FINAL REPORT **PROPOSED DURATION:** Year 3 of 3

Project Title: Enhanced strategies to reduce postharvest splitting of cherries

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Cooperators: TIC Gums, Van Doren Sales, Inc., Chelan Fruit, Stemilt Growers LLC, Allan Bros. Inc., Shield Bags and Printing Company, Washington Fruit & Produce Co., WTFRC, and others.

Budget: **Year 1**: $31,407 **Year 2**: $33,185 **Year 3**: $34,753

Budget 1
Organization Name: Washington State University **Contract Administrator:** Katy Roberts
Telephone: 509-335-2885 **Email address:** katy.roberts@wsu.edu

Item	2016	2017	2018
Salaries	$14,092	$14,656	$15,242
Benefits	$1,235	$1,285	$1,337
Wages	$9,055	$9,417	$9,794
Benefits	$1,275	$1,327	$1,380
Equipment			
Supplies	$5,000	$5,000	$5,000
Travel	$750	$1,500	$2,000
Plot Fees			
Miscellaneous			
Total	$31,407	$33,185	$34,753

Footnotes: Budget is requested to cover salaries and wages for the students working on the project. Money is also requested for purchasing laboratory supplies and small equipment for the experiments. Travel funds are requested to visit our co-operators for project work, specifically for the plant trials.

1. OBJECTIVES:

The original objectives proposed were:

1. Develop an understanding of the mechanism by which gum acacia helps reduce cherry splits.
2. Enhance the film forming ability of gum acacia by other low cost friendly edible coatings and modifiers.
3. Optimize the level of embedded desiccant in the packaging to help reduce cherry splitting.
4. Conduct post-packing cooling studies with enhanced coatings to help reduce stem browning.
5. Evaluate the consumer acceptance of the cherries coated with the optimized edible coatings.

2. SIGNIFICANT FINDINGS

Following are the significant findings of the research carried out:

1. Moisture management is an important factor in controlling the cherry cracking in the post-harvest phase. Excess moisture in the bags does negatively impact the quality of the Cherries. Too dry conditions is also not good, as it would cause the Cherries to shrink and most importantly would lead to the browning of the stems.

2. The air knives effectively remove excess moisture from the fresh cherries before packing. But, it very critical to have the right type of belt to facilitate proper drainage, with the forced air.

3. Removal of excess moisture from cherry surface contributes to the reduction of fruit cracking during refrigerated storage and also improves shelf-life.

4. Air dried cherries showed significant reduction in the cracks during storage studies by more than 60% by the end of 7 weeks compared to other treatments (Figure 11).

5. Air knife position over the belt and the drain belt type has significant impact on the efficacy of surface moisture removal. The drain belts with larger pore/hole sizes drain the water more effectively. The fine mesh belts did not prove to be effective in our trials (Figure 3).

6. Over the period of the last three years of this project, we tested over 16 different types of coatings.

7. From all the testing performed only the, Gum Acacia and the combination of Gum Acacia and Sodium Alginate/Agar showed consistent results both in terms of reducing the fruit splitting and pedicle browning (Figures 5, 6, 7, 8, 9, 10 and 11).

8. Coating of cherries with Gum Acacia (Gum Arabic) solutions consistently reduced the number of cracks during multiple trials.

9. Different concentrations of gum Acacia were tried over the last three years and the concentrations in the range of 0.5% to 1.0% were all found to have similar effects.

10. Packaging with desiccant significantly decreased the cracking during storage, in some experiments, but not all.

11. The treatment with “Gum Acacia” coating and the “surface moisture removal” together provided the best benefit with significant reduction in the number of cracks during storage and the pedicle browning. The percentage reduction of the cracks and pedicle browning at the end of 5 weeks storage were > 55% compared to other treatments (see Figure 7 and 8).

12. In addition to reduction in the number cracked cherries, the treatments also provided a benefit of reduced pedicle browning.

13. It is important to note that, in some trials we did not see significant benefits, especially when the excess moisture removal was not effective.

14. Gum Acacia (var. Senegal) mixed with the fungicide treatment provided by the facility was shown to be the most effective for fruit cracking and weight loss, during the last set of experiments conducted in the year 2018.

