

# Quantitative microbial risk assessments need to consider quality parameters to accurately predict produce food safety risks

## Summary

Produce, such as chopped romaine lettuce, can be rejected at various stages of the supply chain due to the presence of quality defects, which are presumed to influence both product quality and safety. The aim of this project is to inform decision-making in industry about rejection of product (e.g., chopped romaine) due to quality defects that may impact food safety. We have developed a quantitative microbial risk assessment (QMRA), which can assess food safety risks associated with quality defects and can thus inform food safety interventions and management strategies. Concurrently, we have started experimental work to characterize the impact of “watersoak” defects on the growth dynamics of *Listeria monocytogenes* and *Escherichia coli* O157:H7 on chopped romaine lettuce; these experimental data will inform the QMRA.

## Benefits to the Industry

These data provide insight into the food safety risks associated with various quality defects in romaine lettuce. The current QMRA findings suggest that packages with mechanically damaged leaves may represent a minimally higher risk of *E. coli* O157:H7 growth. As the current version of the QMRA does not consider pathogen dynamics through subsequent stages of the supply chain (e.g., distribution), further developing the QMRA through retail will provide a more thorough understanding of the food safety risks associated with mechanically damaged romaine. Similarly, our experimental data on watersoak will be incorporated into the QMRA, and will allow for: (i) ranking risks associated with various quality defects, and (ii) evaluating the efficacy of management strategies at reducing risks associated with quality defects.

## Objectives

1. Develop a QMRA to model food safety risks considering produce quality defects and their impact on pathogen survival and growth.
2. Perform inoculation studies on chopped romaine lettuce to collect input parameters to improve the QMRA.
3. Validate the QMRA model and its predictions through inoculation studies.
4. Run scenario analyses to model the impact of different “last mile” scenarios on produce food safety risks.

## Methods

**QMRA Development.** The QMRA is parameterized to represent a supply chain that is contaminated with *E. coli* O157:H7 (adapted from Bulut et al., 2025) and currently spans stages from product arrival at the processor through packaging. The QMRA was modified to incorporate the impact of quality defects, starting with mechanical damage due to the availability of literature data about this defect.

**Experimental Assessment.** Chopped romaine was obtained from an industry collaborator. Watersoak was generated by freezing romaine at  $-20^{\circ}\text{C}$  for 30 minutes followed by thawing the leaves at  $4^{\circ}\text{C}$ . Defect-free and watersoaked romaine samples were spot inoculated, separately, with two strains of *L. monocytogenes* and one strain of *E. coli* O157:H7. Pathogen dynamics on the inoculated samples were assessed, in duplicates, at  $4^{\circ}\text{C}$ ,  $12^{\circ}\text{C}$  and  $21^{\circ}\text{C}$ .

## Results to Date

**QMRA Results:** The QMRA simulates pathogen dynamics (growth and die-off) during cold storage, as well as inactivation during washing (Figure 1). Incoming produce is assigned a baseline level of mechanical damage, which can increase during processing. After packaging, the concentration of *E. coli* O157:H7 was predicted to be (i)  $1.2 \pm 1.0$  and (ii)  $1.1 \pm 1.0 \log_{10}\text{CFU}/\text{package}$  (Figure 2), respectively, for mechanically damaged or defect-free leaves.

**Experimental Results:** Pathogen dynamics appear to be influenced by watersoak (Figure 3). For example, by day 3 of storage at  $12^{\circ}\text{C}$ , *E. coli* O157:H7 showed a net growth of  $1.6 \log_{10}\text{CFU}/\text{leaf}$  on watersoaked leaves but a net decrease of  $0.2 \log_{10}\text{CFU}/\text{leaf}$  on defect-free leaves.

