PROJECT No.: ARS 532 Terminating Report

TITLE: Postharvest Treatments Which Reduce Scald

YEAR INITIATED: 1994-1995 **CURRENT YEAR:** 1999-2000
TERMINATING YEAR: 1999-2000

PERSONNEL: Eric A. Curry, Plant Physiologist
USDA, ARS, PWA, Wenatchee, WA

JUSTIFICATION:

Superficial storage scald is a disorder that develops on the apple fruit surface after several months in cold storage. It occurs on the main apple cultivars grown in the northwest and may be a major source of postharvest loss if not controlled. The postharvest antioxidant chemical diphenylamine (DPA) has been an effective inhibitor of the disorder on 'Delicious' and 'Granny Smith' apples. Over the course of this project we have looked at a number of alternatives to DPA as well as combinations of alternatives to reduce the amount of DPA needed to control scald. These alternatives have included heated water, controlled atmosphere, and addition of calcium, squalene, and various other experimental or purported scald reduction agents. This report summarizes many of the experiments conducted over the course of the project as well as specific experiments conducted this past year.

OBJECTIVE:

The objectives of this project were to continue work with controlled atmosphere, DPA, as well as several natural antioxidants and formulations that have shown promise for scald reduction.

PROGRESS: 1994-1998

In 1992, 9 ‘Delicious’ and ‘Granny Smith’ apples, and 9 ‘d’Anjou’ pears were harvested from 20 moderately to heavily cropped, mature trees located in commercial orchards near the Tree Fruit Research Laboratory in Wenatchee, Washington. Pears were harvested on August 18, and ‘Delicious’ and ‘Granny Smith’ apples on August 31, and September 23, respectively. In the laboratory, one fruit from each tree was placed on a single tray thereby making 9 trays of similar fruit. Treatments included an untreated control, farnesene, farnesol,

farnesyl acetate, farnesyl acetone, geraniol, squalene, and wheat germ oil. All treatments were applied as 100% active material wiped on the fruit and the excess removed with dry cheesecloth. Fruit were placed in clean trays (plus plastic liners for pears) and stored in boxes -1C for 6 months (5 months for pears). After storage fruit were held for 7 days at 22C and evaluated for scald. In addition, three 2.0-cm plugs were removed symmetrically around the shoulder of each fruit and the 2-mm epidermal layer extracted with hexane for measurements of antioxidants (OD200nm), and conjugated trienes (OD258nm) according to methods previously described. Extracted samples were combined for a single measurement per fruit. A tray of 20 fruit was also evaluated for maturity at harvest. Scald development in storage on untreated 'd'Anjou' pears was relatively low during this particular season. Nevertheless, fruit treated with farnesene, squalene, and wheat germ oil reduced scald from 19% in control fruit to 2, 1, and 0% respectively. In these treatments, the antioxidant content (OD200nm) was increased with farnesene, unchanged with squalene and reduced with wheat germ oil. On the other hand, they all reduced the level of conjugated trienes (Table 3). Farnesol, farnesyl acetate, farnesyl acetone, and geraniol all increased scald (or symptoms similar to it) more than 5-fold. The OD200nm in the peel increased from all these treatments, however, the triene content decreased in all except those treated with geraniol in which case it increased. (On some fruit treated with geraniol, the peel was severely damaged resulting in molded and unusable fruit). In 'Delicious' apples, scald after 6 months storage at –1C was reduced by α-farnesene, farnesol, farnesyl acetate, farnesyl acetone and squalene. Wheat germ oil had no effect. On the other hand, geraniol completely blackened the fruit surface, causing severe damage and subsequent infection by various microorganisms. In all treatments where scald was reduced, the OD200nm increased. All treatments except farnesol showed higher levels of trienes (OD258nm). In 'Granny Smith', apples scald levels were reduced by all treatments except geraniol where the fruit surface was completely blackened as was the case for 'Delicious'. Farnesol induced the greatest increase whereas treatment with farnesyl acetate showed the least. Squalene treated fruit had an incidence of scald equal to 20% of the control. All treatments except wheat germ oil increased the OD200nm. All treatments except α-farnesene reduced the level of trienes (OD258nm). Since it was previously reported that the oxidation of α-farnesene was directly related to the development of scald in both apple and pears, it was somewhat of a surprise to see the opposite occur. Analysis by gas chromatography of the farnesene used in this study indicated it was composed of a mixture of compounds. There was no separation of isomers intended in the synthesis and it is possible that one of the other compounds had a significant influence. Another possibility for such complete scald control in pears is that the farnesene acted more like an oil wipe, reducing the amount of oxygen available

for oxidative reactions, thereby reducing the oxidation of a-farnesene to the deleterious conjugated trienes. Analysis of squalene, on the other hand, revealed a single peak. Therefore, if the mode of scald inhibition is not, as previously suggested, that of reducing the availability of oxygen, it is likely directly attributable to squalene itself. Another curiosity with respect to previous reports was the effect of geraniol application. Previous workers injected 'Granny Smith' with geraniol and found it reduced scald. Although the peel of fruit we treated topically was completely darkened, this may have been simply a phytotoxic reaction to an excessive dose. Clearly, some anomalies warrant further investigation.

