

## ADAPTING PERFORATED BOX LINERS TO THE CALIFORNIA KIWIFRUIT INDUSTRY

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### Abstract

The performance of California kiwifruit packed using solid liners, perforated liners, and micro-perforated liners on the rate of initial cooling time, water loss, and quality attributes after shipping was evaluated under controlled laboratory and commercial conditions. Controlled cooling tests using a portable cooling tunnel indicated an important cooling time reduction (reaching 7/8 cooling time) without affecting quality when perforated liners were used instead of solid ones. The use of these vented box liners will result in direct energy savings to packinghouses proportional to the reduction in cooling times. Also, shorter cooling times will allow scheduling operations for the off-peak utility periods. Fruit quality attributes such as fruit firmness, soluble solids, and titratable acidity were not affected by any of the box liner treatments. Kiwifruit weight loss depended on the box liner vented area (V.A.) and storage temperature. After 18 weeks at 0°C kiwifruit packed in the solid (0% V.A.), perforated (0.6% V.A.) and micro-perforated (1.2% V.A.) box liners had water losses of 0.7, 2.4 and 5.2%, respectively. Fruit shrivel was only observed on fruit packaged in the micro-perforated liners when water loss exceeded 4.0% in relation to the harvest fresh weight. In one of the two seasons, pitting incidence was measured on fruit from the micro-perforated box liner treatment.

### 1. Introduction

Kiwifruit shriveling due to cumulative postharvest water loss is one of the major complaints of kiwifruit consumers in the United States. To limit such water loss, producers and handlers in the kiwifruit industry package fruit in solid polyethylene liners (McDonald, 1990; Arpaia et al., 1994) for both domestic and export markets. Packaged fruit are forced air cooled to approximately 0°C and stored in an ethylene free environment for up to 6 months. This improves storage quality by reducing shrivel but creates other problems. First, because liners are not vented no convection cooling (throughout the fruit) can occur, therefore, cooling is by conduction around the liners. The cooling times for fruit packed in solid liners are longer and uneven. Thus, flesh softening and decay may occur at

temperatures above 0°C. Secondly, fluctuation in temperatures can cause condensation within the solid liner, which may promote growth of decay organisms.

We believe that cooling times can be reduced and quality maintained by using perforated polyethylene liners instead of the traditional solid ones. Perforated liners will allow some contact of cooling air with the product being cooled, thereby providing some convection along with conduction cooling. Any reduction in cooling times will result in proportional reductions in direct energy savings to packinghouses. This will also allow packers to push some operations to the utilities' off-peak hours when energy costs are lower.

## 2. Materials and methods

### 2.1. Experiment I

During the 1996 kiwifruit season, liners with different amount of vented area (V.A.) were chosen to compare cooling times of kiwifruit placed in a commercial cooling tunnel. A solid liner (0% V.A.), a perforated liner (0.6% V.A.) and a third microperforated liner (with 1.2% V.A.) were chosen. A 0.5  $\mu\text{m}$  thickness polyethylene high-density liner was used as a base for the perforated and microperforated liners. Kiwifruit were picked at commercial maturity and packed in corrugated boxes with a 6.0% vented area (V.A.). The packed fruit were cooled immediately in a commercial forced-air tunnel to 0°C and stored in an ethylene free environment at 0°C and a relative humidity of 85%. Fruit were removed at different times during storage for quality evaluation and weight loss. The quality evaluations included fruit firmness (N), soluble solids (%), titratable acid (%), decay and cosmetic appearance.

Each treatment consisted of 24 pallets of kiwifruit. Three temperature recorders were placed in each of two pallets of fruit per treatment. One recorder was placed in the center box and the other two in the outside box, one in the fruit and the other in air to measure the room temperature. To monitor water loss, two tiers from each treatment (12 boxes) were weighed at the time of packaging and the weights were taken every two weeks during the 17-week storage period.

