Solutions to brush sanitation tailored to the producer's appetite for capital investment and labor intensity

Summary

Produce brushes are essential for cleaning and polishing fruit but are difficult to sanitize effectively. As brushes deteriorate with use, they become even more difficult to sanitize and can harbor microorganisms, including pathogens like *Listeria monocytogenes*, leading to cross-contamination of produce. Even though brushes are an important part of postharvest processing, there is no evidence-based guidance for when facilities should replace them, so replacement varies industry-wide. Little work has been done on the hygiene of brushes as they wear. This study aims to investigate the effect of brush deterioration on sanitation outcomes and test the use of steam treatments on wax removal and *Listeria* inactivation. This work will aid the industry by providing evidence to make informed decisions regarding brush bed management.

Objectives

1. Identify the impact of brush deterioration on pathogen retention.
2. Define deterioration markers for replacing brushes to mitigate pathogen retention.
3. Trial steam to clean and sanitize brushes of varying deterioration states.
4. Trial protocols with collaborating apple facilities and evaluate microbial outcomes.

Methods

In a collaborating facility, common microbial hygiene indicators (aerobic plate count, Enterobacteriaceae, and total Gram-negatives) were measured on wash, dry, and wax brushes post-production before sanitation and post-sanitation. After 5 months of baseline monitoring, brushes were replaced and monitored for another 5 months. A linear mixed-effects model assessed sanitation efficacy pre- versus post-replacement. Brushes were also swabbed and tested for *Listeria* spp. immediately before and after replacement.

In lab experiments, polyethylene (PE) and nylon brushes were subjected to steam treatments to evaluate effects on bristle deterioration, wax removal, and *Listeria* inactivation. Brushes were treated after wax application and bristle splay and length measured. Brushes were inoculated with *Listeria innocua* before wax application (spot) or incorporated into wax before application (mixed), followed by steam treatment and enumeration.

Results to Date

Microbial indicator counts were collected before and after sanitation to evaluate sanitation efficacy. These data were compared before and after brushes were replaced. A linear mixed effects model indicated that sanitation resulted in greater microbial reductions after brush replacement ($p < 0.05$). However, sanitation occasionally increased microbial load on wax brushes before and after replacement. The majority of wax brushes were *Listeria* spp. positive prior to replacement, and no brushes were *Listeria* spp. positive after replacement.

In laboratory experiments, *Listeria*-inoculated brushes showed lower reductions without wax than with wax after steam treatment (100˚ C) for both materials (**Fig. 3**). However, steam increased splay and reduced bristle length in PE brushes, while nylon was not affected (**Fig. 4-6**).

Benefits to the Industry

This work will provide evidence to the industry that will support decision-making regarding the hygienic design and sanitation strategies for their brush beds. Replacing brushes involves tradeoffs, including cost and downtime, and these decisions are often facility-specific, based in part on the volume of product and risk tolerance of the site. By investigating the effect of brush deterioration on sanitation outcomes and evaluating steam treatments as a strategy for wax removal and *Listeria* spp. inactivation, this work aims to provide practical, evidence-based guidance. Our goal is to provide the industry with the relevant information that will help them make defensible decisions tailored to their site, optimizing sanitation strategies while balancing operational and food safety priorities.

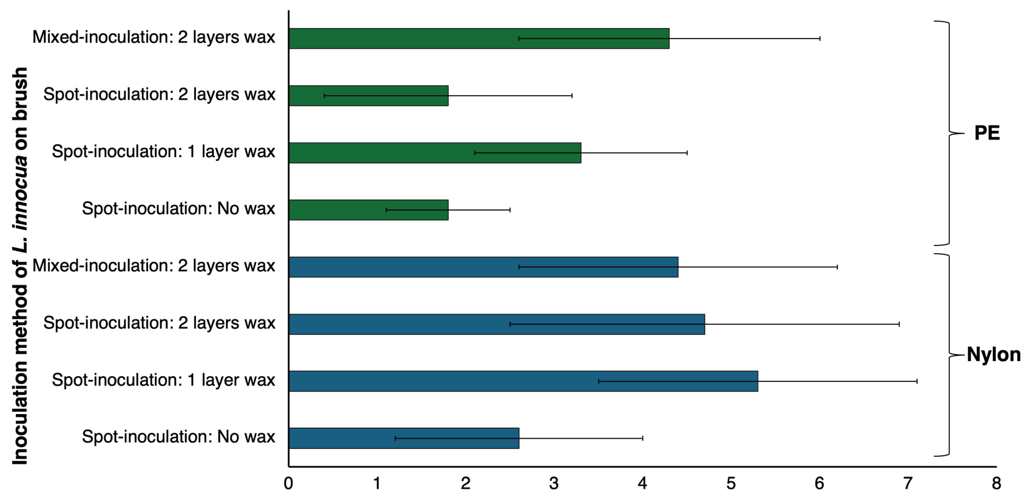

Fig. 3. Average reduction (log CFU/brush) of *L. innocua* after wet steam treatment (outlet temperature: 100 °C) of brush in a poly-vinyl tent (152.4 × 91.4 cm^2) as a function of material type and wax accumulation.

