FINAL REPORT

WTFRC Project # PH-04-441 **WSU Project # 13C–4164–1203**

Project title: Lenticel Breakdown: Time in Storage, Fuji and Fungicides

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Objectives:
Improve the industry's ability to pack fruit susceptible to lenticel breakdown by:

- Characterizing the role of storage on the propensity of Gala apples to develop lenticel breakdown (LB).
- Understanding whether high solution conductivity levels play a role in developing LB in Gala apples.
- Determining the effect of fungicides on Gala apples susceptible to LB.
- Determining the effect of presizing and length of time between presizing and packing on LB development in Gala apples.
- Determining the susceptibility of Fuji apples to known packingline chemicals.
- Determining the effect of presizing and length of time between presizing and packing on LB development in Fuji apples.

Significant Findings:

- Gala apples from some orchards have a higher risk of developing LB and develop more severe LB than other orchards.
- The aniline dye test developed by Dr. Curry (USDA-ARS) accurately discriminated between Gala apples from orchards that are susceptible and those that less susceptible to LB.
- Gala apples treated with SmartFresh™ at harvest developed more LB than those not treated when fruit were stored in CA for 4 months. Treated fruit stored less than 4 months developed the same amount of LB as those not treated.
- The longer Gala apples were stored the more LB they developed.
- Cleaners applied at higher than label rate increased the severity and number of Gala apples that developed LB.
- Cleaner formulation had an effect on the incidence and severity of LB damage. The pH neutral cleaner showed the most LB damage, followed by the acidic cleaner. The alkaline cleaner was not significantly different than water only.
- Carnauba wax utilized in this work did not affect LB damage.
- Sodium hypochlorite concentration, dump tank temperature, and conductivity levels did not affect LB incidence or severity.
- Fruit subjected to a dump tank showed more LB damage than control fruit, which was packed without dump tank treatment.
- Delay in packing of 5 to 7 days after dump tank treatments increased the incidence and severity of LB damage in Gala apples.
- Gala apples that were presized developed more LB after packing than apples that were not presized.

- Apples packed immediately after being presized had less LB than those packed 1 to 3 weeks after being presized.
- Gala apples from the fungicide trials are still in storage and have not yet been evaluated.
- Cleaner formulation and application rate had an effect on the incidence and severity of LB damage in Fujis, similar to that seen in Gala apples.
- Fuji apples that were presized prior to packing showed more LB damage than fruit not presized.
- The interval between presizing and packing did not have a significant effect on the amount of LB damage in Fuji apples.

Methods Employed in 2004-2005:

Methods—Gala Harvest

At harvest, Gala apples were purchased from three orchards that had been recommended by Dr. Eric Curry as having had significant LB damage in several of the past three years. Sixteen cherry bins of apples were purchased from each orchard. Eight bins from each orchard were treated with SmartFresh™ prior to storage in the WTFRC/Stemilt research rooms. Six bins of fruit from each orchard were stored in RA and 10 bins from each orchard were stored in CA. This fruit was removed at monthly intervals and used for the storage, sodium hypochlorite and fungicide experiments described below.

In addition, two wooden apple bins of fruit were purchased from each orchard to be used in the presize experiments. All of this fruit was treated with SmartFresh™ and stored in the WTFRC/Stemilt CA room.

At harvest, 20 fruit from each orchard were tested using the aniline blue dye bath to determine susceptibility to LB damage.

Results—Gala Harvest

The aniline dye test developed by Dr. Curry (USDA-ARS) accurately discriminated between Gala apples from orchards that are susceptible and those that less susceptible to LB. Figure 1 shows the correlation between the dye bath score (top line) and the average LB damage for each orchard over the 6 month examination period. Fruit treated with SmartFresh™ prior to storage (center line) had more LB damage overall than fruit not treated with SmartFresh™ (lower line).

