Title
Produce safety risk assessment data gaps

Project authors
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Project summary
Quantitative Microbial Risk Assessment (QMRA) incorporates laboratory and field-based data into mathematical models to address the spread of microbial agents through environmental exposures and to characterize the nature of adverse outcomes (e.g., the risks of illness or death). Since every scenario of a QMRA cannot be wholly investigated, educated assumptions help fill existing data gaps. The use of assumptions during QMRA studies limits the effectiveness and applicability of safety procedures and policies. Therefore, this project aimed to 1) determine the data gaps that exist in relation to risk assessments for leafy green produce safety through the examination of the published scientific literature and through discussions with stakeholders in the leafy green industry, 2) identify existing data that may address identified gaps, and 3) classify each gap on the completeness of available data and the efforts required to address them. The true gaps identified during this study are all steps in the harvest category. There were numerous steps in the pre-harvest and harvest categories with limited data. Post-harvest generally had moderate data available for all steps. Identifying and classifying these gaps in the index of (in)completeness will enhance the competitiveness of leafy greens by focusing on the steps where research, education, or product development are truly necessary to improve food safety.

Project purpose
Quantitative Microbial Risk Assessment (QMRA) incorporates laboratory and field-based data into mathematical models to address the spread of microbial agents through environmental exposures and to characterize the nature of adverse outcomes (e.g., the risks of illness or death). In the produce industry, researchers, industry professionals, and government agencies use QMRA to explore contamination and risk reduction practices during food production, processing, and distribution. Exposure and dose-response data are required to accurately complete any QMRA study. When data are missing, assumptions are made using values from unrelated studies or fields, such as utilizing data generated from non-agricultural settings for the produce industry.

Since every scenario of a QMRA cannot be wholly investigated, educated assumptions fill existing gaps. Scientific and risk assessment gaps can include 1) known gaps not currently addressed in the literature, 2) known gaps that are partially addressed, 3) unknown food safety gaps that have been addressed (partially or completely) during non-food safety research, or 4) unknown and unaddressed gaps.

Known gaps not fully researched require rigorous scientific experiments to be wholly addressed. Gaps that are unknown in current food safety practices (or at least unknown to the greater agriculture community) may be addressed through other studies, requiring a multidisciplinary literature review to locate the missing information. Those gaps that are unknown and unaddressed have the potential to cause the largest adverse effects and will require the greatest effort from researchers, industry professionals, and government agencies.

Fresh produce safety data gaps lead to the use of assumptions during QMRA studies, limiting the effectiveness of safety procedures and policies. ***Therefore, this project had the following specific aims:***

1) Determine the data gaps that exist in relation to risk assessment for leafy green produce safety through the examination of the published scientific literature and leafy green industry stakeholder discussions. Food safety gaps will be identified for pre-harvest, growing/production, harvest, and post-harvest processing of leafy greens.

2) Identify existing data that may address identified gaps. This will be accomplished by examining existing data in the scientific literature to determine if they can be used in place of leafy green data. For instance, data generated from studies with other produce could be evaluated for their relevance to leafy green safety.

3) Classify each gap on the completeness of available data and the efforts required to address them. Once all data has been compiled, they will be examined for completeness in filling the data gap identified under Specific Aim #1 and the relevance of the data used to fill the gap will be scored to determine whether additional studies are necessary.

Addressing these objectives will help inform scientists, the fresh produce industry, and the Arizona Department of Agriculture to direct and prioritize future research efforts and identify the gaps, which once filled, can have the greatest impact on the public's health. This will provide the greatest benefits to the overall industry by increasing consumer good will and limiting expensive recalls.

This project will enhance the competitiveness of specialty crops through education and product development, but primarily through food safety; through the application of QMRA models, producers can take steps to improve the safety of leafy greens. This will therefore increase consumer goodwill and improve perceptions about the safety of leafy green specialty crops. The QMRA scenarios developed during this study will be specific to leafy greens; however, the design of the models and the information gathered could potentially be used in risk assessments for other non-specialty crops in the future with modification. This project has not been submitted to or funded by another Federal or State grant program.

Project activities

Initial efforts included a preliminary literature review which lead to the development of a flowchart (Figure 1). This flowchart highlighted the ideal steps in food safety risk assessment and the necessary pieces of information crucial to wholly understanding each step. This flowchart was critical in supporting the ultimate outcome of identifying leafy green risk assessment gaps through the examination of the published scientific literature. It also helped define the data gap table which served as the framework for the index of (in)completeness and was divided into pre-harvest, harvest, and post-harvest up to post-processing storage before transportation.

The initial flow chart was developed by the investigating scientists with support from research collaborators. The final flowchart was broken into three main areas: pre-harvest, harvest, and post-harvest pre-transportation. Within the pre-harvest, sub-categories were defined as seeds, water, soils, and crops. In the harvest, sub-categories of produce type (iceberg lettuce, romaine lettuce, and spinach/baby leaf products) and harvest conditions. In the post-harvest section, we defined the sub-categories of wash/rinse,

spin dry, processing of leafy greens, and storage of leafy greens. Within each sub-category, specific potential points of contamination were identified. The final flowchart (Figure 1) was converted into a survey and disseminated to food safety specialists, growers, and researchers.

Following the development of the food processing and safety concern flowchart, a survey was developed and sent to 57 food safety specialists, growers, and researchers. This survey questioned participants related to the potential food safety gaps and research needs related to pre-harvest, harvest, and post-harvest. Of the 57 originally identified and solicited experts, 28 (49%) completed the survey and were included in the results. The results were encouraging and resulted in additional points being added to the flowchart and index table. A complete report of the survey results is provided in appendix This survey supported the outcome of identifying leafy green risk assessment gaps through the examination of the published scientific literature.

Following the input from the survey results, the enhanced table was populated with literature meeting specific criteria for leafy greens research. The table was directly tied to the Measurable Outcome of identifying leafy green risk assessment gaps through the examination of the published scientific literature

An in depth scientific literature search was performed on each of the identified specific potential points of contamination for each category and sub-category. A total of 132 articles were used to inform the food safety knowledge gaps index of (in)completeness. While the current study included an extensive literature review and was supported by food safety experts, the authors recognize that certainly additional studies exists which were not identified or included in the index of (in)completeness. We hope the index presented here will serve as a foundation for future researchers to add to and continue developing the effort to make the index truly and wholly comprehensive.

The primary gaps associated with pre-harvest of leafy greens were associated with seed contamination; specifically contamination of seeds pre- and post-germination (Listeria and *Salmonella*) and time to germination (*E. coli*, Listeria, and *Salmonella*). The other important knowledge gap in pre-harvest activities included worker hand hygiene implications for food safety.

Major gaps exist in the harvest category because the sources of microbial contamination (raw material, personal hygiene, harvesting and handling tools, moving equipment, etc.) are largely unknown. This limitation is due to the probability of detection, the number of samples that can be collected, low level of detection, and routinely low levels of microbes in the study environments. Many laboratory studies will be required to answer the many food safety data gaps associated with harvesting leafy greens.

The analysis of food safety data knowledge gaps associated with post-harvest activities was complex and many different parameters influence the quality of food during each step. Studies were identified that examined each of the potential points of contamination. However, no potential contamination step was found to be extensively examined in the literature and therefore, the index suggests all post-harvest/pre-transport are limited.

At the conclusion of our project, a constructive assessment of additional items that should be addressed in future analysis and studies include: climate and extreme weather events and prior land use activities effects on microbial quality of food safety.

Goals and Outcomes achieved

This project identified leafy green risk assessment gaps following the examination of published scientific literature and through discussions with stakeholders in the leafy green industry. The goal was to better inform research and reduce duplicate food safety research efforts in leafy green industry. A stakeholder survey helped determine food safety steps and rank their importance and whether they felt the information available was missing, incomplete, or difficult to find in the current scientific literature. The compiled and comprehensive list can now be circulated to scientists, the fresh produce industry, and the Arizona Department of Agriculture.

A comprehensive literature review was used to develop the index of (in)completeness for leafy green food safety gaps. This index of (in)completeness for leafy green food safety gaps was classified according to the completeness of existing data for leafy greens based on the number of identified references for each sub-category. This information is being made available to immediately to the Arizona Department of Agriculture in this report. Additionally, the index, flow chart, and survey will be disseminated and submitted to a peer-review article in 2017. Additionally, this final report will be distributed in its entirety to scientists and the fresh produce industry to determine where best to commit future research efforts and funding.

Despite the author's immense efforts, one goal was not achieved in its entirety as stated in the initial project proposal. While many gaps were identified, they were not all cross checked against existing related data in other disciplinary studies. The authors felt that many of the gaps were truly unique to leafy green produce and therefore research performed on completely unrelated food types (e.g. cantaloupes) would have little relevance to leafy green food safety.

