FINAL PROJECT REPORT **YEAR**: 2014-15

WTFRC Project Number: CH-14-104

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Cooperators: Shield Bags and Printing Company, Yakima, WA; Stemilt Growers LLC., Wenatchee, WA; Western Sweet Cherry Group, Yakima, WA; Van Doren Sales, Inc., Wenatchee, WA, Tate & Lyle Co., Hoffman Estates, IL; TIC Gums, White Marsh, MD; Pace International LLC, Wapato, WA; AloeCorp Inc., Lyford, TX, Chelan Fruit Co, Chelan, WA, Allan Bros Fruit Co, Naches, WA.

We are very grateful to our co-operators for helping us in many aspects of the execution of this project. Thank you to all the co-operators.

Budget: **Year 1**: $24,567 **Year 2**: $24,932 **Year 3**: N/A

Other funding sources: Partial support from Dr. Ganjyal's new faculty start-up funds to fund the graduate student who worked on this project.

Note: We will be happy to share detailed data that is not included in this report, because of space limitations. In the near future we plan to publish the data in peer reviewed journals that we will share with the commission.

Budget 1:
Organization Name: WSU **Contract Administrator: Carrie Johnston**
Telephone: 509-335-4564 **Email address: carriej@wsu.edu**

Item	**2014**	**2015**
Salaries	$13,510	$14,092
Benefits	$2,252	$2,342
Wages	$1,973	$3,553
Benefits	$192	$345
Equipment	$1,500	
Supplies	$3,500	$3,000
Travel	$1,600	$1,600
Miscellaneous		
Plot Fees		
Total	$24,567	$24,932

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.

OBJECTIVES RECAP

1. Test the feasibility of using cold air impingement drying with optimal relative humidity to effectively remove the residual moisture from the cherries before packaging.
2. Screen various edible coatings on to the cherries for their ability to act as a moisture barrier.
3. Develop packaging strategies with desiccant to reduce the moisture available in the packaging environment for cherries.

SIGNIFICANT FINDINGS

Following are the significant findings of the research carried out:

1. The air knives effectively remove excess moisture from the fresh cherries before packing. Removal of excess moisture from cherry surface contributes to the reduction of fruit cracking during refrigerated storage and also improves shelf-life.

2. 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 (see Figure 6).

3. The 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.

4. We selected 4 different coatings during the first year (by screening 16 total coatings) and tested them in the final plant in the year 2014. Out of these 4 coatings, we found that gum acacia (gum Arabic) was the best in terms of reducing the fruit splitting and pedicle browning.

5. Coating of cherries with gum acacia (gum Arabic) solutions consistently reduced the number of cracks during multiple trials.

6. The gum acacia concentration of 0.5% and 1.0% were tried in the 2nd year of the project. Both showed similar effectiveness. Although it will be important to test higher concentrations to see if it can increase the effectiveness of coating further.

7. Packaging with desiccant significantly decreased the cracking during storage. We tested one level of desiccant in the package during both the years of testing.

8. Packaging with desiccant and with the holes contributed to significant reduction in the cracks (see Figure 5 & 6).

9. The treatment with "gum Arabic" coating and the air drying 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 7 weeks storage were > 55% compared to other treatments (see Figure 6 and 7).

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

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

12. The results thus far have taken us into the direction where we believe that there is the potential to help reduce not only the cracks/splits, but also the stem browning.

13. Based on the results obtained so far, we have now proposed a new 3-year project to continue this work on enhancing the edible coating and the packaging and providing a toolbox of solutions that the cherry industry can implement in the future.

METHODS

Materials and Trials

We tested “Chelan”, “Skeena” and “Sweet Heart” variety of cherries. During first year trials, the pre-sorted, cleaned and sized fruits were packaged in a bag/box system at packaging houses and transported to the pilot plant at School of Food Science, Washington State University (WSU). The cherries were kindly provided by Western Sweet Cherry Group, Yakima and Stemilt Growers LLC, Wenatchee. Additional to the laboratory trials, during the first year we were able to conduct one plant trial at Stemilt packing facility. During this trial we tested four different coatings and the desiccant packing.

In the second year, a total of three plant trials were conducted at Stemilt Growers LLC in Wenatchee, WA (Trial#1), Chelan Fruit in Chelan, WA (Trial#2) and Allan Bros Inc. in Naches, WA (Trial#3) cherry packing houses. After treatments, cherries were packaged, boxed and brought to WSU for storage and quality evaluation.

