Effect of the Rate and Duration of Forced Air Cooling on the Quality of 'Imperial' Apricots and 'Pioneer' and 'Songold' Plums

M.M. Jooste
Department of Horticultural Science
University of Stellenbosch
Matieland, 7602
South Africa

P. Khumalo
ExperiCo
P.O.box 7441
Stellenbosch, 7599
South Africa

Abstract

Gel breakdown (GB) and overripeness (OR) remain the biggest internal Problems with *Prunus armeniaca* L. 'Imperial', which makes the biggest contribution to the total volume of apricots exported from South Africa per annum. *Prunus salicina* L. 'Pioneer', an early season South African plum cultivar, ripens quickly on and off the tree which results in rejections for soft fruit at packing and on arrival overseas. 'Songold', a yellow, midseason plum cultivar tends to develop GB and OR during cold-storage in some seasons, which renders the fruit inedible and results in high rejection rates. Prompt cooling and good temperature management are essential to lower the rate of physiological deterioration of stone fruit. In some commercial depots in South Africa, forced air cooling (FAC) of stone fruit can take as long as 48 to 72 h, depending on the type of packaging. Consequently, the objective of this study was to determine the effect of the rate and duration of FAC on the fruit quality of different stone fruit cultivars. Fruit was subjected to the following FAC rates at a delivery air temperature of -1.0°C to a pulp temperature of 0°C for 6 h, 12 h, 24 h stepwise cooling and 48 h stepwise cooling for the apricot, and 12 h, 24 h, 48 h stepwise cooling, and 72 h stepwise cooling for the two plum cultivars. The fruit was evaluated after cold-storage and a simulated shelf-life period. The trial was conducted in two consecutive seasons. 'Imperial' apricots had the best internal quality after 6 h of FAC, 'Pioneer' plums were not affected by FAC rate or duration, and 'Songold' plums had the best internal quality when FAC was applied for 12 h and longer. These results on plums demonstrate that cultivar differences must be considered when drawing up handling protocols for stone fruit, as a blanket recommendation may lead to the induction of quality defects.

Keywords: *Prunus armeniaca*, *Prunus salicina*, gel breakdown, overripeness, internal browning, flesh firmness, stone fruit

INTRODUCTION

The respiration rate of fresh fruit is mainly determined by the temperature of the product (Mitchell, 1985). Since the final result of respiration is the deterioration and senescence of fruit, it is advisable to keep the respiration rate of the product as low as possible after harvest. Prompt cooling and good temperature management is, therefore, essential to lower the rate of physiological deterioration of stone fruit. Gel breakdown (GB) and overripeness (OR) remain the most important quality problems with 'Imperial' apricots - the apricot cultivar which comprises approximately 50% of the total volume of apricots exported from South Africa per annum. GB is a gelatinous breakdown of the inner mesocarp tissue surrounding the stone, while the outer mesocarp tissue has a healthy appearance. With increasing severity, the disorder spreads outwards, changing from a translucent to a brown discolouration, and is associated with loss of juiciness (Taylor, 1996).

'Pioneer', the first plum cultivar to ripen in the South African plum season, ripens quickly on and off the tree which results in rejections for soft fruit at packing and on arrival overseas. 'Songold', a yellow, midseason plum cultivar tends to develop GB and OR during cold-storage in some seasons, which renders the fruit inedible and results in high rejection rates. Several researchers recommend that the rate of FAC for stone fruit should be as fast as possible to minimise deterioration losses

(Mitchell, 1986; Monzini and Gorini, 1991). Mitchell (1986) suggests that FAC should not exceed a maximum period of 18 to 24 h for stone fruit. In some commercial depots in South Africa, FAC can take as long as 48 to 72 h, depending on the type of packaging and cooling system.
The objective of this study was to determine if the rate of FAC to a pulp temperature of 0°C significantly ($P < 0.05$) affects fruit quality.

