CENTER for PRODUCE SAFETY

**CPS 2011 RFP**
**FINAL PROJECT REPORT**

## Project Title
Sanitization of soft fruits with ultraviolet (UV-C) light

## Project Period
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## Objectives
1. *Determine the efficacy of UV-C light in inactivating E. coli and Salmonella spp. on inoculated fruit;*
2. *Determine the survival and growth of pathogens during post-UV storage;*
3. *Evaluate fruit shelf-life and changes in fruit quality during post-UV storage at 4 and 20°C;*
4. *Ensure and evaluate UV exposure uniformity using a rotating conveyor and film dosimetry;*
5. *Conduct commercial trials to evaluate the feasibility of the UV technology;*
6. *Evaluate consumer acceptance of UV technology.*

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# FINAL REPORT

## Abstract

Aqueous sanitizers such as chlorine are commonly used by the fresh produce industry to minimize pathogen contamination. However, tree-ripe stone fruits such as apricots cannot withstand these vigorous washing steps because of their advanced maturity and softness. To minimize the risk of human pathogen contamination, fruit must be sanitized by non-aqueous technologies. In this project, we assessed the efficacy of UV-C in inactivating two human pathogens (*E. coli* O157:H7 and *Salmonella* spp.) and in maintaining fruit quality and shelf-life of fruits. For the first time, radiochromic film dosimeters were evaluated and applied to UV-C processing of fruits. Furthermore, to ensure uniform UV-C exposure of all fruit surfaces, two types of rotating devices were developed. In addition, a large scale trial was conducted at our industrial collaborator's site to study the effectiveness of UV-C in reducing population of an *E. coli* O157:H7 surrogate. Results showed that apricot fruit were tolerant to UV-C at doses up to 442 mJ/cm$^2$ without significant changes in color, texture, acidity, mealiness or decay of fruit. *E. coli* and *Salmonella* population on apricot fruit after exposure to high doses of UV-C decreased rapidly during post-UV-C, suggesting that human pathogens did not survive well after UV-C exposure. Results also showed that UV-C could reduce *E. coli* O157:H7 and *Salmonella* spp. on apricot fruit by up to 2 log CFU/cm$^2$ in the lab setting. However, in the commercial trial, the reduction was limited (0.5-0.7 log CFU/fruit) even though a sloped belt was used to rotate the fruit. The low reduction in bacterial population is probably due to uneven UV exposure to the surface of fruit as suggested by the radiochromic film dosimeters attached on the fruit surface. Use of reflective material such as stainless steel and aluminum foils did not provide significant improvement in dose uniformity. A rotating device modified in the lab could achieve high uniformity on surface of fruit. The device needs to be scaled up and applied in a commercial setting. A consumer survey (90 respondents) indicated that 67% of consumers found the use of UV-C to enhance the safety of fresh produce moderately to completely acceptable, which was equivalent to the acceptability for use of UV-C to enhance safety of drinking water. A greater percentage of consumers found UV-C treatment to enhance the safety of produce very or completely acceptable (28%) compared to the use of irradiation to enhance the safety of spices (14%) or leafy green vegetables (17%). The successful implementation of this technology may enable the fruit industry to meet the requirements of the FDA Food Safety Act while improving the microbial safety and increasing the consumption of healthful fresh fruits. The UV technology developed in the proposed study will not only allow many grower/packers to continue marketing the tree-ripe fruits, but also will enable the fruit industry as a whole to adapt the technology to other types of fruits such as apples.