### 2.2. Experiment II

In 1997 two perforated liners were used with a V.A. of 3.3% and 0.3%. The standard solid liner was included. Kiwifruit were placed in corrugated boxes with 3.0% V.A., temperature recorders were placed in the center box and outside the box of the pallet to follow the temperature cooling time. Fruit were weighed at the time of packing and temperature and weight loss tracked for a period of six months. The following quality attributes were evaluated at the beginning of the experiment and at regular intervals throughout storage: firmness (N), soluble solids (%), titratable acids (%) decay, general appearance and water loss. Fruit were packed at a commercial operation and forced air cooled to 0°C. After cooling, fruit were moved to 0°C cold room and stored for six months. Some fruit were removed from storage after two months for quality evaluations. Weight loss was measured monthly. After six-month storage, fruit were placed at 5°C for five days to simulate transportation temperatures and then opened and placed at 20°C for three days to

simulate display temperatures. Water loss was measured during storage, transportation and display. Fruit were evaluated for water loss, pitting, decay, shrivel, and general appearance.

### 2.3. Experiment III

Controlled laboratory trials with kiwifruit were conducted using a forced air cooling tunnel that simulates commercial operations to compare cooling times with different liners. This forced air cooling tunnel can simulate commercial parameters of 1/8 pallet and was used to compare the cooling rates of fruit packed in liners having 0%, 0.3%, 0.6% and 1.2% V.A. Airflow in cubic meter per second per kg of fruit ( $\text{m}^3 \cdot \text{s}^{-1} \cdot \text{kg}^{-1}$ ) and static pressure (cm) was measured for the different liners within the tunnel. Kiwifruit packed in shoe boxes (40 x 50 cm) were used for the cooling test. Pulp temperatures during the cooling process were monitored in three fruit in each of three boxes using temperature recorders. From these data the 7/8 cooling times were calculated and comparisons made between treatments.

## 3. Results and Discussion

### 3.1. Experiment I

One half-cooling times of 17.4, 11.5 and 10.5 hours were measured for kiwifruit commercially packed and cooled using 0%, 0.6% and 1.2% vented liners in corrugated boxes with 6.0% V.A. The use of micro-perforated and perforated liners had a reduction in cooling time by approximately 40% and allowed more uniform cooling within the pallet compared to the solid liner under cold storage conditions (Fig.1). We observed lesser free water formation by using perforated liners than solid liners.

When cooled and stored at 0°C in an ethylene free environment, fruit weight loss was dependent on the vented area of the liner. Fruit in micro-perforated liners lost approximately eight times more water than kiwifruit in solid liners during the 17 weeks at 0°C (Fig 2). Shriveling was only observed in fruit packaged in the micro-perforated liners (1.2% V.A.), however, it did not appear until fruit had lost 4.0% of initial harvest weight (Fig 3).

Fruit firmness, soluble solids, titratable acid and decay were not affected during the 17-week cold storage period (data not shown). There was some pitting on fruit cooled in the microperforated liners. It appears that “very fast” cooling and/or dehydration may have been related to pitting development during this season.

To study fruit water losses at different postharvest temperatures simulating warehouse/retail store conditions, kiwifruit packed in the different box liners were exposed to 0°C, 5°C, 10°C, and 20°C temperatures for eight days (Fig. 4). Water loss was related to temperature and box liner V.A., being minimal for the first four days and at temperatures below 12°C. Water loss increased after day four, being 0.2%, 0.4% and 0.75% for fruit packed in solid, perforated and microperforated liners, respectively. At temperatures above 12°C the rate of water loss increased markedly regardless of liner type (Fig.4).

### 3.2. Experiment II

Cooling time was approximately 40% less for perforated than solid liners under commercial conditions--the same as occurred in 1996. Water loss during storage was related to the box liner vented area and storage time (Fig 5). Water loss from kiwifruit was least in the solid liner, intermediate in the 0.3% vented liner, and highest in the 3.3% perforated liner. By 120 days at 0°C, fruit in the 3.3% vented liner had lost a weight of approximately 4.5% while the perforated liner with 0.3% venting had lost approximately 3.0% and the solid liner 0.75% (Table 1). After exposure to simulated transport and display conditions decay was significantly higher in fruit maintained in the solid liner than in either of the perforated liners. It is likely that the higher condensation in the solid liner created an environment more conducive to Botrytis development.

