2021 Center for Produce Safety Symposium
Session V: More Critical Produce Food Safety Topics

Key Learnings

The fifth and final session of Center for Produce Safety's 2021 Research Symposium was conducted on July 13, and featured three presentations from leading research scientists on more vital food safety topics for the produce industry. Session 5 explored the importance of using science to fuel changes in farm practices directed to mitigation of perceived produce safety risks, the role sediments play in irrigation canals in harboring human pathogens and the efficacy of sanitation treatments for irrigation water to prevent pathogen dissemination to crops.

The following executive summary-style Key Learnings is meant to inform and provoke thought with an eye towards inspiring readers to examine their own produce safety programs and to use the research to make improvements. It is not meant as a directive on what must be done to produce safe food. This and other recordings of CPS webinars are available via CPS's website. The latest information about specific research projects mentioned in this document is available via CPS's website, including our extensive research database and other produce safety resources.

1. **Production environments are complex biological systems and cognitive leaps to control pathogens are not advisable**. Daniel Karp from the University of California, Davis shared the results of his project, "*Towards a decision-support tool for identifying and mitigating on-farm risks to food safety"* [Karp 2018]. Farming practices in soil, non-crop vegetation, wildlife and domesticated animal management along with adjoining landscape uses have been modified over the last decade with a view to mitigate food safety concerns. Some changes have been supported by science while others have been driven by intuition. An objective of this project was to evaluate whether some of these changes were scientifically valid. The methodology employed was evidence synthesis using an extensive scientific literature review, synthesis of the accumulated knowledge into summaries and engaging experts to review the findings to determine which practices have scientific foundations and those that lack support or have been shown to be ineffective in risk management. A second objective examined the effects of long-term soil management practices on soil health and *Listeria* and *Salmonella* suppression. Some key learnings from this project include:
    - ***The good, the bad and the hopeful***. The results of the evidence synthesis efforts revealed some agricultural practices offer significant contamination risks and need to be managed closely (e.g., applications of raw manure, production in close proximity to livestock or range lands, etc.) while others have been implemented without evidence that they reduce contamination risks (e.g., removal of riparian areas near fields, elimination of hedgerows, a move away from composts for fear of pathogen contamination instead of validating composting efficacy, etc.). CPS has funded previous research on the impact of riparian zones [Wiedmann 2011]. The synthesis also identified several research gaps that can now be filled to enhance our produce safety knowledge base.
    - ***Preliminary evidence suggests soil microorganisms might be used to suppress Listeria and Salmonella***. Leveraging a unique long-term experiment at Russell Ranch at UC Davis, the research team accessed one-acre plots that have been treated for 27-years with poultry litter composts and routine plantings of cover crops (bell bean, hairy vetch and oats). This unique enterprise permitted testing the impact of the microbiome in these soils against *Listeria* and Salmonella under four growing regimes: (1) poultry litter compost and use of cover crops with no additional fertilizers, (2) poultry litter compost with additional fertilizers and no cover crops, (3) cover crops with additional fertilizers but absent composts, and (4) fertilizers with no composts or cover crops. Each treatment supported different micro-communities. Challenge studies revealed that plots without compost or

cover crop use resulted in microbiomes that had lower *Salmonella* or *Listeria* suppressive capabilities than those that employed composts and cover crops. Indeed, five-times more *Salmonella* persisted in non-composted soils relative to composted soils. However, this suppressive effect diminished over the course of the growing season. 363 *Salmonella*-suppressive isolates have been selected for further study perhaps leading to future biological control strategies to control human pathogens in soils. CPS has previously funded work on suppressive soil microorganisms [Marco 2009, Coaker 2009, Jiang 2018].

2. **Irrigation canal sediments can be a reservoir for pathogens**. Charles Gerba from the University of Arizona discussed his project, "*Development of a model to predict the impact of sediments on microbial irrigation water quality*" [Gerba 2018] Previous efforts to elucidate canal water chemistry and environmental factors that can impact *E. coli* persistence in canal waters and sediments were reported in 2013 [Rock 2013]. This project utilized machine learning models and in-field collection of sediment and water samples to study factors that can result in the resuspension of canal sediments and compromise the microbial quality of the overflowing water. *E. coli*, *Listeria monocytogenes* (Lm) and two divergent norovirus surrogates, MS-2 and phiX174 were evaluated. Some important learnings from this project are:
    - ***Machine learning canal model systems demonstrate sediments act as a reservoir for pathogens***. Higher concentrations of *E. coli were* found in canal sediments than in the overlaying water. Indeed, sediments can have 10-10,000-times greater concentrations of *E. coli* than the overlaying water.
    - ***Pathogens in sediments influence pathogens in the water***. When pathogens reside in canal sediments, disruptive events caused by turbulence resuspends the pathogens in the water and raises the potential that they can be transmitted directly or indirectly to the crop via irrigation. *E. coli* levels in water are also influenced by temperature as increased air or water temperature increases *E. coli* in water while increased salinity decreases *E. coli* levels.
    - ***Pathogens are stabilized by adhesion to sediment soil particles***. Clay particles can harbor 1,000 to 10,000 times greater concentrations of *E. coli* than sand or loam-based sediments. Resuspension of *E. coli* from sediments increases with increasing shear stress and sand content indicating microorganisms are less attached to sand than to clays and loam, making them easier to be resuspended.
    - ***Sediment microbiome analysis can provide a window on the history of the overflowing water***. Pathogens in overflowing canal water eventually settle into the sediments and stabilize. Therefore, the sediments provide a historical perspective of historical water quality passing through the system.
    - ***Microorganisms behave differently in sediments and overlaying water***. Virus phiX174 re-suspended at lower shear stresses than MS-2 indicating that it is less well adhered to the sediments or perhaps the viruses differ in hydrophobicity. No Lm was detected in any of the sediments or overlaying waters suggesting Lm may not be a risk within the context of these studies. However, it must be remembered that Lm can reside in hidden, protected niches not evaluated in these studies.
    - ***E. coli in sediments control E. coli levels in water***. *E. coli* levels in the sediment are related to *E. coli* levels in the overlaying irrigation water. Therefore, it is important that growers and water districts take measures to prevent resuspension during the growing season, i.e., refrain from irrigation after disruptive events like heavy rainfalls or canal maintenance. It is important that canal maintenance, cleaning or dredging are performed off-season. It is important to note that if a water test result is negative for *E. coli*, the sediments could test positive meaning the risk is present should the sediment be disrupted.
    - ***Canal "hot spots" for E. coli can be identified***. It is important to note that some areas in irrigation water systems have higher levels of *E. coli* than others. Splitter boxes and stretches of canals that pass through urban areas or locations where residences are located can demonstrate much higher *E. coli* concentrations than other areas. These hot spots may be associated with different sediment compositions or may reflect localized turbulence or run-off sites. Therefore, it is important for growers