15. Gum Acacia (var. Senegal) with sodium alginate was observed to have the least amount of severe stem browning throughout the 3rd year experiments. The addition of the modifiers was not always effective over the three years of experiments.

16. Gum Acacia (var. Senegal) was shown to have the most average green stems after 6 weeks of storage (Figure 7).

17. Sensory analysis conducted for the last two years of work, showed that the consumer panel was not able to distinguish between the coated and uncoated varieties, after the 1st and the 4th week of storage periods (Table 3 and Figure 12).

18. Overall, we have shown that all the three approaches, i) edible coating application, ii) forced air to remove excess moisture/coating solution and iii) packaging with desiccant embedded in the plastic, can help reduce the postharvest cracking of the fruit to various degrees.

If any facilities would like to try in the production setting, we highly recommend ensuring that they have excellent moisture removal system, to see the intended results.

<u>Summary of the work conducted in the year 3 (2018):</u>

- The best coatings and packaging liners from the 2017 trials were used in this year’s work.
- Studied the interaction effects of the select coatings with packing liners with 2% desiccant and liners provided by packaging facility.
- Conducted two trials on packing lines with Gum Acacia (var. Senegal) with modified agar and sodium alginate, fungicide treatment provided by the facility, and a combination of both Gum Acacia (var. Senegal) and fungicide with the cherry variety Skeena.
- Tested for physical parameters from the above coatings specifically the stem browning, fruit cracking, and overall weight loss over time.
- Performed sensory analysis on the coated cherries to see if consumers can detect any difference in the coated and uncoated cherries, after week 1 and week 4 of storage periods.

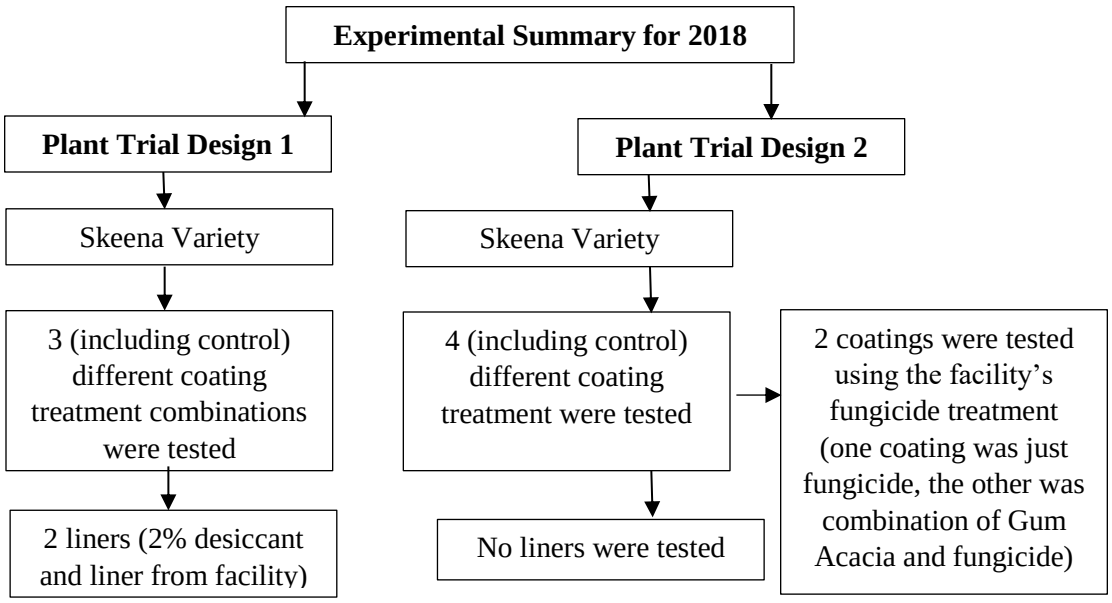


Figure 1. Flow chart showing the summary of the experiments conducted in 2018. All treated cherry samples were subjected to storage studies for 5 to 6 weeks.

Following are the significant findings categorized by Plant Trials:

2.2.1 Skeena Design #1 (Plant Trials) 3 levels of coatings and 2 levels of liners

- Gum Acacia (var. Senegal) (@ 0.5%) showed the best results for controlling stem browning and reducing cracking.
- Gum Acacia (var. Senegal) (@ 0.5%) combined with 2% loaded desiccant was less effective relative with the treatment combined with the regular packaging from the facility, for stem browning.

