Flexible risk process models to quantify residual risks and the impact of interventions

Summary

The produce industry uses pre- and post-harvest assessments to monitor food safety systems and identify deviations from protocols. Yet, there are limited quantitative tools modeling deviations to support decision-making around response. The supply chain risk model (SCRM; **Figure 1**) was previously used to evaluate the tradeoffs between food safety management practices (**Table 1**) for leafy green contamination with Shiga toxin–producing *Escherichia coli* (STEC). Here the SCRM was used to evaluate four small-scale failures introducing contamination or reduced control over safety interventions: (i) discovering a nonfunctioning irrigation treatment system after irrigation, (ii) ineffective harvester equipment sanitation before harvest, (iii) small animal fecal contamination in a field, and (iv) inadequate process wash control. We are also working with industry stakeholders to model new scenarios to inform current industry decision-making.

Objectives

1. Compare the impact of small-scale failures on the overall risk of a positive test at retail ("recall" risk) and the number of lots with the highest levels of contamination ("public health" risk).
2. Work with industry stakeholders to develop new scenarios relevant to current industry decision making, following a defined interactive process for scenario identification, development, technical review, revision, and finalization.

Methods

We modeled small-scale deviation scenarios based on industry partner input, individual 1.5-hour ideation sessions to determine the necessary parameters for a modellable input, and an internal team review of parametrization for each scenario. After internal team review, each scenario was discussed with a respective domain-specific expert, and the model inputs were finalized. We finalized four industry-relevant scenarios for modeling contamination with STEC in leafy greens: (i) discovering a nonfunctioning irrigation treatment system after irrigation, (ii) ineffective harvester equipment sanitation between harvests, (iii) small animal fecal contamination in a field, and (iv) inadequate process wash control. Each scenario was modeled in the SCRM under high and low variability contamination. Lots were categorized by the risk of producing a positive test at retail.

Results to Date

Under high contamination variability, inadequate process wash control resulted in a 9-fold increase in recall risk compared to the baseline, and a meaningful increase in the number of highest public health risk lots (from 16 to 433; **Table 2**). Under low variability, inadequate process wash control likewise resulted in a 10-fold increase in recall risk, but no highest public health risk lots were identified.

Discovering a nonfunctioning irrigation treatment system, ineffective harvester equipment sanitation, and small animal fecal contamination each resulted in less than 2-fold increases in recall risk and negligible changes in the highest public health risk lots across both contamination scenarios. Two additional scenarios were identified through working with industry: (i) practices for bin/tote sanitation and (ii) best practices for irrigation water.

Benefits to the Industry

The key beneficiaries of this project are growers, producers, and buyers. The SCRM could help set best practices and guide reactive decision-making. Where good data and reasonable simplifying assumptions exist, such as with process wash controls and irrigation water treatment systems, these scenarios have immediate value to the produce industry. Where data is less available and requires many assumptions about the spread of contamination, such as with inadequate harvester sanitation and small animal fecal contamination, more research to collect better data or revisions to the SCRM may be required before supporting risk management decisions. Our efforts to work with industry ensure we are evaluating relevant scenarios for the produce industry, and that we are building a sustainable workflow for future use of the SCRM.