## Background

The recent Food Safety Modernization Act established minimum standards for the safe production and harvesting of fruits and vegetables, based on known safety risks. Each registered facility is required to implement preventive controls or provide assurances that the identified hazards be significantly minimized or prevented. Some fruit growers/packers have been marketing high-maturity fruit for years to satisfy consumers' increasing demand for high quality/improved-flavor fresh fruits. The so-called "tree ripe" fruits are usually harvested at greater than normal maturity. Because of the softness associated with advanced maturity, these fruits will not withstand the rigors of typical commercial packing lines. Washing with aqueous sanitizers (or just water) damages fruit surfaces and shortens their shelf-life. To enhance the microbial safety of soft fruit, non-aqueous sanitization techniques are needed. Ultraviolet light is a nonthermal/nonchemical intervention technology that employs physical light energy of a specific wavelength to inactivate microorganisms. The FDA has approved the use of UV light at a wavelength of 254 nm as a disinfectant to treat food. Although the application of UV-C is able to reduce pathogens on the surface of fruits, there are several challenges for the commercial application of UV technology. First, some fruits may develop discoloration after UV-C light treatment, particularly during post-UV storage. Second, pathogens that reside in stem ends, and in crevices and small cracks on the surfaces of fruit may be shadowed and not exposed to UV light. Also, elimination (or reduction) of natural microflora on fruit may promote the growth of any surviving human pathogens. High doses of UV-C may potentially damage and weaken fruit tissues, which could increase the growth of surviving pathogens. For these reasons, re-growth of human pathogens must be evaluated following UV-treatments.

Perhaps the most significant challenge to the commercial application of UV-C UV techniques for disinfection may be limited to geometrically round fruit. Ideally, fruits should be rapidly and randomly rotated in multiple planes, allowing all-surface exposure from multiple directions and angles of the UV light. It is unclear whether currently-used packing lines are capable of generating this type of rotation to ensure uniform UV exposure. Finally, lack of consumer acceptance has limited the use of some technologies that offer increased product safety. Understanding consumer acceptance of UV-C treatment is an important component to advance use of the technology.

## Research Methods and Results

1. *Determine the efficacy of UV-C light in inactivating E. coli and Salmonella spp. on inoculated fruit;*
   Five strains of *E. coli* O157:H7 [RM 6535 (lettuce), RM 7386 (Romaine lettuce), O6FOO475 (spinach outbreak), RM 1484 (apple juice), and Sakai (sprouts)] and a cocktail of four *Salmonella* spp. cultures [*S.* Newport H1275 (sprout), *S.* Montevideo G4639 (raw tomato), *S.* Stanley HO588 (sprout) and *S.* Saintpaul 02-517-1 (cantaloupe)] were used. Strains of *Salmonella* spp. and *E. coli* O157:H7 were grown separately in 10 ml TSB at 37°C with 100 µg/mL of either nalidixic acid (for

*Salmonella*) or rifampicin (for *E. coli* O157:H7) for 24 h. After centrifuging, pellets were washed with 10 ml peptone water (PW), suspended in PW and combined to produce a cocktail of the four or five strains. Apricots were spot-inoculated onto the cheek area of the fruit with 100 µl aliquots. Fruits were dried for 2-3 h in a biohood. Inoculated apricots were placed into a custom-built UV treatment chamber containing two 0.61-m 55W UV-C emitting bulbs. All fruits were positioned with the inoculated surfaces facing upwards towards the UV-C tubes and were treated with UV-C for 0 (control), 2, 5, 10, 20, 40, 60, 90, 120 and 180 sec (UV-C dose, ca. 7.4 mW/ $cm^2$). After UV-C treatment, the fruit skin with the inoculum was recovered and homogenized in 20 ml of buffered peptone water. Fifty µl aliquots of each of the samples were spiral-plated onto two Tryptic Soy Agar (TSA) plates containing 100 µg/mL nalidixic acid (TSAN) and two XLT-4 plates for *Salmonella*, as well as two TSA plates containing 100 µg/mL rifampicin (TSAR) and two Sorbitol MacConkey Agar (SMAC) plates for *E. coli* O157:H7. Plates were incubated at 37°C for 24 h before colonies were counted.