Beneficiaries

Arizona ranks third in the production of fresh vegetables and second in the production of lettuce, broccoli, spinach, and melons. Approximately 55% of cash receipts from Arizona commodities are from crops. The project will benefit growers, processors, farmers, and distributors of various leafy greens in the Southwest agricultural regions. The leafy green food safety gaps index of (in)completeness can be used by the Arizona Department of Agriculture to focus future research that will have the greatest impact on food safety. Additionally, the index can be used regionally and nationally by policy makers as a model to develop locally specific indices or focus research efforts. The ultimate goal of this research was to use the index of (in)completeness for leafy green food safety gaps to establish the level of research needed for the removal of each gap from the list and to improve leafy green food safety. The index was completed and can now be applied for improving leafy green food safety research.

Lessons Learned

Throughout the course of this project the authors learned a great deal about the leafy green industry and developing a comprehensive working of food safety. There is a lot of scientific literature on food safety and the authors discovered that being very specific and limiting searches to exact produce types was

essential in order to create an understandable and manageable table. Future studies attempting to generate indices should establish a the beginning of the project clear and achievable guidelines.

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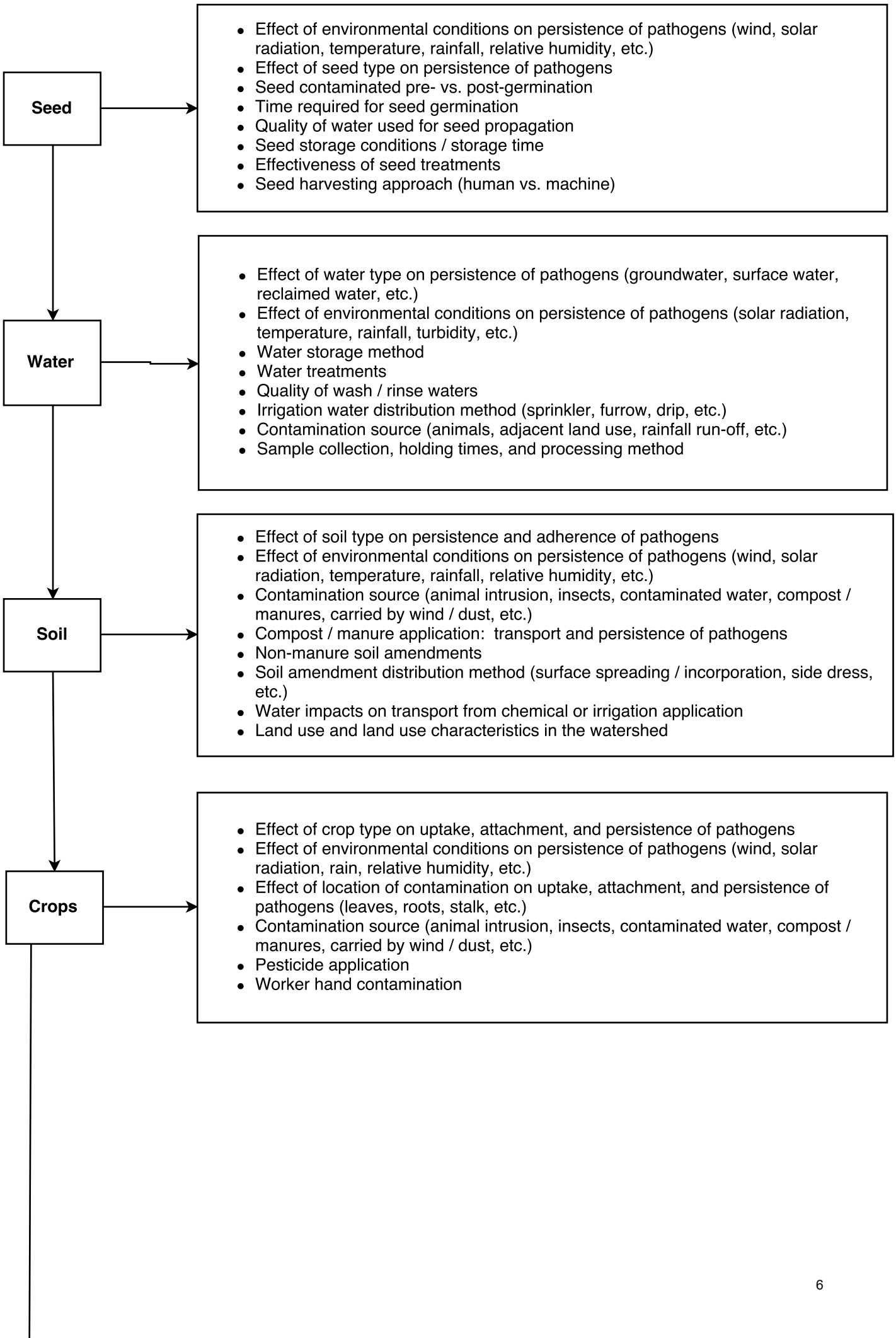
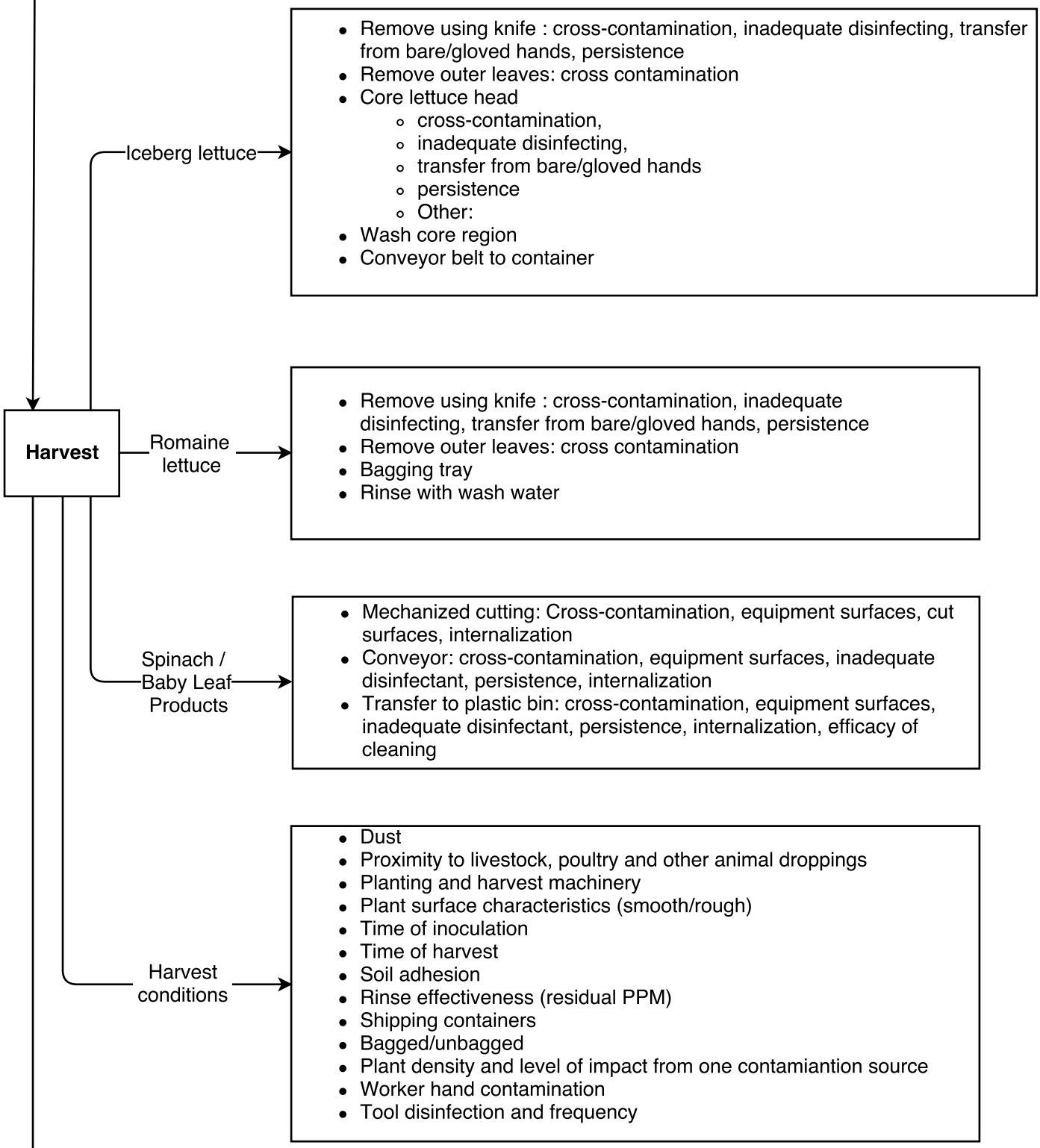
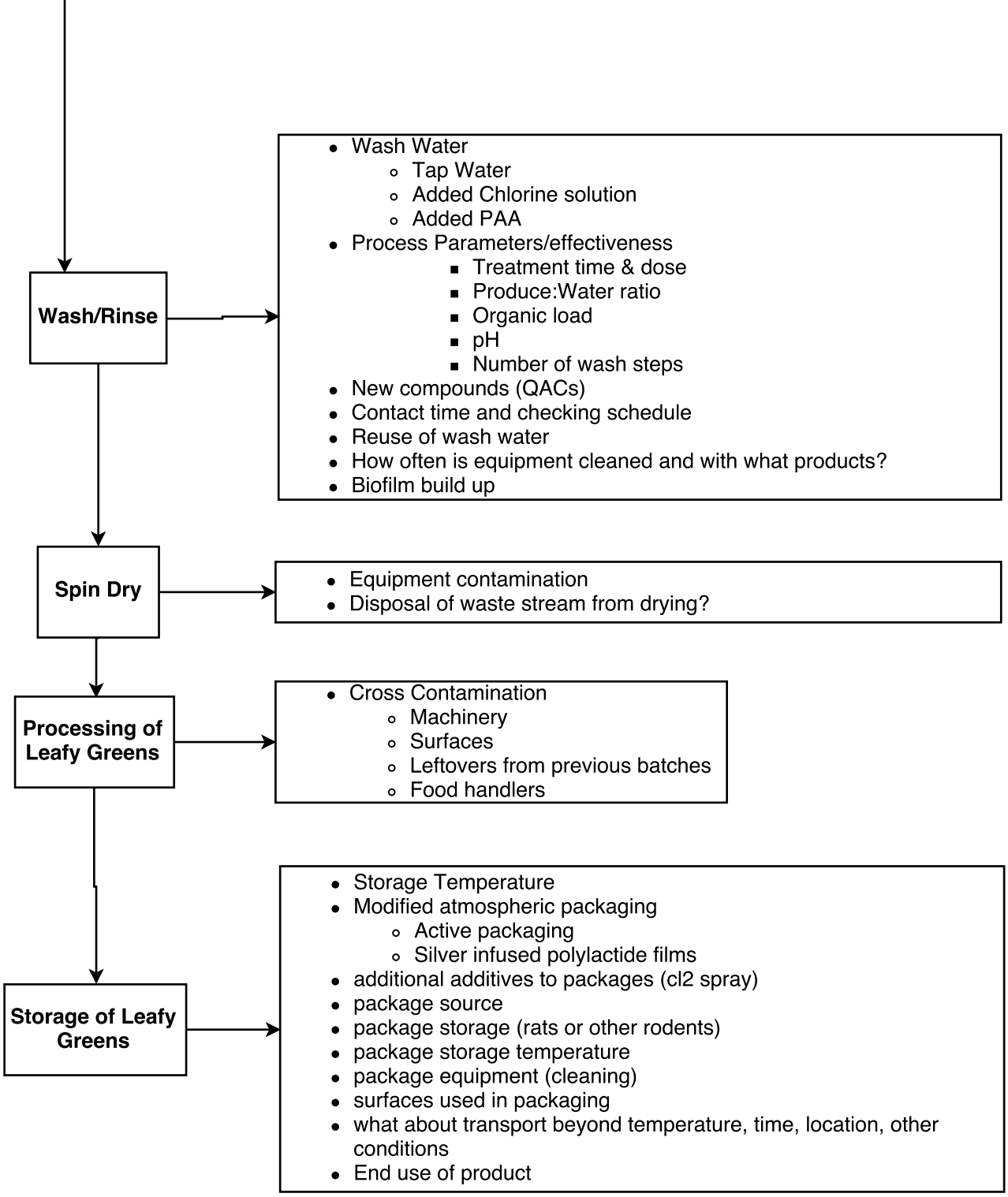
Additional Information