2.2.2 Skeena Design #2 (Plant Trials) 4 levels of coatings with single liner

- Gum Acacia (var. Senegal) (@ 0.5%) combined with fungicide treatment, had the least amount of stem browning.
- Gum Acacia (var. Senegal) (@ 0.5%) combined with fungicide treatment had least average cracking percentages than other coatings.
- Gum Acacia (var. Senegal) (@ 0.5%) was shown to have the most average green stems over the 6-week storage.

2.3 Sensory Analysis

No differences were observed in the parameters of aroma, sweetness, sourness, cherry flavor, stem color, texture, and overall acceptance and appearance amongst the i) Control (no coating) and ii) Gum Acacia (var. Senegal) at 0.5% concentration for treatments of Skeena cherries after 4 weeks of storage.

3. METHODS:

Note: *Materials and Methods described in this section are for the year 2018. For the whole project similar materials and methods were used. In the year 2018, only the Skeena variety was tested. While in the previous years, the other varieties tested included, Chelan and Sweethearts.*

3.1 Materials:

For the year 2018, two plant trials for *var.* Skeena, was conducted with the help of a packing facility in Wenatchee WA. These two trials were conducted in the same packaging environments in the same facility. The first comprised of 3 coatings with a control (water/no coating) treatment and 2 liner types with varying desiccant levels. The second study had 6 different coatings including control (water/no coating) with a single liner. The air knife treatment, to remove the excess coating from the surface was applied for all treatments in the plant. These cherries were then packed in carton boxes and stored in Johnson Hall's ground floor refrigerators at Washington State University (WSU), Pullman. These cherries were stored on in a refrigerated environment on average of 37.1^{o}F & 96% RH. These two trials have been referred to as Design #1 and Design #2 respectively throughout this report.

3.2 Coating Application:

For both designs, the cherries were coated using the dunking method, where the cherry feed drops the cherries into the coating solution for immersion and then taken by the conveyor belt to the packaging part of the line. The excess coating was drained off with the help of the air knife attached to the processing line before the cherries are packaged. Depending on design, the cherries were packaged in standard bags and boxes with some containing either a 2% desiccant liner or liners already provided at the facility. Following this, the cherries were transported to WSU and stored in the walk-in refrigerator for the storage studies. These studies were carried for 6 weeks, with quality parameter testing once every week and sensory testing after week 2 and week 4.

3.3 Coatings Used:

Table #1: Details of coatings used throughout the experiment

Sr. no.	Code	Coating	Solution Conc. %
1	C1	No Coating/ Water	
2	C2	Gum Acacia Senegal 100%	0.5%
3	C3	Gum Acacia Senegal 80% & Sodium Alginate 20%	
4	C4	Gum Acacia Senegal 90% & Agar 10%	
5	F1C2	Gum Acacia Senegal 100% with Fungicide Treatment	
6	F1	Fungicide Treatment	

Table #2: Details of packaging liners used

Sr. no.	Code	Liner with % desiccant loading
1	P1	2%
2	P2	Provided by facility

a) Dipping method

b) Waterfall Method

Figure 2. Coating application methods used in different plant trials.

3.4 Fruit Quality Testing Parameters

Cherries were analyzed for seven quality parameters each week through the entire storage period of respective trials, as described in the original proposal. Quality parameters determined were Weight loss, Cracking, Firmness, Pedicel browning, pH, Total Soluble Solids (TSS) (^{o}Bx), Titratable Acidity (% malic acid). For the year 2018, we only the stem browning, fruit cracking and weight loss were measured.

3.5 Sensory Analysis

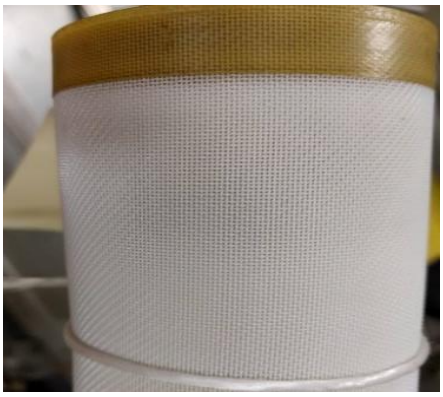
The sensory analysis of untrained panel (n=120) was carried out for the Skeena variety cherries with the coatings listed in section *2.3.* The fruit selected for the sensory analysis belonged to the Liner Type E.