In addition, a cocktail of 4 strains of Shiga toxin-negative *E. coli* O157:H7 (6980-2, 6982-2, CV267 and ATCC 700728) and four strains of attenuated *S.* Typhimurium strains (χ 3985, χ 4096, χ 8089 and ATCC# 700720-LT2) inoculated on apricots were evaluated for their response to UV-C.

Results showed that *E. coli* O157:H7 and *Salmonella* spp. responded similarly to UV-C. As UV dose increased from 0 to 74 mJ/$cm^2$, there was a rapid decrease in populations of *E. coli* O157:H7 and *Salmonella* spp. The populations continued to decrease with further increases in UV dose, but at a much slower rate. UV-C at a dose of 74 mJ/$cm^2$ could achieve 0.9-1.9 log reductions of *Salmonella* spp*.* and *E. coli* O157:H7 on apricots. Increasing the UV-C dose from 74 to 1326 mJ/$cm^2$ only achieved an additional ca. 1 log reduction.

Populations of *E. coli* O157:H7 and *Salmonella* spp. could be expressed as a function of UV-C dose, using the following exponential decay function with $R^2$ values higher than 0.99. The data could also be described by the Weibull model with the doses required to achieve 90% reduction of *E. coli* O157:H7 to be 18 and 29 mJ/$cm^2$ on TSA and SMAC, respectively. The doses required to reduce *Salmonella* population by 90% were estimated to be 17 and 22 mJ/$cm^2$ on TSA and SMAC, respectively. The non-pathogenic *E. coli* O157:H7 and attenuated *S*. Typhimurium responded similarly as the pathogenic counterpart bacteria showing rapid reductions in low dose range.

Electron microscopic images suggested that trichomes with different lengths, stomata and cuticle waxes were observed on apricot surfaces. The inoculated bacteria were attached on the epidermic cuticle around trichome bases. Some bacteria were found inside the stomata, and many were located in the cracks/gaps between the ridging of cuticle wax. The results suggest that UV-C light may be blocked by the surface structures on the apricot surface, preventing UV-C exposure of all bacteria.

2. *Determine the survival and growth of pathogens during post-UV storage;*
   Cocktails of the four pathogenic *Salmonella* spp. and five *E. coli* O157:H7 strains mentioned earlier were prepared and used to inoculate apricots as described above. Spot inoculated apricots were treated with UV-C for 0 (control), 10, and 60 s (UV-C intensity, *ca*. 7.4 mW/ $cm^2$). Following treatment, fruit were stored at 2°C for 21 days as well as at 20°C for 8 days. Populations of *Salmonella* spp. and *E. coli* O157:H7 were recovered periodically from apricots during storage, followed by enumeration on two TSA plates containing 100 µg/mL nalidixic acid (TSAN) and two XLT-4 plates for *Salmonella*, as well as two TSA plates containing 100 µg/mL rifampicin (TSAR) and two SMAC plates for *E. coli* O157:H7.

   Results showed that populations of *E. coli* O157:H7 and *Salmonella* spp. on all apricots decreased during storage at 2 or 20°C. However, samples treated with 442 $mJ/cm^2$ (60-sec) UV-C decreased much more rapidly following UV-C treatments than non-treated controls. After 21 days of storage at 2°C 8 days at 20°C, *E. coli* populations on fruit treated with 442 $mJ/cm^2$ UV-C were more than 3 log CFU/fruit and *Salmonella* populations were at least 2 log CFU/fruit lower than those on the non-treated control. Our results indicate that *E. coli* and *Salmonella* survived well on non-treated apricots during storage either at 2°C or 20°C. More than 5 log CFU/fruit of *E. coli* and *Salmonella* spp. remained on the fruit after 8 days of storage at 20°C or 21 days at 2°C. Following UV-C treatment, particularly at a dose of 442 $mJ/cm^2$, bacteria on apricots decreased more rapidly than those on non-treated fruit during post-UV storage at either 2°C or 20°C.