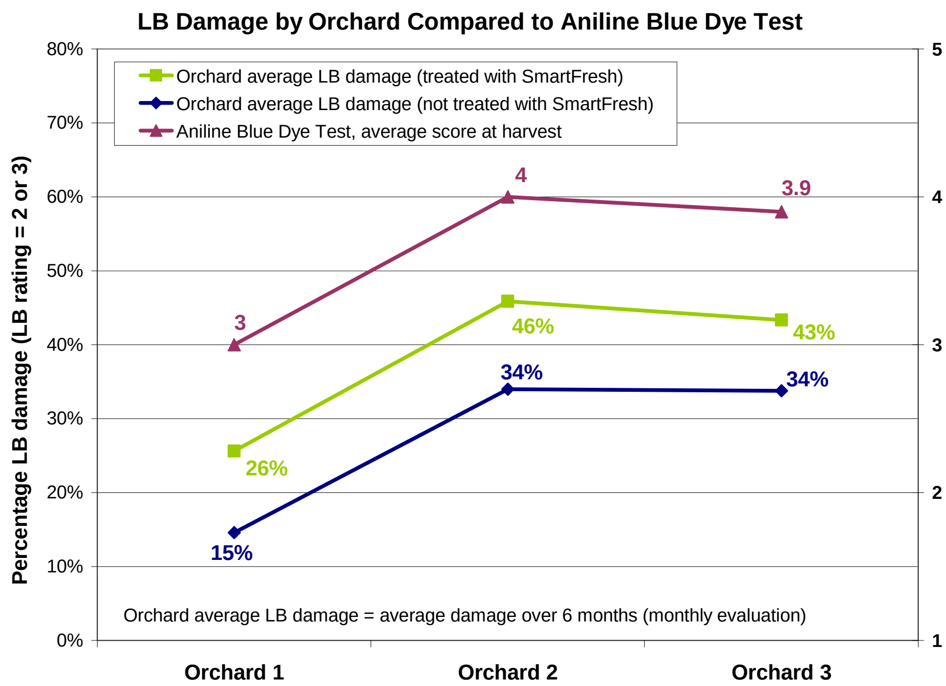

Figure 1. Correlation between aniline blue dye bath score at harvest (top line) and LB damage by orchard. LB damage is shown separately for SmartFresh™ treated fruit.

Methods—Gala Storage Experiment
At monthly intervals, 6 bins of fruit (3 orchards + 3 orchards SmartFresh™) were removed from storage and run over the USDA ARS research packingline. The first three monthly pullouts (November to January) were from RA storage and the last four pullouts (February to May) were from CA storage.

Based on results from the 2003 packingline experiments, 3 different cleaners and a carnauba wax were selected to use on the packingline. Based on usage rates described in the 2003 packinghouse survey, the cleaners were used at the manufacturers recommended application rate and also at 10 times the recommended rate. The 8 treatments used for this experiment are listed below.

1. No cleaner, no wax
2. No cleaner, carnauba wax
3. Acid cleaner @ label rate, carnauba wax
4. Acid cleaner @ 10x label rate, carnauba wax
5. Neutral cleaner @ label rate, carnauba wax
6. *Neutral cleaner @ 10x label rate, carnauba wax
7. Alkaline cleaner @ label rate, carnauba wax
8. Alkaline cleaner @ 10x label rate, carnauba wax

* Due to excessive LB damage, the neutral cleaner at 10x label rate was dropped from the experiment after the fourth pullout date.

The sample size for each treatment was 40 apples from each bin (6 bins). The packingline protocol for all treatments is listed below:

Wash: 2 minutes with water or cleaner (dripped on apples and brushes)
Rinse: 30 seconds warm water (90 to 105 ºF)
Spin dry on brush bed: 2 minutes

Wax: until evenly applied (approx 30 seconds)
Dry: 2 minutes at 110 ºF
Store: Placed on trays and stored in apple boxes

Following the packingline treatments, apples were stored at 33 ºF for five days, at room temperature (approximately 70 ºF) for two days, and evaluated for LB damage using the following scale (Figure 1):

0 = No LB damage
1 = Few lenticels affected, diffuse, damage only in lenticel
2 = Affected lenticels are more widespread on apple, damage only in lenticel
3 = Widespread lenticel damage and surrounding tissue damage

Figure 1. Lenticel Breakdown damage rating scale.

