CENTER for PRODUCE SAFETY

CPS 2024 Special Project
FINAL PROJECT REPORT

Project Title
CPS Tri-State Special Project on Harvest Equipment: A data-informed consensus of “What is Clean?”

Project Period
September 1, 2023 – June 30, 2024

Principal Investigator
Channah Rock, PhD
University of Arizona
Maricopa, AZ 85138
T: 480-628-9794
E: channah@cals.arizona.edu

Co-Principal Investigator
Michelle Danyluk, PhD
University of Florida
Gainesville, FL
T: 863-956-8654
E: mddanyluk@ufl.edu

Graduate Student
LaTauyna Tillman
University of Florida
Gainesville, FL
E: tillmanl@ufl.edu

Collaborators
Justin Kerr
Factor IV Solutions
Atascadero, California
T: 805-464-2113
E: justin@factorivsolutions.com

Trevor Suslow
T&K Suslow Consulting, LLC
T: 530-304-1257
E: tvsuslow@ucdavis.edu

Objective

1. *The intent of this research project is to develop a dynamic, aggregated, and confidential dataset from which to offer leafy greens growers, shippers, handlers, harvest contractors, and processors to integrate outcomes into "real-time" opportunities for continual improvements and preparedness for audits and inspections.*

Funding for this project was provided through the CPS Campaign for Research

FINAL REPORT

Abstract
The CPS Tri-State Special Project on Harvest Equipment aimed to develop a dynamic, aggregated, and confidential dataset to help leafy greens growers, shippers, handlers, harvest contractors, and processors better understand “What is clean?”, while also identifying areas to improve their cleaning and sanitizing practices. The project, conducted from September 2023 to June 2024, was initiated in response to a U.S. Food and Drug Administration sampling assignment targeting harvest machines used for fresh produce, after *Listeria monocytogenes* linked to an outbreak in 2022 was found on a harvest machine. The FDA assignment, part of the FDA's Leafy Greens STEC Action Plan, focused on inspecting and swabbing leafy greens harvest equipment for microbial hazards, particularly in California, Arizona, and Florida. While a final report has yet to be published, there are currently no indications that sampling resulted in a positive detection of either human health hazard assayed, *Listeria monocytogenes* and *E. coli* O157:H7. While industry recognizes that these preliminary findings (although pending) are beneficial, there are very few, if any, key learnings that can be used by industry to better assess current practices or areas for improvement. In order to combat this data gap, our team proposed to evaluate the effectiveness of cleaning and sanitation practices on leafy greens harvest machines, focusing on the reduction of microbial indicators such as Adenosine Triphosphate (ATP), Aerobic Plate Count Bacteria (APC), generic *Escherichia coli* bacteria (gEC) and Total Coliform bacteria (TC), as well as assessing various cleaning and sanitation chemistries and methods used. Over the course of this study, a total of 30 sampling events across the three regions were conducted, involving 23 different harvest machines and collecting 6,196 swab samples. Overall, reductions were seen in all bacterial indicators analyzed from Post-Harvest (PH) to Post-Detergent (PD) and Post-Sanitation (PS) activities. Only 6.2% of swabs exceed 10 CFU generic *E. coli* per swab after harvest (PH), with those values consistently decreasing to 5.3% after the cleaning step (PD) and to 1.1% after the sanitation step (PS). While generic *E. coli* was detected on harvest machines in all three regions, detection was very infrequent and very few positive samples were detected after the sanitation step. This indicates a low prevalence of *E. coli* on harvest machines and a decreased likelihood of transfer post sanitation. Detergent type and application, as well as the tools used during cleaning, have a greater impact on microbial reductions than sanitizers. Chlorinated detergents significantly reduced ATP readings, making them effective for cleaning and sanitation purposes. Key findings also highlight significant variability in cleaning and sanitation practices (i.e., tools used, personnel involved, time spent, etc.), water usage, and the types of detergents and sanitizers employed. Although the study found a high level of worker compliance with cleaning SOPs, there were concerns about the persistence of elevated ATP levels post sanitization. Improved reductions were observed after simple modification of protocols, including the use of ladders or platforms to gain access to elevated machinery, increased attention to catch points and harborage areas, and ensuring appropriate coverage of sanitizing chemicals on surfaces. The study also observed that the duration of cleaning significantly impacted the reduction of microbial parameters, emphasizing the importance of thorough cleaning practices prior to sanitation. This project underscores the need for standardized cleaning and sanitation performance criteria and offers insights into best practices that can be integrated into real-time opportunities for continual improvements and audit preparedness in the leafy greens industry.