We are very grateful to all the co-operators who have supported us significantly during the trials.

Edible coatings

During initial trials (in 2014), a total of 4 different coatings that were prescreened during lab testing, were applied on the cherry fruit surface. In the initial prescreening over 16 different coatings were tested in the laboratory. The 4 coatings were selected based on the ease of application and their ability to dry without leaving any residue in the bags during storage.

Locust Bean Gum, TICA film and Gum Acacia (Gum Arabic) were obtained from TIC Gums (White Marsh, MD) while Aloe Vera coating was obtained from Aloe Corp (Eastern USA). All the coatings were prepared by first dissolving them in warm water at various concentrations as follows Aloe Vera (0.5%), TICA film (0.5%), Gum Arabic (1%) and Locust Bean Gum (0.3%). All coatings were cooled to room temperature before applying to the Cherries. Cherries were coated by dipping them in the solutions followed by blowing air through air-knives for removing the excess coating from the surface. Based on the performance of edible coatings during first year trials, Gum Acacia (1 and 2%) and TICA (0.5 and 1%) solutions were used for coatings of cherries during the second year trials During the 2nd year’s work, only gum acacia was found to be more effective and was the only one used for the trials. The solution concentrations of 0.5% and 1% were tried during this year.

The coatings were applied by two different methods, during the plant trials. In the first method (Figure 2a), cherries were dipped in coating solutions in the last section of the packing line (where the fungicide is usually applied) and then passed on the air knives and the packaging. In the second method (Figure 2b), the coating solution was poured on to the cherries, followed by air drying of coatings and packaging. Both methods of coating application were effective.

Excess surface moisture removal

The surface moisture on the cherries was removed with an air knife system. (Air Control Industries Inc., Maine). The system consisted of two air knives along with an air blower. The system was installed over conveyor belt on the packaging line just before packing. Please see Figure 2, showing the air knife system.

Packaging

Plastic films incorporated with desiccant agent were fabricated by Shield Bag and Printing Company, Yakima. The same plastic film without desiccant was also used as control treatment. Both films were used to prepare bags with and without holes.

A total of 24 holes were punched on each bag distributed as follows: 8 in the bottom and 8 in each face of the bag (front and back). The holes diameter was 8.343 mm (or 0.3284 in). Commercially available bags used for cherry packaging were also used as another control.

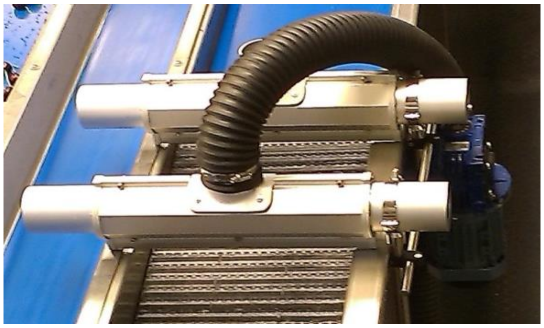
The set of different treatment includes; bag without desiccant and without holes, bag without desiccant and with holes, bag with desiccant and without holes, bag with desiccant and with holes, and a standard industry bag.

During first year trails, five bags for each treatment were filled with 25 cherries while in the second year trials, packaging bags were completely filled with cherries.

The bags were kept in the cold room maintained at 40-41˚F and relative humidity 86% for 4-6 weeks for storage studies. Based on the findings from first year trials, bags with holes were used in the second year trials.

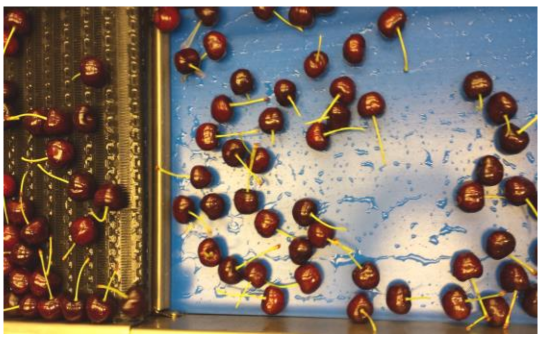
(a) Dipping method *(b) Water fall method*

Figure 1. Methods of edible coating application in the packing house



(a) Air Knife System Installed

(b) Air knife System in Operation



(c) Cherries without Air Drying

(d) Cherries with Air Drying

Figure 2. Air drying system developed for removing the excess moisture in fresh cherries.