Figure 1. Final flowchart
Table 1. Scientific literature review index of (in)completeness
Appendix 1: Survey results


Seed
Effect of environmental conditions on persistence of pathogens (wind, solar radiation, temperature, rainfall, relative humidity, etc.)
Effect of seed type on persistence of pathogens
Seed contaminated pre- vs. post-germination
Time required for seed germination
Quality of water used for seed propagation
Seed storage conditions / storage time
Effectiveness of seed treatments
Seed harvesting approach (human vs. machine)
Water
Effect of water type on persistence of pathogens (groundwater, surface water, reclaimed water, etc.)
Effect of environmental conditions on persistence of pathogens (solar radiation, temperature, rainfall, turbidity, etc.)
Water storage method
Water treatments
Quality of wash / rinse waters
Irrigation water distribution method (sprinkler, furrow, drip, etc.)
Contamination source (animals, adjacent land use, rainfall run-off, etc.)
Sample collection, holding times, and processing method
Soil
Effect of soil type on persistence and adherence of pathogens
Effect of environmental conditions on persistence of pathogens (wind, solar radiation, temperature, rainfall, relative humidity, etc.)
Contamination source (animal intrusion, insects, contaminated water, compost / manures, carried by wind / dust, etc.)
Compost / manure application: transport and persistence of pathogens
Non-manure soil amendments
Soil amendment distribution method (surface spreading / incorporation, side dress, etc.)
Water impacts on transport from chemical or irrigation application
Land use and land use characteristics in the watershed
Crops
Effect of crop type on uptake, attachment, and persistence of pathogens
Effect of environmental conditions on persistence of pathogens (wind, solar radiation, rain, relative humidity, etc.)
Effect of location of contamination on uptake, attachment, and persistence of pathogens (leaves, roots, stalk, etc.)
Contamination source (animal intrusion, insects, contaminated water, compost / manures, carried by wind / dust, etc.)
Pesticide application
Worker hand contamination


Harvest
Iceberg lettuce
Remove using knife : cross-contamination, inadequate disinfecting, transfer from bare/gloved hands, persistence
Remove outer leaves: cross contamination
Core lettuce head
cross-contamination,
inadequate disinfecting,
transfer from bare/gloved hands
persistence
Other:
Wash core region
Conveyor belt to container
Romaine lettuce
Remove using knife : cross-contamination, inadequate disinfecting, transfer from bare/gloved hands, persistence
Remove outer leaves: cross contamination
Bagging tray
Rinse with wash water
Spinach / Baby Leaf Products
Mechanized cutting: Cross-contamination, equipment surfaces, cut surfaces, internalization
Conveyor: cross-contamination, equipment surfaces, inadequate disinfectant, persistence, internalization
Transfer to plastic bin: cross-contamination, equipment surfaces, inadequate disinfectant, persistence, internalization, efficacy of cleaning
Harvest conditions
Dust
Proximity to livestock, poultry and other animal droppings
Planting and harvest machinery
Plant surface characteristics (smooth/rough)
Time of inoculation
Time of harvest
Soil adhesion
Rinse effectiveness (residual PPM)
Shipping containers
Bagged/unbagged
Plant density and level of impact from one contamiantion source
Worker hand contamination
Tool disinfection and frequency


Wash/Rinse
Wash Water
Tap Water
Added Chlorine solution
Added PAA
Process Parameters/effectiveness
Treatment time & dose
Produce:Water ratio
Organic load
pH
Number of wash steps
New compounds (QACs)
Contact time and checking schedule
Reuse of wash water
How often is equipment cleaned and with what products?
Biofilm build up
Spin Dry
Equipment contamination
Disposal of waste stream from drying?
Processing of Leafy Greens
Cross Contamination
Machinery
Surfaces
Leftovers from previous batches
Food handlers
Storage of Leafy Greens
Storage Temperature
Modified atmospheric packaging
Active packaging
Silver infused polylactide films
additional additives to packages (cl2 spray)
package source
package storage (rats or other rodents)
package storage temperature
package equipment (cleaning)
surfaces used in packaging
what about transport beyond temperature, time, location, other conditions
End use of product

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Pre-Harvest	Planting	Seeds	Contamination pre-germination		*E. coli*	L, S, watercress, celery, coriander	(1,2)	2
Pre-Harvest	Planting	Seeds	Contamination pre-germination		Listeria			1
Pre-Harvest	Planting	Seeds	Contamination pre-germination		*Salmonella*	Alfalfa sprouts	(3)	1
Pre-Harvest	Planting	Seeds	Contamination post-germination		*E. coli*		(2,4)	2
Pre-Harvest	Planting	Seeds	Contamination post-germination		Listeria			1
Pre-Harvest	Planting	Seeds	Contamination post-germination		*Salmonella*			1
Pre-Harvest	Planting	Seeds	Time to germination		*E. coli*			1
Pre-Harvest	Planting	Seeds	Time to germination		Listeria			1
Pre-Harvest	Planting	Seeds	Time to germination		*Salmonella*			1
Pre-Harvest	Planting	Seeds	Persistence/Survival of pathogen (seed type)		*E. coli*	S, Butterhead lettuce	(1,5–7)	3
Pre-Harvest	Planting	Seeds	Persistance/Survival of pathogen (seed type)		Listeria	S, L	(5)	2
Pre-Harvest	Planting	Seeds	Persistance/Survival of pathogen (seed type)		*Salmonella*	S, Butterhead lettuce	(5–7)	2
Pre-Harvest	Fertilization/Watering	Water	Quality of water for cleaning		*E. coli*	General	(8–10)	2

