Cold Stored Peaches and Plums Respond Differently to 1-Methylcyclopropene (SmartFresh™)

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Abstract
Australian summerfruit exports by sea freight are limited to overseas markets within 14 days sailing time as the storage life of most summerfruit is less than three weeks at ideal storage and transport temperatures. The aim of our research (HAL SF07019) is to identify genes that control storage life of summerfruit. This knowledge will enable development of genetic markers to help summerfruit breeders select improved cultivars. Some enzymes involved in normal ripening are known to be regulated by ethylene produced naturally by summerfruit. It is thought that cold storage disrupts this normal ripening processes resulting in the development of symptoms such as mealiness or internal browning (in peaches and nectarines) or gel browning (in plums). It has previously been reported that treating peaches and nectarines with 1-methylcyclopropene (1-MCP, SmartFresh™), the ethylene action blocking agent, generally makes low temperature disorders in peaches and nectarines worse but improves the storage life of plums. We treated fruit with 625 parts per billion of 1-MCP in sealed drums for 24 hours at 20 ºC before cool storage. We found that low temperature disorders were more severe following storage at 0ºC in Zee Lady peaches harvested at early maturity and treated with 1-MCP but treating Radiant, Ruby Red and October Sun plums with 1-MCP generally improved storage life. The best results were obtained with October Sun, which is a late cultivar with excellent quality and a long storage life. Comparative studies are being conducted to identify genes that account for the differences in responses to 1-MCP in cold stored peaches and plums and the improved storage life of late maturing plums.

Keywords; summerfruit, ripening, storage, ethylene, mealiness

Introduction
Access of Australian summerfruit by sea freight is restricted to overseas markets within 14 days sailing because the cool storage life of peaches, nectarines and most plums is less than three weeks at the ideal storage temperature of 0ºC. In addition, in-transit cold disinfestation against fruit flies (14 days at 1-3 ºC) required by some importing countries leaves little time for orderly distribution in the importing country. This paper describes the results of the cold storage trials on peach, plum and a plumcot conducted as part of a Horticulture Australia project (SF 07019). In these trials, samples of fruit were transferred at weekly intervals from cold storage at 0° and 5°C to a ripening temperature of 20ºC. After five days the fruit were destructively assessed for low temperature disorders. In earlier storage trials in which the fruit were stored only at 0ºC, the stage of maturity at harvest could partly explain the negative responses of peaches and nectarines and the positive responses of plums to 1-MCP. Peaches and nectarines are usually harvested during development Stage 4 when the fruit have started to produce ethylene and softening has begun whereas plums are generally harvested in late Stage 3 before ethylene production increases (McGlasson et al., 2009). If plums are left until ethylene production starts to increase, the fruit rapidly softens and shelf life is short.

Results
Zee Lady peaches
Zee Lady peaches were obtained from a commercial grower at Cobram, Victoria at two stages of maturity; an early maturity stage and at regular commercial maturity (Table 1). These fruit were then stored at 0^{o} and 5^{o}C.

Table 1. Maturity of Zee Lady peaches used in the storage trial

	Soluble solids concentration (SSC%) (mean %)	Titratable acidity (mmoles H^+/g)
Early maturity	10.5 ±1.2	0.92 ±0.18
Regular maturity	12.4 ±1.3	0.70 ±0.14

Storage life of peaches were assessed in two ways; (a) flesh mealiness was measured by juice recovery from flesh samples (as juice recovery decreases as flesh mealiness increases) and (b) development of flesh browning. Flesh browning was expressed as a severity index. Fruit with a severity index of 20 or higher were considered unacceptable.

Figure 1 shows the effects of maturity at harvest, storage temperature and 1-MCP treatment on mealiness (juice recovery) from Zee Lady peaches during storage. Juice recovery from fruit of early maturity treated with 1-MCP decreased after two weeks at 5ºC but juice recovery from mature peaches remained high for at least three weeks in both 1-MCP treated and control (not treated) fruit. Juice recovery did not decrease until the fifth week of storage at 0ºC. The fruit that were most adversely affected by treatment were the early maturity fruit treated with 1-MCP and the control mature fruit. Flesh browning was more severe in fruit of both maturities treated with 1-MCP and stored at 5ºC and became unacceptable within three weeks of storage in more mature fruit (Figure 2). Browning in the early maturity fruit was unacceptable after 4 weeks at 0ºC. These results show that the fruit harvested at early maturity and treated with 1-MCP were more severely affected by low temperature disorders, but the 1-MCP treatment had a small beneficial effect on mature fruit. When flavour and appearance were also taken into account we concluded that maximum storage life of Zee Lady is about four weeks at 0° but only two weeks at 5ºC.

Plums

Storage trials using a range of plum varieties, Radiant (suppressed climacteric, slow ripening, yellow flesh), Ruby Red (normal climacteric, rapid ripening blood plum), October Sun (normal climacteric, yellow flesh with crisp texture) and Flavor Fall plumcot (normal climacteric, yellow flesh) were conducted at 0º and 5ºC storage temperatures.

Radiant

Radiant plums were harvested at a commercial orchard in Bilpin, NSW. Radiant plums are a difficult cultivar to work with under the growing conditions at Bilpin because the fruit can be misshapen, shrivel at the blossom end and can shed easily. As a result, the fruit used in these experiments were highly variable. The results in Figure 3 show that flesh firmness (as measured by penetrometer) decreased progressively following cool storage at both 0º and 5º C and that 1-MCP treatment retarded softening of fruit stored at 5ºC for two weeks. When mealiness (Figure 4) and flesh browning (Figure 5) werte also taken into account, the storage life of untreated Radiant plums was less than four weeks at 5°C and less than six weeks at 0°C. Treatment with 1-MCP clearly improved storage life at both storage temperatures but we were unable to accurately estimate the extent of this improvement because we could not obtain enough fruit to allow weekly transfers of fruit from cool storage to 20°C.