3. *Evaluate fruit shelf-life and changes in fruit quality during post-UV storage at 4 and 20°C;*
   Robada apricots in the commercial maturity stage harvested from an orchard in Central Washington State were treated with UV-C in a commercial facility. The UV-C intensities ranged from 10.3 to 16.8 $mJ/cm^2$. The speed of the conveyers was adjusted so that the total time that fruit traveled through the two chambers was ca. 20 or 40 sec. Control fruit samples (UV exposure time = 0 sec) were conveyed through the same chambers without exposure to UV-C light. Following treatment with UV-C for 0, 20 and 40 sec, the fruit were transported to the laboratory and stored at 2°C for 0, 1, 2 and 3 weeks plus 3 additional days at 20°C or at 20°C for 1, 4, 7 and 10 days before visual quality, color, firmness, soluble solids content (SSC), and titratable acidity (TA) were analyzed.

   During storage, fruits softened rapidly and TA decreased regardless of UV-C treatments. There were no significant changes in SSC during storage at either storage temperature. Instrumental color parameters (L*, hue and chroma values) of the sun-exposed side of the fruit surface did not change significantly during storage nor was it affected by UV-C. The L*, hue and chroma values of shaded sides of the fruit generally decreased during storage, particularly during the first few days of storage at 20°C. However, there was no visual difference in the scores of browning

among the three treatments for most sampling days during storage. UV-C had no effect on the decay of fruit during storage at 2°C or 20°C. Our results in the present study suggest that UV-C treatment at the doses we used did not have a significant effect on decay, and overall, the fruit had a low incidence of decay, regardless of UV-C treatment.

4. *Ensure and evaluate UV exposure uniformity using a rotating conveyor and film dosimetry;*
To study the UV-C dose uniformity on a fruit, the film dosimetry system that was previously used for gamma radiation was first evaluated. Two types of radiochromic films were exposed to different doses of UV-C and the color of films were measured after UV-C exposure using absorbance at 600 and 510 nm. In addition, the color stability of films following UV exposure, temperature effect on color development of the radiochromic films during UV-C exposure, and effect of UV-C light intensity were investigated. Results showed that the radiochromic films were sensitive to UV-C light as they changed to blue or pink color upon exposure to UV. The developed color after UV-C irradiation was stable for at least 15 days at dark and ambient temperature. Temperature (22°C vs 4°C) at which the films were exposed did not affect color changes as a result of UV-C exposure. $A_{510nm}$ as a function of dose could be expressed as polynomial equations and the equations were used to predict doses on six locations on the fruit surface (see below). Our results indicate that the radiochromic films can be used to indicate UV-C dose.

Two types of rotating devices were tested to enhance dose uniformity. The first one was a sloped belt that connected two UV-C treatment chambers. After fruit exited the first chambers, fruit were randomly rolled into second chambers. Radiachromic films (FWT-60-00) were attached to six different surface locations of each 60 fruit. The fruit was then processed through the UV-C chambers (total treatment time: 20 seconds). Absorbance of each film was measured at 510 nm using a radiachromic reader. The UV-C doses received by the fruits were calculated based on $A_{510nm}$ from a standard curve established using the same films receiving known doses of UV-C.

Results showed that there were large variations in UV doses among the six locations tested on each fruit. Fruit size did not affect the UV-C dose uniformity. Some areas of the fruit surface received 10 times greater doses of UV radiation than other areas. Even though, on average, each fruit received UV doses more than 100 mJ/cm$^2$, one third of fruits had part of the fruit surface receiving less than 20 mJ/cm$^2$ of UV-C. It appears that the sloped belt between two UV-C chambers was not able to ensure dose uniformity of fruit. The rotation on the sloped belt was a random process with no insurance of a piece of fruit being turned to opposite surface and being exposed to UV-C on both sides.