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Pre-Harvest	Fertilization/Watering	Water	Quality of water for cleaning		Listeria	General	(11,12)	2
Pre-Harvest	Fertilization/Watering	Water	Quality of water for cleaning		*Salmonella*	General	(8,9,13)	3
Pre-Harvest	Fertilization/pesticides	Water	Quality of water for chemical application		*E. coli*	General	(8,9,13,14)	3
Pre-Harvest	Fertilization/pesticides	Water	Quality of water for chemical application		Listeria	General	(8,9,14)	2
Pre-Harvest	Fertilization/pesticides	Water	Quality of water for chemical application		*Salmonella*	General	(8–10,13–15)	3
Pre-Harvest	Irrigation	Groundwater	Persistence and natural decay	Irrigation water	*E. coli*		(16,17)	2
Pre-Harvest	Irrigation	Groundwater	Persistence and natural decay	Irrigation water	Listeria		(18,19)	2
Pre-Harvest	Irrigation	Groundwater	Persistence and natural decay	Irrigation water	*Salmonella*		(16,20–22)	3
Pre-Harvest	Irrigation	Groundwater	Persistence and natural decay	Sprayers	*E. coli* *Salmonella*	R, L	(23–27)	3
Pre-Harvest	Irrigation	Reclaimed water	Persistence and natural decay	Rainfall run off	*Salmonella*		(28)	2
Pre-Harvest		Surface water	Persistence and natural decay	Surface water run off	*E. coli* *Salmonella* Listeria	General	(29–32)	3

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Pre-Harvest		Soil	Soil type effects on persistence and adherence		*E. coli* *Salmonella* Listeria	L	(33,34)	2
Pre-Harvest			Animal contamination (wildlife)	Mammals and birds	*E. coli* *Salmonella* Listeria	General	(35,35–40)	4
Pre-Harvest			Animal contamination (domestic)	Dogs	*E. coli* *Salmonella* Listeria	General	(41)	2
Pre-Harvest			Proximity to livestock	Cattle and Poultry	*E. coli* *Salmonella* Listeria	General	(42–46)	3
Pre-Harvest		Soil	Use of biosolids: persistence, transport, and natural decay		*E. coli*	General	(47–58)	4
Pre-Harvest		Soil	Use of biosolids: persistence, transport, and natural decay		Listeria	General	(48,49,59)	2
Pre-Harvest		Soil	Use of biosolids: persistence, transport, and natural decay		*Salmonella*	General	(47–51,58–62)	3
Pre-Harvest		Soil	Use of manure: persistence, transport, and natural decay		*E. coli*	General	(54,58,63–68)	4
Pre-Harvest		Soil	Use of manure: persistence, transport, and natural decay		Listeria	General	(63,64,69)	2
Pre-Harvest		Soil	Use of manure: persistence, transport, and natural decay		*Salmonella*	General	(58,63–66,68,70–73)	4

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Pre-Harvest		Air	Effects of dust: persistence, transport and natural decal		*E. coli*		(42,43,45,46, 74–76)	4
Pre-Harvest		Air	Effects of dust: persistence, transport and natural decal		Listeria		(42–46,74)	3
Pre-Harvest		Air	Effects of dust: persistence, transport and natural decal		*Salmonella*		(42–46,74)	3
Pre-Harvest	Growth	Crops	Crop specific uptake (internalization)		*E. coli*	S, L, parsley	(51,77–84)	4
Pre-Harvest	Growth	Crops	Crop specific uptake (internalization)		Listeria	L, cultivated rocket, wild rocket and corn salad	(77,81,84)	2
Pre-Harvest	Growth	Crops	Crop specific uptake (internalization)		*Salmonella*		(78,81,84–87)	3
Pre-Harvest		Crops	Crop specific attachment		*E. coli* Listeria *Salmonella*	R, L	(88–91)	3
Pre-Harvest			Location of inoculum		*E. coli* *Salmonella*	L, S	(50,90,92–95)	3
Pre-Harvest	Worker Health/Hygiene		Worker hand contamination		*E. coli* *Salmonella*	L, S	(96,97)	2
Harvest	Cutting	Remove using knife	Cross-contamination from knife	Soil	*E. coli*	IL	Matthews 2009 (98)	2

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Harvest	Cutting	Remove using knife	Cross-contamination and persistence	Cutting Knife	*E. coli*	IL	(98–101)	4
Harvest	Coring	Core lettuce head with tool	Cross-contamination and persistence	Coring Tool	*E. coli*	IL	(98,100–102)	4
Harvest	Coring	Core lettuce head with tool	Wash core region with chlorine	Coring Tool	*E. coli*	IL	(100)	2
Harvest	Coring	Core lettuce head with tool	Wash coring tool with chlorine	Coring Tool	*E. coli*	IL	(100,102)	2
Harvest	Cutting	Worker's hands	Transfer from Bare hands	Bare hands			(103)	2
Harvest	Cutting	Worker's hands	Transfer from bare/gloved hands	Bare/gloved hands	*Salmonella*	IL	(104)	1
Harvest	Coring	Worker's hands	Transfer from bare/gloved hands	Bare/gloved hands		IL	Matthews 2009	1
Harvest		Worker's hands	Transfer from bare/gloved hands	Bare/gloved hands			(105)	1
Harvest	Cutting	Remove outer leaves	Cross-contamination	Bare/gloved hands		IL		0
Harvest	Cutting	Cut head from stalk	Transfer from bare/gloved hands	Bare/gloved hands			(106,107)	2
Harvest	Cutting	Manual/Mechanized cutting	Internalization	Cut edges of lettuce	*E. coli* Listeria *Salmonella*	IL, R	(85,89,93,108,109)	5
Harvest	Transport		Conveyor belt to container		*E. coli*	Il, R, S	(110,111)	2
Harvest	Cutting	Mechanized cutting	Inadequate disinfecting	Equipment surfaces	*Salmonella*	L	(112)	1
Harvest	Transport	Cross-contamination from produce	Inadequate disinfecting	Conveyor surfaces		Leafy greens	Matthews 2009	1

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Harvest	Cutting	Remove outer leaves	Cross-contamination	Bare/gloved hands		R		0
Harvest	Processing	Bag	Inadequate disinfecting	Bagging tray		R		0
Harvest	Washing	Rinse with wash water	Quality of wash water			R		
Harvest	Transport	Contact with equipment	Cross-contamination from produce	Equipment surfaces	*Salmonella*	R	(113)	1
			Cross-contamination	Equipment surfaces	*E. coli*	IL, R, S	(114)	1
Harvest	Cutting	Mechanized cutting	Cross-contamination	Contact Surfaces		Baby Leaf Products	(80,115)	2
Harvest	Cutting	Mechanized cutting	Inadequate disinfecting	Machines		Baby Leaf Products		0
Harvest	Transport	Conveyor	Contamination from produce	Equipment surfaces	*E. coli*	Baby Leaf Products	(110,114)	1
Harvest	Transport	Conveyor/Bins	Contamination from produce	Equipment /Container surfaces	Listeria	Cabbage	(116)	1
Harvest	Transport	Conveyor	Inadequate disinfecting			Baby Leaf Products		1
Harvest	Transport	Conveyor	Persistence			Baby Leaf Products		0
Harvest	Storage	Containers/Bins	Cross-contamination		*E. coli*	Baby Leaf Products	(117)	1
Harvest	Storage	Containers/Bins	Cross-contamination	Container surfaces		Baby Leaf Products		1
Harvest	Storage	Containers	Surfaces		*Salmonella*	L	(113)	1
Harvest	Storage	Containers	Inadequate disinfecting	Container surfaces				1
Harvest	Storage	Containers	Persistence					1

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Harvest			Proximity to livestock, poultry and other animal droppings AND dust	What is a safe distance to harvest?	*E. coli* Listeria *Salmonella*	General	(42–46,74–76)	8
Harvest	Worker Health/Hygiene		Worker hand contamination		*Salmonella*	L	(96,118)	2
Post-Harvest	Wash/Rinse	Wash water cross-contamination /transfer	Tap water	No sanitizer	*E. coli*	L, IL, R, BS	(114,119–121)	3
Post-Harvest	Wash/Rinse		Added Chlorine solution	treatment time & dose	*E. coli*	L, R	(120,122)	2
Post-Harvest	Wash/Rinse		Added PAA	Produce:water ratio	*E. coli*		(119)	2
Post-Harvest	Wash/Rinse		organic load		*E. coli*	L, IL	(119,122)	2
Post-Harvest	Wash/Rinse		Other solutions/additives	pH			(120)	2
Post-Harvest	Wash/Rinse		number of wash steps	cross-contamination	*E. coli*	L	(121)	2
Post-Harvest	Wash/Rinse		water/wash solution temp		*E. coli* Salmonella	Alfalfa seeds	(123–126)	2
Post-Harvest	Wash/Rinse	Specific equipment used		1st Wash Bath	*E. coli*	L	(127)	2
Post-Harvest	Wash/Rinse			2nd Wash Bath	*E. coli*	L	(127)	2