to routinely monitor the environments their canals run though and evaluate conditions both up- and down-stream from their operations.

3. **Irrigation water treatment does eliminate the risk of pathogen contamination**. Channah Rock from the University of Arizona reported on her project "*Agricultural water treatment – southwest region*" [Rock 2019]. This project has its origins in the 2018 *E. coli* O157:H7 outbreak linked to romaine lettuce from the winter dessert production area. The FDA investigation of that outbreak pointed to irrigation water as a *potential* source of the contamination. Subsequently, in July 2020, the FDA announced a new protocol for the development and registration of sanitation treatments for preharvest agricultural water aligning on a requirement for a minimum 3-log reduction of target organisms compared to controls. The Rock team's research program utilized laboratory and field-level work to evaluate the efficacy of treating irrigation canal water with sanitizers to reduce the risk of pathogen transference to crops and to address concerns regarding the impact of irrigation water sanitizers on the microbial communities in the rhizo- and phyllosphere. Important learnings from this work include:
   - ***The basics hold true – sanitizer, dose, temperature and contact time are critical***. Using irrigation water from Maricopa and Yuma, AZ and Edinburg and Uvalde, TX shipped to the Rock lab, dose optimization studies were performed. Two sanitizers, PAA (6 and 8 ppm) and sodium hypochlorite (2 and 4 ppm) were tested against the target organisms: generic *E. coli*, total coliforms and an EPA/FDA, 7-strain cocktail of *E. coli* O157:H7 at both 12C (53.6°F) and 32C (89.6°F) with contact times of 1 and 5 minutes. With the one-minute contact time, sodium hypochlorite (free chlorine) outperformed PAA in all water samples at both temperatures and exceeded the 3-log reduction threshold. However, if the contact time was increased to 5-minutes, PAA also achieved the 3-log reduction threshold especially under the elevated 32C temperature. Additionally, when testing treatment efficacy, it is important to remember that sample volume matters, i.e., a non-detect in 100-mL of water does not mean non-detect in if larger water volumes are collected. Water sample size and improved detection has been the focus of a previous CPS project [insert link to Hill final report, 2014]. The key for growers is to understand their water sanitation operating conditions and verify their does levels, contact time, and sampling regimes are adequate for their irrigation system.
   - ***Microbial "breakthrough" always occurs***. Using one-acre leafy greens field plots and measuring generic *E. coli*, total coliforms and inoculated TVS353 (a surrogate for *E. coli* O157:H7, the research team took water samples from irrigation ditches, first and last sprinkler heads at set times for up to 3-hours. In every instance, "breakthrough" occurred over time as the target organisms were detected at the first and last sprinkler heads independent of the sanitizer in the system. Irrigation systems are dynamic; system "stabilization" is highly variable beyond the point of system pressurization meaning that the killing effect of the sanitizer can take 30-60 minutes to become measurable. Sanitizers do not kill microorganisms instantaneously and temperature is important; 32C resulted in greater log reductions than 12C. At the field level using commercial irrigation systems, all treatments (free chlorine, PAA or UV) showed considerable variability, averaging a 1.5-log reduction versus the control. It is speculated the variability could be due to incomplete sanitizer mixing in the system or spikes of microorganisms entering the system and overwhelming the sanitizer present. It is important for growers and regulators to note that all treatments can be optimized to have success in reducing target organisms, but no treatment is 100-percent effective regardless of chemistry, dose, acreage, water source, quality of water, or operator. No treatment in this project consistently met the FDA reduction objective of 3-logs. *Irrigation* water *sanitation is best thought of as a <u>risk reduction</u> strategy and not risk elimination*.
   - ***Be practical in choice of sanitizer monitoring tools***. Generally, meters are more sensitive and color change methods can be highly subjective. Test strips are the least accurate, but they are also easier to use and inexpensive. At least initially, it makes sense to focus on the tools that are most likely to be used correctly. In either case, operator training is critically important.

- ***Microbiome changes were observed on plant tissue for PAA and free chlorine treatments, but not in soil or root zone***. In fields irrigated with either chlorine or PAA treated water, the research team evaluated the phyllosphere (spinach leaves), rhizosphere (roots) and soils for changes at time intervals pre- and post-treatment. Population changes were found only in the phyllosphere. Longer term study is likely warranted, but within the context of this project, the impact on the microbiomes of the root zones/soil appear minimal.

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