Background
In the Fall of 2023, the U.S. Food And Drug Administration (FDA) announced a sampling assignment specifically targeting sampling of harvest machines used for fresh produce. The FDA

announced the assignment, including the inspections of harvest operations and collection of environmental samples from harvest equipment, after an outbreak strain of *Listeria monocytogenes* was recovered from harvest equipment in 2022 matching a historical outbreak. At that time, FDA was seeking to gain insights about the potential for human pathogens to persist on harvest equipment after routine cleaning and sanitizing and the potential for subsequent transmission to produce. The assignment centered largely on the inspection and swabbing of harvest equipment. The assignment was part of the FDA's Leafy Greens STEC Action Plan, an ongoing preventative effort to help ensure the microbiological safety of leafy greens. (https://www.fda.gov/food/sampling-protect-food-supply/fy-2324-inspection-and-environmental-sampling-leafy-green-harvest-equipment-listeria-monocytogenes)

The assignment specifically targeted romaine lettuce harvesters in California, Arizona, and Florida. While the assignment initially seemed to be fairly straightforward, many questions were raised by industry about how to logistically conduct a sampling assignment of this nature while still maintaining operations, product orders, ensuring appropriate food safety Standard Operating Procedures (SOPs), among other questions. In response to industry feedback, the agency adjusted the assignment in December 2023 to improve execution and logistics for the duration of the assignment.

The inspections focused on the harvest operations of three produce companies and entities with whom they work (e.g., growers, harvesters). The three specific produce companies were selected due to their potential linkage to leafy green outbreaks of foodborne illness in recent years. Additionally, the inspections focused largely on equipment used in the harvest of "carton ready" and "process ready" leafy greens, and included equipment used in field harvest activities related to leafy greens intended for processing.

Over the course of the assignment, the FDA tested for the following microbial hazards: *Listeria monocytogenes* and *Escherichia coli* O157:H7. In total there were 28 inspections (10 AZ, 12 CA, 6 FL), with the FDA swabbing one harvester per inspection. During each inspection a minimum of two samples were collected (i.e., one sample to test for each analyte), and each inspection consisted of at least 64 environmental swabs. While a final report has yet to be published on the FDA website, to our knowledge no samples resulted in a positive detection of either human health hazard assayed, *L. monocytogenes* or *E. coli* O157:H7. While industry recognizes that these preliminary findings (although pending) are beneficial, there are very few, if any, key learnings that industry can use to better assess current practices as well as areas for improvement.

In recognition of this large gap in understanding and information transfer, a broad sector of the leafy greens industry came together as a call-to-action on harvest equipment cleaning and sanitation performance and standardized performance criteria. Across the key states named within the FDA assignment (CA, AZ, and FL), several leading firms expressed interest to be enrolled in a baseline assessment of field harvest equipment in relation to the development of standards of industry practice for "What is clean?".

Goal: The intent of this research project was to develop a dynamic, aggregated, and confidential dataset from which to offer leafy greens growers, shippers, handlers, harvest contractors, and processors to integrate outcomes into "real-time" opportunities for continual improvements and preparedness for audits and inspections.

Research Methods

Over the course of the study the University of Arizona worked alongside The University of Florida, Factor IV Solutions, and industry partners to conduct a longitudinal baseline assessment of cleaning and sanitation practices of harvest machines used for fresh produce. The team focused on 3-point Belt Harvesters and Self-propelled Belt Harvesters (*Figs. 1 and 2*).

Figure 1. 3-point Belt Harvester

Figure 2. Self-propelled Belt Harvester

Sample Time Points: For each sample collection event, the sample teams collected samples at three predetermined time points. These including the following: immediately “Post Harvest” (PH), following the cleaning step “Post Detergent” (PD) and following application of a sanitizer “Post Sanitation” (PS).