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Post-Harvest	Drying	Spinning	Equipment contamination and persistence	dewatering centrifuge; cross-contamination /transfer	*E. coli*	IL, R, BS	(110)	2
Post-Harvest	Drying	shaker table	Equipment contamination and persistence	cross-contamination /transfer	*E. coli*	IL, R, BS	(110)	2
Post-Harvest	Processing	Cross-contamination	Machinery	Shredding equipment	*E. coli*	IL, R, BS	(110,114)	2
Post-Harvest	Processing			Bore Hole	*E. coli*	L	(127)	2
Post-Harvest	Processing			cutting knife	*E. coli* Listeria	L	(128)	2
Post-Harvest	Processing			Conveyor belt	*E. coli*	L	(127)	2
Post-Harvest	Processing			stainless steel surfaces	*Salmonella*		(129)	2
Post-Harvest	Processing		Surfaces	shredding	*E. coli*	IL, R, BS	(110,114)	2
Post-Harvest	Processing		Leftovers from previous batches	shredding	*E. coli*	IL, R, BS	(114)	2
Post-Harvest	Processing		Worker hand transfer		*Salmonella*	L	(113)	2
Post-Harvest	Processing		Worker hands		*E. coli*	L	(127)	2
Post-Harvest	Processing		Condensation or moisture	vacuum cooling-induced infiltration	*E. coli*	L	(130)	2

Category	General Steps/Process Component	Potential Source(s) of Contamination	Factors of Pathogenic Incidence	Specific risk factors	Microorganism	Type of Leafy Green*	References	Rank of Gap**
Post-Harvest	Storage		Storage Temp: persistence		*E. coli*	IL	(131)	2
Post-Harvest	Storage		Modified atmospheric packaging	Vacuum cooling, infiltration	*E. coli*	L	(130,132)	2
Post-Harvest	Storage		PLA	Active packaging	*E. coli*	IL	(131)	2

*Type of leafy green: L=lettuce; IL=iceberg lettuce; BS=baby spinach; R=romaine; S=spinach

****1=information completely missing from literature; 2=limited data available in literature (1-3 references); 3=moderate data available in literature (4-7 references); 4=well studied (8+ references)**

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Appendix 1

Food Safety Gaps Online Survey Report

Food Safety Data Needs Grant Funded by the Arizona Department of Agriculture
Survey and Data Generated by University of Arizona researchers Marc Verhougstraete PhD, Kristen Pogreba-Brown PhD, MPH and Kelly Bright, PhD

This online survey was originally distributed on August 8, 2016 to a list of 57 food safety specialists, growers and researchers. Following two reminder emails, a total of 28 responses were completed (however each person did not answer all questions). The full survey as it was seen by participants in provided in Appendix 1, including the flow charts to which participants were given to determine the researchers' designations for each step. The following is a summary of the data provided within the survey. Survey questions are shown in blue throughout the report for reference.

Participants were asked to describe the stage at which they were involved in the production of leafy greens. All of the respondents stated they were involved in the pre-harvest production. The other stages, harvest and post-harvest were about a 50/50 split. Depending on their selection on this question, they were asked a series of questions related to the potential food safety gaps and research needs related to each of these areas.

Specifically related to the production of leafy greens, what part of the process are you involved in (check all that apply)?

Answer	%	Count
Pre-Harvest	100.00%	23
Harvest	56.52%	13
Post-Harvest	43.48%	10
Total	100%	23

Participants were asked to describe the stage at which they were involved in the production of leafy greens. All of the respondents stated they were involved in the pre-harvest production. The other stages, harvest and post-harvest were about a 50/50 split.

Appendix 1

Do you feel there are additional research needs or information gaps related to any of the following - you will have the opportunity to provide additional details on the next page (check all that apply)?

Answer	%	Count
Seeds	20.00%	4
Water	65.00%	13
Soil	60.00%	12
Crops	65.00%	13
Total	100%	20

PRE-HARVESTING

Table 1. Gaps by Production Stage

* Note – All choices were check all that apply		**Specifically related to the production of leafy greens, what part of the process are you involved?**		
		Pre-Harvest: Growing or field production	**Harvest: Harvesting and packing**	**Post-Harvest: Processing, storage and shipping**
For PRE-HARVEST do you feel there are additional research needs or information gaps related to any of the following...	**Seeds**	4	2	0
	Water	13	7	4
	Soil	12	8	6
	Crops	13	9	6

Appendix 1

For the following set of questions, a list of possible gaps was provided and respondents were asked to rank each one from most to least important. The goal of these questions is to identify research needs that are deemed the most important by the growers and food safety specialists in the field.

To interpret ranking tables, the ranking are along the top with 1 being the most important and 9 the least important. For example for the response below 'Contamination of seeds pre or post germination', 50% (n=2) people ranked it 1, 25% (n=1) ranked it second and 25% (n=1) ranked it fifth. Responses in **bold** are those that were ranked highest overall.

Please rank the top 5 concerns as they relate to **SEED** contamination. Drag and drop each response in the order you feel is most (#1) to least important. You can also fill in any additional concerns you have and include them in the ranking as well.

Question	1	2	3	4	5	6	7	8	9	Total
Effect of environmental conditions of persistence of pathogens (wind, solar radiation, temperature, rainfall, relative humidity, etc)	25%	0%	25%	50%	0%	0%	0%	0%	0%	4
Effect of seed type on persistence of pathogens	0%	25%	0%	50%	0%	25%	0%	0%	0%	4
Contamination of seeds pre or post germination	50%	25%	0%	0%	25%	0%	0%	0%	0%	4
Time required for seed germination	0%	0%	0%	0%	0%	25%	50%	25%	0%	4
Quality of water used for seed propagation	25%	25%	0%	0%	50%	0%	0%	0%	0%	4
Seed storage conditions/storage time	0%	0%	0%	0%	25%	50%	25%	0%	0%	4
Effectiveness of seed treatments	0%	25%	75%	0%	0%	0%	0%	0%	0%	4
Seed harvesting approach (human vs. machine)	0%	0%	0%	0%	0%	0%	25%	50%	25%	4
Other (optional)	0%	0%	0%	0%	0%	0%	0%	25%	75%	4

Other (text response)

Effect of geographical location of seed propagation

Appendix 1

Please rank the top 5 concerns as they relate to **WATER** contamination. Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	6	7	8	9	Total
Effect of water type on persistence of pathogens (groundwater, surface water, reclaimed water, etc)	30.8%	15.4%	30.8%	23.1%	0.0%	0.0%	0.0%	0.0%	0.0%	13
Effect of environmental conditions of persistence of pathogens (solar radiation, temperature, rainfall, turbidity, etc)	23.1%	30.8%	15.4%	23.1%	7.7%	0.0%	0.0%	0.0%	0.0%	13
Water storage methods	0.0%	0.0%	7.7%	0.0%	30.8%	38.5%	23.1%	0.0%	0.0%	13
Effectiveness of water treatments (chlorine, UV, ozone, etc)	15.4%	7.7%	7.7%	23.1%	7.7%	30.8%	7.7%	0.0%	0.0%	13
Irrigation water distribution method (sprinkler, furrow, drip, etc)	0.0%	23.1%	7.7%	30.8%	0.0%	7.7%	23.1%	7.7%	0.0%	13
Contamination source (animals, adjacent land use, rainfall run-off, etc)	30.8%	15.4%	23.1%	0.0%	23.1%	0.0%	0.0%	7.7%	0.0%	13
Sample collection, holding times, and processing methods	0.0%	7.7%	7.7%	0.0%	15.4%	7.7%	38.5%	23.1%	0.0%	13
Frequency of irrigation	0.0%	0.0%	0.0%	0.0%	16.7%	16.7%	8.3%	58.3%	0.0%	12