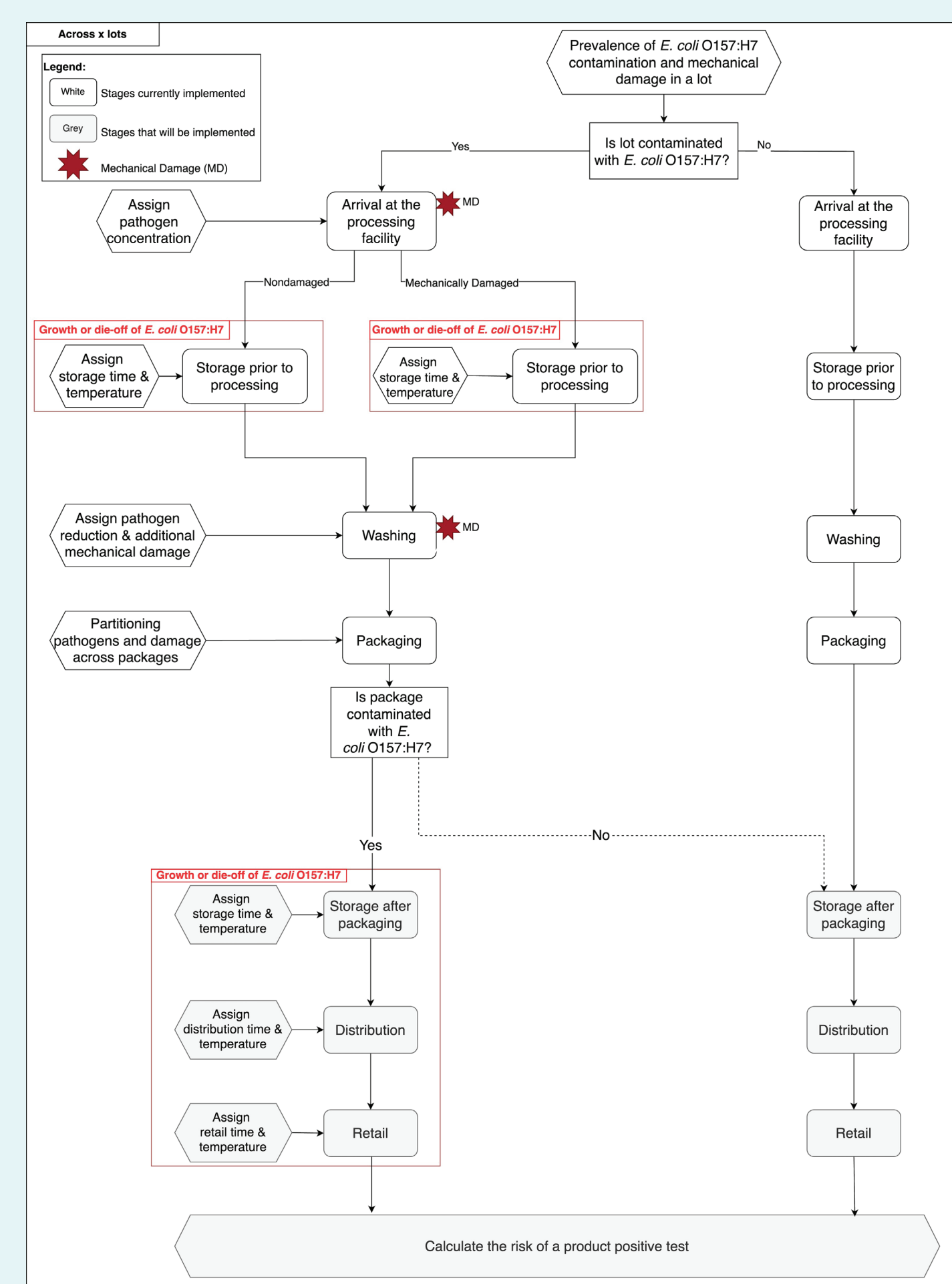


Figure 1. The QMRA framework covers stages from product arrival at the processor until retail and represents a supply chain that is contaminated with *E. coli* O157:H7; boxes shaded in white are currently implemented. The red stars representing “mechanical damage” indicate where we implemented introduction of mechanical damage.