4. RESULTS & DISCUSSION

From the experiments conducted during the year 2018, the following are the key points,

- During the first set of trials in 2018, we did not have effective surface moisture removal, which led us not to rely on that set of data, as high moisture in the packages led to mold growth.
- The second set of trials were much better, although there was still some moisture left in the packages
- Gum Acacia (var. Senegal) performed well with the packing liner loaded with 2% desiccant in terms of reducing cracking.
- The effect of the modifiers with Gum Acacia (var. Senegal), did not show any significant added benefits with desiccant embedded packaging.
- Gum Acacia (var. Senegal) which had proven to have the best effects on reducing cracking and stem browning in previous year's study did perform well again this year.
- In the plant trial, modifiers; Agar and Sodium Alginate, with Gum Acacia (var. Senegal) were tested to check if any synergistic effect to improve the fruit quality. Gum Acacia (var. Senegal) alone provided better results relative to the combinations.

a) Belt with larger pore sizes



b) Mesh belt with smaller pores

Figure 3. Different types of drain belts used in the plant trials.

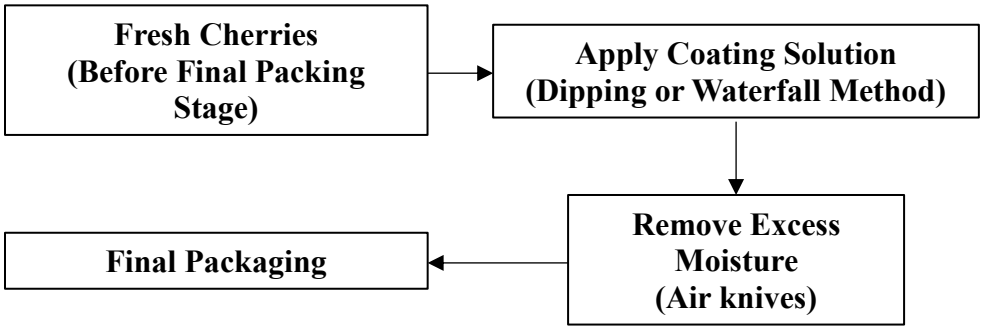


Figure 4. The flow chart showing the process of application of the coatings.

