Color and material optimization of brushes for improved light-based sanitation

Summary

Waxer and washer brushes clean or coat thousands of fruits or vegetables before they are sanitized. Previous research has shown that even frequently sanitized brushes can harbor high microbial populations. Since brushes are hard to clean using only conventional sanitizers adjunct light-based antimicrobial lights at frequencies of 222 nm and 405 nm could be used after conventional cleaning operations to reduce surviving spoilage and pathogenic bacterial populations. Since the efficacy of antimicrobial lights could vary based on material and color of the brush bristles, we compared differences in inactivation of *Listeria monocytogenes*, *Salmonella enterica* and *Escherichia coli* on polypropylene, polyethylene, polyester and nylon bristles, with colors: white, black, green, blue, red, gray, after exposure to 222 nm and 405 nm light.

Objectives

1. Evaluate the influence of brush filament color and brush filament material in affecting the antimicrobial efficacy of blue light (405 nm) and far-UVC light (222 nm) against *Salmonella enterica*, Shiga toxin–producing *Escherichia coli* (STEC), and *Listeria monocytogenes*.
2. Evaluate synergistic mitigation between residual peroxyacetic acid on brushes and antimicrobial lights.
3. Validate the effectiveness of 405-nm blue light and 222-nm far-UVC in reducing microbial buildup on washer and waxer brushes in peach and apple packinghouses through the packing season.

Methods

Colonies of *Salmonella enterica* (*S.* Poona, S. Newport and S. Montevideo), *Escherichia coli* (*E. coli* O157:H7, *E. coli* O121 and *E. coli* K12) and *Listeria monocytogenes* (G1091, 19115, 2011L) were scraped and suspended in 10 ml of PBS.

Suspensions of the same species were mixed to obtain a 30 ml cocktail. Bristles were compacted into 2g portions and inoculated by dipping into the cocktail and dried for 4h.

The bristles were then placed under the antimicrobial lights (222 nm and 405 nm) at 20 cm from the lights, for a duration of 8h. Control treatments consisted of exposure to incandescent light (IL) and without light (WL).

After 8h, the bristles (2g) were added to 20 ml of sterile PBS, vortexed for 15 seconds and enumerated.

Results to Date

White polypropylene bristles had significantly higher pathogen reductions than other colors. White polyester bristles had significantly higher pathogen reduction than Red and Black bristles (**Fig 1&2**). Color did not significantly impact pathogen reduction on polyethylene and nylon bristles after antimicrobial light exposure (**Fig 3&4**). Reductions of 5.09±0.6 log CFU/g in *L. monocytogenes* population (White polypropylene bristle+222 nm) (**Fig 1**), 3.06±0.27 log CFU/g in *E. coli* population (White polyethylene bristle+ 405 nm) (**Fig 3**) and 1.94±0.55 in *S. enterica* (White nylon bristle+222 nm) (**Fig 4**) were observed. On all materials tested, 405 nm resulted in significantly higher reductions in pathogen population than control treatments. Exposure to 222 nm light led to significantly higher ($p \leq 0.05$) reduction in pathogen population on polyester and polypropylene bristles than control treatments.

Benefits to the Industry

These findings demonstrate that brush material and color can significantly enhance antimicrobial light–based sanitation in produce processing. White polypropylene and polyester bristles achieved greater pathogen reductions than darker bristles. Antimicrobial light at 405 nm consistently reduced pathogen populations across all materials, while 222 nm light provided enhanced reductions on polyester and polypropylene. Notably, up to ~5-log reduction in *Listeria monocytogenes* and ~3-log reduction in *E. coli* were observed under optimized conditions. These results support targeted selection of bristle materials and integration of antimicrobial lighting into brush systems, as a post-sanitation hurdle to enable more effective controls against pathogen harborage. Adoption of these strategies can improve hygiene, reduce contamination risks, and enhance compliance with preventive food safety standards in the produce industry.