Results—Gala Storage Experiment
Cleaner formulation had an effect on the incidence and severity of LB damage. The pH neutral cleaner showed the most LB damage, followed by the acidic cleaner. The alkaline cleaner was not significantly different than water only. Cleaners applied at higher than label rate increased the severity and number of Gala apples that developed LB.

Gala apples treated with SmartFresh at harvest developed more LB damage when fruit were stored longer than 4 months. The longer Gala apples were stored the more LB damage they developed (Figure 2). See Table 1 for a summary of cleaners, application rate and SmartFresh™ treatment.

Table 1. Average LB damage on Gala apples evaluated over 6 month period (November 2004 to April 2005), by cleaner and SmartFresh™ application. Damage is expressed as an average rating (0 = none to 3 = severe) and as a percentage of cull fruit (LB damage = rating of 2 or 3).

Cleaner and Wax Treatment	pH	Application Rate	SmartFresh™=NO		SmartFresh™=YES	
			Avg. rating	Culls (%)	Avg. rating	Culls (%)
Water, No Wax	7.7	NA	0.50	14%	0.63	19%
Water, Carnauba Wax	7.7	NA	0.45	13%	0.84	27%
Acid Cleaner, Carnauba	2.3	1x	0.51	14%	0.80	26%
Acid Cleaner, Carnauba	1.5	10x	1.47	48%	1.79	61%
Neutral Cleaner, Carnauba	8.2	1x	0.73	22%	1.11	35%
Neutral Cleaner, Carnauba	8.5	10x	2.56	87%	2.70	91%
Alkaline Cleaner, Carnauba	12.3	1x	0.46	13%	0.77	23%
Alkaline Cleaner, Carnauba	13.2	10x	0.79	24%	1.05	32%

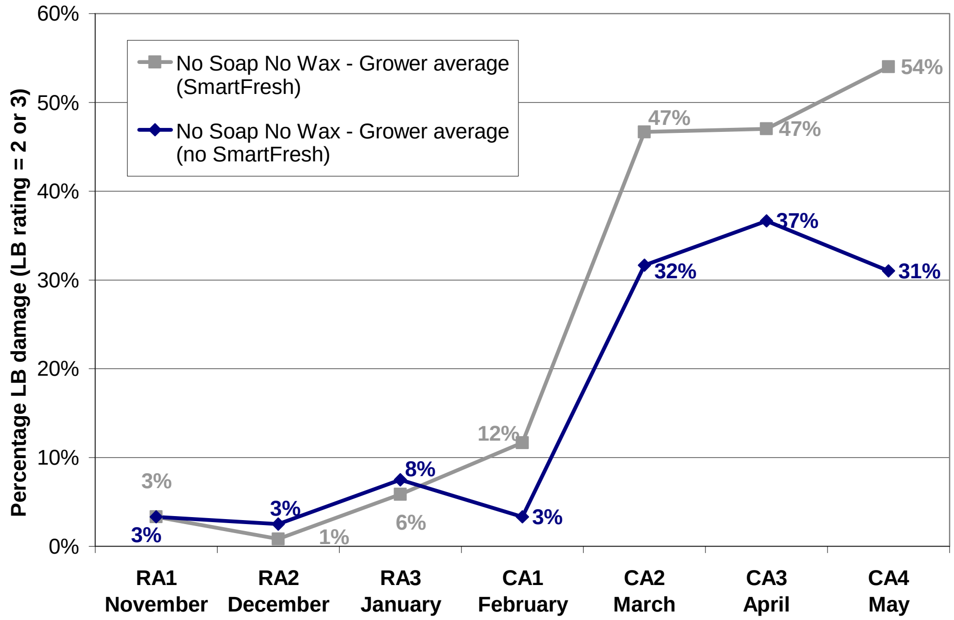

Figure 2. Increase in LB damage in Gala apples over time (average of 3 susceptible orchards). Apples were run over the packingline with no chemicals. LB damage is shown separately for SmartFresh™ treated fruit.