Fruit quality determinations

Cherries were analyzed for five quality parameters at regular storage interval. Quality parameters evaluated were including weight loss, color, firmness, ˚Brix, and pH. Weight loss was determined by weighing the samples with digital balance (Startorious, MCL). Color and firmness measurement were performance in a subsample of ten cherries in each treatment. Color change of Chelan and Skeena cherries was measured in the skin with a tristimulus colorimeter (Color spectrophotometer CM-5, Konica Minolta) which provided CIE L^* (lightness), a^* (green to red) and b^* (blue to yellow) values. Fruit firmness was determined by measuring the force required to compress the fruit 2 mm using texture analyzer TA-TX2 equipped with a 3 mm diameter convex probe at a speed of 20 mm min $^{-1}$ (Salato et al., 2013). Every fruit was measured on the equatorial plane and the registered forces were averaged and reported. Then the content on each bag was manually crushed to extract the cherries juice which was used for ˚Brix and pH determination by triplicate in each storage stage. Total soluble solid (TSS) expressed as ˚Brix were determined in each slurries by refractometry with han-held temperature-compensated digital refractometer (Refracto 30GS, Mettler Toledo). The pH values were measured by using a pH meter (Symphony B30PCI). The cherries were also examined visually for cracks and mold growth. Pedicel browning was also observed and expressed as the percentage of fruit with >30% stem surface discoloration.

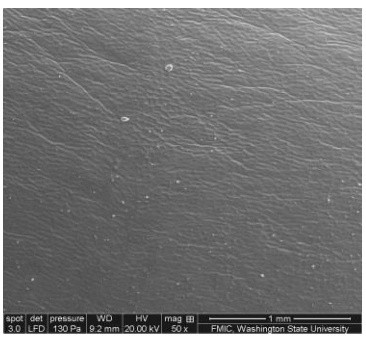
RESULTS AND DISCUSSION

Please refer to Figure 3 for the brief overview of all the testing done during the years 2014 and 2015. In the year one we conducted extensive laboratory testing to arrive at the best 4 coatings and we did conduct one plant trial with all the 4 different coatings. During 2015, we conducted 3 different plant trials. In only the first trial of 2015, we used 2 coatings (gum acacia and TICA film) and only one coating (gum acacia) was used, as it was found to be more effective from all the previous trials.

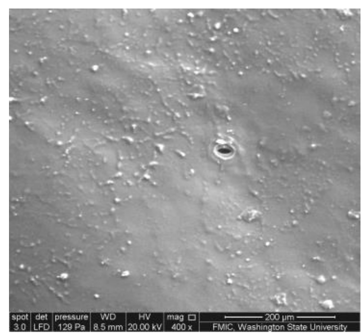
Laboratory trials and Plant trial (summer 2014)

Microscopy studies of the fruit surface

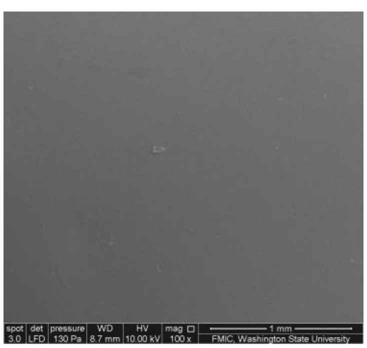
The micrographs obtained using Scanning Electron Microscope (FEI, Model Quanta 200F, FEI Company, U.S.A.) indicated pores of 20 microns in size and the uneven surface (Figure 4a and b). This uneven surface can serve as pooling spots for excess moisture. Our hypothesis is that edible coating can smooth out the fruit surface (Figure 4c and d) and decrease moisture accumulation on the surface even. This should also decrease moisture absorption into the cherries thus contributing to the reduction of cherry cracking.