Sample Locations: For each of the harvest machine sampling events, the team collected swab samples at up to 5 individual locations (A-E) (*Fig. 3*). Each sampling location was standardized across all three states, and sampling teams were calibrated to ensure consistency in sampling approach for the duration of the study.

- **Section A:** Drive roller, Top of Conveyance, Inside Conveyance
- **Section B:** Belt Guides, Side Walls, Support Rollers on Bottom
- **Section C:** Spray Tunnel Inside, Spray Tunnel Flaps, Spray Tunnel Mounts to Harvester (weld/bolts)
- **Section D:** Incline Drive Roller, Top of Conveyance, Inside Conveyance
- **Section E:** Collar Structure, Collar Belt or Cute, Collar Mounts (weld/bolts)

Figure 3. Harvester Sample Collection Locations A through E

Sample Types: The team collected swabs to assess surface prevalence (presence/absence) and concentration for a variety of indicator measurements, including Adenosine Triphosphate (ATP) using the Charm Field Format meter and swabs, Aerobic Plate Count bacteria (APC), generic *E. coli* (gEC), and Total Coliform bacteria (TC).

All swabs were submitted to Eurofins Laboratories (https://www.eurofins.com/environment-testing/) in each state where the study was being conducted (as appropriate) and followed AOAC Standard Methods (Aerobic Plate Count – AOAC 990.12; Total Coliforms/*E. coli*- AOAC 991.14 and/or SMEWW 9223) used by commercial laboratories for better comparability across states. Charm FieldSwab ATP swabs (https://www.charm.com/products/test-and-kits/atp-tests/fieldswab/) were used for all ATP assessments in field while all microbiological swabs were conducted using World Bioproducts EZ Reach™ sponge sampler (https://www.worldbioproducts.com/ezreach-sponges.html) for collecting environmental surface samples containing neutralizing buffer. Standard swabbing technique, pressure, and surface area were aligned across all sampling teams and locations (AZ, FL, CA) across the study. Swabbing commenced at project initiation, per harvester unit, and consisted of the following swabbing frequency:

- 25-point swab pre-cleaning (post-harvest)
- 25-point swab post-cleaning (wash down, detergent application, and rinse)
- 10-point swab post-cleaning and post-sanitizing (wash down, detergent application, rinse, and sanitizer).

In addition to microbiological parameters collected above, the team also collected substantial metadata for each event using iAuditor software to track each event in real time. A table of meaningful parameters collected is listed below (**Table 1**).

Table 1. iAuditor Software Metadata Type

Type of Detergent, mix ratio (ex: 4 oz. to 1 gallon of water)	Wind speed at time of swab collection
Type of Sanitizer, residual ppm of chlorine, quat, PAA, etc.	Belt type(s): monolithic, vinyl cloth backed, stainless belt bar and chain
Type of Brush and surface assignment	Access to collar (can it be lowered or is platform or ladder used for cleaning high points
Method of Application for Detergent and Sanitizer (pump sprayer, venturi or batch foamer)	Number of employees completing the event
Time of day	Total time to collect ATP and Micro swabs
Temperature at time of wash	Belt speed, total time per rotation during wash
Product harvested	List of specialty tools or chemicals used
Location of wash (in-field, adjacent road, shop, etc.)	Total gallons of water used in wash
ATP results (Charm NOVALUM IIX w/ 20,000 RLU pass setting)	Micro results for all locations

At the onset of the project, an additional offering for project participants (harvest machines) was the option to track harvest machine and cleaning and sanitizing equipment over the course the project. This would have allowed the research and extension team to evaluate location, movement, usage, and storage to build on the metadata to better inform potential impacts on harvest machine sanitation. Asset tracking verification of time in motion and range was recommended for the following six asset types: (1) pressure washer(s), (2) food contact brush, (3)sanitation truck or trailer, (4) detergent device, (5) sanitizer device, and (6) harvest machine. While industry was enthusiastic about this additional type of monitoring, logistically it was not feasible for this initial study. However, future work could include this additional monitoring to complement microbiological and locational metadata.