Methods—Gala Sodium Hypochlorite Experiment

The purpose of the sodium hypochlorite experiment was to determine the effect of sodium hypochlorite concentration on LB damage in susceptible Gala apples. Benchtop testing determined that sodium hypochlorite solutions alone do not cause LB damage (even at very high concentrations), so all fruit in this experiment were subjected to a 100 ppm sodium hypochlorite dump tank followed by packing on the USDA ARS research packingline. The sodium hypochlorite experiment was performed in three parts: (1) dump tank temperature and sodium hypochlorite concentration, (2) dump tank temperature and sodium hypochlorite concentration with a delay before packing and (3) sodium hypochlorite concentration with increasing conductivity. Control fruit for these experiments was fruit that was run over the packingline without a dump tank treatment. The control fruit were packed using the same cleaner treatment as the sodium hypochlorite fruit. The fruit used for these experiments was from the same bins as the Gala storage experiment (described above).

1. *Dump Tank Temperature and Sodium Hypochlorite Concentration (December 2004 and February 2005)*—Cold (38 ºF) fruit was placed into either a cold (50 ºF) or warm (100 ºF) dump tank for 15 minutes. The sodium hypochlorite level in the tank was either 0 ppm or 100 ppm (free chlorine). Immediately following the dump tank treatment, the fruit was removed from the dump tank and passed over the packingline with either the "No Cleaner, No Wax" treatment or the "Alkaline Cleaner @ label rate, Carnauba Wax" treatment. The packingline protocol (wash, rinse, wax, and dry times) and LB damage rating protocol were the same as the Gala Storage Experiment described above.

2. *Dump Tank Temperature and Sodium Hypochlorite Concentration with a Delay before Packing (January 2005)*—Cold (38 ºF) fruit was placed into either a cold (50 ºF) or warm (100 ºF) dump tank for 15 minutes. The sodium hypochlorite level in the tank was either 0 ppm or 100 ppm (free chlorine). Immediately following the dump tank treatment, half of the fruit was removed from the dump tank and passed over the packingline with the "Alkaline Cleaner @ label rate, Carnauba Wax" treatment. The other half of the fruit removed from the dump tank (not rinsed), and

returned to cold storage for 7 days. After 7 days, the fruit was removed from cold storage and passed over the packingline with the "Alkaline Cleaner @ label rate, Carnauba Wax" treatment. The packingline protocol (wash, rinse, wax, and dry times) and LB damage rating protocol were the same as the Gala Storage Experiment described above.

3. *Sodium Hypochlorite Concentration with Increasing Conductivity (January, March and April 2005)*—Cold (38 ºF) fruit was placed into a cold (50 ºF) dump tank for 15 minutes. The sodium hypochlorite level in the tank was either 0 ppm or 100 ppm (free chlorine). Conductivity was increased in one of three ways (1) adding sodium chloride (table salt), (2) adding magnesium (Epsom salt) or (3) adding organic matter to use up the free chlorine and then adding additional sodium hypochlorite to bring the free chlorine level back up to 100 ppm. Immediately following the dump tank treatment, half of the fruit was removed from the dump tank rinsed with cold water and passed over the packingline with the "Alkaline Cleaner @ label rate, Carnauba Wax" treatment. Several of the trials included a delay in packing, in which the fruit were removed from the dump tank, rinsed and placed in cold storage for up to 7 days before packing. The packingline protocol (wash, rinse, wax, and dry times) and LB damage rating protocol were the same as the Gala Storage Experiment described above.

Results—Gala Sodium Hypochlorite Experiment

1. *Dump Tank Temperature and Sodium Hypochlorite Concentration (December 2004 and February 2005)*—Dump tank temperature and sodium hypochlorite concentration did not have an effect on LB incidence or severity on Gala apples. The dump tank fruit had more LB damage than the control fruit (packed without dump tank treatment).