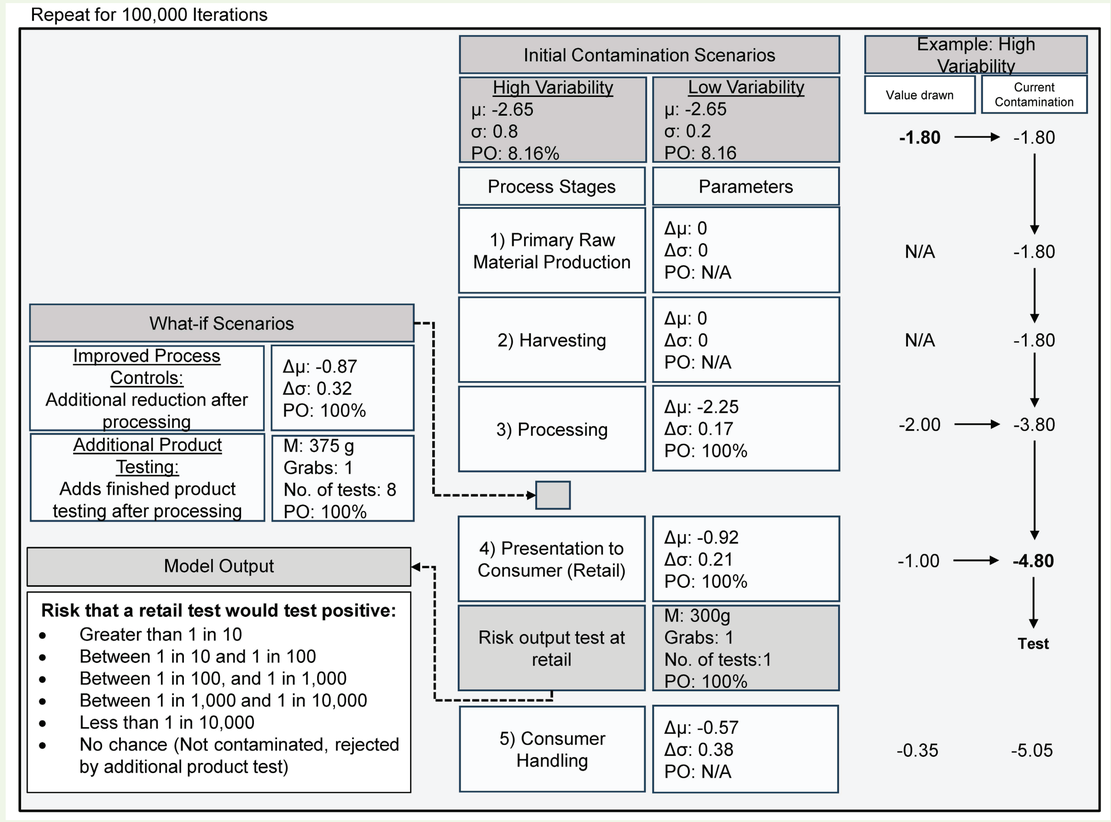

Figure 1: Model and scenario analysis framework. The model consists of five main process stages, contamination events, and sampling at retail. For the analysis, two contamination events are evaluated, high and low variability. In addition, two what-if scenarios are evaluated improved process controls and finished product testing. Mean (μ), and standard deviation (σ), and the probability of occurrence (PO) are defined for contamination events at any process stage. For finished product testing and a sample at retail, the mass of the test (M), grabs, number of tests, and PO are defined.

Scenario	Variability in initial preharvest contamination	Number of lots with the highest risk of a positive test at retail	Recall risk/Overall risk of a positive test at retail
Baseline	High	23	**1 in 4,020**
	Low	<1	**1 in 20,065**
Additional product testing (8 x 375 g over one day)	High	<1	**1 in 11,048**
	Low	<1	**1 in 21,431**
Improved process control (Additional ~1 Log_{10} reduction during process wash)	High	3	**1 in 20,063**
	Low	<1	**1 in 113,178**

[a]Highest risk of a positive test at retail corresponded to the probability of a positive test at retail being > 1 in 10; the number of lots is out of 100,000 total lots.

Table 1: Previously published results of scenario analysis for well understood industry food safety management practices.

Scenario	Specific description of the evaluated scenario	Variability in initial preharvest contamination	Number of lots by the risk of testing positive at retail: Highest	Number of lots by the risk of testing positive at retail: Lowest (Non-contaminated lots)	Recall risk/ Overall risk of a positive test at retail
Baseline	Baseline model	High	16	91,835	**1 in 4,500**
		Low	<1	91,835	**1 in 20,000**
Failure in irrigation water treatment system	Effect of irrigating plants with Type B -> Type A water at the threshold for failure per LGMA metrics, 2 days prior to harvest	High	16	84,309	**1 in 4,100**
		Low	<1	84,309	**1 in 14,600**
Ineffective harvester sanitation	Effect of not sanitizing Zone 1 surface(s) of a mechanical harvester between harvests	High	16	84,309	**1 in 4,400**
		Low	<1	84,309	**1 in 18,500**
Small animal fecal contamination	Effect of small animal defecation in fields, before it is found during the next preharvest assessment	High	16	88,711	**1 in 4,400**
		Low	<1	88,711	**1 in 19,000**
Inadequate process wash control	Effect of washing product with inadequate free chlorine (<10 ppm)	High	433	91,835	**1 in 500**
		Low	<1	91,835	**1 in 2,000**

[a]Highest risk of a positive test at retail corresponded to the probability of a positive test at retail

Table 2: Ongoing scenario analysis results for small-scale failures introducing contamination or reduced control over safety interventions.

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