Appendix 1

Please rank the top 5 concerns as they relate to **SOIL** contamination. Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	6	7	8	9	Total
Effect of soil type on persistence and adherence of pathogens	8.3%	16.7%	33.3%	16.7%	8.3%	16.7%	0.0%	0.0%	0.0%	12
Effect of environmental conditions of persistence of pathogens (wind, solar radiation, temperature, rainfall, relative humidity, etc)	33.3%	25.0%	16.7%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12
Contamination source (animal intrusion, insects, contaminated water, compost I manures, carried by wind/dust, etc.)	25.0%	33.3%	16.7%	16.7%	0.0%	0.0%	8.3%	0.0%	0.0%	12
Compost/manure application: transport and persistence of pathogens	16.7%	8.3%	25.0%	0.0%	25.0%	8.3%	16.7%	0.0%	0.0%	12
Non-manure soil amendments	0.0%	0.0%	0.0%	8.3%	25.0%	16.7%	0.0%	50.0%	0.0%	12
Soil amendment distribution method (surface spreading/incorporation, side dress, etc.)	8.3%	8.3%	0.0%	16.7%	16.7%	25.0%	25.0%	0.0%	0.0%	12
Contamination from splashing or flow of irrigation/chemical application	0.0%	8.3%	0.0%	8.3%	16.7%	25.0%	25.0%	16.7%	0.0%	12
Land use and land use characteristics in the watershed	8.3%	0.0%	8.3%	8.3%	8.3%	8.3%	25.0%	33.3%	0.0%	12

Appendix 1

Please rank the top 5 concerns as they relate to **CROP** contamination. Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	6	7	Total
Effect of environmental conditions on persistence of pathogens (wind, solar radiation, rain, relative humidity, etc.)	38.5%	30.8%	15.4%	0.0%	15.4%	0.0%	0.0%	13
Effect of crop type on uptake, attachment, and persistence of pathogens	7.7%	30.8%	38.5%	7.7%	0.0%	15.4%	0.0%	13
Effect of location of contamination on uptake, attachment, and persistence of pathogens (leaves, roots, stalk, etc.)	7.7%	15.4%	23.1%	23.1%	30.8%	0.0%	0.0%	13
Contamination source (animal intrusion, insects, contaminated water, amendments, compost/manures, carried by wind/dust, etc.)	46.2%	15.4%	0.0%	23.1%	7.7%	7.7%	0.0%	13
Contamination from splashing or flow of irrigation / chemical or pesticide application	0.0%	0.0%	15.4%	7.7%	30.8%	46.2%	0.0%	13
Contamination by workers (transfer from hands/gloves, clothing/smock, etc.)	0.0%	7.7%	7.7%	38.5%	15.4%	30.8%	0.0%	13

Appendix 1

Of the problems you ranked the most important, what specific information do you think it would be important to learn to improve pre-harvest practices or reduce the chances of contamination?

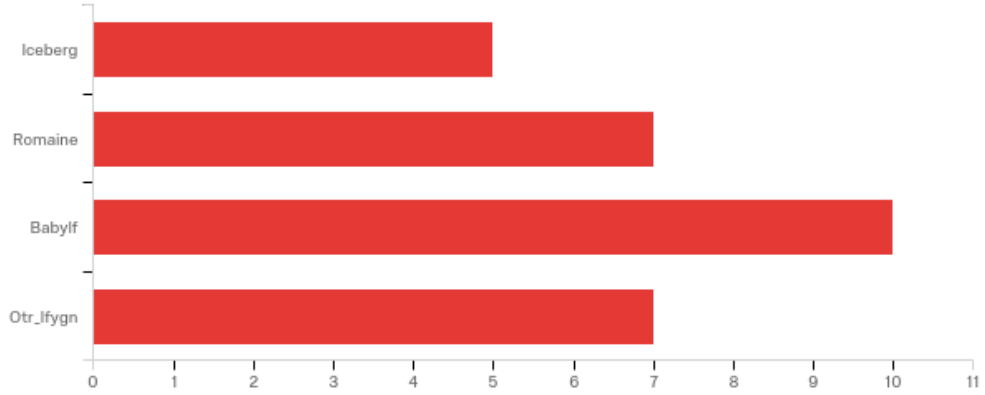
Below are comments from respondents in open text boxes.

Of the problems you ranked the most important, what specific information do...
I was impressed with how complete the list is.
How varying practices related to irrigation source and timing as well as amendments contribute to pathogen intrusion and persistence.
It would be great now how much of a contamination really occurs when we have an animal intrusion in the field per commodity (ie. cilantro vs whole head romaine). It would also be beneficial to know if a larger buffer is needed based on the animal that intruded (i.e deer vs dog). Also are there environmental factors that enhances or inhibits the propagation of pathogens in the soil and or product caused by an animal intrusion.
Source of contamination, factors affecting persistence, mitigation
Water quality
Possible crop contamination by insects under a variety of circumstances. Right now we're looking at the LGMA 400' buffer as being too limited but considering the lack of outbreaks attributed to insect contamination of human pathogens, are we getting information on mid-west experiments conducted under different climatic and different (?) insect species that are not typical for AZ and CA conditions. Also, AZ has really hot summer conditions so is the ground significantly "solarized" to eliminate or reduce pathogens to a significant level?
relative risk of water source and relative risk of soil amendments of animal origin
Why certain crops on the same land and the same water source have different pathogen testing results? As recycled/reclaimed/reconditioned (all currently used terms) water becomes more prevalent, what are the associated risks and preventative measures?
Water Storage methods - collection and reuse of irrigation water in tailwater systems specifically and the likelihood or presence of contamination in these systems. Possible ways to treat these systems effectively. Soil environmental conditions on persistence of pathogens, how long these pathogens can survive in the soils in the desert. How far these pathogens can travel in the wind, their persistence in the desert environment, and the uptake of pathogens in different crops.
Understanding the contamination source in order to be able to take measures to prevent the contamination in the first place

Appendix 1

HARVESTING

Related to the HARVESTING of leafy greens, which products do you specifically work with? (check all that apply)



Answer	%
Iceberg	41.67%
Romaine	58.33%
Baby Leaf	83.33%
Other Leafy Green	58.33%
Total	100%

Other Leafy Greens

Bunched greens
Cabbage
Leaf lettuce
generally all types
Cabbage, Kale, Chards, Kohlrabi
all leafy greens

Appendix 1

* Note – All choices were check all that apply		Specifically related to the production of leafy greens, what part of the process are you involved?		
		Pre-Harvest: Growing or field production	**Harvest: Harvesting and packing**	**Post-Harvest: Processing, storage and shipping**
Related to the HARVESTING of leafy greens, which products do you specifically work with?	**Iceberg lettuce**	5	5	4
	Romaine lettuce	7	7	5
	Spinach/Baby Leaf products	10	10	7
	Other (please specify)	7	7	5

While there are differences between the PROCESSES for each crop, the points of possible contamination are fairly similar (we will link the crops you selected above to the responses below). Please rank your top 5 concerns by dragging and dropping your responses in order (#1 is of most concern). You can also fill in any additional concerns you have and include them in the ranking as well.

Question	1	2	3	4	5	6	7	8	9	Total
Concentration and persistence of pathogens on bins/conveyor belt surfaces	20.0%	30.0%	40.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	10
Contamination by workers (transfer from hands/gloves, clothing/smock, etc.)	20.0%	20.0%	20.0%	20.0%	0.0%	10.0%	0.0%	10.0%	0.0%	10
Cross-contamination (between any of the following - soil / lettuce or product to cutting tool/coring tool/conveyor belt/bins/other lettuce/outer leaves)	40.0%	20.0%	10.0%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10
Effectiveness of raw product wash/rinse waters (disinfectant residual)	0.0%	20.0%	0.0%	30.0%	40.0%	10.0%	0.0%	0.0%	0.0%	10
Disinfection of cutting/coring tools	0.0%	0.0%	20.0%	10.0%	30.0%	20.0%	10.0%	10.0%	0.0%	10
Disinfection of conveyor belt/plastic bins/equipment surfaces	10.0%	10.0%	0.0%	10.0%	10.0%	30.0%	20.0%	10.0%	0.0%	10
Cross-contamination from outer leaves to inner leaves during harvest	0.0%	0.0%	10.0%	0.0%	0.0%	20.0%	60.0%	10.0%	0.0%	10
Internalization of pathogens through cut leaf edges	10.0%	0.0%	0.0%	0.0%	20.0%	0.0%	10.0%	60.0%	0.0%	10

Appendix 1

What **HARVEST CONDITIONS** are of most concern? Drag and drop each response in the order you feel is most to least important (#1 is of most concern).

