Digital farm-to-facility food safety testing optimization

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- Industry collaborators: Dr. Eric Wilhelmsen, Jim Brennan from Smart Wash solutions/Taylor Farms; Rebecca Unwer from Walmart; Suresh de Costa from Lipman Family Farms; Bibiana Urbina from Chipotle
- Academic Collaborators: Dr. Renata Ivanek and Dr. Ece Bulut from Cornell University

Summary

Optimal food safety testing in the industry is limited by inconsistent requirements for produce testing, legacy approaches focusing on single points in the supply chain, and inability of testing schemes to bound a contamination event. This project focuses on addressing research gaps by conducting a scenario analysis to assess the impact of product testing at different stages of the farm-to-consumer process. A total of 42 scenarios were generated (**Figure 1**), and the scenario analysis demonstrates that the sampling plan efficacy on exposure reduction is limited when an optimal system with GAPs and GMPs is in place. Compared to interventions, such as washing and pre-harvest holding, sampling shows limited effect at reducing consumer exposure.

Objectives

1. Build a Field-to-Facility generic supply chain model of produce safety testing.
2. Adapt the supply chain and collect parameters to represent a variety of commodities with distinct risk profiles and risk-management options.
3. Optimize testing across the supply chain of each commodity incorporating representative testing programs at primary production, harvesting, receiving, processing, and packing, and assessing their impact to manage safety.

Methods

A farm-to-consumer process model was built in Python. A 100,000 lb leafy green field was modeled to be contaminated with 100,000 cells of *Escherichia coli* O157:H7. Three contamination spreads were modeled: (i) random contamination, (ii) a cluster covering 10% of the field, and (iii) a cluster covering 1% of the field.

Two baseline systems were developed to represent processing systems: (i) a No-Intervention system that represents a farm-to-consumer process with suboptimal agricultural and manufacturing practices, and (ii) an All-Intervention system that represents a system with GAPs and GMPs; there, interventions such as pre-harvest holding, pre-cooling, and washing were applied. Seven sampling plans at different processing stages were applied to both systems (descriptions in **Table 1**). An exposure assessment and a factor sensitivity analysis were performed to assess the efficacy of sampling and process interventions.

Results to Date

The scenario analysis was conducted to assess the efficacy of 7 sampling plans, across 2 baseline systems, under 3 different contamination spreads. The results show:

- Sampling plans are better at reducing consumer exposure more when the system lacks other food safety controls (the No-Intervention system, **Figure 2**).
  - This is due to relatively higher contamination at process stages sampled in the No-Intervention system
- In contrast, sampling plans do little to reduce consumer exposure when good food safety preventative controls are in place (the All-Intervention system, **Figure 2**).
- The factor sensitivity analysis shows that interventions have a greater effect than sampling at reducing the total pathogen levels that reach the consumer (**Figure 3**).
  - Interventions such as washing, pre-wash, and pre-harvest holding were more effective at preventing consumer exposure than any of the sampling plans.
  - Sampling plans under the No-Intervention conditions have a greater effect at preventing consumer exposure than sampling plans when the All-Intervention system was in place.

Benefits to the Industry

The key beneficiaries for this project are those growers and other individuals who are subject to different testing requirements imposed due to inconsistencies in customer and regulatory requirements. This project demonstrates that sampling plans show limited power when GAPs and GMPs are in place. The results of this project will potentially provide confidence to growers, producers, and buyers on where to focus their risk mitigation efforts. This model provides science-based evidence and will continue to assess the effect of conducting food safety sampling for other commodities.

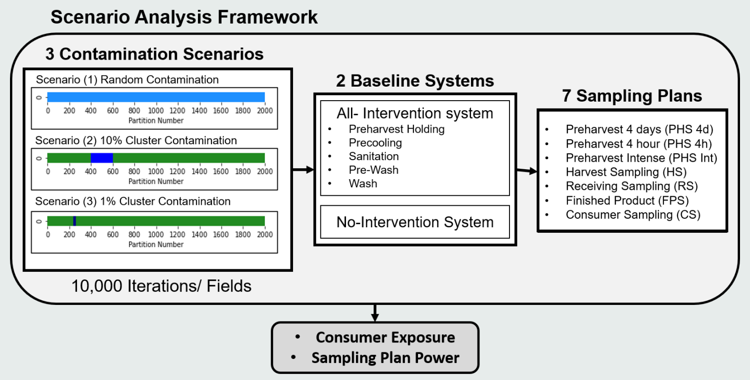

Figure 1. The scenario analysis consists of 42 scenarios: 3 contamination patterns were modeled across 2 baseline systems, and 7 sampling plans were evaluated, one at a time on each system to evaluate the effect of sampling on consumer exposure.