Results and Discussion

Over the course of the study the team conducted a total of 30 sampling events across all three regions: 11 in Arizona, 9 in California, and 10 in Florida. Of the total visits (n=30), the team was able to assess 23 different harvest machines responsible for the harvest of four crop types: Romaine, Cabbage, Green Leaf, and Iceberg. In total, the research team collected 6,196 swab samples that represent over 550,000 sample data points for pathogens, indicators, and associated metadata.

The following table outlines the variably in environmental conditions observed throughout the study (**Table 2**). In general wind speeds were low for most sampling events, however temperatures ranged greatly across the three regions assessed, ranging from 58 to 87 °F.

Table 2. Environmental Conditions

	Wind (MPH)	**Temperature (º F)**
Min	1	58
Median	8	73.5
Mean	9.5	72.7
Max	27	87

Cleaning of harvest equipment accounted for the largest amount of time spent during a cleaning and sanitation event (**Table 3**). On average, across all events, the amount of time spent cleaning was 90.5 minutes, with 22 minutes being the minimum amount of time spent during that step. Alternatively the amount of time spent on the sanitation step of each event ranged from 8 to 89 minutes, with 20.1 minutes as the average time spent on sanitation. It should be noted that for some events cleaning and sanitation were combined, although it was rare (n=4) (Table 3).

Significant variability in water usage for each cleaning and sanitation event was observed, with a minimum of 65 gallons and a maximum of 500 gallons. On average, most events used approximately 200 gallons of water. This finding is important, as some cleaning crews benefit from using a dedicated truck with access to additional water (not directly from the harvest machine). Those crews with additional access to water tended to use more water on average than those without. Although the volume of water used did not significantly correlate with the overall reduction in microbiological parameters in our initial analysis, the time spent on each event did correlate with reduction. This indicates that the ability of cleaning and sanitation crews to spend sufficient time reducing organic loading on the machines is a crucial predictor of their effectiveness in adequately sanitizing the machines.

Additional variability in the number of dedicated crew members assigned to cleaning and sanitation were recorded, with a minimum of 1 and a maximum of 7 employees. One anecdotal observation with the use of large cleaning and sanitation crews, is that there may be increased opportunities for cross-, or re-contamination of food contact surfaces. In several events, multiple people working on different parts of the harvest machine resulted in cross spray from a dirty location to a clean location. We recommend crews standardize their cleaning and sanitation process from one side (or end) to the other (i.e., avoid cleaning both sides, or ends, at the same time), and focus on cleaning and sanitation from top down, avoiding excessive splash. By doing this, the crews can reduced the potential likelihood for overspray and cross contamination.

Table 3. Cleaning and Sanitation Event Details

	Total (min)*	Cleaning (min)	Sanitizing (min)	Water (Gal)	Dedicated Staff
Min	22	22	8	65	1
Median	104	85.5	13.5	200	2
Mean	105.2	90.5	20.1	198.5	2.8
Max	225	203	89	500	7

Variability was also seen in the type of detergents used by cleaning and sanitation crews. These included: non-chlorinated alkaline, sodium hydroxide, chlorinated caustic blend, chlorinated sodium hydroxide, chlorinated potassium hydroxide, and a proprietary acid blend. Much less variability was seen in the sanitizers that were used, with only three products evaluated: Chlorine, Silver ion/Chlorine blend, and the use of Quaternary Ammonium Chloride (Quat). The team was surprised to not see any Peroxyacetic Acid (PAA) based products or Chlorine Dioxide based products in use, which may warrant additional evaluation in the future.

During each sampling event, teams not only assessed the types of chemistries being applied to machines, but also the range in residual concentration of the sanitizers being used. For this study, residual concentrations (ppm) of sanitation chemicals ranged from 4 to upwards of 400 ppm, with the vast majority of users targeting the 100 to 200 ppm residual range common for free chlorine. For each event, crews indicated their ability to verify sanitizer residual through the use of test strips or meters, however this practice was not always observed.