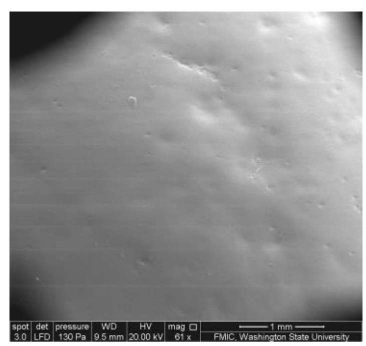
(a) Surface without coating



(b) Surface without coating



(c) Surface with coating (TICA film)



(d) Surface with coating (Gum Acacia)

Figure 4. Microscopy images of fresh cherry surface with and without the coatings

Effect of air drying and edible coatings on fruit quality

The coating of “gum Arabic” solution when stored in bags with both the regular company bags (control bags) and the bags incorporated with desiccant (desiccant bags) reduced the number of cracks in Skeena cherries (Figure 6). The titrable acidity reduced during storage the influence of coatings and air drying was small. The ºBrix of cherries was not influenced by the treatment conditions. The firmness of cherries was reduced with storage time but the “gum acacia” and “aloe vera" coatings were able to lower the changes in firmness. Both TICA film and "gum acacia" helped reduce the cracks in the cherries significantly. These cherries with edible coatings were all air dried. The change in color was small and consistent will all treatments.

Air drying alone helped reduce the number of cracks (Figure 6). The addition of the coatings helped this more and the effects were more prominent when we looked at the pedicel (stem) browning data (Figure 7). The treatment with the "gum acacia" coating with air drying and stored in the control bag was found to have the least number of brown stems. This suggests that the coating helps to provide a seal on the stems and reduces the rate of moisture loss from the stems to the surroundings.

Effect of packaging on fruit quality

The number of cracks in the cherries was less in desiccant bags compared to the control bags (Figure 5) for Skeena variety in the laboratory trials. The packaging did not show significant added benefit over the coating treatment alone in the plant trials for the Skeena variety (Figure 6). The weight loss in cherries generally increased with storage time. The weight loss in Skeena (5.7%) was higher than Chelan (4.2%) during 35 days of storage. Bags with no perforation had lower losses in the cherry weight. This is because perforation allowed water vapor to escape from the bag.

Incorporation of desiccant in packaging bags significantly reduced the weight loss in Chelan but had less influence in Skeena. The pH and ºBrix of cherries did not change significantly during storage time. The influence of types of packaging on pH and ºBrix was also not significant. The firmness of cherry was not influenced by the packaging conditions. The change in color of cherries was small during storage but packaging conditions did not influence the total color change. The packaging films incorporated with desiccant and having perforation reduced the number of cracks for both types of cherries during and at the end of storage time.

Plant trials (summer 2015)

Effect Surface moisture removal and edible coatings

The "gum Arabic" showed the reduction in the cracks over the storage period of 6 weeks (Figure 8). Figure 8 shows the data of the cracks in cherries from our plat trial #3, when the air knives performed really well. The effectiveness of the air knives was really great during this trial. From this data and from the other trials it was conclusive that the air knives were effective in reducing the cracks, as they removed the excess moisture from the cherry surface before they were packaged in the bags.

The coating (gum Arabic) was effective in reducing the cracks (Figure 6) over the storage period of 6 weeks. From our data from all the plant trials during 2015 this was the trend we observed. In some cases the inclusion of desiccant bags made a difference and in some cases it did not.

The weight loss in coated and uncoated cherries was in the range of 2.6 to 3.5%. Edible coatings and surface moisture removal slightly increased the weight loss in the cherries from trial#1, while cherries from trial #2, weight loss were in the range of 3.6 to 4.9%. Again, surface moisture removal and edible coatings increased the weight loss.

In general, edible coatings significantly reduced the cracking from 7.7% to 3.8% in cherries from trial #1 while in cherries from trial #2 the cracking reduced from 5% to 2.5%. For trial#1 cherries, TICA coating of 0.5% solution was most effective while Gum Arabic coating of 1% was more effective for trial#2 cherries. It is to be noted that the air knives set-up did not perform well during trial#1. Gum Arabic coating of 1% solution was most effective in maintaining the firmness of all the trials.

Packaging

In trial#1, the weight loss in cherries (uncoated and no moisture removal) increased up to 3.6% during five weeks of storage depending on the packaging. It is to be noted that the air knives set-up did not work well during this trial. The weight loss in desiccant incorporated bags (3.6%) was slightly higher than weight loss in company bags (2.6) and control bags (2.4%). However, for the trial #2, there was no significant difference in weight loss of cherries stored in different bags. The weight loss during five weeks of storage was around 3.6%. For trial #1, the % of cracking in desiccant bag (6.4%) was lower than company (7.7%) and control bags (12.3%). For trial #2, the overall cracking was lower than trial #1 and it was in the range of 0.8 to 5% depending upon the bag. Desiccant incorporated bags helped retain fruit firmness for trial#1 while types of bags did not significantly influence the cherry firmness.

