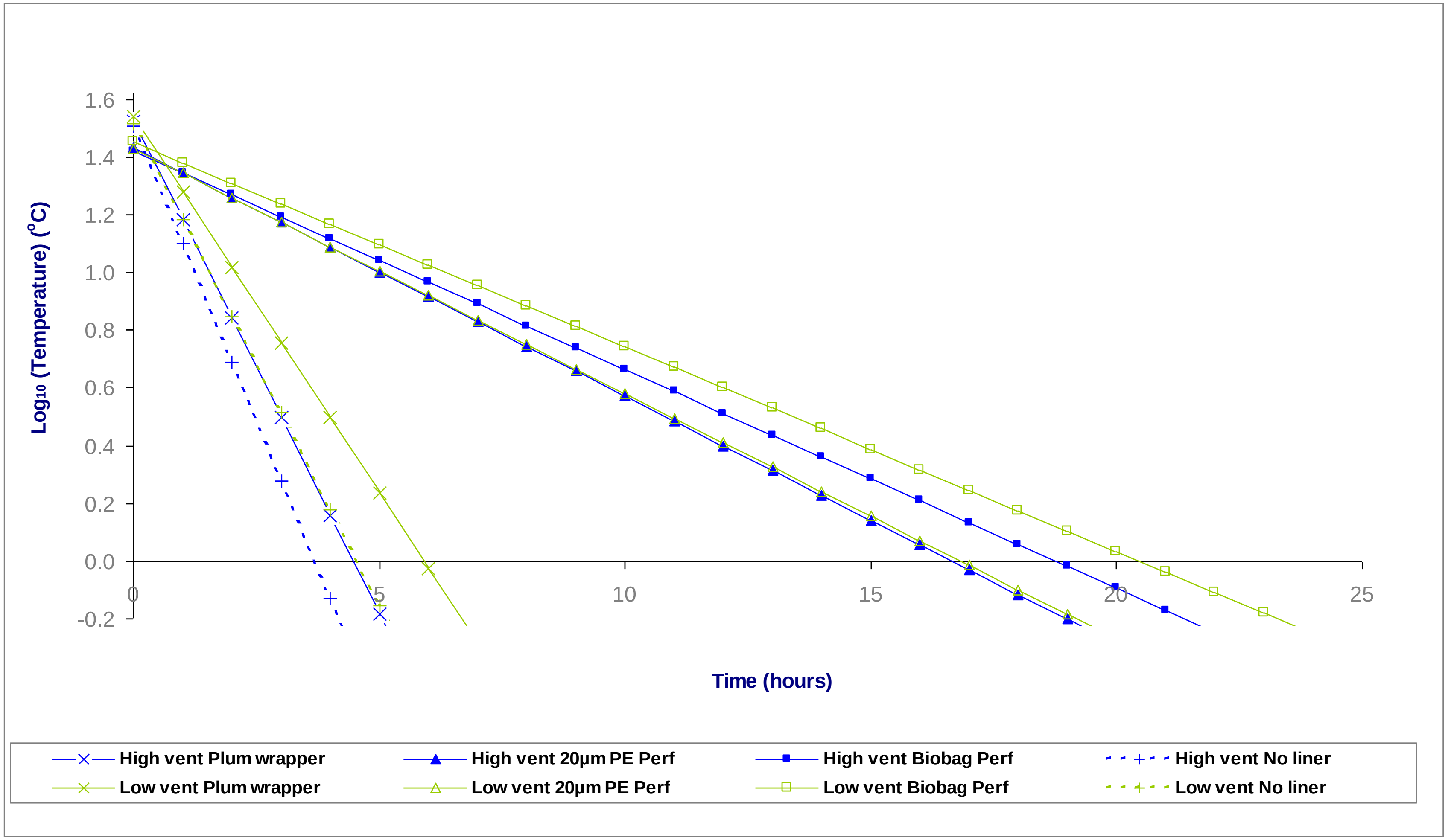



**Figure 4:** $Log_{10}$ fruit pulp temperature of Sapphire plums during forced-air cooling in high vent and low vent transport packaging with and without different inner packaging liners (Perf = Perforated; Non Perf = Non Perforated)