For machine cleaning and sanitation where crews needed access to elevated conveyers, chutes, or inclines, only 69.2% of workers had access to a platform or ladder; providing the equipment needed for sanitation crews to access all locations and achieve a top-down cleaning approach is an easily achievable key recommendation from this project. Just over half (53.3%) of crews had dedicated sanitation trucks, while an additional third had dedicated sanitation trailers (33.3%) for each event. Of the crews assessed, 88% had access to hygienically designed brushes for cleaning, with 56% of the brushes being coded for a location of use on the harvest machine (i.e., food contact vs. non-food contact). In addition to brushes, there were a variety of other tools that cleaning and sanitation crews used to aid in their tasks, including belt scrub pads, scrub pads, sponges, and steel wool. While the use of various tools to assist cleaning and sanitation had fairly good agreement across regions, we had anticipated more crews would have access to additional tools that they could use in real time to assess the effectiveness of their cleaning and sanitation practices. Of the total crews evaluated, only 43.3% had access to an ATP machine (or other tool) to assess the change in values over the course of a cleaning and sanitation event. While such equipment may be assumed to be cost prohibitive, there are a variety of different meters and swabbing type tools that can be used as a “quick check” to assess and verify cleaning and sanitation effectiveness.

ATP swabs are generally used to verify cleaning, with an acceptable value set as a go/no-go point before moving on to sanitation. ATP is commonly used in manufactured foods settings as well as in packinghouses. In general, industries such as food and beverage processing, hospitality, and the water sector use rapid ATP tests to quickly assess sample or surface cleanliness. Living cells and organic matter use ATP, and is often considered the universal unit of energy. It is important to note that most microbial cells and foods contain some level of naturally occurring ATP. ATP swabs with luminometers detect residual ATP as an indicator of surface cleanliness. For this study the team used the Charm novaLUM II-X system. While many ATP meters exist, the team elected to use this specific meter as the preferred platform because of the inclusion of buffered reagents that may be better designed for use with sanitizers as well as its design for use in outdoor environments. While an acid sanitizer or oxidizer can affect the test outcome, the research team has previously recorded less variance than with those tools that use an unbuffered reagent.

For our evaluations of ATP on harvest machine surfaces, the team set an acceptability threshold of 20,000 Relative Light Units (RLUs). This threshold was established by our collaborator Factor IV evaluation of field sanitation events comparing RLUs and TPC (Total Plate Count) bacteria. For reference, the limits set for each surface with each different type of ATP meter will vary, and results are not directly comparable across platforms; however in many manufactured foods environments the acceptable limits on food contact surfaces may range from 5–50 RLUs, while in a packinghouse environment those limits may range from 200–400 RLUs. **Table 3** below outlines ATP data collected across all harvesters, time points, and locations. The vast majority of samples collected immediately after harvest (PH) across all locations (A through E) indicated elevated levels of ATP above the 20,000 RLU threshold (96.8%). A 34.9% reduction was recorded in the percentage of samples above the set threshold between harvest (96.9%) and cleaning (62.0%), with an additional reduction of 20.7% above the threshold post sanitation (41.3%). None of the five areas evaluated had statistically different results in the number of samples exceeding the threshold for any given time point. While reductions in ATP were recorded across the study, the high percentage of samples exceeding the 20,000 RLU threshold at the Post Sanitation (PS) stage warrants additional evaluation of this number as a threshold.

Table 3. Evaluation of Adenosine Triphosphate (ATP) Swabs Greater Than or Equal to 20,000 RLUs

***Total Swabs**	**PH (n=660) 96.9%**	**PD (n=489) 62.0%**	**PS (n=382) 41.3%**
A (n=155)	97%	59%	53%
B (n=150)	99%	61%	47%
C (n=151)	95%	56%	39%
D (n=105)	98%	72%	35%
E (n=105)	94%	62%	32%

**** Every swab was collected at the PH time interval while only a sub-set was collected at PD and PS collection time points.***