There was no pitting on fruit and the general appearance of the fruit from all treatments was very good. Shriveling did not appear until water loss was > 4.0%. However, approximately 4.0% fruit in the 3.3% vented liner reached that level after being held for three days in simulated retail conditions.

Although box liners will reduce water loss, airflow is somewhat restricted during the cooling of kiwifruit and rate of cooling of fruit is delayed. Perforated liners allow some airflow through the fruit, resulting in reduced static pressures and decreased cooling times. Solid liners allowed less water to escape from the fruit, however, condensation within the liner created an environment likely to facilitate growth of Botrytis.

### 3.3. Experiment III

Time required to reach 7/8 cooling was related to airflow rates and box liner venting (Table 2), as the airflow rate increased the time required to reach 7/8 cooling was reduced. In the solid liner a higher static pressure was needed to reach the same flow rate around the enclosed fruit as that attained in the perforated liner. When the solid liner was used, the time required to reach 7/8 cooling remained the same over the air flow range of 0.00031-0.00072 m<sup>3</sup>•s<sup>-1</sup>•kg<sup>-1</sup> of fruit. When the air flow rate was 0.00052 m<sup>3</sup>•s<sup>-1</sup>•kg<sup>-1</sup> or greater, fruit packed in perforated liners were cooled approximately 50% faster than fruit enclosed in solid liners.

Fruit were packed using the 0.3% vented liner in a corrugated shoe box with 6.0% vented area. In this type of box, three vents were located in the bottom (3.0% V.A.) and another three on the top (3.0% V.A.) equally spaced along the side. In a full packed box, the 6.0% vented box had a shorter cooling time, than the 3.0% vented box. However, if boxes are not filled above the top vents, cold air takes the low resistance pathway above the fruit increasing their cooling time (Table 3). By adding a bottom pad and reducing the internal gap between fruit and box lid, cooling time is reduced compared with no-padding treatment.

Based on our results, we concluded that the use of perforated liners (0.3-0.6% V.A.) is a promising alternative to solid liners for reducing cooling times with minor effect on the quality of kiwifruit. The amount of venting is a compromise between cooling time reduction and water loss potential over time held in storage.

#### 4. References

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McDonald, B., 1990. Precooling, storage, and transport of kiwifruit. p. 429-459. *In*: I.J. Warrington and G.C. Weston (eds.), *Kiwifruit: science and management*. Ray Richards Publisher in association with the New Zealand Soc. Hort. Sci., Auckland.

Table 1 - Visual quality attributes of kiwifruit packed using different polyethylene liners after six month storage at 0°C, five days at 5°C and three days at 20°C, 1997 season. Experiment II.

Treatment (liner)	Shrivel (%)	Pitting (%)	Decay (%)	Water loss (%)
Solid liner (0%)	0.0 a	0.0	7.6b	1.5a
Perforated (0.3%)	2.0b	0.0	1.0a	4.6b
Perforated (3.3%)	3.8c	0.0	2.5a	6.4c
p-Value	0.0003	ns	0.011	0.0001
LSD	1.61	----	4.4	0.5

Table 2 - Cooling time for kiwifruit volume packed in corrugated box using different vented area box liners.