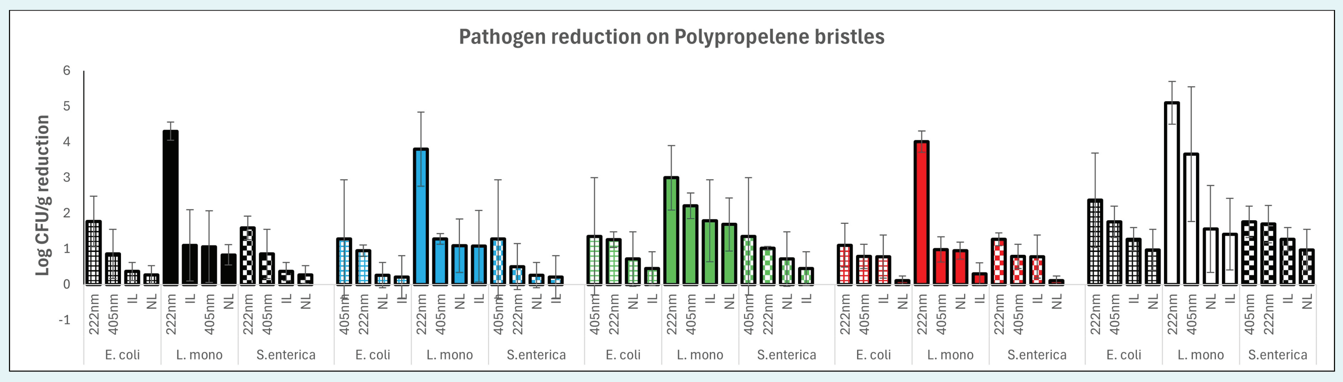

Figure 1:
Effect of 222 nm, 405 nm, fluorescent light (WL) and dark (NL) exposure on population reduction of *E. coli*, *L. monocytogenes* and *S. enterica* on black, blue, green, red and white, polypropylene bristles.

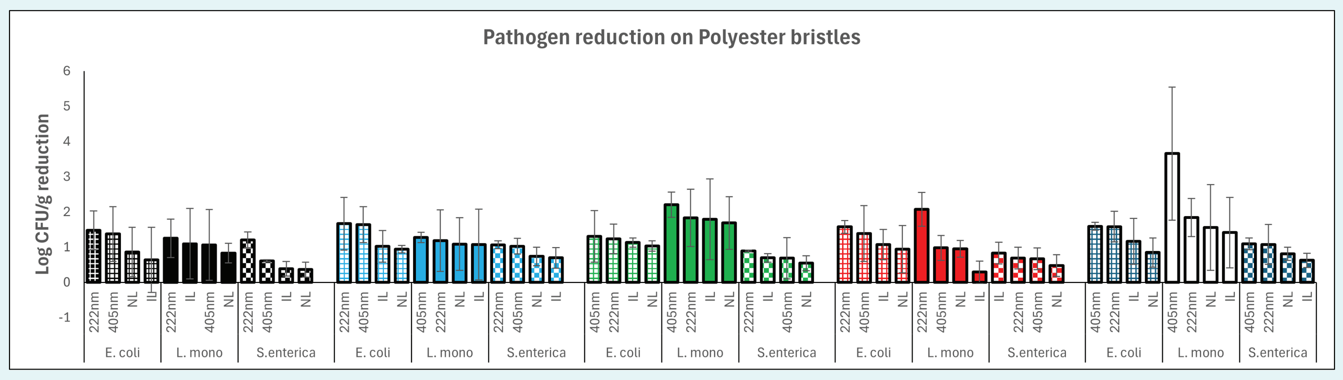

Figure 2:
Effect of 222 nm, 405 nm, fluorescent light (WL) and dark (NL) exposure on population reduction of *E. coli*, *L. monocytogenes* and *S. enterica* on black, blue, green, red and white, polyester bristles.