Table 4 and **Figure 4** outline the log change in populations of Total Coliform bacteria (log CFU/swab) between different time points across all locations. When a value is shown as a zero "0", this indicates that there was no change in the log CFU values of TC bacteria during the cleaning or sanitation step. During the cleaning step (PH to PD) the change in bacterial concentrations ranged from 4.25 logs (max), to -6.71 logs (min). The negative value in the minimum change in reductions means that concentrations were actually higher (or increased) between cleaning steps. This indicates a high level of variability in the bacterial loading on the harvest machines, as well as efficacy of detergents and crews in removing organic matter and reducing bacterial populations. It also points to the fact that the job of the detergent is not necessarily to reduce bacterial concentration, but rather to break up organic matter and bacteria that may be adhered to food contact surfaces on the harvesters in order to allow them to be broken down by the sanitizer in a later step. When looking at the log CFU change in populations of Total Coliform bacteria during the sanitation step (PD to PS) we see a much smaller variability, with bacterial concentrations ranging from a -3.99 log change (min) to a 2.34 log change (max). Overall the combined cleaning and sanitation (PH to PS) of harvest crews was effective, as indicated by the maximum 3.54 log change; however, work remains to be done as indicated by a -6.13 log change (min) in Total Coliform bacteria from PH to PS for machines evaluated. The mean and median changes in TC populations during both the cleaning and sanitizing steps of approximately zero (meaning that, when averaged across the industry, the work done during cleaning and sanitation did not significantly impact microbial populations) is indicative of a tremendous opportunity for improvement.

Table 4. Log Change in Populations of Total Coliform Bacteria Between Swab Time Points (log CFU/swab)

	PH TO PD (n=493)	**PD TO PS (n=208)**	**PH TO PS (n=381)**
Maximum Reduction	4.25	2.34	3.54
Median	0.00	0.00	0.00
Mean	-0.09	-0.36	-0.32
Minimum Reduction	-6.71	-3.99	-6.13