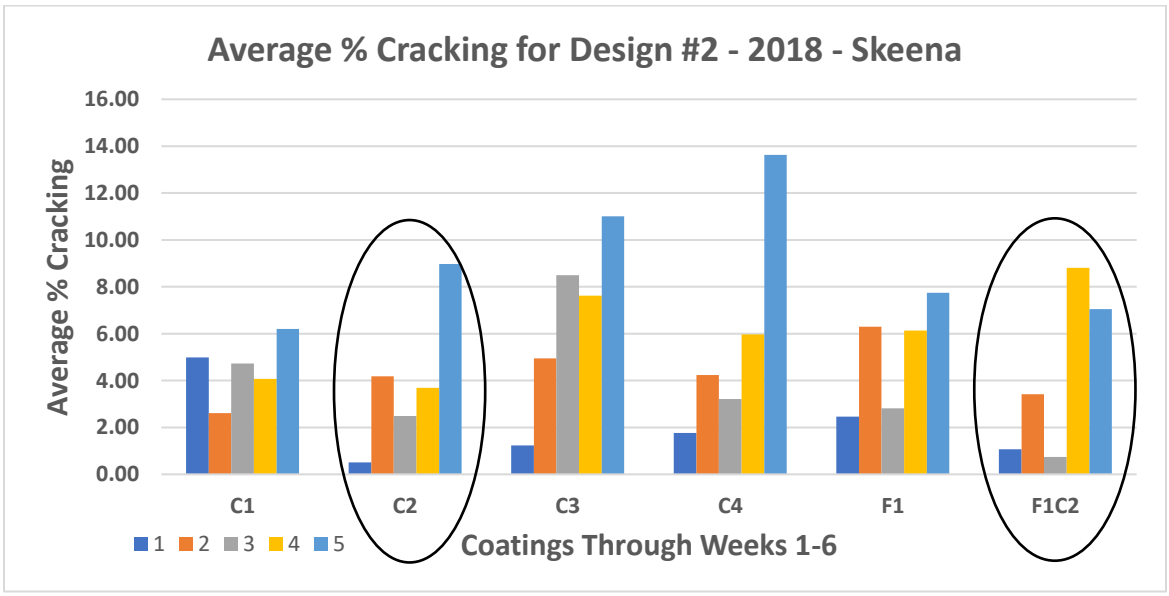


Figure 5. Cherry cracking data over the storage period of 5 weeks. Numbers 1 to 5 indicate the weeks of storage.

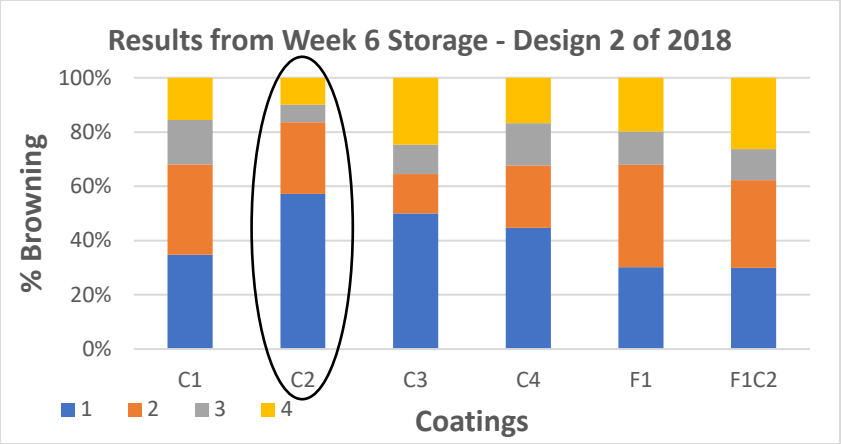


Figure 6. Stem browning results from Design 2, of the 2018 Trials for Skeena variety. (1 to 4, represent the varying stem color from green to brown, with 1 representing very green and 4 representing very brown)

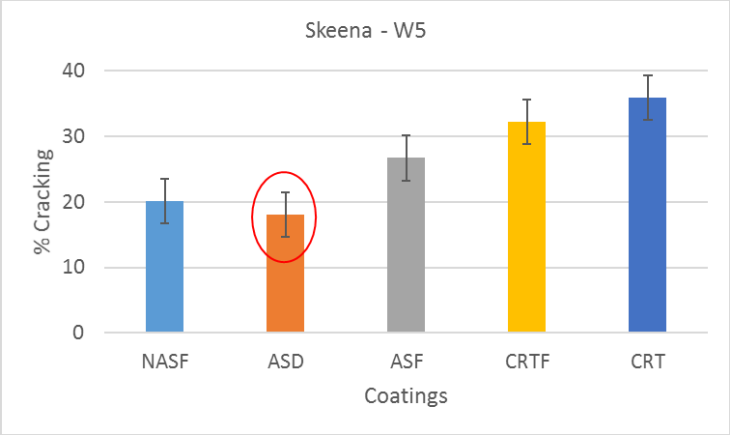
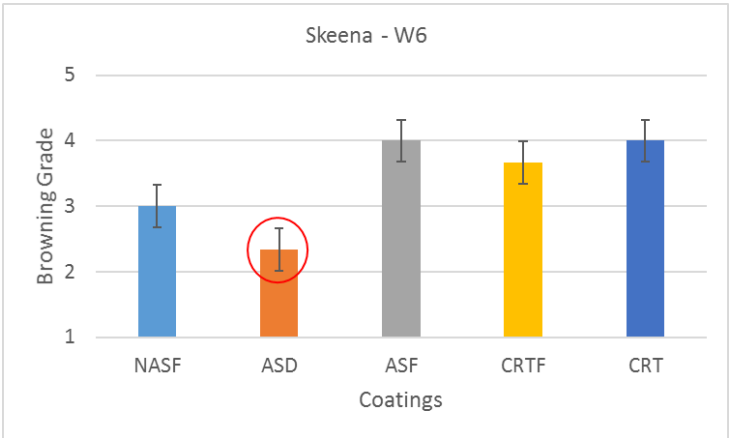


Figure 7. Percent cracking in cherries with difference coatings on Week 5 (W5) for the plant trials with Skeena variety. ASD - Gum Acacia Senegal (100%) at 0.5% concentration.