Combined effects of treatments

The weight loss in trial#1 cherries packaged with control bags was lowest with TICA coating at 0.5% while for trial#2 cherries TICA coating at 1% with control film and Gum Arabic coating of 1% solution with desiccant bag were resulted in lower weight losses. This suggests that the coating helps reduce the moisture transfer from the cherries to the atmosphere. Gum Arabic coating of 1% with desiccant bag for cherries from trial#1 and TICA coatings at 1% in desiccant bag minimized the fruit cracking. For maximum fruit firmness, Gum Arabic coatings of 1% solution with control bag and no coating with desiccant bag were the best for cherries from trial #1 while for cherries from trial#2, Gum Arabic at 1% with company bags and no coatings with desiccant bags were equally effective in maintaining the firmness. Overall, Gum Arabic coatings of 1% solution and desiccant bags combination were the best for reducing the cracking and maintaining the overall quality of cherries.

Final remarks

All three treatments i.e. surface moisture removal, edible coatings and packaging incorporated with desiccant significantly reduced cherry cracking and pedicle browning. The treatments marginally increased the weight loss while they had positive influence on fruit firmness. All treatments had minimal or no influence on other chemical quality parameters such as pH, ºBrix, and color. The treatments such as surface moisture removal, edible coatings and packaging film incorporated with desiccant significantly reduced the number of cherries with cracks.

SIGNIFICANCE TO THE INDUSTRY & POTENTIAL BENEFITS

Post-harvest cracking/splitting of cherries is one of significant issues to the industry. Any reduction in fruit cracking/splitting and pedicle browning will have direct positive economic impact to the industry. The results from this study are encouraging and suggest that the surface moisture removal, edible coatings and packaging incorporated with desiccant can significantly reduce fruit cracking and pedicle browning.