2. *Dump Tank Temperature and Sodium Hypochlorite Concentration with a Delay before Packing (January 2005)*—Dump tank temperature and sodium hypochlorite concentration did not have an effect on LB incidence or severity on Gala apples. The dump tank fruit packed the same day had approximately the same amount of LB damage as the control fruit (packed without dump tank treatment). The delay in packing caused a significant increase in the incidence and severity of LB damage (Table 2).

3. *Sodium Hypochlorite Concentration with Increasing Conductivity (January, March and April 2005)*—Dump tank temperature, sodium hypochlorite concentration and increasing conductivity did not have an effect on LB incidence or severity on Gala apples. The dump tank fruit packed the same day had approximately the same amount of LB damage as the control fruit (packed without dump tank treatment). The delay in packing caused a significant increase in the incidence and severity of LB damage. Results are similar to those shown in Table 2.

Table 2. Average LB damage on Gala apples evaluated after dump tank treatment and packing. Fruit was packed immediately after the dump tank (+0) or returned to cold storage for 7 days and packed (+7). All fruit was packed using alkaline cleaner at label rate and carnauba wax. Damage is expressed as an average rating (0 = none to 3 = severe) and as a percentage of cull fruit (LB damage = rating of 2 or 3).

		SmartFresh™=NO		SmartFresh™=YES	
Dump Tank Treatment	**Pack**	**Avg. rating**	**Culls (%)**	**Avg. rating**	**Culls (%)**
50 ºF, No chlorine, 15 min.	+0	0.19	4%	0.40	11%
50 ºF, No chlorine, 15 min.	+7	0.59	15%	1.08	35%
50 ºF, 100 ppm chlorine, 15 min.	+0	0.14	2%	0.33	9%
50 ºF, 100 ppm chlorine, 15 min.	+7	0.53	13%	1.65	60%

Methods—Gala Fungicide Experiment
The purpose of the fungicide experiment was to investigate the role of fungicides on the incidence and severity of LB damage in susceptible fruit. The fungicide experiment was performed in May 2005 using three different fungicides: thiabendazole (Mertect 340-F), fludioxonil (Scholar) and pyrimethanil (Penbotec). The fungicides were mixed with carnauba wax according to the manufacturer's instructions and applied to the apples using the wig-wag unit on the USDA ARS research packingline. Prior to waxing, the apples were washed using either the "No Cleaner" treatment or the "Alkaline Cleaner @ label rate" treatment. The packingline protocol (wash, rinse, and dry times) and LB damage rating protocol were the same as the Gala Storage Experiment described above.

Results—Gala Fungicide Experiment
The apples used in the fungicide trials are still in storage and have not yet been evaluated.

Methods—Gala Presize Experiment
The purpose of this experiment was to determine the length of time between presizing and packing on the incidence and severity of LB damage in Galas. All of this fruit was treated with SmartFresh™ prior to storage. In February 2005, three bins of fruit (1 from each orchard) were removed from CA storage and run over the presizer at Stemilt. A control bin from each orchard was not presized. Fruit from the 6 bins was then divided into samples and run over the USDA ARS research packingline 2, 8, 22 and 36 days after presize. The 2-, 8- and 22-day fruit was subjected to the same 8 treatments (water only, cleaners and wax), packingline protocol (wash, rinse, dry times) and LB damage rating protocol as the Gala Storage Experiment described above. The 36-day fruit was rated for LB damage prior to packing and run over the packingline using the water only and cleaners at label rate treatments.

Results—Gala Presize Experiment
Gala apples that were presized developed more LB after packing than apples that were not presized. Apples packed immediately after being presized had less LB than those packed 8 or 22 days after being presized. After 36 days, the incidence of LB damage in the presized fruit declined (Table 3).

Table 3. Average LB damage on Gala apples evaluated after presizing and packing. Fruit was presized and packed at four different intervals. Damage is expressed as an average rating (0 = none to 3 = severe) and as a percentage of cull fruit (LB damage = rating of 2 or 3). All fruit were treated with SmartFresh™ prior to storage.

