STORAGE SCALD OF APPLES

Dr. Eugene Kupferman
WSU-TFREC, 1100 North Western Ave.
Wenatchee, WA 98801
kupfer@wsu.edu

WHAT IS STORAGE SCALD?

Simply put, storage scald is the diffuse browning of the skin of apples or pears that appears after storage. Storage scald has also been called superficial scald and common scald.

Appearance

Storage scald is a diffuse browning of the skin of the fruit; there are no crisp margins between affected and unaffected tissue. This browning is only skin deep and the flesh is usually not affected. The discoloration is usually irregular in shape varying from light brown to dark brown. It can occur on any part of the skin. In some cases the lenticels are not affected, leaving uninjured green spots (Figure 1).

Figure 1. Storage scald.

Occurrence

Storage scald appears most often on the less colored side of red colored fruit—the side of the fruit facing the inside of the tree, but randomly on green cultivars. It is also found on less mature fruit. Storage scald appears only after the fruit has been in either regular storage or controlled atmosphere storage.

Severity

Storage scald is the most economically serious postharvest disorder of apples and pears.

Disorder Progression

Storage scald most often appears after fruit have been removed from storage. Except in the most severe cases, scald does not appear on fruit while in storage; it develops following removal from storage. Storage scald develops faster at warmer temperatures; thus warming the fruit during packing will speed visualization of the disorder. Apples with scald will usually visualize the maximum amount of scald within a few days at ambient temperatures, or longer if temperatures are colder. Thus it is quite common for apples to look fine leaving the packinghouse, but develop serious scald symptoms by the time they reach the consumer in a distant market.

Similar Problems

Other types of skin browning are often confused with scald, including soft scald, which is a problem of senescence or low temperature breakdown. Soft scald has discrete brown lesions that are smooth, slightly sunken and confined to the equatorial parts of the apples. There is a sharp margin between affected and unaffected tissue. The flesh may be pale brown, soft and spongy.

Figure 2. Delayed sunburn.

There is also the disorder called delayed sunburn that develops on apples in storage from heat either immediately prior to harvest or following harvest (Figure 2). Varieties that have multiple harvests may have fruit with this problem when previously shaded fruit become exposed to the sun. It is also possible to develop this problem on fruit on the top of the bin following harvest is exposed to the sun. Delayed sunburn is not seen clearly at harvest, but develops over time in storage. It is often round and may be quite burned in appearance. It will not worsen over time following storage nor will any postharvest treatment reduce its development.

PREHARVEST FACTORS INFLUENCING SCALD

Scientists have connected a number of preharvest factors with the risk of storage scald. Here are some of the preharvest factors.

1. **Variety** – apple varieties vary in their susceptibility to storage scald (Table 1).

Table 1. Estimate of susceptibility to storage scald at commercial maturity of various apple cultivars.

Variety	Low Risk	Moderate Risk	High Risk
Braeburn	X		
Fuji	X		
Gala	X		
Golden Delicious	X		
Granny Smith			X
McIntosh	X		
Red Delicious		X	X
Rome Beauty		X	
Spartan	X		

2. **Maturity** – less mature fruit will scald more easily than more mature fruit (Figure 3).
3. **Orchard temperatures** – scientists have been examining weather records to determine their correlation with the risk of scald. See the next section (*Orchard Climate and Scald*) for this discussion.
4. **Red color** – varieties with greater coverage of red skin color will scald less than striped or tricolor apples. The green portion of the fruit will scald more easily than the red portion. Fruit from the center of the tree will scald more easily.
5. **Nutrient content** – fruits with high nitrogen and low calcium content have a greater risk of scald. Fruits with higher potassium have a greater risk of scald.

6. **Fruit size** – larger fruit have a tendency to scald more than smaller fruit. Very small, immature fruit from the inside of the tree also will scald easily.
7. **Soil moisture content** – orchards with low moisture content will have a greater risk of scald.
8. **Spraying** – spraying Granny Smith fruit with Ethephon has shown that scald can be reduced, but not as effectively as when diphenylamine (DPA) is used (Washington and New Zealand). See Figure 4.