Figure 7 and 8, show the results on the % cracking and pedicle browning in the cherries, from the plant trials in <u>2016.</u>

It is clear from the Figure 7 that all the coatings showed a reduction in the cracking compared to the control treatment (CRT) and the fungicide treatment (CRTF).



on Week 6 (W6) for the plant trials with Skeena variety. ASD - Gum Acacia Senegal (100%) at 0.5% concentration.

The pedicle browning was significantly reduced by the coating "Gum Acacia – Senegal". It was the most effective. The coating, NASF (Gum Acacia – Seyal + Sodium Alginate), also was effective in reducing the pedicle browning (Figure 8).

These results show the effectiveness of the selected edible coatings in reducing the cracking and the stem browning.

Figure 9 and 10, show the results on the % cracking and pedicle browning in the cherries, from the plant trials in 2017. A significant reduction in cracking was observed at week 3 with Gum Acacia Senegal with Liner embedded 0% desiccant.

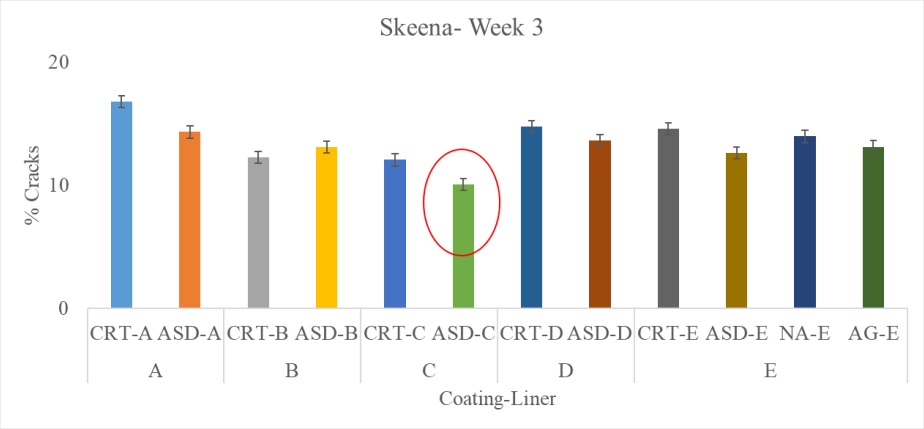
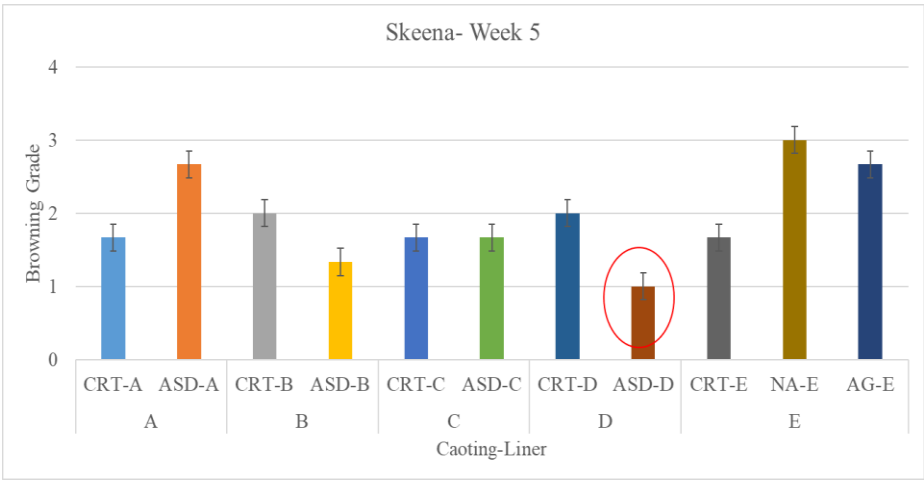