Presize to Packing Interval	Presize=NO		Presize=YES	
	Avg. rating	Culls (%)	Avg. rating	Culls (%)
+2 Days	0.92	29%	1.88	63%
+8 Days	0.84	27%	2.74	95%
+22 Days	0.97	32%	2.57	89%
+36 Days	1.42	43%	2.10	70%

Methods—Fuji Harvest and Treatment
At harvest, Fuji apples were purchased from three orchards that had significant LB damage in several of the past three years. Two bins of apples were purchased from each orchard. All of this fruit was treated with SmartFresh™ and stored in the WTFRC/Stemilt CA room.

1. *Fuji Presize*—In March 2005, three bins of fruit (1 from each orchard) were removed from CA storage and run over the presizer at Stemilt. A control bin from each orchard was not presized. Fruit from the 6 bins was then divided into samples and then run over the USDA ARS research packingline 4 and 11 days after presize. The fruit was subjected to the same 8 treatments (water

only, cleaners and wax), packingline protocol (wash, rinse, and dry times) and LB damage rating protocol as the Gala Storage Experiment described above.

2. *Fuji Temperature*—To determine the effect of dump tank temperature on LB damage in Fuji apples, cold (38 ºF) control fruit (not presized) was placed into either a cold (50 ºF) or warm (100 ºF) plain water dump tank for 15 minutes. Immediately following the dump tank treatment, half of the fruit was removed from the dump tank and passed over the packingline with the "Alkaline Cleaner @ label rate, Carnauba Wax" treatment. The other half of the fruit removed from the dump tank and returned to cold storage for 7 days. After 7 days, the fruit was removed from cold storage and passed over the packingline with the "Alkaline Cleaner @ label rate, Carnauba Wax" treatment. The packingline protocol (wash, rinse, wax, and dry times) and LB damage rating protocol were the same as the Gala Storage Experiment described above.

Results—Fuji Harvest and Treatment

1. *Fuji Presize*—Fuji apples that were presized prior to packing showed more LB damage than fruit not presized, although this difference is not statistically significant. The interval between presizing and packing (4 days versus 11 days) did not have a significant effect on the amount of LB damage. The effect of cleaner type and concentration was the same as for Gala apples. Cleaner formulation had an effect on the incidence and severity of LB damage. The pH neutral cleaner showed the most LB damage, followed by the acidic cleaner. The alkaline cleaner was not significantly different than water only. Cleaners applied at higher than label rate increased the severity and number of Fuji apples that developed LB. Figure 3 shows the effect of cleaner type and concentration on non-presized and presized fruit (packed 11 days after presizing).

2. *Fuji Temperature*—The dump tank temperature had an effect on LB damage in Fuji apples. Fruit in the 100 ºF dump tank had more LB damage than fruit in the 50 ºF dump tank. Fruit that was packed immediately after dump tank had more LB damage than fruit that was returned to cold storage and packed after 7 days.