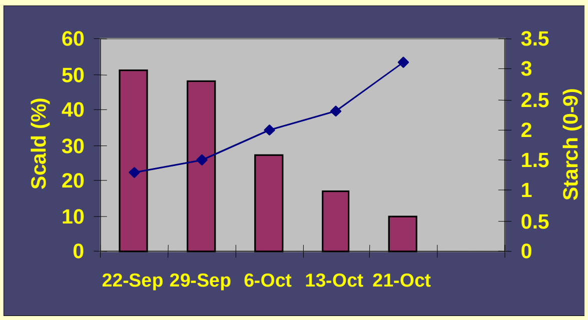

Figure 3. Maturity and scald.

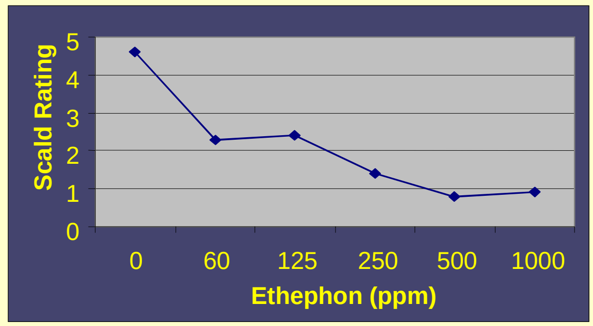

Figure 4. Ethephon and scald.

ORCHARD CLIMATE AND SCALD

There are two aspects of orchard temperatures that relate to the risk of storage scald. These are the accumulation of cold (nighttime) temperatures and the temperature during the day.

Scientists at several fruit growing locations have determined that cold temperatures immediately prior to harvest reduce the risk of storage scald. Temperatures below 10 ºC (50 ºF) in the month prior to harvest correlate well with diminished risk of scald. For example, in orchards in Washington state, there is less risk of storage scald to Granny Smith apples than when the same variety is grown in California where they do not get cold temperatures close to harvest. In fact, the Washington Apple Maturity Program has been relying upon accumulated cold temperatures as an important indicator of harvest maturity. Thus, when Red Delicious accumulate 150 hours below 10 ºC, the risk of scald is minimal and growers feel it is safe to harvest (Figure 5).

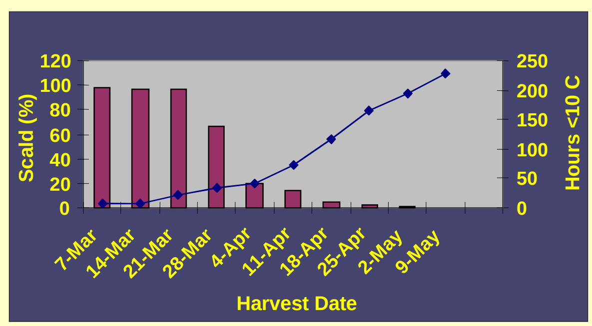

Figure 5. Cold temperatures and scald.

Analysis of cold units accumulated below different base temperatures has shown that using 10 ºC gives a correlation superior to other threshold temperatures. However, the strength of the correlation varies by location. Base 10 ºC is stronger in the eastern United States than in the west and the base 10 ºC has not proven to be consistently applicable under New Zealand conditions. The number of days below 10 ºC is a better indicator than hours below 10 ºC.

A model is being developed using harvest date, starch score, and the number of preharvest days below 10 ºC to predict whether a given lot of Red Delicious apples will develop severe, moderate or slight scald. It is worthwhile to note that as scald risk decreases, as indicated by the model, the concentration of DPA necessary to control scald also decreases. Thus, storage operators may be able to reduce the concentration of DPA as the harvest season progresses.

Obviously this is a complex issue as fruit are maturing at the same time scald risk is decreasing. Is it the cold temperatures working to reduce scald risk or the advancing maturity? Work by Dr. Bramlage of the University of Massachusetts has shown that the number of hours below 10 ºC appears to be more important at reducing the risk of scald than it does to advance maturity. In his region they can accumulate a great number of hours below 10 ºC in a 24-hour period and scald is greatly reduced, whereas maturity is not dramatically affected.

However, this may not work in all growing regions. A region in which temperatures are normally cool may need a drop in temperatures to increase scald protection to a greater degree than in a growing region in which the temperatures are warmer.

Then there is the effect of high (daytime) temperatures. English researchers report that usually high temperatures during the growing season increase the risk of scald. In Washington, temperature above 25 ºC (77 ºF) during the month prior to harvest increases the risk of scald. Low moisture or rainfall will do likewise.