MATERIALS AND METHODS

'Imperial' apricots and 'Pioneer' and 'Songold' plums of optimum export maturity were sampled from local packhouses on the respective harvest dates of each cultivar. A complete randomised design with six replicates comprising one carton of approximately 70 fruits each was used per treatment. Fruit of each cultivar was subjected to the following FAC rates at a delivery air temperature of -1.0°C to a pulp temperature of 0°C:6 h, 12 h, 24 h stepwise cooling (viz. 6 h 10°C + 6 h 2°C + 12 h 0°C) and 48 h stepwise cooling (viz. 12 h 10°C + 12 h 5°C + 12 h 2°C + 12 h 0°C) for the apricot, and 12 h, 24 h, 48 h stepwise cooling (viz. 12 h 10°C + 24 h 2°C + 12 h 0°C), and 72 h stepwise cooling (viz. 24 h 10°C + 24 h 5°C + 12 h 2°C + 12 h 0°C) for the two plum cultivars (Fig. 1).
After the simulated FAC periods, the apricots were cold-stored for 36 days at -0.5°C. The 'Pioneer' plums were cold-stored for 10 days at -0.5°C, 9 days at 7.5°C and 16 days at - 0.5°C, and the 'Songold' plums for 10 days at -0.5°C, 12 days at 7.5°C and 20 days at - 0.5°C. Half of the fruit in each carton were evaluated after the described cold-storage period, and the remaining half of the fruit in each carton was subjected to a shelf-life period of 3 days at 15°C and was subsequently evaluated. The trial was conducted in the 2002 and 2003 seasons.

RESULTS AND DISCUSSION

'Imperial' Apricots

1. Evaluation after the Cold-Storage Period. Mass loss was highest in fruit FAC to 0°C within 6 h (Table 1). However, shrivel levels were low in all treatments despite the difference in mass loss between treatments. No GB or OR was observed. The same results were obtained in both years the trial was conducted.

2. Evaluation after the Shelf-Life Period. Shrivel and decay levels were low, and did not differ significantly between treatments (Table 2). No or low OR was observed. GB levels were lowest in fruit FAC within 6 h. In both seasons the shortest FAC period had the most benefit for internal fruit quality of 'Imperial' apricots. This result agrees with the recommendation of Monzini and Gorini (1991) that apricots must be rapidly FAC as soon as possible after harvest to obtain the best flesh firmness and internal fruit quality. However, results show that there is a risk of high mass loss in fruit cooled within a short period (< 12 h).

'Pioneer' Plums

1. Evaluation after the Cold-Storage Period. Mass loss increased with a decrease in FAC time (Table 3). Low shrivel levels were observed in all treatments despite the difference in mass loss between the treatments. In both seasons, fruit FAC within 12 h had the highest flesh firmness. Mitchell (1986) also found that quicker cooling time resulted in firmer fruit with 'Suncrest' peaches. Flesh firmness is an important parameter for overseas fruit buyers, and since 'Pioneer' plums tend to become soft and overripe in transit, this treatment may be beneficial for the cultivar. OR was only observed in the 72 h stepwise cooling treatment, which indicates that this treatment holds a risk for 'Pioneer' fruit quality. GB levels were low in all treatments in both seasons.

2. Evaluation after the Shelf-Life Period. There were no significant differences between treatments for any of the parameters measured in both seasons (Table 4). Results suggest that 'Pioneer' plums are not sensitive to cooling rates. As good standard practice, it is suggested that FAC should, however, be shorter than 48 h.

'Songold' Plums

1. Evaluation after the Cold-Storage Period. In the 2003-season there were no significant differences between the different treatments for the parameters which were measured (data not shown). However, in the 2002-season, fruit which was cooled stepwise to 0°C within 72 h had significantly ($P < 0.05$) the lowest flesh firmness (Table 5). This result agrees with Mitchell's (1986) findings on 'Suncrest' peaches that flesh firmness decreases with an increase in FAC time. Unacceptably high (> 2.0%) internal browning (IB) levels were observed in fruit FAC to 0°C within 12 h, 24 h and 48 h, and OR was also observed in fruit FAC to 0°C within 24 h and 48 h in the 2002-season. IB is a brown discolouration of the mesocarp tissue, which, with increasing severity, changes from light to dark brown and is associated with loss of juiciness (Taylor, 1996).

2. Evaluation after the Shelf-Life Period. In both seasons, fruit FAC to 0°C within 12 h was the firmest, but had the highest shrivel levels in the 2003-season (data not shown), and significantly ($P < 0.01$) the highest IB levels in the 2002-season (Table 6). In the same season, fruit which was FAC to a pulp temperature of 0°C in approximately 72 h had no IB, while all the other treatments had unacceptably high IB levels. These results suggest that 'Songold' plums must not be FAC to 0°C too fast to prevent shrivel and IB.

CONCLUSIONS

'Imperial' Apricots

Fruit which was FAC to 0°C within approximately 6 h had the best internal fruit quality compared to the other treatments subjected to longer FAC. Since different cold stores have different cooling capacities, it is suggested that individual cold room operators must refine this knowledge to ensure optimum fruit quality maintenance.