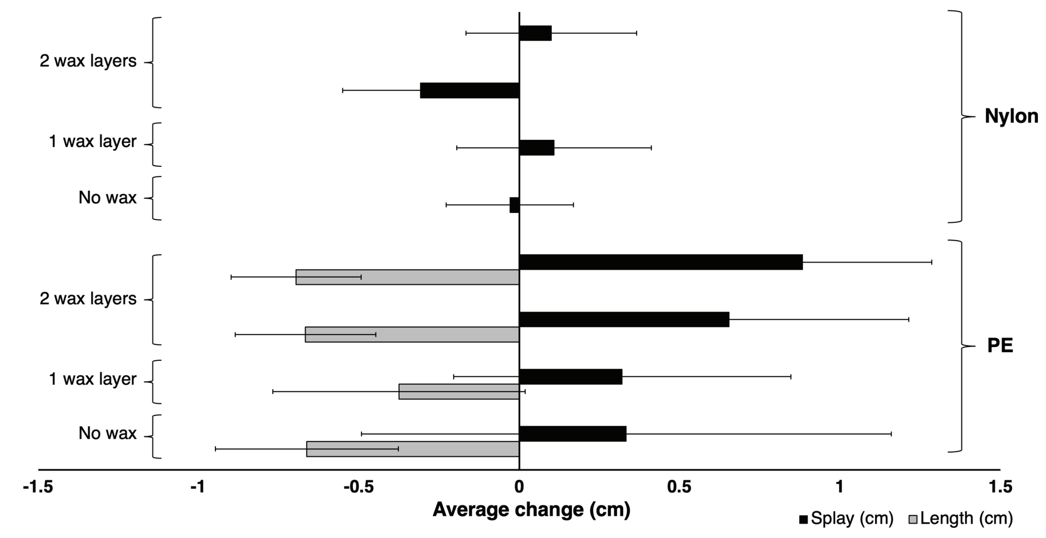

Fig. 4. Average change in bristle splay (cm) and length (cm) after wet steam treatment (until achieving surface temperature: 73.8 °C) of brush in a poly-vinyl tent (152.4 × 91.4 cm^2) as a function of material type and wax accumulation.

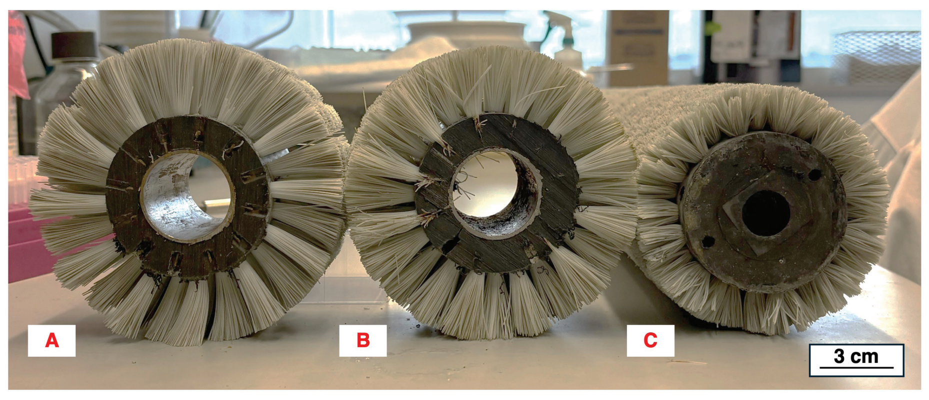

Fig. 5. Change in (A) PE brush bristle length (cm) after wet steam treatment (outlet temperature: 100 °C) approximately (B) 1 and (C) 15 min after brush surface temperature achieved 73.8 °C.

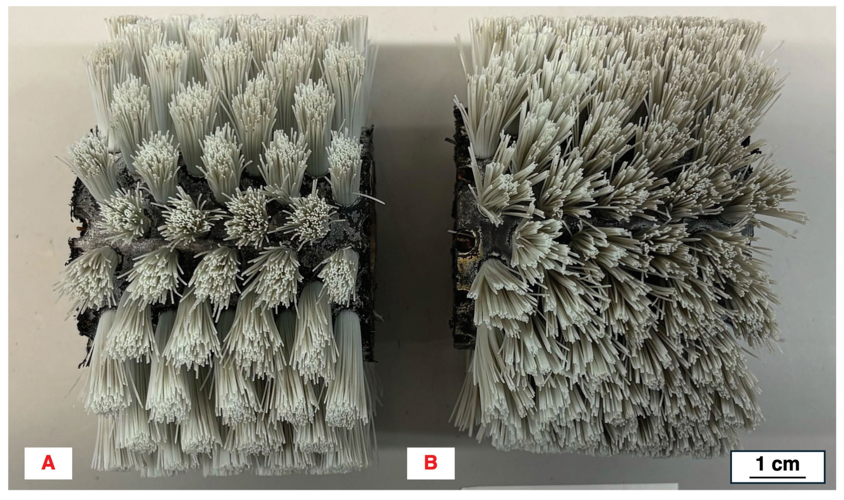

Fig. 6. Change in (A) PE brush bristle splay (cm) after wet steam treatment (outlet temperature: 100 °C) approximately (B) 1 min after brush surface temperature achieved 73.8 °C.

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