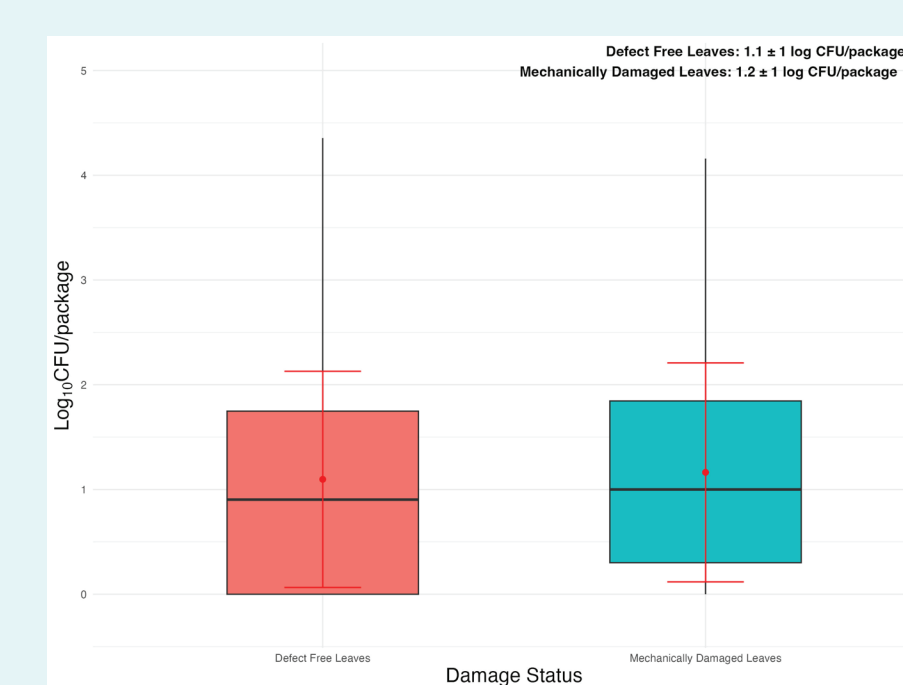


Figure 2. Predicted *E. coli* O157:H7 concentration on romaine lettuce post-packaging, depending on the damage status of the leaves.

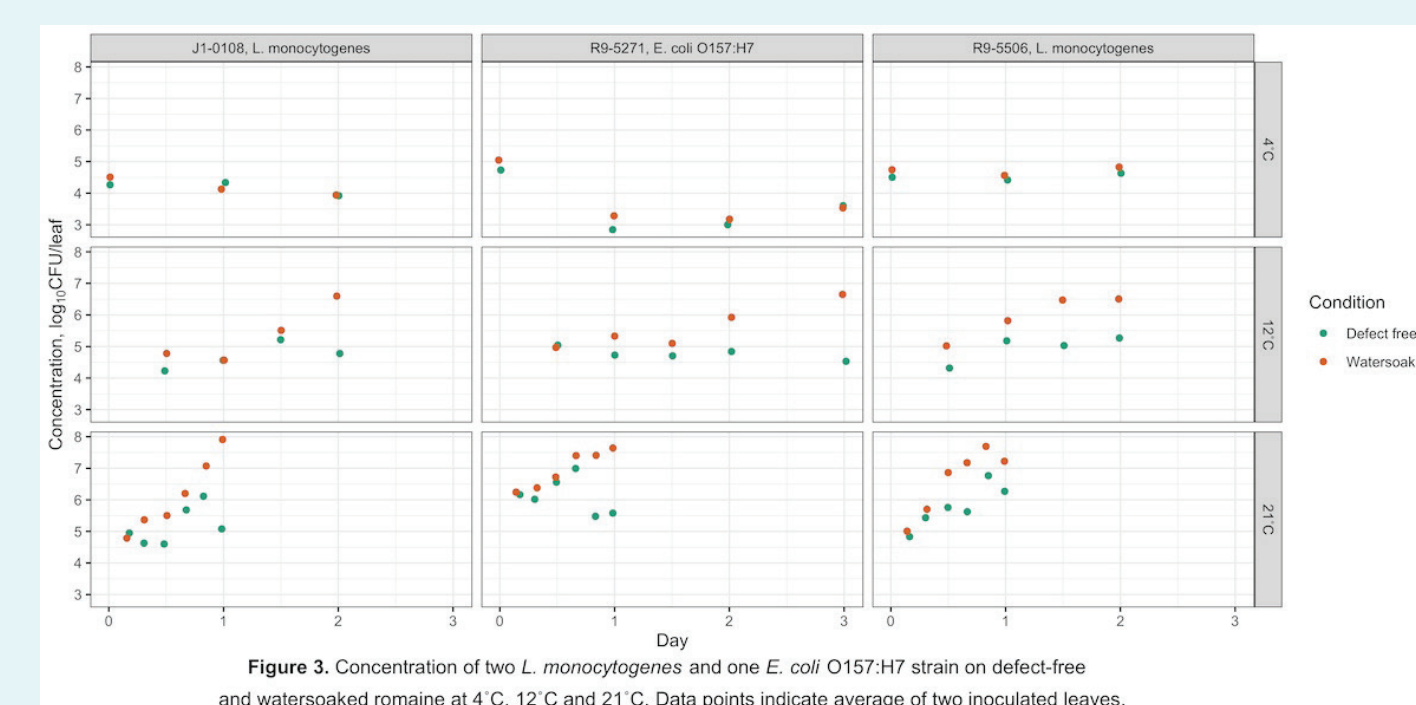


Figure 3. Concentration of two *L. monocytogenes* and one *E. coli* O157:H7 strain on defect-free and watersoaked romaine at  $4^{\circ}\text{C}$ ,  $12^{\circ}\text{C}$  and  $21^{\circ}\text{C}$ . Data points indicate average of two inoculated leaves.



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