**Table 1 :** Packaging combinations and storage regimes employed for the evaluation of forced-air cooling and post storage quality maintenance of plums, apples and pears

| **Fruit type** | **Plum** | | **Apple** | | **Pear** | |
|---|---|---|---|---|---|---|
| **Cultivar** | **Sapphire** | **Larry Anne** | **Golden Delicious (Ex RA)** | **Pink Lady (Ex RA)** | **Bon Chretien (Ex RA)** | **Forelle (Ex RA)** |
| ▪ **Higher Venting (RPC)** | ▪ Plum Wrap (Perf)<br>▪ 20µm PE bag (Perf) 54 X 2<br>▪ Biobag (Perf)<br>▪ No Liner | ▪ Plum Wrap (Perf)<br>▪ 20µm PE bag (Perf) 54 X 2<br>▪ Biobag (Perf)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 37µm PE bag (Perf)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (NP)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 37µm PE bag (Perf)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (NP)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 37µm PE bag (Perf)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (NP)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 37µm PE bag (Perf)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (NP)<br>▪ No Liner |
| ▪ **Lower Venting (STD corrugated)** | ▪ Plum Wrap (Perf)<br>▪ 20µm PE bag (Perf) 54 X 2<br>▪ Biobag (Perf)<br>▪ No Liner | ▪ Plum Wrap (Perf)<br>▪ 20µm PE bag (Perf) 54 X 2<br>▪ Biobag (Perf)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (NP or MP)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (MP)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (MP)<br>▪ No Liner | ▪ 37µm PE bag (NP)<br>▪ 20µm PE bag (NP)<br>▪ Biobag (MP)<br>▪ No Liner |
| **Storage** | | | | | | |
| ▪ **Regime** | ▪ 10d @ -0.5°C<br>7d @ 7.5°C<br>18d @ -0.5°C | ▪ 42d @ -0.5°C | ▪ 49d @ -0.5°C | ▪ 49d @ -0.5°C | ▪ 49d @ -0.5°C | ▪ 49d @ -0.5°C |
| ▪ **Shelf life** | ▪ 5d @ 10°C (open liners) | ▪ 5d @ 10°C (open liners) | ▪ 5d @ 20°C (open liners) | ▪ 5d @ 20°C (open liners) | ▪ 5d @ 20°C (open liners) | ▪ 5d @ 20°C (open liners) |

**Table 2:** Post-storage quality of Bon Chretien pears packed in various packaging formats as determined after cold storage for 7 weeks at -0.5°C and subsequent shelf-life comprising 5 days at 20°C

| Examination parameter | Interaction[3] | Outer Packaging[2] (Factor A) | | Inner packaging[2] (Factor B) | | | | | Prob >F[1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | High vent (RPC) | Lower vent (Corrugated) | 37µm PE Non Perforated | 37 µm PE "BH"[4] Perforated | 20µm PE Non Perforated | Biobag | No Liner | A | B | AxB |
| Mass loss after cold storage and shelf life simulation (%) | High vent<br>Low vent | | | 2.11bc<br>0.70ab | 2.51c<br>0.52a | 1.79abc<br>0.65ab | 1.95abc<br>1.10abc | 5.07d<br>4.60d | ** | ** | * |
| Flesh firmness (kg) | High vent<br>Low vent | | | 2.07e<br>1.36abc | 1.83de<br>1.30ab | 1.88de<br>1.33ab | 1.89de<br>1.18a | 1.72cde<br>1.57bcd | ** | NS | ** |
| Skin Colour[5] | High vent<br>Low vent | | | 3.87ab<br>3.94ab | 3.79ab<br>4.46c | 3.76a<br>4.17bc | 3.81ab<br>4.16bc | 3.97ab<br>3.93ab | ** | * | ** |
| DA index[6] | High vent<br>Low vent | | | 0.51abc<br>0.56bc | 0.60c<br>0.29a | 0.52abc<br>0.32ab | 0.61c<br>0.33ab | 0.68c<br>0.59c | ** | ** | ** |
| Shrivel (%) | | 2.14 | 1.82 | 0.00a | 0.00a | 0.00a | 0.00a | 9.90b | NS | ** | NS |
| Internal Breakdown (%) | | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - | - | - |
| Decay (%) | | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - | - | - |

1. ANOVA table with NS (non-significant) and *, **, *** represent significance at the 5%, 1% and 0.1% levels, respectively
2. Values followed by different letters in a column and row, indicate significant differences according to Tukey's test
3. If itemised, an interaction occurred between Factor A and Factor B
4. Bags perforated to the "Beurre Hardy" specification
5. Skin ground colour measured with URS colour chart on a scale where 1 = green and 5 = yellow
6. DA meter with 0.0 indicating no chlorophyll and higher levels showing higher chlorophyll levels

