RESEARCH IN PROCESS

A systematic review of *Listeria* growth and survival on fruit and vegetable surfaces: responding to critical knowledge gaps

SUMMARY

There are critical knowledge gaps regarding the risk of *Listeria monocytogenes* on intact fruit and vegetable surfaces. Within the last decade, *L. monocytogenes* has been associated with outbreaks linked to contaminated intact produce, including cantaloupe, stone fruit, and caramel apples. While *L. monocytogenes* has been isolated from a wide variety of environments, including produce production and urban, natural, processing, and retail environments, nearly all (99%) listeriosis infections are attributed to contaminated food. For that reason, controlling the growth or survival conditions is essential to minimize contamination events as food moves throughout the supply chain. This is especially important for produce that is often consumed raw, or with minimal processing. Since it is widely accepted that *L. monocytogenes* may be present in produce production environments, data is needed on *L. monocytogenes* behavior on whole produce when handled/stored at typical and abuse conditions over the typical shelf life.

OBJECTIVES

1. Conduct a systematic review to identify and characterize published data on the growth and survival of *L. monocytogenes* on intact fruit and vegetable surfaces.
2. Perform *L. monocytogenes* growth and survival experiments on intact fruit and vegetable commodities at selected conditions to fill critical data gaps.
3. Develop risk models for a sub-set of fruit and vegetable storage or handling conditions shown to display growth or enhanced survival of *L. monocytogenes.*

METHODS

Systematic Review

Searches were conducted using the following Medical Subject Heading (MeSH) terms: Listeria monocytogenes, growth, survival, intact, and produce. All MeSH search terms were modified for each database and exploded to find all related subheadings. To be eligible for inclusion, literature had to show sufficient information on methodology, experimental conditions, and quantitative growth and survival data over time. Two of the authors (CM and JZ) independently reviewed all relevant literature based on title and abstract. Discrepancies were resolved by discussion and consensus with another reviewer (LS). Information regarding relevant experimental conditions were extracted and entered into a standardized electronic format. When studies did not provide numerical data, images of data visualizations were reverse-engineered to extract the underlying numerical data using a semi-automated Web Plot Digitizer. Also, growth rates were obtained through linear regression models. Two reviewers (LS and DS) conducted a quality assessment on data extraction.

RESULTS TO DATE

The search identified 3,459 citations. After the data mining process, such as removal of duplicate data and review of relevant articles that met the inclusion criteria, a total of 29 articles were included (**Figure 1**). The 29 prospective studies included 21 commodities. In general, the studies suggest that *L. monocytogenes* growth and survival on surfaces of intact produce differ substantially by commodity. Furthermore, handling and storage parameters influenced *L. monocytogenes* growth and survival on produce surfaces:

- Contaminated produce held at ambient temperatures (≥20°C) had higher growth rates compared with contaminated produce held at lower temperatures (4±2°C, 10±2°C) (**Table 1**).
- Roughness (↑), nutrient availability (↑), and competitive background microflora (↓) all influenced growth/survival.
- At cooler storage temperatures (≤10°C), relative humidity influenced growth/survival, where low RH limited survival.
- Large shifts in CO_2 and O_2 concentrations within storage containers may suppress the growth/survival of *L. monocytogenes* on produce surfaces.
- Pathogen carrying capacity influenced growth/survival of *L. monocytogenes* on produce surfaces.

BENEFITS TO THE INDUSTRY

It is critical for the produce industry to understand *L. monocytogenes* growth/no growth conditions on intact fruits and vegetables to establish parameters during handling and storage that can be applied to reduce *L. monocytogenes* proliferation or long-term survival. The knowledge collected on which whole produce commodities support *L. monocytogenes* growth and/or long-term survival at various handling and storing conditions observed along the supply chain will assist industry professionals in managing their risk. Also, this will be key to assisting the industry at establishing optimal parameters along the supply chain for intact produce.