Many questions remain:

- What happens when the temperatures never dip below 10 ºC and the internal maturity indices (i.e., starch) indicate the fruit is ready for harvest?
- What happens when the daytime temperatures are high – do the fruit lose their resistance to scald? If so, how much resistance is lost by how much hot temperature?
- How much do maturity and temperature interact? Thus, if the temperatures turn cold early in the maturation season, are these temperatures as effective in reducing scald as when the cold comes later and the fruit are more mature?

POSTHARVEST CHEMICAL CONTROL

Ever since the discovery of DPA in the 1950s there has been little research into alternative chemicals for the control of storage scald. Prior to DPA, mineral oil was used on the fruit as a liquid or paper wrap to control scald. Since the registration of DPA, only the chemical ethoxyquin has been added for scald control. Ethoxyquin is not as effective as DPA and is labeled for use only on pears in the United States at the present time. There were a number of trials in which DPA and ethoxyquin were tested together and alone against scald on various apple cultivars.

DPA must be applied soon after harvest and is most effective on fruit at ambient temperature. It is applied as a dip or drench, most often at 2,000 to 2,500 ppm. Delaying control even by as little as 10 days after harvest can reduce the effectiveness of DPA.

DPA use is currently under review by the U.S. Environmental Protection Agency, and indications are that it will be reregistered for use in the United States.

The fogging of DPA into closed storage rooms has not been tested in the United States, as it is not a legal treatment. It has been used in Europe and South Africa with mixed results.

Other chemicals such as sesame oil, Vitamin E, ascorbic acid (Vitamin C), BHT, BHA and other antioxidants have been tested and although they reduce scald, they have not been as effective as DPA. Postharvest drenches with calcium salts have been shown to reduce the severity of scald only slightly.

NON-CHEMICAL POSTHARVEST CONTROL

A number of strategies have been employed to reduce the risk of storage scald thorough manipulation of the storage atmosphere. Let's consider several of them.

Ultra-low oxygen storage

In a number of storage rooms in British Columbia, Canada, growers are storing Red Delicious apples without any scald treatment by coupling information on risk, as indicated by orchard temperatures and maturity, with very low levels of oxygen (0.7%) (Figure 6). Ultra-low oxygen (ULO) reduced scald better than application of DPA (Table 2). One must remember that they are doing this effectively with Red Delicious and are located in a growing district with cooler temperatures than that in Washington or California. Yet, they have been doing this commercially successfully for several years.

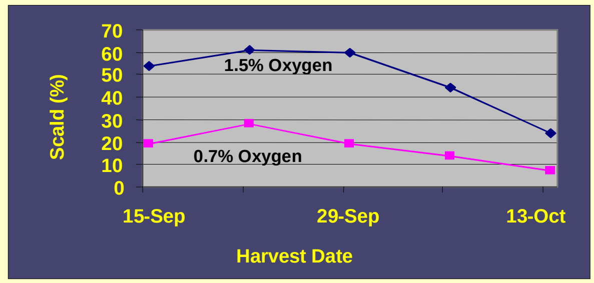

Figure 6. Ultra-low oxygen storage.

Table 2. Low oxygen and scald.

Treatment	Scald Severity				Total Scald
	Clear	Slight	Moderate	Severe	
DPA	50	17	21	12	**50**
Low oxygen	42	20	23	15	**58**

Dr. Nardin reported in 1993 on research in the South Tyrol about his results with ULO and low oxygen. He cited the positive results with ULO (0.9 to 1.2% oxygen) when there was appreciable ventilation (5 to 6 air changes/day) during the storage period.

My own experiments with commercially harvested and untreated Red Delicious in Washington have reinforced the value of atmospheres below 1.0% oxygen in reducing scald in long-term storage.

Initial Low Oxygen Shock ILOS

Exposure of Granny Smith to 0.5% oxygen reduced scald over continuous storage at 1% in Australia, but this did not positively affect Red Delicious in the same trial (Figure 7). In another trial, ILOS (10 days at 0.5% oxygen) followed by CA (1% oxygen, 3% carbon dioxide, 1 ºC [34 ºF]) without DPA controlled scald on Granny Smith and Red Delicious in South Africa (Figure 8). ILOS also markedly reduced scald in Granny Smith, Rome and Red Delicious in Michigan trials.