In 1996, 10 'Delicious' and 'Granny Smith' apples and 16 'd'Anjou' pears were harvested from 20 moderately to heavily cropped, mature trees located in commercial orchards within 10 km of the Tree Fruit Research Laboratory in Wenatchee, Washington. Pears were harvested on August 29, and 'Delicious' apples on September 10. In the laboratory, one fruit from each tree was placed on a single tray thereby making multiple trays of similar fruit. Treatments included an untreated control, DPA at 0, 0.05, 0.1 and 0.2%, and ETQ at 0.0675, 0.135 and 0.27% (pears only) with and without 5% squalene plus 0.05% Tween 20. A tray of 20 fruit was also evaluated for maturity at harvest. All treatments were applied to fruit 24 hours after harvest by dipping for 1 minute. Fruit were allowed to air dry for 30 minutes and then placed on clean, dry, fiber trays. Trays (plus plastic liners for pears) were placed in boxes and stored at -1C for 10 or 6 months for apples and pears, respectively. After storage, fruit were held for 7 days at 22C and evaluated for scald. All treatments were replicated 3 times using fruit from different orchards. After 6 months at -1C plus 7 days at 20C, a 5% emulsion of squalene reduced scald to 0% on 'd'Anjou' pears, whereas only at 0.27% did ETQ achieve the same level of control (Table 7). In 'Delicious' apples after 10 months at -1C plus 7 days at 20C, DPA at 0.2% reduced scald to 55%. The combination of 5% squalene plus 0.2% DPA reduced scald to 7%. Treating with squalene emulsions showed no phytotoxicity whereas treating with surfactant alone increased the severity. On apples treated with scald emulsions, scald evaluations after 10 months showed insufficient control. An evaluation was also made at 6 months at which time scald control was significantly better (data not shown). Apparently, in regular storage there is a limit to the efficacy of squalene. Investigations continue using reduced concentrations of squalene in combination with other antioxidants as well as with DPA, ETQ, calcium and heat. The other work on pears was done as an extension of a previous preliminary trial with DPA in 1995 that indicated a DPA drench of 2000 ppm controlled scald to 25% of the 0-ppm control whereas a 10% squalene emulsion controlled scald 100%. There was a minor amount of spotting in the DPA trials due to uneven coating and

freestanding drips. In 1996, DPA at 2000 ppm controlled scald to about 13% of the 0-ppm control and a 5% squalene dip again controlled scald 100%. No spotting damage was evident In addition, the squalene treatments were more uniform in color and less ripe. The addition of 5% squalene reduced the amount of ethoxyquin or DPA necessary to completely control scald to ¼ this amount. Thus, squalene either alone or in concert with commercial antioxidants improves scald control and delays fruit ripening. In the last group of experiments, I wanted to examine the source of DPA injury on 'd'Anjou' pears since a number of countries use this compound, apparently without any deleterious effects. In the first experiment, DPA was applied to 'd'Anjou' pears at the rate of 1000, 2000, 4000, and 8000 ppm. In addition, ETQ at 2700 ppm and 5% squalene in either a macroemulsion or microemulsion (Dr. Bob Hagenmeier, USDA) were used. Fruit were allowed to air dry and then placed on trays in plastic liners at -1C. After 6 months regular storage, evaluations were made for scald as well as surface DPA injury. Results showed as DPA dose increased, scald decreased. At 4000 ppm DPA was as effective as ETQ at 2700 ppm. At 2000 ppm, scald was reduced by about 90%. The only chemical injury seen was at 8000 ppm and had the appearance of darkened patches. At this rate, damage could also have been due to increased surfactant levels. The microemulsion formulated by Dr. Hagenmeier controlled scald better than the simple macroemulsion however there was some skin shrivel associated which we are attempting to eliminate. In a second trial, fruit were placed in a small, rectangular, plastic container with drainage holes in the bottom. These fruit were drenched with various rates of DPA and placed immediately (without drying) in regular or CA storage. After 6 months the total number of contact points were counted (about 200) and the number of darkened or damaged lenticels noted. Results indicate when fruit were put in regular storage while wet there was increasingly more damage to lenticels with increasing DPA. Mertect alone induced about 9% damage whereas DPA at 2000 and 4000 ppm, caused 16% and 23% damage, respectively. Fruit placed in CA chambers immediately had almost no damage. Lastly, an ethoxyquin extender was evaluated for reducing cost of chemicals. Drenching fruit with 2700 ppm ETQ resulted in 99% scald control. Reducing the rate of ETQ by 50% and adding the extender reduced scald from 93% to 0%.

PROGRESS: 1998-1999

Because the early maturing ‘Golden Supreme’ apples are harvested before any chilling hour accumulation, and may be stored for 4 or more months, DPA and MCP were evaluated for efficacy. For both trials, apples were harvested on 8/20 from the Royal Slope area. For the DPA trial, fruit were treated with 0, 1000, or 2000 ppm DPA and stored for 3 or 6 months in regular or CA storage. No Scald was evident at 3 months in

any of the treatments. After 6 months, fruit in CA (2%/2%) had about 3 times the scald of that in regular storage. In regular storage, 1000 ppm DPA or higher reduced scald to a score of 1 or less (based on 0=none, 300=worst). Untreated fruit in CA had a scald score of 204 compared with 35 for fruit treated with 1000 ppm DPA and 4 for fruit treated with 2000 ppm. At 9 months, only CA fruit remained, of which 75% or more of all treatments had unacceptable scald ratings. After 3 months, AO levels in regular and CA control treatments were 72OD and 78OD, respectively. α-Farnesene levels were 5.1OD and 2.2OD respectively. After 9 months, AO and a-farnesene levels for fruit in CA were 12OD and 10OD respectively.

For the MCP trial, fruit were treated at harvest or 10 weeks after harvest with 1.0 or 0.1 ppm for 1 hour and stored 20 weeks in regular storage. Only the fruit treated at harvest showed typical MPC behavior of delayed ripening and no scald. Both rates showed much the same effects with regards to fruit quality and scald. Treating after 10 weeks showed no effect whether fruit was treated at 0C or 20C. Additional ripening for 10 weeks only induced scald in untreated fruit. MCP treated fruit were still firm and scald-free.