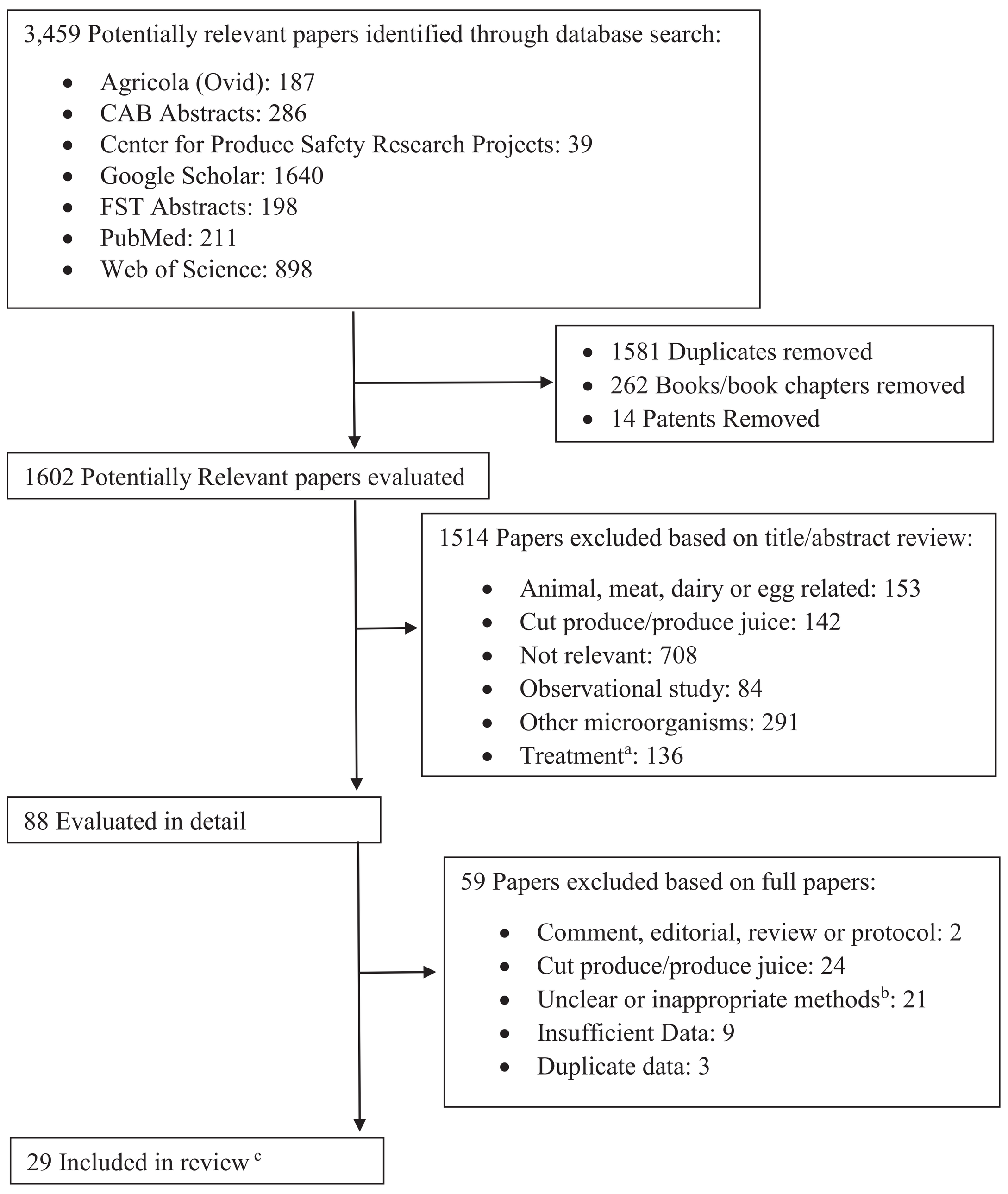

Figure 1. Schematic representation of study selection

[a] e.g., UV, chemical sanitizer

[b] Dip inoculation was excluded as it may promote internalization and therefore is out of the scope of this review

[c] Studies had to include sufficient information (i.e., enough information for studies to be reproduced) on methodology (e.g., inoculation methods), experimental conditions (e.g., storage temperatures), and quantitative growth and survival data (e.g., log CFU/g) over time to be eligible for inclusion. For studies in which the control group fit or partially fit the selection criteria, the pertinent, corresponding data were included for review. Conference abstracts, reports (e.g., CPS final grant reports), and dissertations were also reviewed for selection as long as data were not duplicated in research manuscripts.

Table 1. Growth[a] or Survival[b] Rate (log CFU/g/day) and Standard Deviations[c] of *L. monocytogenes* for the 21 Produce Commodities

Commodity	Growth Rate at Refrigeration Temperature (4°C ± 2 °C)	Growth Rate at Display Case Temperature (10°C ± 2 °C)	Growth Rate at Ambient Temperature (≥ 20°C)
Apple	-0.012	--- [d]	-0.013 ± 0.01
Asparagus	-0.041 ± 0.04	0.104 ± 0.08	0.614
Avocado	---	---	-0.155
Blueberries	-0.050	-0.110	---
Canary melon	0.358	---	7.228 ± 6.23
Cantaloupe	-0.070 ± 0.17	0.092 ± 0.30	0.127 ± 0.38
Celery	-0.196 ± 0.05	0.119 ± 0.04	0.463 ± 0.12
Cranberries	-0.130	---	---
Cucumbers	0.132 ± 0.00	0.127 ± 0.09	0.434 ± 0.54
Jalapenos	---	0.089	---
Kale	0.187	---	---
Lettuce	---	-0.113 ± .007	-0.397 ± 0.09
Mango	-0.083 ± 0.02	0.008	-0.004 ± 0.11
Mushroom	-0.072	-0.002	---
Nectarine	---	---	-0.034 ± 0.26
Peaches	---	---	0.034 ± 0.16
Persimmons	---	0.492 ± 0.10	3.148 ±1.86
Raspberries	-0.007	---	0.533
Spinach	0.096 ± 0.08	0.243 ± 0.23	3.732 ± 3.15
Sprouts	-0.071 ± 0.06	0.028 ± 0.03	---
Strawberries	-0.340 ± 0.08	---	-1.246 ± 0.30

[a] Positive rate of change
[b] Negative rate of change
[c] Growth/survival rate is average based on all studies/replicates

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