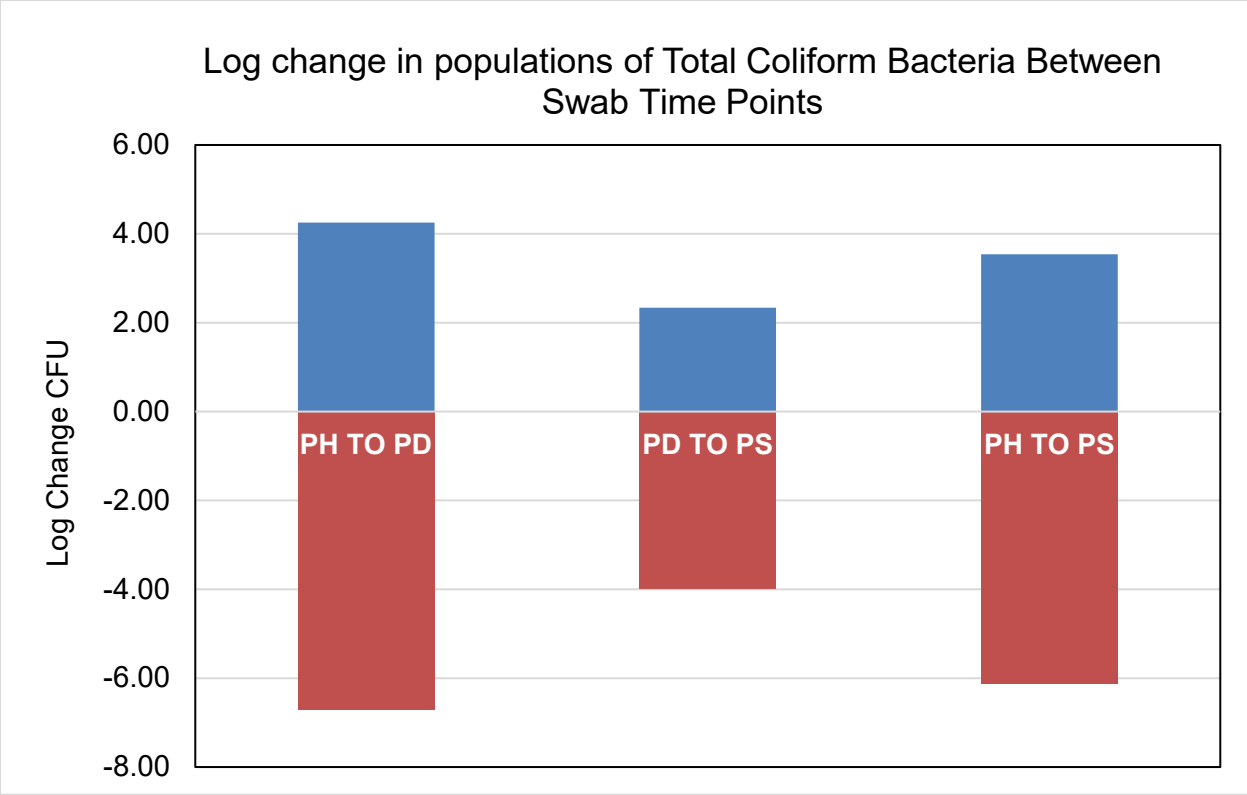

Figure 4. Log Change in Populations of Total Coliform Bacteria Between Swab Time Points (log CFU/swab)

Because *E. coli* detection on harvesters was rare, rather than analyzing the population levels we are presenting the results as a frequency of the population exceeding the limit of detection (10 CFU/swab) (**Table 5**). Only 6.2% of samples had detectable populations of *E. coli* exceeding 10 CFU/swab after harvest (PH), with those values decreasing to 5.3% after the cleaning step (PD) and to 1.1% with detectable populations of *E. coli* after the sanitation step (PS). This data indicates that while generic *E. coli* was detected on harvest machines in all three regions, detection was rare even on soiled equipment directly after harvest, and especially after sanitation. This low general prevalence of *E. coli* on harvest machines indicates a low likelihood of transfer from equipment to leafy greens when following current sanitation programs, and that *E. coli* is not a useful indicator for verification of cleaning and sanitizing activities.

Table 5. Evaluation of generic *E. coli* between swab time points, indicating percentage of swabs with populations greater than or equal to 10 CFU/swab

*Total Swabs	PH (n=659) 6.2%	PD (n=492) 5.3%	PS (n=382) 1.1%
A (n=155)	5.2%	2.6%	0.6%
B (n=146)	7.1%	6.4%	1.4%
C (n=148)	4.0%	5.3%	0.7%
D (n=105)	11.4%	3.8%	1.9%
E (n=105)	3.8%	8.6%	1.0%

***** *Every swab was collected at the PH time interval while only a sub-set was collected at PD and PS collection time points.*

Outcomes and Accomplishments

Over the course of the study the team conducted a total of 30 sampling events across all three regions. A total of 11 visits occurred in Arizona, 9 visits in California, and 10 visits in Florida. Of the total visits, the team was able to assess 23 different harvest machines responsible for four crop types; Romaine, Cabbage, Green Leaf, and Iceberg. In total, the research team collected 6,196 swab samples that represent over 550,000 sample data points for pathogens, indicators, and associated metadata.

Summary of Findings and Recommendations

The recommendations for improving harvest equipment cleaning and sanitation practices include the following:

1. **Detergent and Equipment Impact**:
    - Detergent type and application, as well as the tools used during cleaning, have a greater impact on microbial reductions than sanitizers alone.
    - Chlorination detergents significantly increased ATP, Total Coliform bacteria and generic *E. coli* reductions, making them effective for cleaning and sanitation purposes.

2. **Cleaning Steps and Procedures**:
    - The cleaning (detergent) step itself has the most significant impact on reducing Aerobic Plate Count bacteria and ATP on harvest machines.
    - It is crucial to standardize the cleaning process from one side to the other and focus on a top-down cleaning approach to reduce potential cross-contamination risks.

3. **Crew Management**:
    - Managing the number of dedicated crew members and their cleaning protocols can help minimize cross contamination. For example, it is recommended to avoid simultaneous cleaning of both sides of the machine and instead clean systematically from the top down.

4. **Real-Time Evaluation**:
    - ATP can be used effectively to evaluate cleaning and sanitation effectiveness in real time, aiding in immediate corrective actions if needed.