Question	1	2	3	4	5	6	7	8	9	10	11	12	Total
Contamination by dust	33.3%	25.0%	8.3%	8.3%	0.0%	0.0%	0.0%	16.7%	0.0%	0.0%	8.3%	0.0%	12
Proximity to livestock, poultry, or animal droppings	25.0%	25.0%	25.0%	0.0%	8.3%	0.0%	8.3%	0.0%	8.3%	0.0%	0.0%	0.0%	12
Effect of planting density (level of impact from one contamination source)	0.0%	0.0%	16.7%	16.7%	8.3%	8.3%	0.0%	8.3%	16.7%	16.7%	8.3%	0.0%	12
Effect of bed row size (narrow or wide)	0.0%	0.0%	0.0%	8.3%	8.3%	0.0%	16.7%	16.7%	16.7%	16.7%	16.7%	0.0%	12
Effect of method of harvesting (manual or mechanized, cut leaves or whole head/heart, cored, etc.)	25.0%	0.0%	8.3%	0.0%	25.0%	8.3%	16.7%	0.0%	16.7%	0.0%	0.0%	0.0%	12
Effect of plant surface characteristics (smooth/rough, open/closed head)	0.0%	0.0%	0.0%	25.0%	16.7%	25.0%	8.3%	8.3%	0.0%	16.7%	0.0%	0.0%	12
Time of contamination in relation to harvest	16.7%	8.3%	16.7%	25.0%	0.0%	8.3%	8.3%	8.3%	0.0%	8.3%	0.0%	0.0%	12
Adhesion of pathogens to soil	0.0%	25.0%	8.3%	0.0%	0.0%	16.7%	16.7%	8.3%	8.3%	8.3%	8.3%	0.0%	12
Packaged in the field or transported to packaging facility	0.0%	0.0%	0.0%	0.0%	8.3%	16.7%	16.7%	8.3%	8.3%	16.7%	25.0%	0.0%	12
Frequency of testing for wash/rinse water disinfectant	0.0%	8.3%	8.3%	8.3%	8.3%	8.3%	0.0%	8.3%	16.7%	8.3%	25.0%	0.0%	12

residual (ppm)													
Plastic bin/cutting tool/coring tool/equipment disinfection frequency	0.0%	8.3%	8.3%	8.3%	16.7%	8.3%	8.3%	16.7%	8.3%	8.3%	8.3%	0.0%	12

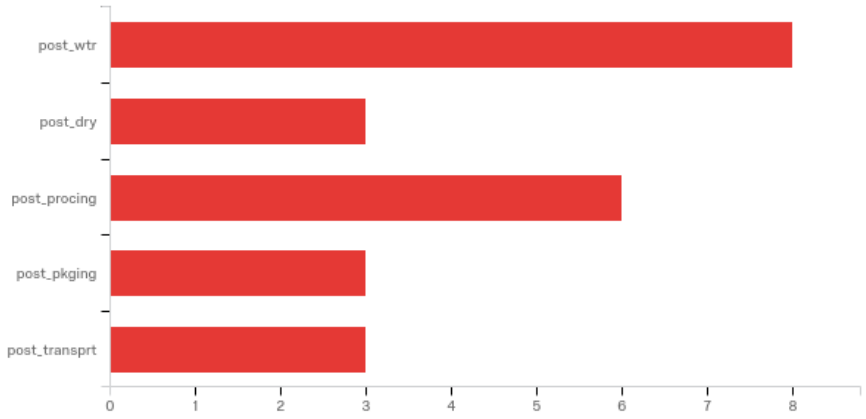
Of the problems you ranked the most important, what specific information do you think it would be important to learn to improve harvest practices or reduce the chances of contamination?

I still see people packing leafy greens on the ground and I would like to find out, finally, whether it should be allowed or not.
Determine if short term exposure of fecal material prior to harvest is a real concern. That is, a flock of birds land on a field of lettuce ahead of the harvesting crews and if we need to take more actions like sanitize glove and knives more frequently.
Mechanical harvesting versus traditional hand harvesting.
Sanitation of equipment - effectiveness of sanitizers, frequency of disinfection. Effect of Method of harvesting. Harvesting seems to be the most likely point of contamination - I would think this is the valuable area we need more resources put into.
How frequently the wash water should be tested.

Appendix 1

POST-HARVEST

Finally, for **POST HARVEST**, what steps of the process do you feel there are chances for contamination (check all that apply)?



Answer	%
Water	88.89%
Drying	33.33%
Processing	66.67%
Packaging	33.33%
Transport	33.33%
Total	100%

* Note – All choices were check all that apply		**Specifically related to the production of leafy greens, what part of the process are you involved?**		
		Pre-Harvest: Growing or field production	**Harvest: Harvesting and packing**	**Post-Harvest: Processing, storage and shipping**
For POST HARVEST, what steps of the process do you feel there are chances for contamination?	**Wash/Rinse**	8	8	7
	Spin Dry	3	3	3
	Processing of Leafy Greens	6	6	5
	Packaging/Storage of Leafy Greens	3	3	2
	Transport	3	3	3

Appendix 1

What **WASH WATER/RINSE** conditions are the top 5 concerns during post-harvest? Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	6	7	8	9	Total
Frequency of water replenishment	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	37.5%	37.5%	0.0%	8
Effect of biofilm formation on equipment/processing surfaces	0.0%	25.0%	12.5%	12.5%	12.5%	0.0%	12.5%	25.0%	0.0%	8
Reuse of wash/rinse water	0.0%	0.0%	25.0%	25.0%	0.0%	12.5%	0.0%	25.0%	12.5%	8
Other (optional)	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	75.0%	8
Effectiveness of wash/rinse waters (disinfectant residual)	50.0%	25.0%	12.5%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	8
Frequency of testing for wash/rinse water disinfectant residual (ppm)	0.0%	0.0%	37.5%	25.0%	12.5%	25.0%	0.0%	0.0%	0.0%	8
Effect of type of wash/rinse water (chlorine, hydrogen peroxide, peroxyacetic acid, QACs, etc.)	25.0%	0.0%	0.0%	25.0%	25.0%	12.5%	12.5%	0.0%	0.0%	8
Effect of type of washing/rinsing (flume, spray, etc.)	12.5%	0.0%	12.5%	0.0%	12.5%	25.0%	25.0%	0.0%	12.5%	8
Effect of process parameters (treatment time, sanitizer concentration, organic load, pH, temperature, number of wash steps, produce to water ratio, etc.)	12.5%	37.5%	0.0%	0.0%	12.5%	25.0%	12.5%	0.0%	0.0%	8

Optional Text

We don't process but supply to processors.
Industry needs a "safe harbor" level for sanitizer concentrations due to lack of research and solid validation methods.
Effect of type of produce on wash / rinse effectiveness

Appendix 1

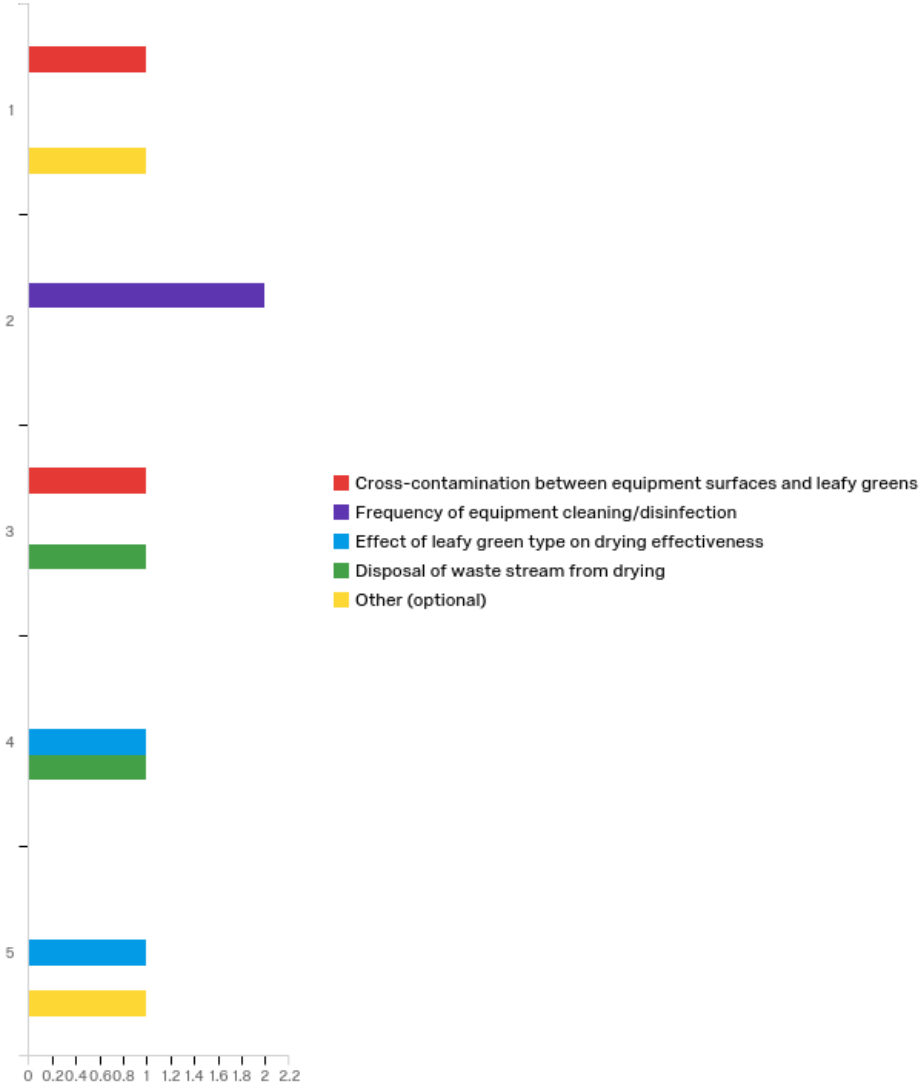
What **SPIN DRY** conditions are of most concern during post-harvest? Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	Total
Cross-contamination between equipment surfaces and leafy greens	50.0%	0.0%	50.0%	0.0%	0.0%	2
Frequency of equipment cleaning/disinfection	0.0%	100.0%	0.0%	0.0%	0.0%	2
Effect of leafy green type on drying effectiveness	0.0%	0.0%	0.0%	50.0%	50.0%	2
Disposal of waste stream from drying	0.0%	0.0%	50.0%	50.0%	0.0%	2
Other (optional)	50.0%	0.0%	0.0%	0.0%	50.0%	2