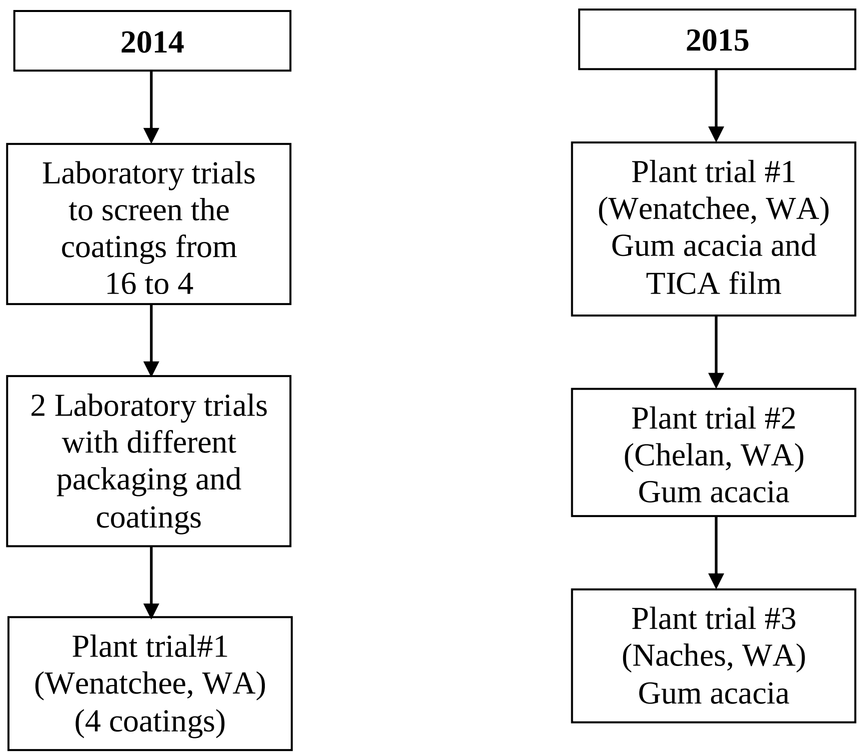
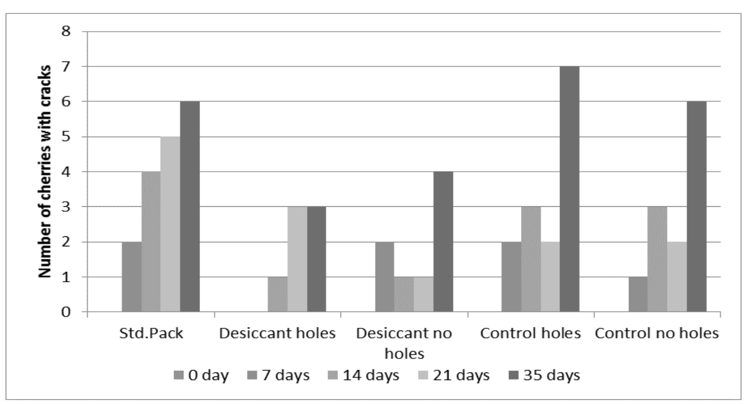
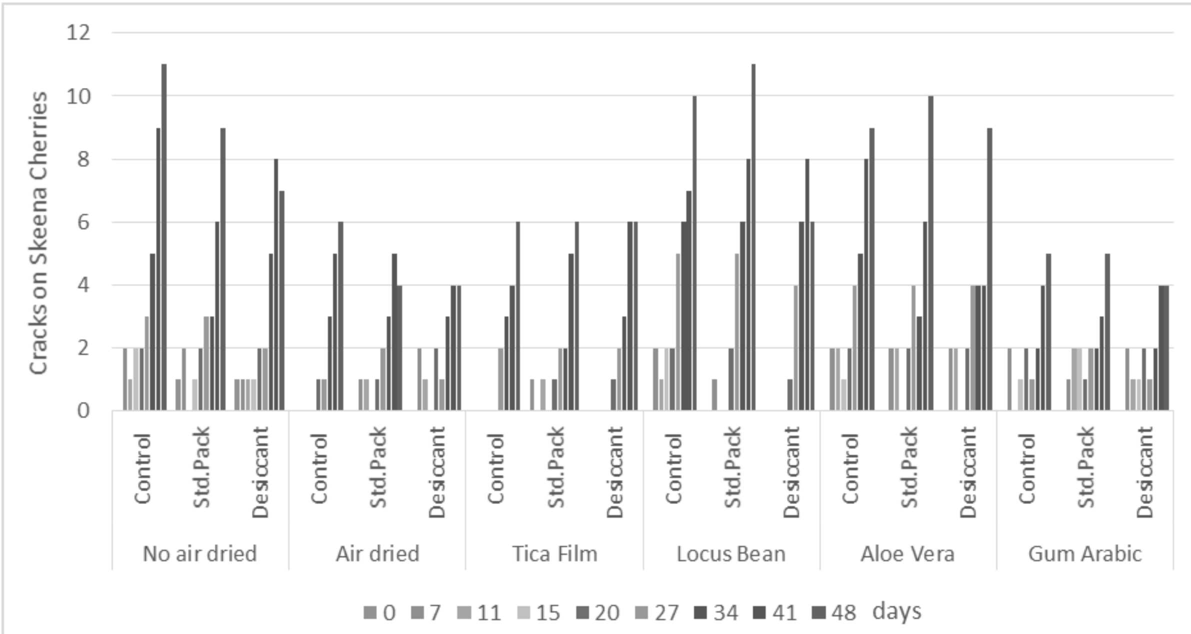


Figure 3: Summary of the trials conducted during the duration of this project (2014 and 2015)