5. **Worker Training and Education**:
    - Continuous improvements on the reduction of bacterial concentrations and the percentage of positive samples were observed throughout the study, highlighting the impact of ongoing worker training and education on reducing microbiological presence on harvest machines.

6. **Opportunities for Improvement**:
    - Simple changes, such as the availability of ladder/platform, dedicated brushes, verification tools, dedicated employee time, appropriate chemicals (foamers, coverage, contact times), and highlighting areas of concern to cleaning crews, can significantly improve cleaning and sanitation effectiveness.

7. **Microbial Sampling and Analysis**:
    - This study included systematic sampling at various points on the harvest machines and tested for indicators like Adenosine Triphosphate (ATP), Aerobic Plate Count bacteria (APC), generic *E. coli* (gEC), and Total Coliform bacteria (TC) to measure the effectiveness of the cleaning and sanitation procedures.
    - APC values correlate the most strongly with ATP values using a pairwise function with a confidence level of 0.95.
    - While not suggested as mandatory inclusion in industry SOPs, collection of baseline microbiological monitoring data could be useful to support worker training and evaluation of cleaning and sanitation procedures for industry.

These recommendations aim to provide a standardized approach to cleaning and sanitation that can be integrated into real-time operations, leading to continual improvements and better preparedness for audits and inspections in the leafy greens industry.

Grower Key Findings

- Practices and challenges were similar across all three states evaluated (AZ, CA, and FL).

- Data reported in this study likely represents a best-case scenario, as equipment was cleaned immediately following harvest day (i.e., did not sit overnight), and in some cases firms were preparing or had recently prepared for FDA sampling assignment visit(s).

- Overall, reductions were seen in generic *E. coli* analyzed from Post-Harvest (PH) to Post-Sanitation (PS) activities, with very few detections of generic *E. coli* bacteria after cleaning and sanitation were complete.

- ATP can be used as an effective tool to evaluate cleaning and sanitation effectiveness in real time.

- In general, bacterial concentrations and percentage of positive samples improved between sampling visits, identifying the impact of worker training and education in reducing microbiological loading on harvest machines.

- Opportunities exist for improvement, including very simple changes such as the availability of ladder/platform, appropriate brushes, verification tools, dedicated employees for cleaning and sanitation only, time, training, chemicals (foamers/coverage/contact times), and pointing out areas of concern to harvest cleaning and sanitation crews.

References

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4. U.S. Food and Drug Administration (2023) FY 23/24 Inspection and Environmental Sampling of Leafy Green Harvest Equipment for *Listeria monocytogenes* and *E. coli* O157:H7 (https://www.fda.gov/food/sampling-protect-food-supply/fy-2324-inspection-and-environmental-sampling-leafy-green-harvest-equipment-listeria-monocytogenes) accessed July 31st, 2024.

5. U.S. Food and Drug Administration (2022) Dole Fresh Vegetables, Inc. Announces Voluntary Recall for Certain Salads Processed at its Springfield, OH and Soledad, CA Facilities and Containing Iceberg Lettuce Due to Possible Health Risk from Listeria monocytogenes (https://www.fda.gov/safety/recalls-market-withdrawals-safety-alerts/dole-fresh-vegetables-inc-announces-voluntary-recall-certain-salads-processed-its-springfield-oh-and) accessed July 31st, 2024.

6. U.S. Food and Drug Administration (2021) Outbreak Investigation of Listeria monocytogenes: Dole Packaged Salad (https://www.fda.gov/food/outbreaks-foodborne-illness/outbreak-investigation-listeria-monocytogenes-dole-packaged-salad-december-2021#:~:text=FDA%20analyzed%20the%20positive%20samples,causing%20illnesses%20in%20this%20outbreak) accessed July 31st, 2024.

APPENDIX

Publications and Presentations – 2024

1. CPS Special Project : What is Clean?, CPS Research Symposium, June 18–19
2. CPS Special Project : What is Clean?, Hartnell College, May 2
3. CPS Special Project : What is Clean?, CPS IAG Update, April 26
4. CPS Special Project : What is Clean?, CPS BOD Update, April 24
5. FDA Sampling Update, Florida Lettuce Advisory Committee, April 10