Because the sloped belt could not ensure dose uniformity on all parts of fruits, we tested another type of rotating device by modifying a hot dog roller in which the heater was disconnected and a new motor was installed so that the speed of the roller was increased. The effectiveness of the roller was compared to UV treatment

systems using reflective materials without the use of rotating devices. The reflective materials were control (no reflector), stainless steel sheet, and aluminum foil. Because apricots were out of season, apple fruit were used in the study. Radiochromic films were attached at six different locations of each of 12 apple fruit. Results showed that fruit with rotating device had much better UV-C uniformity than those without the rotating device as indicated by the coefficient of variations (CV) and the ratio of maximum/minimum doses. CV of doses was 32.2, 59.6, 29.9 and 7.7% with control, stainless steel, aluminum foil and the rotating device, respectively. Therefore, use of the rotating device can dramatically increase dose uniformity. The device needs to be scaled up and tested at a commercial setting.

5. *Conduct commercial trials to evaluate the feasibility of the UV technology;*
The commercial UV-C treatment system consisted of two 10-foot UV-C treatment chambers. Each treatment chamber was placed on the top of a trough, which housed the conveyer belts. The two UV-C chambers were connected with an inclined belt which was used to rotate fruit between the two UV-C chambers.

   To study the efficacy of the UV-C treatment system at a commercial facility, non-pathogenic bacteria has to be used. We evaluated the suitability of *E. coli* ATCC 25922 as a surrogate for *E. coli* O157:H7 by comparing the strain with a cocktail of five pathogenic strains *E. coli* O157:H7 (RM 6535 from lettuce, RM 7386 from Romaine lettuce, O6FOO475 from spinach, RM 1484 from apple juice, and Sakai from sprouts). Results showed that reductions of *E. coli* ATCC 25922 by UV-C were not significantly different from those of *E. coli* O157:H7 although, on average, inactivation of *E. coli* ATCC 25922 was lower than that of *E. coli* O157:H7. These results suggested that ATCC 25922 could be used as a surrogate for *E. coli* O157:H7 in UV-C treatments on the surface of apricots.

   Our results suggest that UV-C, used in the commercial setting, only achieved 0.5-0.7 log CFU/fruit inactivation of surrogate *E. coli* ATCC 25922. When a modified rotation device was used in the laboratory setting, UV-C treatment at similar doses reduced *E. coli* ATCC 25922 populations by 1.0-1.2 log CFU/fruit and *E. coli* O157:H7 populations by 1.3-1.8 log CFU/fruit. The low reduction of *E. coli* ATCC 25922 in the commercial setting was probably due to uneven UV dose distribution on the surface of the fruit as doses were less than 20 $mJ/cm^2$ of UV-C on some surface locales.

6. *Evaluate consumer acceptance of UV technology.*
Little is known about consumer acceptance of UV-C treatments on fresh fruits. The use of ionizing irradiation, an effective food safety intervention, on some commodities has not been widely utilized due to poor consumer acceptance. Therefore, understanding consumer perspectives and acceptance of UV-C technology on fresh fruit is important to ensure that new food safety technologies can be positively utilized by the industry and effectively market products to consumers. A telephone survey of 90 Washington residents was conducted to study the acceptability of UV-C technology and UV-C treated fruits and vegetables. The majority of consumers surveyed (66%) consumed fresh fruits and vegetables daily.

Additionally, 26% consumed fresh, whole tree fruit daily and 31% indicated weekly consumption of fresh, whole tree fruit. Although 29% of consumers indicated that concern over food poisoning sometimes (1-2 times per year) kept them from purchasing fresh fruits and vegetables, 26% indicated that concern over food poisoning never kept them from purchasing fresh fruits and vegetables.