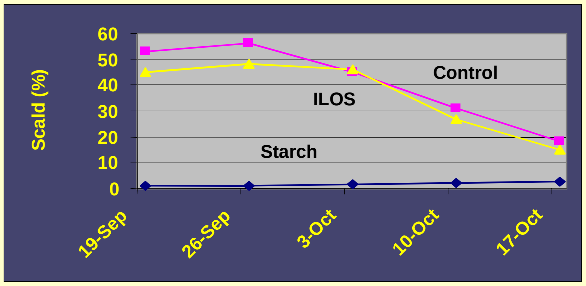

Figure 7. ILOS and scald.

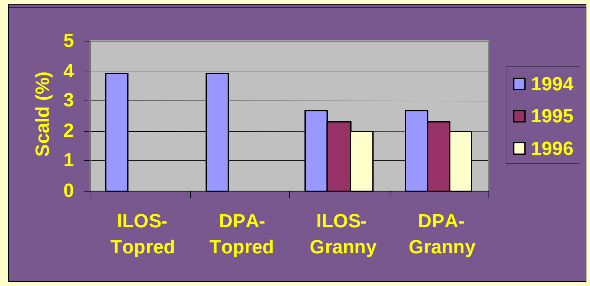

Figure 8. ILOS for Grannys and Reds.

Purging CA Systems

Storage scald is reduced on fruit that are well ventilated. Michigan researchers have reported successful control of scald using a hollow fiber membrane air separator in a purge mode to supply air at 1.5% oxygen with carbon dioxide below 3% at 0 or 3 ºC (32 or 37 ºF). The atmosphere is established within 7 days of loading the room and fruit are held in a continuous purging system (Table 3). The purge was at a rate sufficient to maintain the atmosphere.

Table 3. Purge vs. static CA storage and scald rate.

CA Regime	Harvest Date	Scald Incidence
Purged	Sept. 26	6%
Static	Sept. 26	58%
Purged	Nov. 4	0%
Static	Nov. 4	2%

Temperature

Scientists have noted that superficial scald is a true low temperature disorder. Would raising the temperature in the storage reduce scald? Trials have shown that it might, but quality would be adversely affected.

Ethylene

The elimination of ethylene to below 1 ppm has been reported to delay the development of scald in England, but not in Canada. It has shown only limited benefit in Michigan tests as well.

Carbon Dioxide

Elevated levels of carbon dioxide (10% for Golden Delicious) have also been shown to reduce scald in certain cultivars. It must be remembered that cultivars differ in their susceptibility to damage by carbon dioxide, which may be external and/or internal.

Ethanol vapor

Trials in Michigan showed that the application of ethanol vapor suppressed scald following storage. Ethanol vapor at 6,000 ppm for 1 to 2 weeks at the start of storage reduced scald after 4 months in CA, but not for longer periods. This was more effective with Red Delicious than with Rome or Granny Smith.

Ventilation

Restricted ventilation increased the risk of scald in a number of studies. Thus fruit in polybags or packed have a greater risk of scald than those stored in open bins.

Length of Time in Storage

Reducing the time in storage has been shown to reduce the risk of scald in limited instances. It is thought many of the chemical reactions that promote scald take place within the first month of storage, and with increased time in storage the risk rises.

Prestorage Heating

Tests in Washington show that hot water treatment (50 ºC [122 ºF] for 60 seconds) can effectively reduce scald in Granny Smith, but skin color and condition can be affected. The effective temperature is very close to the injury temperature, so conditions must be perfect. It is interesting to note that applying warm DPA is more effective than cold. This may be the reason for uneven results when DPA is applied on fruit already in storage.

Other experiments in Israel and Italy have shown that high moisture air (>38 ºC [>100+ ºF]) for 48 hours following harvest reduced scald following storage. Again, in some varieties heating fruit can speed internal browning and external color change.

SUMMARY: PRACTICAL METHODS TO MINIMIZE STORAGE SCALD

1. Choose an orchard site with a large shift in day/night temperature at harvest
2. Choose varieties low in susceptibility
3. Keep apples supplied with calcium; minimize nitrogen application
4. Promote a uniform crop on the tree
5. Harvest fruit slightly more mature
6. Keep track of cold temperatures and add to harvest indicators
7. Cool fruit rapidly
8. Use antioxidants when indicated
9. Store suitable fruit in ULO
10. Use purge rather than recirculating CA
11. Maximize ventilation
12. Minimize the length of time in storage