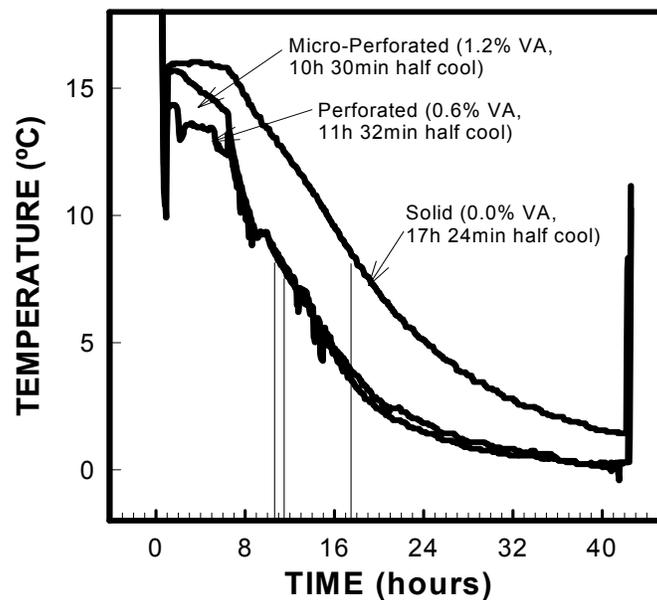
Type of Liner	Airflow rate $m^3 \cdot s^{-1} \cdot kg^{-1}$ fruit	Static pressure <sup>z</sup> (cm of water)	Hours to reach 7/8 cooling
Perforated liner (0.3% V.A.)	0.00072	3.81	13.8
	0.00052	1.52	15.9
	0.00026	1.02	21.8
Perforated liner (0.6% V.A.)	0.00052	1.27	9.0
	0.00031	1.02	12.0
Micro-perforated liner (1.2% V.A.)	0.00068	1.27	6.0
	0.00043	1.14	7.0
Solid liner (0%V.A.)	0.00072	1.02	21.0
	0.00052	9.91	23.2
	0.00031	2.54	22.5

<sup>z</sup> Static pressure values shown are for air path through three-tier register. For the four-tier stacking, the static pressure should be multiplied by a factor.

Table 3 - The effect of packaging in relation to venting pattern on cooling time.

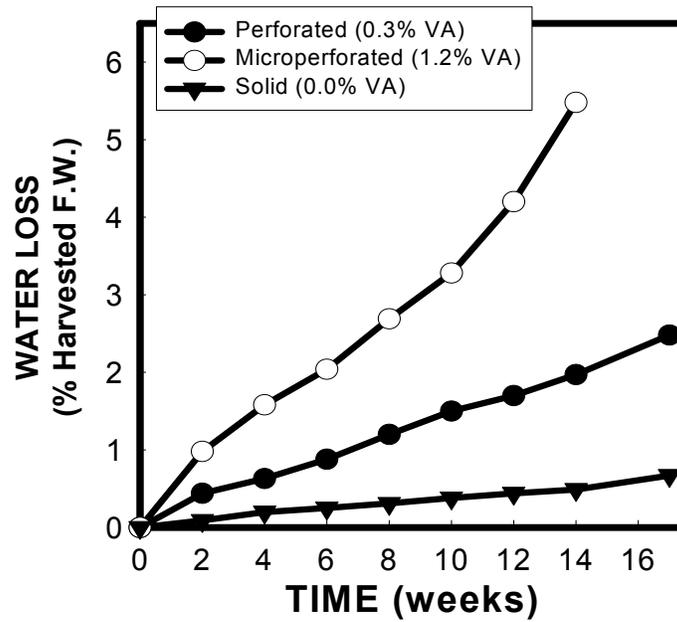
Liner (0.3% vented area)	Airflow rate $\text{m}^3 \cdot \text{s}^{-1} \cdot \text{kg}^{-1}$	Static Pressure (cm of water)	Cooling time (hours)
Shoe box 6% V.A.	0.00074	3.81	13.5
Shoe box 6% V.A. + padding	0.00074	3.81	12.6
Shoe box 3% (top vents closed)	0.00074	3.81	18.3

Figure 1 - Cooling times of volume filled kiwifruit (41.3 cm x 35.6 cm x 24.1 cm, 10 kg box)