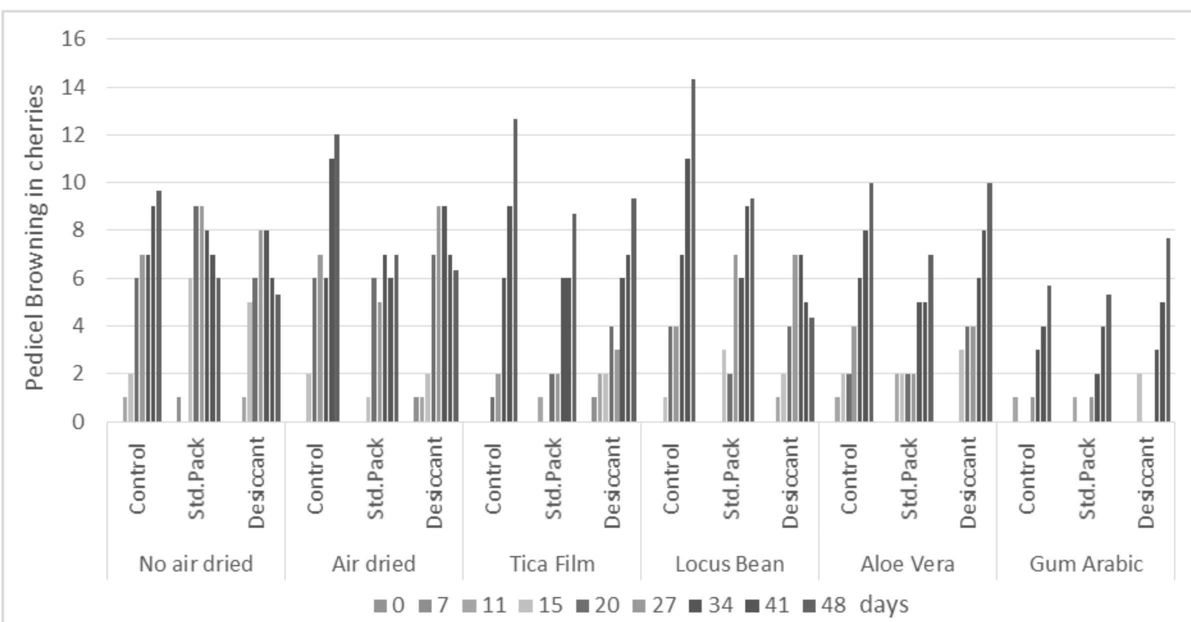
(2014 Trial)

Figure 5. Cracks observed in Skeena Cherries during storage studies (laboratory trials)



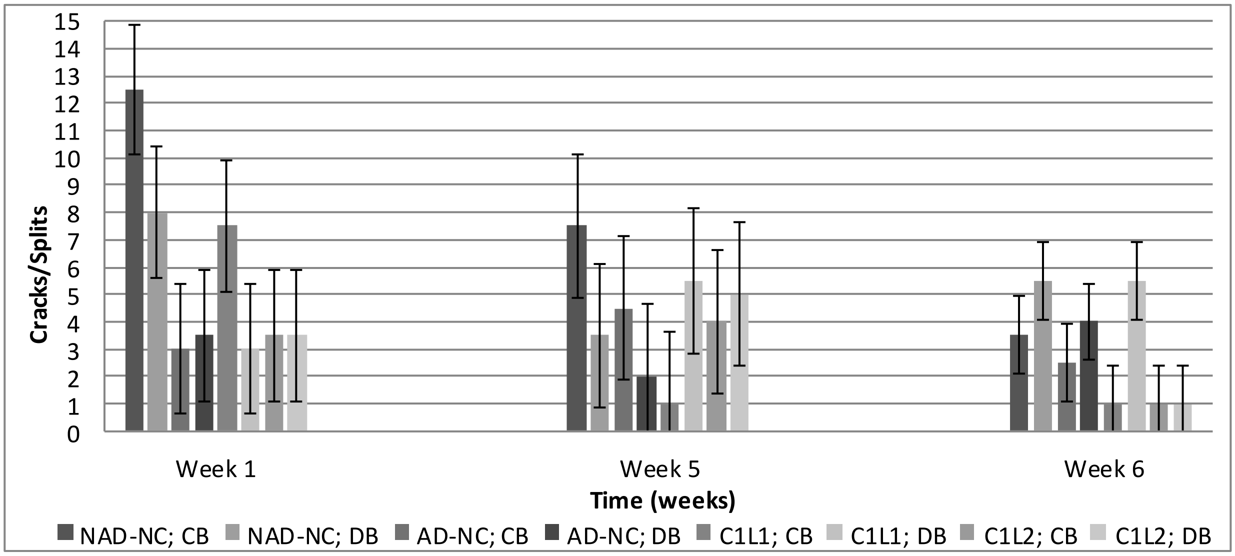
(2014 Trial)

Figure 6. Cracks observed in Skeena Cherries during storage studies (plant trial)