Optional Text

Sanitary Design aspects of construction to make the dryer easily cleanable and reduce harborage areas

Appendix 1


1
2
3
4
5
0 0.20.40.60.8 1 1.2 1.4 1.6 1.8 2 2.2
Cross-contamination between equipment surfaces and leafy greens
Frequency of equipment cleaning/disinfection
Effect of leafy green type on drying effectiveness
Disposal of waste stream from drying
Other (optional)

Appendix 1

What **PROCESSING** conditions are of most concern during post-harvest? Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	6	7	8	Total
Concentration and persistence of pathogens on equipment surfaces	16.7%	50.0%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	6
Contamination by workers (transfer from hands/gloves, clothing/smock, etc.)	0.0%	16.7%	16.7%	16.7%	33.3%	16.7%	0.0%	0.0%	6
Effect of produce type on sanitizer effectiveness (whole head or fresh cut, rough or smooth surfaces, internalization of microbes into cut edges)	0.0%	0.0%	16.7%	33.3%	16.7%	33.3%	0.0%	0.0%	6
Cross-contamination (between any of the following - leafy greens/equipment surfaces/plastic bins/other leafy greens)	16.7%	16.7%	16.7%	16.7%	16.7%	0.0%	16.7%	0.0%	6
Effect of leftover leafy greens from previous batches (leading to contamination of water, surfaces or bins)	16.7%	16.7%	0.0%	0.0%	0.0%	16.7%	33.3%	16.7%	6
Frequency of equipment cleaning/disinfection	16.7%	0.0%	16.7%	16.7%	16.7%	16.7%	16.7%	0.0%	6
Effect of biofilm formation on equipment/processing surfaces	16.7%	0.0%	0.0%	16.7%	16.7%	16.7%	33.3%	0.0%	6
Other (optional)	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	83.3%	6

Other (text)

Effectiveness of overall plant sanitation especially in high hygiene areas

Appendix 1

What **PACKAGING/STORAGE** conditions are of most concern during post-harvest? Drag and drop each response in the order you feel is most (#1) to least important.

Question	1	2	3	4	5	6	7	8	9	10	Total
Effect of product end use (mixed cut salad or whole lettuce, grocery store or restaurant, etc.)	0.0%	33.3%	33.3%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3
Effect of packaging material	0.0%	0.0%	0.0%	0.0%	0.0%	66.7%	0.0%	33.3%	0.0%	0.0%	3
Effect of produce type on packaging effectiveness	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%	66.7%	0.0%	0.0%	0.0%	3
Effectiveness of modified atmospheric packaging (active packaging, silver infused polylactide films, etc.)	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	66.7%	0.0%	0.0%	3
Effectiveness of other package additives	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	66.7%	0.0%	3
Package transport/storage conditions (rodent/ insect intrusion, storage temperature, storage time, etc.)	0.0%	33.3%	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3
Quality of water used for hydro cooling	33.3%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	3
Cross-contamination between equipment surfaces and leafy greens	33.3%	0.0%	0.0%	0.0%	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%	3
Frequency of equipment cleaning/disinfection	33.3%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	3

Appendix 1

What **TRANSPORT** activities are of most concern?

Question	1	2	3	Total
Transport from field to processing facility	0.00%	100.00%	0.00%	1
Transport from facility to retailer/consumer	100.00%	0.00%	0.00%	1
Other (optional)	0.00%	0.00%	100.00%	1

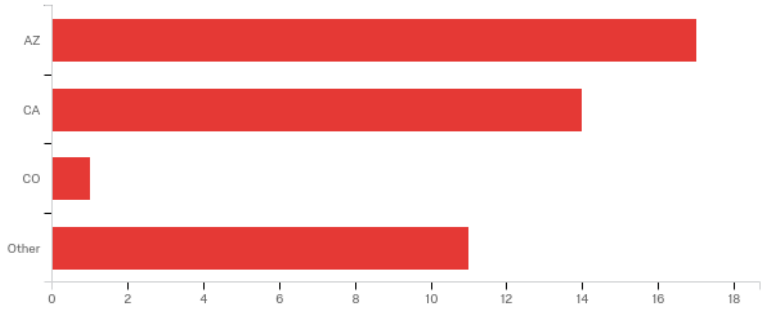
Of the problems you ranked the most important, what specific information do you think it would be important to learn to improve post-harvest practices or reduce the chances of contamination?

Participant Comments

I believe growers and harvesters need to be educated to the fact that wash lines are not a kill step and that your food safety program should not be designed to "get by" the food safety inspectors of your buyers.
Determine what is the optimal chemicals and conditions to eliminate pathogens on the surface of the leaf as well as in the wash water.
The difference in potential pathogen levels between straight pass using fresh water versus using recycled water.
Understanding the level of cross-contamination in the processing of fresh produce.

Appendix 1

What state(s) do you work in (check all that apply)?



Answer	%
AZ	68.00%
CA	56.00%
CO	4.00%
Other	44.00%
Total	100%

Other (please include)

New York
Northeast/Southeast USA
Indiana
Maryland
Ciudad Morelos, Baja California Mexico
South
Mexico
New Mexico, Mexico, Nevada, Florida
Florida
Florida

Appendix 1

Do you work at all in Mexico?

Answer	%	Count
Yes, often	20.00%	5
Yes, not often	20.00%	5
No	60.00%	15
Total	100%	25

How would you describe your PRIMARY job description?

Answer	%	Count
Grower	15.38%	4
Processor	3.85%	1
Food Safety Specialist	57.69%	15
Regulator	11.54%	3
Researcher	11.54%	3
Packer	0.00%	0
Shipper	0.00%	0
Harvester	0.00%	0
Total	100%	26

What size of farm do you work with most (as defined by FSMA guidelines)?

Answer	%	Count
Small (less than $25,000 generated revenue)	4.35%	1
Medium (generated revenue greater than $25k, but less than $500k)	13.04%	3
Large (greater than $500k generated revenue)	82.61%	19
Total	100%	23

Appendix 1

How many years have you been in the food production industry?

Answer	%	Count
Less than 1 year	0.00%	0
1-2yrs	3.85%	1
3-5yrs	15.38%	4
6-10yrs	15.38%	4
More than 10yrs	65.38%	17
Total	100%	26

Please indicate your level of Fresh Produce Safety knowledge or skill? (check all that apply)

Answer	%	Count
I am aware of some fresh produce safety programs	56.00%	14
I have participated in a food safety training program	80.00%	20
I know what a food safety plan is and how to write and implement one	76.00%	19
I keep records and documents of key areas in my food safety program	56.00%	14
I have participated and passed a food safety audit	56.00%	14
I am compliant in a food safety program (such as USDA GHP/GAP, Group GAP, Harmonized GAP, AZLGMA, commodity specific GAPs or a buyer driven compliance program)	68.00%	17
Total	100%	25

Appendix 1
Job Description by Farm Type and Experience

		Primary Job Description				
		Grower	**Processor**	**Food Safety Specialist**	**Regulator**	**Researcher**
What size of farm do you work with most (as defined by FSMA guidelines)?	**Small Farm**	0	0	1	0	0
	Medium Farm	1	0	0	1	1
	Large Farm	3	0	13	1	2
How many years have you been in the food production industry?	**Less than 1**	0	0	0	0	0
	1-2	0	0	1	0	0
	5-6	0	0	1	1	2
	7-10	1	0	3	0	0
	More than 10 years	3	1	10	2	1
Please indicate your level of Fresh Produce Safety knowledge or skill? (check all that apply)	**Aware of fresh produce safety programs**	0	1	10	3	0
	Participated in a food safety training program	1	1	13	3	2
	Knows what a food safety plan is and how to write and implement one	1	1	13	2	2
	Keeps records and documents of key areas in my food safety program	1	1	11	0	1
	Participated and passed a food safety audit	2	1	11	0	0
	I am compliant in a food safety program (such as the USDA GHP/GAP, Group GAP, Harmonized GAP, AZLGMA, commodity specific GAPs or a buyer driven compliance program).	3	1	12	0	1