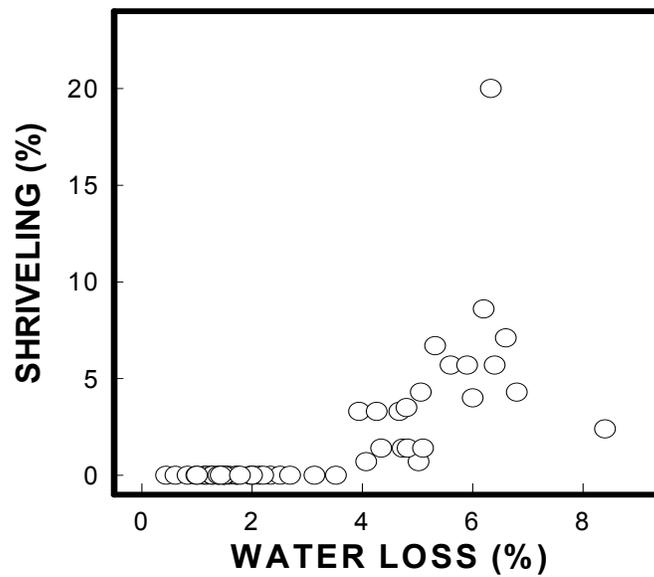
measured in the six boxes in the third tier from the top of 72 box pallets, 1996 season.

Figure 2 - Water loss of kiwifruit packaged in solid, perforated or microperforated



polyethylene box liners measured during storage at 0°C as a percentage of the initial weight, 1996 season.

Figure 3. Relationship between water loss and kiwifruit shriveling symptom development



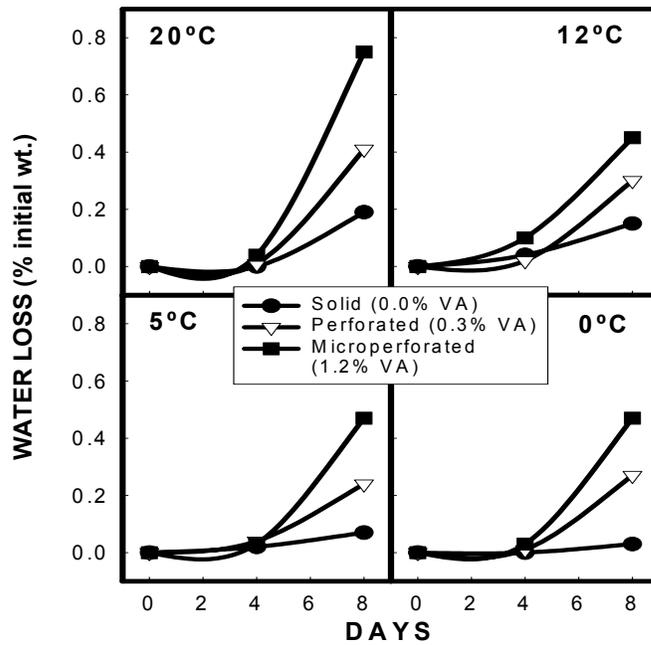


Figure 4 - Water loss of kiwifruit packaged in solid, perforated, or microperforated polyethylene liners and stored at 0, 5, 12 or 20°C, 1996 season.

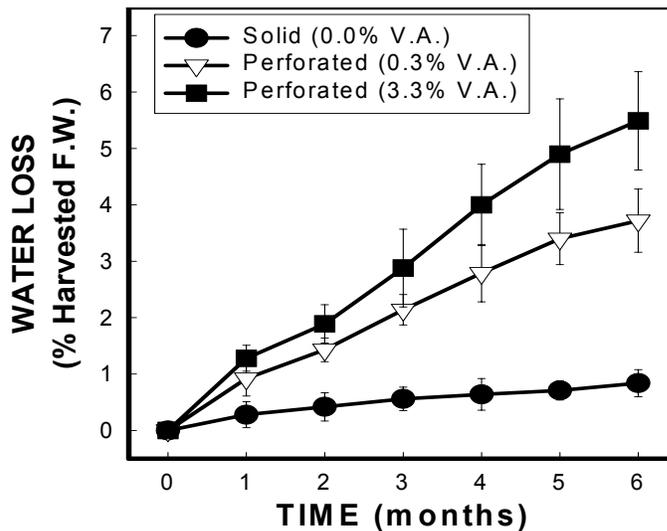


Figure 5 - Water loss of kiwifruit packaged in solid (0% vented), perforated 1 (0.3% vented), and perforated 2 (3.3% vented) polyethylene box liners during storage at 0°C as a percentage of weight at harvest, 1997 season.