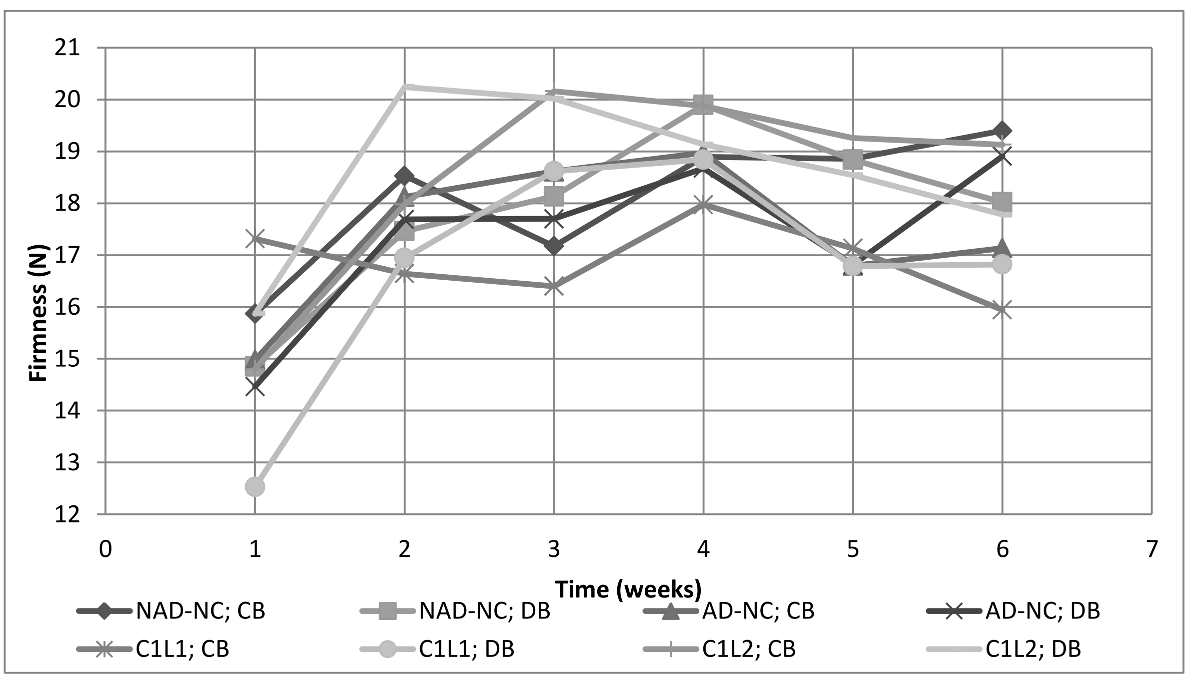
(2014 Trial)

Figure 7. Pedicle browning observed in Skeena Cherries during storage studies (Plant Trials)



(2015 Trial#3)

Figure 8. Cracks observed in Sweetheart Cherries during storage studies (packing house trial #3)
NAD = No Air Drying; AD – Dir Dried; NC = No Coating; C1L1 = Coating 1 (gum acacia) Level 1 (0.5%), C1L2 = Coating 1 (gum acacia) Level 2 (1.0%); CB = Company Bag, DB = Desiccant Bag



(2015 Trial#3)

Figure 9. Firmness of Sweetheart cherries during storage studies (packing house trial #3)
NAD = No Air Drying; AD – Dir Dried; NC = No Coating; C1L1 = Coating 1 (gum acacia) Level 1 (0.5%), C1L2 = Coating 1 (gum acacia) Level 2 (1.0%); CB = Company Bag, DB = Desiccant Bag

EXECUTIVE SUMMARY

A three pronged approach was taken to develop a set of solutions to reduce the postharvest cherry cracking/splitting. Through the two years of work, we have shown that all the three approaches, i) edible coating application, ii) air drying to remove excess moisture/coating solution and iii) packaging with desiccant embedded in the plastic, can help reduce the postharvest cracking of the fruit. Coating of cherries with gum Acacia (gum Arabic) solution consistently reduced the number of cracks during multiple trials. In addition to reduction in the number cracked cherries, this treatment also provided the benefit of reduced pedicle browning. The results thus far have taken us into the direction where we believe that there is the potential to help reduce not only the cracks/splits, but also the stem browning. Further work is needed to refine these solutions and conduct extensive testing in the production facilities.