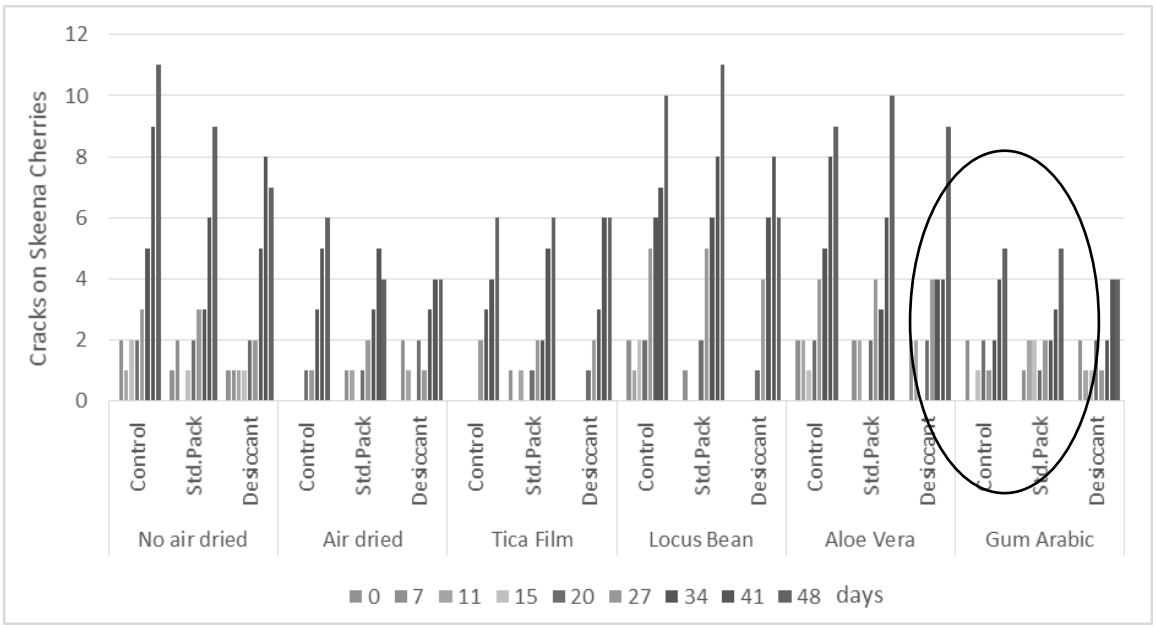
Figure 9. Percent cracking in cherries with ASD and Control at various liner levels at Week 3 for the plant trials with Skeena variety. ASD - Gum Acacia Senegal (100%) at 0.5% concentration. Liner C – 0% desiccant loading.



The pedicle browning was significantly reduced by the coating "Gum Acacia – Senegal" with Liner having 6% desiccant loading.

Figure 10. Pedicle browning in cherries with difference coatings on Week 5 for the plant trials with Skeena variety. ASD - Gum Acacia Senegal (100%) at 0.5% concentration. Liner D – 6% desiccant loading.

These results show the effectiveness of the selected edible coatings in reducing the cracking and the stem browning.



(2014 Trial)

Figure 11. Cracks observed in Skeena Cherries during storage studies (plant trial)

Table #3: Mean hedonic scale values for sensory attributes of fresh cherries for appearance, aroma, sweetness, sourness, cherry flavor, texture and overall acceptability. Each value is mean of 120 responses and represents a value along a 9-point hedonic scale. Values within a row followed by the same letter are not significantly different ($p<0.05$).