Over one-third of consumers (37%) rarely seek information on how foods are commercially handled. Survey results indicated that consumer awareness of some commonly used processing technologies appeared to be low, which could make communication about current and new technologies challenging. The highest level of awareness of food processing technologies for product safety was for pasteurization of milk and chlorination of drinking water (49% and 48%, respectively). Alternatively, 60% of consumers were not at all aware of the use of chlorine for product safety in raw poultry processing and 55% were not at all aware of chlorine use for safety in fruit and vegetable processing. A consumer survey (90 respondents) indicated that 67% of consumers found the use of UV-C to enhance the safety of fresh produce moderately to completely acceptable, which was equivalent to the acceptability for use of UV-C to enhance safety of drinking water. A greater percentage of consumers found UV-C treatment to enhance the safety of produce very or completely acceptable (28%) compared to the use of irradiation to enhance the safety of spices (14%) or leafy green vegetables (17%). Over one-third (40%) of consumers were very or completely interested in learning about UV-C treatment of produce. The terms and "ultraviolet light" and "ultraviolet" were preferred by a higher percentage of consumers (37% and 27%, respectively) to describe a food safety technology involving UV-C treatment of produce compared to terms using "pulsed light" (5%). The consumer survey advanced the understanding of consumer acceptance of UV-C technology for enhancing safety during produce processing.

In addition to above experiments in objectives 1-6, we have conducted the following studies: 1. Effect of hair (trichome) on the UV-C efficacy in reducing *E. coli* O157:H7 population quality of peaches. 2. Effect of UV-C on membrane permeability and viability of *E. coli* O157:H7 using ethidium monoazide-qPCR and live/dead viability test kit.

**Outcomes and Accomplishments**

All project objectives were completed. Our industry collaborator is fully supportive by providing the fruits and making their facility available for conducting the research.

This project demonstrated the efficacy of UV-C in reducing populations of *E. coli* O157:H7 and *Salmonella* spp. Results showed that 1-2.5 log reductions of the two human pathogens could be achieved. The Shiga-toxin negative *E. coli* O157:H7 and attenuated *Salmonella* spp. behaved similarly as the pathogenic *E. coli* and *Salmonella* spp. *E. coli* ATCC 25922 was slightly more resistant to UV-C than the cocktailed *E. coli* O157:H7 strains, suggesting that *E. coli* ATCC 25922 can serve as a surrogate of pathogenic *E. coli* O157:H7.

In addition, the survival of the human pathogens during post-UV storage at two temperatures was evaluated. While pathogens on the non-treated fruit survived well during storage, pathogens on fruit treated with UV-C at a dose of 442 mJ/cm$^2$ decreased rapidly during storages. At least 2 log lower populations of *E. coli* ad *Salmonella* Spp. on apricot treated with 442 mJ/cm$^2$ could be achieved after post-UV storage compared to the non-treated control.

A better understanding consumer acceptance of UV-C treatment for produce was gained. Acceptance of UV-C treatment for the safety of produce did not appear to differ from the acceptance of other technologies commonly used for safety in food processing. A consumer preference for using "ultraviolet light" in terminology describing UV-C technology was identified.

Quality of apricots following UV-C treatments was evaluated during two storage temperatures (2 and 20°C). UV-C did not affect appearance, firmness, acidity, mealiness or decay of fruits as all fruit had lower decay rate, suggesting that apricot fruit can tolerate high doses of UV-C.

Two types of film dosimeters were evaluated for their suitability for indicating UV-C doses. Results suggested that films developed blue or pink color after irradiation. The intensity of color corresponded to the absorbed doses received. The films are small in size (1cm square) and were used to evaluate dose uniformity for individual fruit.

A UV-C treatment system was installed in a commercial setting composed of two UV-C chambers connected with a sloped belt. Based on the film dosimetry, some fruit surface received very low dose of irradiation. As a result, the reduction of *E. coli* ATCC 25922 was only 0.5-0.7 log/CFU/fruit, suggesting the sloped belt was not effective in rotating fruit to receive uniform dose distribution. A rotating device has been modified from hot dog roller to use on apples and apricots. Results showed that the modified roller provided uniform dose on individual fruits compared to stainless steel and aluminum as reflective materials.

