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WAX BRUSH SANITATION RESEARCH, 2024 - 2026

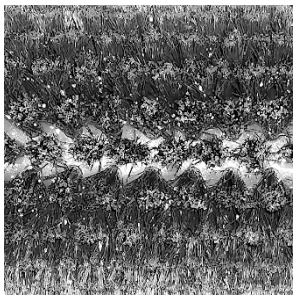
Three years and over $1 million of CPS/CFFA-funded research into wax brush sanitation will be wrapping up this year. The following is a summary of work completed to date.

This research was made possible by support from the Center for Produce Safety and the California Fresh Fruit Association along with collaborations among select stone fruit industry members, George Nikolich Consulting, Inc., and research scientists at the University of California, Davis, Cornell University, and the University of Georgia.

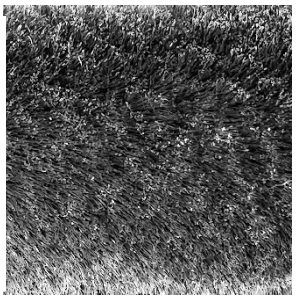
Bottom-line mitigation strategy emerging across brush sanitation studies

- **Clean before wax dries** — this is the single most-important intervention, since wet-wax removal is easy and dried-wax removal is difficult and leaves sanitizers largely ineffective.
- **Choose nylon over horsehair/polyethylene blends** — better pathogen die-off and less wax retention.
- **Use alkaline cleaners with heat** for any dried wax residue, followed by conventional sanitizers. In general, the use of chlorinated alkaline cleaners is recommended for cleaning all types of brushes used to wash and wax fresh fruits and vegetables.
- **Track brush wear physically** and consider replacing brushes on a schedule informed by deterioration markers, not just visual inspection — wax brushes in particular may need more frequent replacement given their disproportionate association with *Listeria* positivity.
- **Intensive practices like cleaning-out-of-place meaningfully outperform routine in-place cleaning** under commercial conditions.
- **"Open" tuft spacing of wax brushes improves sanitation efficacy.** Superior sanitation performance and efficiency was associated with more space between tufts. Those operations using wax brushes with an open tuft pattern did not report any concerns with respect to fungicide application or polishing effects. Tuft pattern and spacing can be specified when ordering brushes.

"Open" tuft pattern; core remains visible even after extensive use.



"Closed" tuft pattern; core not visible when new or after extensive use.



- **Common commercial fruit coatings support the survival and growth of bacteria.** Make sure to address potential contamination from fruit coating delivery systems by including containers, mix tanks, and all associated components, including tubing and application heads in a master sanitation schedule with appropriate SSOP.

Summary of CPS-funded research (Anthropic. (2026). *Claude 5 Sonnet)*

- **Nylon consistently outperforms horsehair/polyethylene (50/50) blends** for pathogen die-off. Across studies, *Listeria monocytogenes* (LM) declined faster and more completely on nylon than on 50/50 brushes, both unwaxed (nylon: ~4.5 log reduction vs. 50/50: ~2.5 log over 84 days) and waxed (both ~5–5.5 log, but 50/50 plateaued at a higher residual level).
- **Dried wax is the harder problem.** Wet wax rinses away easily (>99% removal with plain water rinsing, regardless of wax type or brush material), but once wax dries (~24 hours at ambient conditions), removal drops sharply — plain water rinsing removed as little as ~1–23% of dried wax depending on wax type and brush material.
- **Alkaline cleaners outperform neutral cleaners and water** for dried wax removal; effectiveness improves further with elevated temperature (50°C) and multiple wash cycles compound removal rates (>85–90% achievable after 2–3 cycles with heat).
- Across three California stone-fruit packinghouses sampled over two seasons, aerobic plate counts, coliforms, and fungal counts dropped several logs with intensive practices like **cleaning-out-of-place (COP)** and brush scrubbing, versus routine in-place cleaning.
- Sequencing data showed that even when overall culturable counts didn't change much, **cleaning/sanitation shifted microbial community composition** — meaning simple plate counts may understate the effect of sanitation on community structure.
- Apple facilities similarly found sanitation gave significantly better microbial reduction **after brushes were replaced** than with old brushes, and that wax brushes specifically were the most likely to test *Listeria* spp.-positive before replacement (none were positive after replacement).
- Worn/deteriorated bristles had ~3x the splay (width) and reduced height compared to newer bristles, and **wax brushes showed numerically lower sanitation-driven reductions** than wash or dry brushes — suggesting wax brushes deteriorate hygienically faster and may need more frequent replacement or more aggressive protocols.
- UV-C (222 nm) and blue light (405 nm) applied directly to brush filaments achieved meaningful pathogen reductions without chemical residue — up to ~5-log reduction of LM (white polypropylene bristles + 222 nm) and ~3-log reduction of *E. coli* in optimized conditions.
- Light penetration is imperfect — reductions were highest in the outer/top portions of filaments and notably lower in the middle and bottom portions, meaning light-based treatment works best as a **surface-level, post-sanitation hurdle**, not a standalone solution for deeply embedded contamination.

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