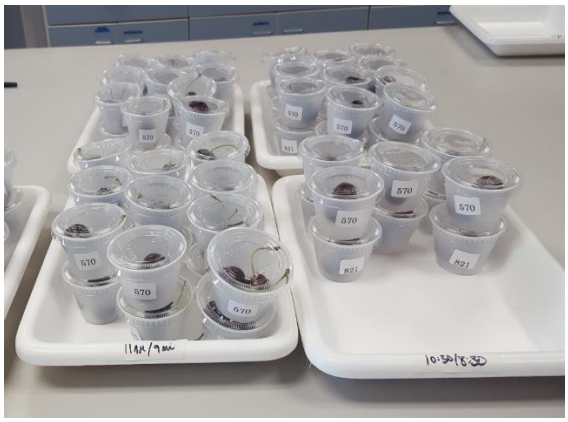
Week 1

Attribute	Coating	Control
Overall Appearance	6.54b	7.11a
Color of Fruit	7.17a	7.31a
Size	7.64b	7.82a
Stem Color	5.83a	5.99a
Aroma	5.80a	5.63a
Texture	7.10a	7.38a
Juiciness	7.17a	7.24a
Sweetness	6.99a	6.91a
Sourness	6.57a	6.63a
Cherry Flavor	6.86a	6.90a
Overall Acceptance	7.28a	7.27a

Week 4

Attribute	Coating	Control
Overall Appearance	6.54 b	7.11 a
Color of Fruit	7.17 a	7.31 a
Size	7.64 b	7.82 a
Stem Color	5.83 a	5.99 a
Aroma	5.80 a	5.63 a
Texture	7.10 a	7.38 a
Juiciness	7.17 a	7.24 a
Sweetness	6.99 a	6.91 a
Sourness	6.57 a	6.63 a
Cherry Flavor	6.86 a	6.90 a
Overall Acceptance	6.75 a	7.05 a

(a)



(b)

Figure 12. Pictures of cherries during sensory evaluation, a) Grocery shelf-style bags of cherries for individual evaluation; b) Soufflé cups of cherries in serving order and organized by time pulled from refrigeration to ensure equitable panelist experience.

5. IMPACTS TO THE CHERRY GROWERS

The results from the project provide potential solutions for the post harvesting fruit cracking and stem browning issues. These solutions may not provide 100% reduction in cracking and stem browning, but does provide significant reduction, that maybe enough in some cases to increase the shelf-life by a few days in the market.

If the process of application of the coatings and excess moisture removal is followed carefully,

- The solutions can aid in reducing the cracking and the pedicle browning, there by extending the shelf life for the Cherries to be sold in the market by retaining the fruit quality.

- For the international markets, where the Cherries are cooled further using forced air cooling, this solution can help reduce the stem browning that occurs due to drying during forced air cooling process.

- This will potentially help increase the income for the Cherry growers, due to extended shelf-life of the Cherries.

Executive Summary

Postharvest cherry cracking and stem browning are major issues for fresh cherry markets. These issues can lead to significant economic losses, due to deteriorating fruit quality. It has been hypothesized that the excess moisture in the packaging can lead to its absorption into the fruit. This absorbed moisture along with the change in the physiology of the fruit can lead to the cracking of the fruit. If the conditions are too dry that can lead to the browning of the stems. Both the fruit cracks and brown stems can lead to lower consumer acceptance.

In this project, we tested various edible coatings (both lipid and water soluble) to evaluate their efficacy in reducing the fruit cracking in the post-harvest storage. From the three years of rigorous testing both on the laboratory and production scale, we were able to conclude that the, Gum Acacia (Gum Arabic) was the most effective in reducing the cracking and delaying the stem browning. This coating showed the best results compared to all other coatings that were tested.

The coating can be applied on the packing line, towards the end of the line, just before the last step of packing process. Either the dipping method or the waterfall method of application can be used, like the way the fungicide is applied in some packing facilities. Immediately after the application of the coating, a set of air knives can used to remove as much of the surface moisture as possible. In this process of surface moisture removal, the use of proper drain belt is critical. If the surface moisture is not removed properly then the benefits of the coating were not seen, as the excess moisture leads to mold growth. After the moisture removal, the cherries can be packaged in the regular packaging.

During the last two years of the project, sensory evaluation of the cherries was conducted, to determine if the consumers can differentiate between the coated and uncoated cherries. The cherries (coated and uncoated) that were in the storage for 1 week and 4 weeks, were tested. Based on the testing conducted, the consumer did not notice any obvious differences between the treatments.

Due to the size of this project, all the studies conducted were applied in nature. It is recommended that further studies be conducted to understand the fundamental aspects behind the observed results. Further studies are needed to evaluate the performance of the coatings in the industrial setting and during the typical transportation conditions, both at the national and international levels.