'Pioneer' Plums

While 'Pioneer' plums subjected to a short FAC time (12 h) were firmer than fruit subjected to longer cooling times after the cold-storage period, there were no significant differences in quality after shelf-life. This suggests that 'Pioneer' plums are not sensitive to cooling rates. As good standard practice, it is suggested that cooling should, however, be shorter than 48 h.

'Songold' Plums

Rapid cooling of 'Songold' plums should be avoided. Cooling to 0°C in less than 12 h increased the risk of IB in the 2002-season. The same treatment increased the risk of shrivel in 2003, even though the fruit was firmer compared to slower cooling. It is therefore recommended to FAC 'Songold' plums to 0°C in a time period longer than 12 h. As good standard practice, it is suggested that the cooling should, however, be shorter than 48 h.

The results on the plums demonstrates that cultivar differences must be considered when drawing up handling protocols for stone fruit, as a blanket recommendation may lead to the induction of quality defects.

ACKNOWLEDGEMENTS

Sincere thanks go to Dr. M. Taylor for his helpful comments and advice, and to Mr. B.Brock for technical assistance. The financial support of the Deciduous Fruit Producer's Trust is gratefully acknowledged.

Literature Cited

Mitchell, F.G. 1986. Influence of cooling and temperature maintenance on stone fruit

quality. Deciduous Fruit Grower 36: 205-211.
Monzini, A. and Gorini, F. 1991. Pre-freezing, storage and industrial use of apricot with relationship to quality. Acta Hort. 293: 599-655.
Taylor, M.A. 1996. Internal disorders in South African plums. Deciduous Fruit Grower 46:328-335.

Tables

Table 1. Fruit quality of 'Imperial' apricots cooled with different FAC rates (delivery air temperature -1.0°C) after cold-storage of 36 days at -0.5°C in the 2003 season.

Treatment	Parameters[1]				
	Shrivel (%)	Decay (%)	GB (%)	OR (%)	Mass loss (%)
6 h FAC	0.3	0.3	0.0	0.0	10.0a
12 h FAC	1.4	0.7	0.0	0.0	9.5a
24 h Stepwise cooling	1.1	0.4	0.0	0.0	6.6c
48 h Stepwise cooling	0.0	0.8	0.0	0.0	7.8b
Prob.>F[2]	ns	ns	ns	ns	***

[1]Values in same column followed by different letters indicate significant differences (P < 0.001) according to the LSD test.
[2]One-way ANOVA table where NS, * and *** represent non-significant, significant at the 5% level or significant at the 0.01% level, respectively.

Table 2. Fruit quality of 'Imperial' apricots cooled with different forced air cooling rates (delivery air temperature -1.0°C) after cold-storage of 36 days at -0.5°C plus a shelf-life period of 3 days at 15°C in the 2003 season.

Treatment	Parameters[1]			
	Shrivel (%)	Decay (%)	GB (%)	OR (%)
6 h FAC	0.4	0.0	0.0b	0.0
12 h FAC	1.1	0.4	5.8ab	0.0
24 h Stepwise cooling	0.0	1.4	9.2a	0.0
48 h Stepwise cooling	0.0	0.0	1.6b	0.0
Prob.>F[2]	ns	ns	*	ns

1 to 2 - see Table 1 for definitions.

Table 3. Fruit quality of 'Pioneer' plums cooled with different forced air cooling rates(delivery air temperature -1.0°C), after cold-storage of 10 days at -0.5°C, 9 days at 7.5°C and 16 days at -0.5°C in the 2003 season.

Treatment	Parameter[1]						
	Shrivel (%)	Decay (%)	Flesh firmness (kg)	GB (%)	IB (%)	OR (%)	Mass loss (%)
12 h FAC	0.0	0.0	3.7	2.5a	0.0	0.0	3.1
24 h FAC	0.0	0.0	3.4	0.0b	0.0	0.0	2.3
48 h Stepwise cooling	0.0	0.0	3.2	0.0b	0.0	0.0	1.8
72 h Stepwise cooling	0.0	0.0	2.8	0.8ab	0.0	2.5	1.6
Prob.>F[2]	ns	ns	ns	*	ns	ns	ns

[1]Values in same column followed by different letters indicate significant differences (P < 0.001) according to the LSD test.
[2]One-way ANOVA table where NS, * and ** represent non-significant, significant at the 5% level or significant at the 1% level, respectively.