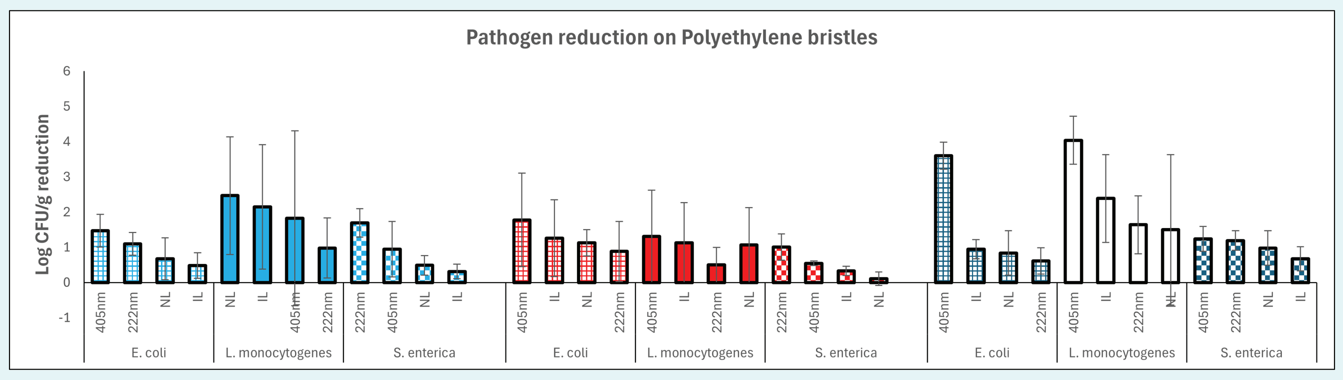

Figure 3:
Effect of 222 nm, 405 nm, fluorescent light (WL) and dark (NL) exposure on population reduction of *E. coli*, *L. monocytogenes* and *S. enterica* on blue, red and white, polyethylene bristles.

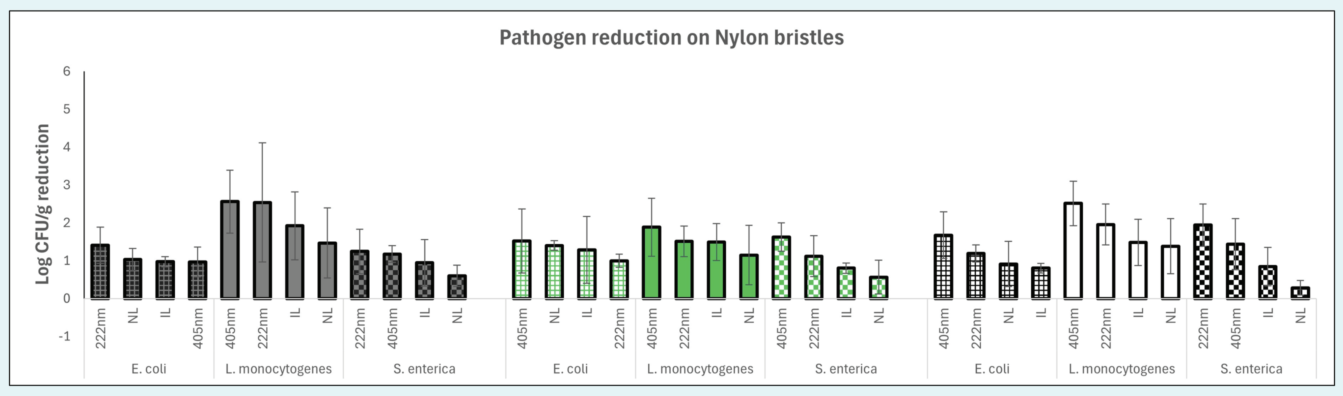

Figure 4:
Effect of 222 nm, 405 nm, fluorescent light (WL) and dark (NL) exposure on population reduction of *E. coli*, *L. monocytogenes* and *S. enterica* on gray, green, and white, nylon bristles.

Figure 5:
Method sequence

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