Prestorage Heat Treatment Delays Development of Superficial Scald on 'Granny Smith' Apples

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Abstract. A prestorage heat treatment of 38C for 4 days applied to 'Granny Smith' apples (*Malus domestica* Borkh.) before regular air storage at 0C inhibited the development of superficial scald. Heat-treated apples stored for 3 months had superficial scald levels similar to diphenylamine (DPA)-dipped apples, while all nontreated control apples had scald. After 5 or 6 months of storage, this inhibition of scald development by prestorage heat treatment declined. The prestorage heat treatment inhibited the accumulation of α -farnesene and conjugated trienes in apple cuticle during storage, while DPA inhibited only α -farnesene oxidation. This treatment may be a substitute for chemical treatments against scald not only for short-term storage of 'Granny Smith' but possibly also for other scald-susceptible apple cultivars.

Superficial scald is a disorder that affects apples during extended storage. It is characterized by irregular areas of skin browning that may be faint upon removal of the fruit from storage, but that darkens and expands when the apples are kept at room temperature. Commercial control of superficial scald is through application of either diphenylamine (DPA) or ethoxyquin applied as a prestorage dip (Smock, 1961). Since chemical treatments of fresh fruit are becoming less acceptable to consumers, we have been investigating alternative methods of controlling storage disorders. Prestorage heat treatments can enhance the keeping quality of apples in storage (Klein and Lurie, 1990; Porritt and Lidster, 1978). The objective of this study was to examine the effect of prestorage heat treatment on superficial scald and on the levels of α -farnesene and the oxidation products, conjugated trienes, two volatiles that have been connected to the development of superficial scald (Anet and Coggiola, 1974; Huelin and Coggiola, 1970).

'Granny Smith' apples were harvested three times at 2-week intervals during the 1987 commercial harvest and twice during the 1988 harvest. Four replicates of 20 fruit each were dipped in 3000 ppm of DPA for 20 sec while a further four replicates served as controls at each harvest. The apples in each replicate were harvested from a group of three trees. Additional groups of four replicates each were heated at 38 ± 1 C for 2 or 4 days before being placed in storage. All treatments were placed in 0C, 90% RH regular air storage

for 3 and 6 months in 1987 and for 5 months in 1988.

Apple cuticle α -farnesene and conjugated triene levels were measured at removal from storage in four replicates of four apples from each treatment. Each fruit was weighed and surface area calculated from the weight, using the equation of Anet and Coggiola (1974). Each of the four apples per replicate was dipped sequentially in 100 ml of hexane for 2 min. The solution was filtered, brought to 100 ml, and its absorption measured at 232 nm for α -farnesene and 281 to 290 nm for conjugated trienes. Amounts were calculated using extinction coefficients reported by Anet (1972).

Table 1. Scald development in 'Granny Smith' apples from three harvests after storage for 3 months in air at 0C plus holding 1 week at 20C.^a

Treatment	Harvest					
	1		2		3	
	Scald		Scald		Scald	
	%	Index	%	Index	%	Index
Control	100	73	100	70	100	61
2 days, 38C	81	23	100	47	68	31
4 days, 38C	0	0	12	3	0	0
DPA	0	0	0	0	0	0
LSD 0.05	11.9	17.5	9.5	21.3	18.8	12.6

^aValues are means of four replicates of 10 fruit each.

^bIndex = [(% light x 1) + (% medium x 2) + (% severe x 4)]/4.

Table 2. Superficial scald development on 'Granny Smith' apples after storage in air at 0C for 3 or 6 months (first season), or 5 months (second season) plus 1 week at 20C.^a

Treatment	1987		1988		1987	
	3 months scald		5 months scald		6 months scald	
	%	Index ^b	%	Index	%	Index
Control	100	61	100	85	100	83
2 days, 38C	68	31	82	37	100	84
4 days, 38C	0	0	62	20	56	28
DPA	0	0	25	11	0	0
LSD 0.05	18.8	12.6	21.0	16.9	14.6	14.2

^aValues are means of four replicates of 10 fruit each.

^bIndex: see Table 1.

Superficial scald was determined on four replicates of 10 fruit held 1 week at 20C. Incidence of superficial scald was reported as both percentage of fruits affected and the intensity of the scald using the formula (% light x 1) + (% medium x 2) + (% severe x 4)/4 (Lurie et al., 1989).

After 3 months of 0C storage and 1 week at 20C, all control fruit from all three harvests showed scald, while DPA-dipped fruit had no scald (Table 1). Fruit heated for 2 days before storage showed a high percentage of scald but its severity, as indicated by the scald index, was much less than the control apples. Fruit heated for 4 days had no scald in two out of the three harvests, and in all cases the incidence of scald did not differ significantly from DPA-treated fruit. Since untreated fruit from even the latest harvest was very sensitive to scald development, the apples from the latest harvest in each season were used in further studies.

The heat treatment became less effective in preventing scald as the fruit were stored for a longer period (Table 2). After 5 or 6 months of 0C storage and 1 week at 20C, apples heated for 4 days had scald incidence averaging 60%, while DPA-treated apples had 0% to 25% scald.

The highest level of conjugated trienes was found in cuticle extracts from control apples and the lowest in DPA-dipped apples (Table 3). A prestorage 4-day heat treatment decreased the level of conjugated trienes found in apples after 3 months of storage, and this level was highly correlated to the scald incidence that developed ($r = 0.96$, $P = 0.001$). After 6 months of storage, the correlation between scald and conjugated trienes was lower but still significant ($r = 0.633$, $P = 0.001$). The α -farnesene level in fruit removed after 3 months of storage was lower in fruit heated for 4 days than in control fruit.

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Table 3. Levels of conjugated trienes and α -farnesene in apple cuticle upon removal from storage at 0°C.

Treatment	Storage duration			
	3 months		6 months	
	Conjugated trienes	α -Farnesene	Conjugated trienes	α -Farnesene
		$\mu\text{mol}\cdot\text{cm}^{-2}$		
Control	18.5	118	17.6	47.0
2 days, 38C	17.7	105	13.7	36.4
4 days, 38C	7.3	75	13.9	44.7
DPA	1.7	70	2.7	61.5
LSD 0.05	2.4	27	5.5	16.4

*Values are means of four replicates of four fruit each.

DPA-treated fruit contained significantly higher levels of α -farnesene; however, after 6 months of storage the level of α -farnesene was lower than in similar fruit stored for 3 months. This change was expected since α -farnesene has been shown to accumulate during the first 3 to 4 months of storage and then to decline (Anet and Coggiola, 1974; Lurie et al., 1989).

As reflected by the conjugated trienes and α -farnesene data, heat treatment appeared to have a different mode of action in reducing scald than did DPA dips. DPA inhibited the oxidation of α -farnesene without affecting its accumulation and was effective for all

periods of storage examined. Heat treatment slowed the accumulation of both α -farnesene and conjugated trienes, although by 6 months of storage both had reached the same levels as those in control apples. Heating for 4 days before storage was effective in preventing scald for the first 3 months of storage, but after that the inhibition disappeared and scald began to increase. Therefore, at present, this treatment can substitute for chemical treatment of scald for only short-term storage. However, it is possible that combining heat treatment with a lower concentration of antioxidant than is used normally will permit extended scald-free storage. Also, the heat

treatment may have a longer effect in controlled atmosphere storage. In addition, shorter times of heat treatment at a higher temperature may be found to be more effective in preventing scald than 4 days at 38C.

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