Compared to apricots, UV-C at the same doses reduced higher population of *E. coli* and *Salmonella* on apples, probably due to smooth surface of apple fruit. SEM image showed that there are cracks, stomatae, and trichomes on the surface of apricots which limited the effectiveness of UV-C.

For the peach experiment, hairs on the peaches appear to have no effect on the reduction of *E. coli* caused by UV-C treatments.

**Summary of Findings and Recommendations**

UV-C can be used to enhance the microbial safety of apricots with reductions of *E. coli* O157:H7 and *Salmonella* spp. on apricot fruit ranging from 1 to 2.5 log CFU/fruit without significant impact on fruit quality.

The dosimetry system developed in the project may be applied by the fruit industry to assess the dose uniformity of individual fruit.

*E. coli* ATCC 25922 may serve as a suitable surrogate for the pathogenic counterpart in validating UV-C effectiveness on the surface of apricots and, potentially, other fruits.

A rotating device was developed and tested in the lab setting. Future efforts should be on scale up and application of the device in a commercial facility to achieve a higher reduction of pathogens.

The UV-C system should be used in conjunction with other good manufacturing practices and good agricultural practices to be optimized in order to enhance microbial safety of soft fruits.

Consumer acceptance of UV-C technology for produce appears to be similar, or in some cases, better than currently used food processing technologies for produce and other food items. The term “ultraviolet light” was the most preferred term to refer to UV-C treatment of produce.

The implementation of this technology will enable the fruit industry to improve the microbial safety and increasing the consumption of healthful fresh fruits. The UV technology developed in the proposed study will not only allow many grower/packers to continue marketing the tree-ripe apricots, but also will enable the fruit industry as a whole to adapt the technology to other types of fruits such as apples.

## APPENDICES

### Publications and Presentations (required)

Yan, R., X. Fan, J. P. Mattheis, J. Gurtler, K. Killinger. 2013. Effects of UV-C on microbial reduction and quality of apricots in a commercial setting. IFT Annual Meeting, July 13-16, 2013, Chicago, IL.

Yun, J., R. Yan, J. Gurtler, X. Fan. 2013. Inactivation and survival of *E. coli* O157:H7 and *Salmonella* spp. on apricot fruit following UV-C ultraviolet light exposure. IAFP Annual Meeting, July 28-30, 2013, Charlotte, NC.

Yan, R., J. P. Mattheis, J. Gurtler, K. Killinger, J. Sites, X. Fan. 2013. Effects of UV-C light on microbial inactivation and apricot quality in a commercial processing facility.

Yun, J., R. Yan, X. Fan, J. Gurtler, J. Phillips. 2013. Fate of *E. coli* O157:H7, *Salmonella* spp. and potential surrogate bacteria on apricot fruit, following exposure to UV-C light. Intern.

### Budget Summary (required)

All funds have been utilized except those on travel. Most of the funds ($43,400) received by ARS were used to hire two visiting scientists (one 12 months and another for 7 months) and one part time student who conducted the experiments. Salaries/benefits were moved to Contractual (subcontract) for ARS hiring visiting scientists. $12,968 was used by ARS to purchase supplies including plating media, lab disposables, radiochromic films, a computer, and UV-C tubes.

$4,849 was used for traveling to Quincy, WA to conduct trials at commercial facility and Tree Fruit Research Lab, Wenatchee, WA. The remaining of the Travel budget $3,776) will be used by PI and two CO-PIs to attend the CPS symposium in Syracuse, NY. We overspent ~$200 on supplies due to unexpected higher shipping cost. Therefore, we may need to transfer $200 from Travel to Supplies. Page charges ($800) were used to buy supplies.

The WSU subcontract involved approximately $4,400 for student wages and employer contributions. The contract with WSU SESRC for survey services was $6,000 and $994 was spent for travel for project meetings in Pennsylvania and Washington.

### Tables and Figures (optional)

### Suggestions to CPS (optional)