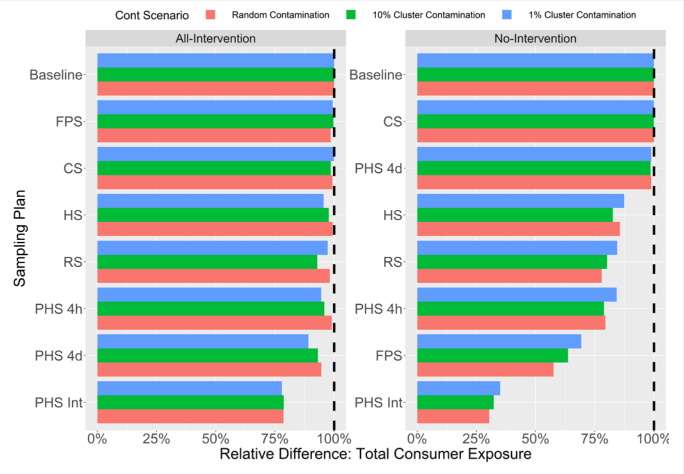

Figure 2. Results from the scenario analysis. Sampling plans have limited effect in the All-Intervention system (most relative differences show 90% or more remaining exposure). Sampling plans have a greater effect (some reduce exposure to 25–80%) in the No-Intervention system due to higher pathogen contamination at sampling points. See Table 1 for Y-axis labels.

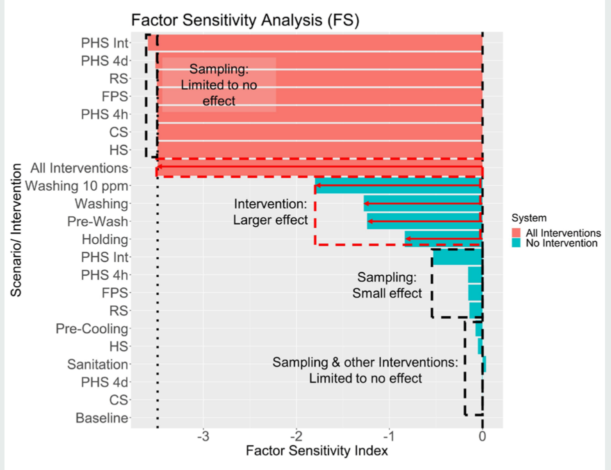

Figure 3. Results from the factor sensitivity analysis. Factor sensitivity (FS) is essentially the log reduction between the total exposure from a scenario and the baseline system with no food safety interventions [Log_{10}(condition/ baseline), for 10,000 field iterations]. The greater the absolute FS, the more effect that a specific scenario/condition has on total consumer exposure. Interventions have greater factor sensitivity than the sampling plans. When the All-Intervention system is in place, sampling plans show limited to no effect. See Table 1 for Y-axis labels.

Sampling Plan	Total Number of Samples	Samples per lot	Samples per sublot	Samples per Pallet	Samples per FP production hour	Sample Mass (g)	Total Mass sampled (g)	Grabs per sample (#)	Total Grabs (#)	Rejection Rule
Pre-Harvest 4 day (PHS 4D)	1	1	-	-	-	375	**375**	60	**60**	**"Field"**
Pre-Harvest 4 hour (PHS 4H)	1	1	-	-	-	375	**375**	60	**60**	**"Field"**
Pre-Harvest Sampling Intense (PHS Int)	10	10	1	-	-	375	**3750**	60	**600**	**"Field"**
Harvest Sampling (HS)	1	1	-	-	-	375	**375**	60	**60**	**"Field"**
Receiving Sampling (RS)	25	-	-	1	-	15	**375**	2.4 uniform (2 or 3)	**60**	**"Field"**
Finished product Sampling (FPS*)	5	1	-	-	1	200	**1000**	4	**20**	**"Field"**
End Consumer Sampling (CS**)	63	-	-	1		25	**1575**	3	**189**	**"Field"**

* Based on packing 20,000 lb of finished product per hour. Each hour, 4 bags are sampled for a composite sample mass of 200 g.
** Based on a 4/5# case, 80 cases per pallet. 100,000 yields 63 pallets of product. For Foodservice.

Table 1. The 7 individual sampling plans modeled. Columns describe the plan stratification, number of sample grabs, their mass, and rejection rules.