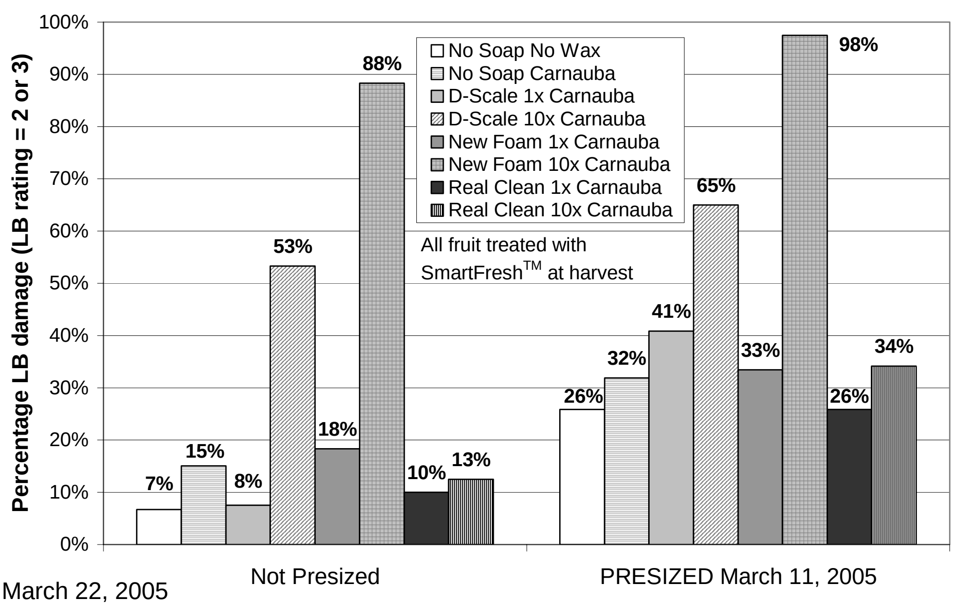

Figure 3. Presized versus non-presized Fuji apples (average of 3 susceptible orchards). All fruit was treated with SmartFresh™ prior to storage.

Discussion:

Progress has been made on identifying those postharvest factors that affect the incidence and severity of LB damage on both Gala and Fuji apples. The aniline blue dye test at harvest predicted the amount of LB damage after storage. Packers should employ this test or consider all fruit as susceptible to LB damage. The role of the maturity of the fruit at harvest is not certain and will be explored in 2005.

The longer susceptible fruit were stored the more severe the LB damage became, thus packers should schedule packing by LB susceptibility.

Apples treated with SmartFresh™ developed more LB when stored for 4 months than those not treated. In the early season there was no difference. It is not certain whether air storage coupled with SmartFresh™ application will have the same pattern of LB damage. This is included in a 2005 proposal to AgroFresh™.

Chemicals used on the packingline affect LB incidence and severity. Susceptible fruit treated with cleaners applied at above label rate developed more LB than those treated with a lower concentration. Fruit treated with a neutral cleaner developed more LB than those treated with an alkaline or acidic cleaner at label rate. There was no effect of carnauba wax on LB incidence. Additional work testing cleaners is not planned.

Presized fruit developed more LB after packing than fruit that was packed directly. Experiments this year with sodium hypochlorite (bleach) used by packers to provide inexpensive chlorine for spore control purposes determined that it did not affect LB incidence. Therefore the effect of presizing on LB was not the result of the use or misuse of bleach. Apples left in water baths developed higher incidence of LB in a preliminary trial. Research on the role of water immersion is proposed for 2005. Bin filling machinery was not tested in 2004, but is proposed for 2005.

Until we understand more about fruit anatomy and physiology and specifically how cuticle cracking and lenticel development are affected by growing conditions imposed by the environment and orchard practices the industry is restricted to limiting postharvest practices to those which cause the least damage to the fruit. To minimize LB damage on Gala apples, packers can take the following steps:

- Know your apples. Perform the aniline blue dye test to determine susceptibility to LB damage, or treat all Galas as if they are susceptible.
- Use SmartFresh™ only on non-susceptible fruit, or on fruit that will be stored for four months or less.
- Store susceptible fruit for short periods only. The longer fruit is in storage, the more likely it is to develop LB damage.
- Do not presize susceptible fruit.
- Minimize the length of time fruit is in contact with water and brushes.
- Minimize the amount of chemicals on the packingline.

Budget:

Project title: Lenticel Breakdown: Time in Storage, Fuji and Fungicides
PI: Eugene Kupferman
Project duration: 2004 (1 year)
Current year: 2004
Project total (1 year): $33,429
Current year request: $33,429

Item	**Year 1 (2004)**
Salaries[1]	$11,192
Benefits (41%)	4,589
Wages[2]	7,584
Benefits	1,214
Equipment	
Supplies[3]	8,350
Travel	500
Miscellaneous	
Total	$33,429

[1] Chris Sater, Ag Research Associate (0.75% for 5 months).
[2] Nancy Buchanan time-slip (0.50% for 5 months).
[3] Conductivity meter, fruit, packing supplies and chemicals.