Ruby Red

Ruby Red plums were obtained from small 4-year-old trees at a commercial orchard at Bilpin, NSW. In this season, there was a high incidence of sunburn which limited the supply of fruit and only allowed examination of stored fruit only at intervals of two weeks during storage. Ripe fruit become very soft and overstored fruit rapidly developed flesh browning and mealiness. Symptoms of browning (Figure 6) or mealiness (Figures 7) were detected after four weeks storage at both 0º

and 5°C but by this time the appearance of the untreated control fruit was unacceptable. Treatment with 1-MCP significantly reduced the severity of these disorders, but only the 1-MCP treated fruit stored at 0ºC were still acceptable after four weeks of storage.

October Sun

October Sun plums at commercial maturity were obtained from an orchard in Shepparton, Victoria where the ground colour of the fruit had changed from a light green to a light yellow / green with a light red blush on skin exposed to sunlight. October Sun fruit remain crisp even when they develop an overall blush when fully ripe. Treatment with 1-MCP delayed the ripening of the fruit after transfer to 20ºC (Figure 8). The most obvious symptom of over-storage was mealiness and its incidence was scored subjectively as for the other plum cultivars. Symptoms of mealiness were detected after four weeks storage at both 0º and 5ºC but were significantly less in 1-MCP treated fruit (Figure 9). The flavour and texture of these fruit were excellent during storage. This trial showed that when treated with 1-MCP, October Sun fruit could be successfully stored at 5ºC for four weeks and at least six weeks at 0ºC.

Flavor Fall plumcot

Fruit of this interspecific hybrid of apricot and plum and fruit were obtained from Shepparton, Victoria at commercial maturity. The incidence of mealiness was scored subjectively in fruit held for 5 days at 20ºC following transfer from storage at 0º and 5ºC (Figure 10). Mealiness was detected after two weeks of cool storage and became progressively worse in subsequent removals from cool storage. Treatment with1-MCP retarded the development of mealiness. The storage life of Flavor Fall plumcots appears limited to two weeks at 5º and less than six weeks at 0ºC when fruit are treated with 1-MCP. Further storage trials on fruit of Flavor Fall treated with 1-MCP with removals from cool storage at weekly intervals are required to establish the practical limits to storage life of this cultivar.

Non-destructive maturity test for plums

The determination of fruit maturity for harvest is important to optimise eating quality and storage life. The determination of maturity in plums is a problematic as the fruit are often dark skinned and are harvested too soon before acid levels have dropped appreciably and soluble solids (SSC) have peaked. Work by Carlos Crisosto et al.(2005) at the University of California has shown that consumers prefer plums with more than 12% SSC. We used a hand held spectrometer (iQ Nirvana, Allied Spectronics, Sydney, NSW) to measure changes in SSC, chlorophyll and anthocyanins during fruit development in Radiant and Ruby Red plums. This instrument does not injure the fruit and can be used in the orchard to non-destructively monitor fruit changes.

Italian workers (Ziosi et al. 2008) have recently developed a maturity index for peaches and nectarines (I_{AD}) based on the differences in absorbance of light at the wavelengths 670 and 720 nm. As chlorophyll (the green pigment) disappears from the fruit during ripening, this index decreases as evidenced by changes in the ground colour of the skin detected by eye. We thought that changes in light absorbance by anthocyanins, the red and purple pigments, especially in blood plums would also have to be incorporated into a maturity index for plums. We conducted small scale trials with Radiant and Ruby Red plums. The results showed that the I_{AD} system can be applied using only measurements of changes in chlorophyll. Larger scale trials with more cultivars relating I_{AD} to physiological and destructive measurements of maturity are required to confirm the benefits of this system. The portable spectrometer we used enables the simultaneous measurement of both SSC and I_{AD} and is a good tool for growers and researchers.

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Figure Legends

Figure 1. Zee Lady peaches harvested at early and regular commercial maturity stages were assessed five days after transferring the fruit from cool storage to 20ºC. MCP refers to 1-methylcycopropene applied at 625 parts per billion in air for 24 hours at 20ºC before cool storage. The bars on each column represent the standard deviations of the means of data for 30 fruit (n=30.

Figure 2..Severity of flesh browning in Zee Lady peaches following cool storage. Other details as for Figure 1.

Figure 3. Flesh firmness (Newtons) of Radiant plums at harvest (0 weeks) and following transfer from cool storage to 20ºC for 5 days. Firmness was measured at two places per fruit, after removing patches of skin, with a penetrometer using an 8mm tip. Other details as per Figure 1.

Figure 4. Severity of mealiness in Radiant plums following cool storage. Other details as in Figure 3.

Figure 5. Severity of browning in Radiant plums following cool storage. Other details as in Figure 1.

Figure 6. Severity of flesh browning in Ruby Red plums following cool storage. Other details as in Figure 1.

Figure 7. Severity of mealiness in Ruby Red plums following cool storage. Other details as for Figure 1.

Figure 8. Differences in red colour development in October Sun plums five days after transfer to 20ºC from cool storage for 4 weeks. The two rows of fruit on the left were stored at 5º and the two rows on the right at 0ºC. The light coloured fruit (rows two and four from left) were treated with 1-MCP before storage. The patches of skin were removed before measuring flesh firmness with a penetrometer.

Figure 9. Severity of mealiness in October Sun plums following cool storage. Other details as for Figure 1.

Figure 10. Severity of mealiness in Flavor Full pluots following cool storage. Other details as for Figure 1.