**Table 3:** Post-storage quality of Sapphire plums packed in various packaging formats as determined after cold storage according to the dual-temperature regime for 6 weeks

| Examination parameter | Outer Packaging[2] (Factor A) | | Inner packaging[2] (Factor B) | | | Prob >F[1] | | |
|---|---|---|---|---|---|---|---|---|
| | High vent (RPC) | Lower vent (Corrugated) | 20 µm PE 54 x 2 mm Perforated | Plum Wrapper | No Liner | A | B | AxB |
| Mass loss during FAC and cold storage (%) | 3.11 | 3.27 | 0.99a | 3.83b | 4.74b | NS | ** | NS |
| Flesh firmness (kg) | 3.23 | 3.36 | 3.17 | 3.34 | 3.37 | NS | NS | NS |
| DA Index[3] | 0.60 | 0.57 | 0.62 | 0.54 | 0.60 | NS | NS | NS |
| Shrivel (%) | 9.60 | 7.44 | 2.33a | 10.40b | 12.83b | NS | * | NS |
| Internal Browning (%) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - | - | - |
| Overripe (%) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - | - | - |
| Decay (%) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | - | - | - |

1. ANOVA table with NS (non-significant) and *, **, *** represent significance at the 5%, 1% and 0.1% levels, respectively
2. Values followed by different letters in a row, indicate significant differences according to Tukey's test
3. DA meter with 0.0 indicating no chlorophyll and higher levels showing higher chlorophyll levels

**Table 4 :** Opportunities for removal, reduction or replacement for internal packaging of plums, apples and pears intended for export

| Fruit Kind | Cultivar | Population | Remove | Reduce | Replace | Comments |
|---|---|---|---|---|---|---|
| Plum | Sapphire | 1 | | | ✓ | Perforated Biobag has potential to replace the 20 µm PE bag |
| | Sapphire | 2 | | | ✓ | Perforated Biobag has potential to replace the 20 µm PE bag |
| | Sapphire | 3 | | | | Removal of polymer moisture barriers not advised, due to high shrivel potential |
| | Larry Anne | 1 | | | ✓ | Perforated Biobag has potential to replace the 20 µm PE bag |
| | Larry Anne | 2 | | | ✓ | Perforated Biobag has potential to replace the 20 µm PE bag |
| | Larry Anne | 3 | | | ✓ | Removal of polymer moisture barriers are not advised, due to high shrivel potential. The perforated 20 µm PE bag should be used in combination with high vented outer packaging |
| Apple | Golden Delicious | 1 | | ✓ | ? | 20 µm PE bag results were similar to 37 µm and 60 µm PE bags<br>Laser perforated Biobag has potential to replace the 20 µm PE bag |
| | Golden Delicious | 2 | | ✓ | ✓ | 20 µm PE bag results were similar to 37 µm and 60 µm PE bags<br>Laser perforated Biobag has potential to replace the 20 µm PE bag |
| | Golden Delicious | 3 | | ✓ | ✓ | 20 µm PE bag results were similar to 37 µm PE bags<br>Laser perforated Biobag has potential to replace the 20 µm PE bag |
| | Pink Lady | 1 | ?[1] | ✓ | ✓ | 20 µm PE bag results were similar to 37 µm and 60 µm PE bags<br>Laser perforated Biobag has potential to replace the 20 µm PE bag |
| | Pink Lady | 2 | ?[1] | ✓ | ✓ | 20 µm PE bag has potential to replace 37 µm and 60 µm PE bags<br>Laser perforated Biobag has potential to replace the 37 µm PE bag |
| | Pink Lady | 3 | ?[1] | ✓ | ✓ | 20 µm PE bag has potential to replace 37 µm PE bags<br>Removal of polymer moisture barrier can be evaluated at semi-commercial level |
| Pear | Bon Chretien | 1 | | | ✓ | Laser perforated Biobag has potential to replace PE bags<br>The 20 µm PE bag resulted in yellower fruit |
| | Bon Chretien | 2 | | | ✓ | Laser perforated Biobag has potential to replace PE bags |
| | Bon Chretien | 3 | | | ✓ | 20 µm PE bag results were similar to 37 µm PE bags (caution; see also Bon Chretien 1) |
| | Forelle | 1 | | ✓ | ✓ | 20 µm PE bag results were similar to 37 µm and 60 µm PE bags<br>Laser perforated Biobag has potential to replace the 20 µm PE bag |
| | Forelle | 2 | | ✓ | ✓ | 20 µm PE bag results were similar to 37 µm and 60 µm PE bags<br>Laser perforated Biobag has potential to replace the 20 µm PE bag |
| | Forelle | 3 | | ✓ | ✓ | 20 µm PE bag results were similar to 37 µm PE bags |

1. Removal of moisture barriers resulted in significant moisture loss, but no shrivel occurred during experiments, so further trials are required to confirm this