Table 4. Fruit quality of 'Pioneer' plums cooled with different forced air cooling rates (delivery air temperature -1.0°C), after cold-storage of 10 days at -0.5°C, 9 days at 7.5°C and 16 days at -0.5°C plus a shelf-life period of 3 days at 15°C in the 2003 season.

Treatment	Parameter[1]					
	Shrivel (%)	Decay (%)	Flesh firmness (kg)	GB (%)	IB (%)	OR (%)
12 h FAC	0.0	0.0	2.2	5.0	0.0	0.8
24 h FAC	0.0	0.0	2.2	12.5	0.0	2.5
48 h Stepwise cooling	0.0	0.0	2.4	5.0	0.0	2.5
72 h Stepwise cooling	0.6	0.0	2.6	13.3	0.0	3.3
Prob.>F[2]	ns	ns	ns	ns	ns	ns

1 to 2 - see Table 3 for definitions.

Table 5. Fruit quality of 'Songold' plums cooled with different forced air cooling rates (delivery air temperature -1.0°C), after cold-storage of 10 days at -0.5°C, 12 days at 7.5°C and 20 days at -0.5°C in the 2002 season.

Treatment	Parameter[1]					
	Shrivel (%)	Decay (%)	Flesh firmness (kg)	GB (%)	IB (%)	OR (%)
12 h FAC	1.9	0.4	2.5a	0.0	13.3a	0.0b
24 h FAC	1.8	0.0	2.6a	0.0	5.0ab	8.3a
48 h Stepwise cooling	4.8	0.0	2.4a	1.6	3.3b	3.3ab
72 h Stepwise cooling	1.3	0.0	1.6b	1.6	1.6b	0.0b
Prob.>F[2]	ns	ns	**	ns	*	*

1 to 2 - see Table 3 for definitions.

Table 6. Fmit quality of 'Songold' plums cooled with different forced air cooling rates (delive1y air temperature -1.0°C), after cold-storage of 10 days at -0.5°C, 12 days at 7.5°C and 20 days at -0.5°C plus a shelf-life period of 3 days at 15°C in the 2002 season.

Treatment	Parameter					
	Shrivel (%)	Decay (%)	Flesh fmnness (kg)	GB (%)	IB (%)	OR (%)
12 hFAC	1.4	0.4	1.9a	33.3b	40.0a	0.0
24 hFAC	3.7	0.4	1.8a	66.6a	10.0b	0.0
48 h Stepwise cooling	2.2	0.0	1.8a	48.3b	8.3b	0.0
72 h Stepwise cooling	2.3	0.5	1.3b	48.3b	0.Ob	0.0
Prob.>F[2]	ns	ns	**	**	**	ns

1 to 2 - see Table 3 for definitions.

Figures

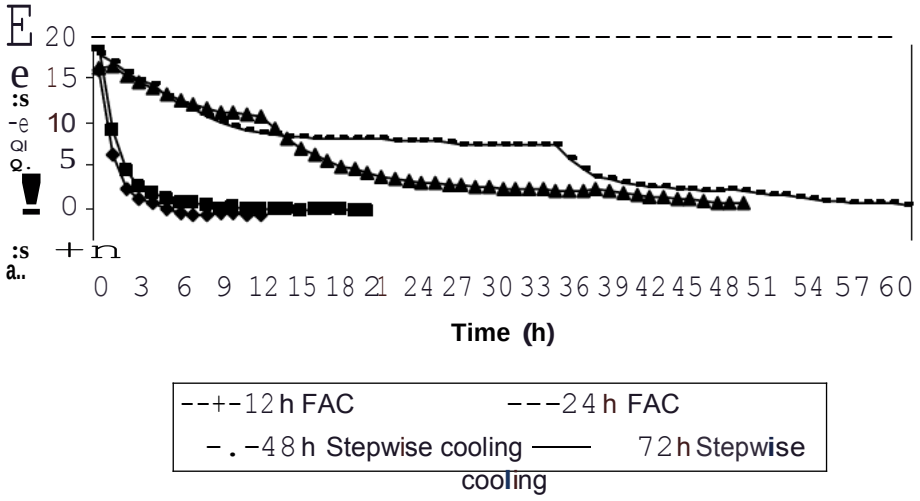

Fig. 1. Pulp temperatures of 'Songold' plums during FAC at different rates in the 2003 season.