Synergistic antimicrobial activity of food-grade compounds in wax coatings on fruits during wax drying

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Authors

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Summary

The inherent inhibitory activities of commercial wax formulations were evaluated against bacterial pathogens. Overall, carnauba oil–based waxes showed stronger inhibitory activities than vegetable oil–based wax, and the carnauba oil–based wax containing morpholine showed the strongest inhibitory activities among tested wax formulations. In addition, higher inhibitory activities were observed against gram-positive bacteria (*Listeria innocua* and *Enterococcus faecium*) compared to the gram-negative bacteria (*Escherichia coli* O157:H7). Based on the inoculation test performed on the orange skin, bacterial cells were less susceptible when inoculated on the orange skin before applying the wax coating compared to cells inoculated with the wax coating on the orange skin. These results provide useful information in developing control strategies using food-grade compounds and mild heat to lower the microbial cross-contamination of the fruits during wax coating procedures.

Objectives

1. Assess the synergistic interaction of food-grade antimicrobial compounds or extracts with mild-heat to achieve rapid inactivation of bacteria in a wax suspension.
2. Assess the role of synergistic treatment (optimal combination of food-grade antimicrobial compounds in a wax coating and mild-heat identified in Objective 1) in the inactivation of the pathogens inoculated in a wax composition on the surface of apples and citrus fruits.
3. Measure the influence of synergistic treatment in the inactivation of the pathogens inoculated on the surfaces of apples and citrus, including the stem and calyx regions.
4. Evaluate the influence of the optimal synergistic treatments identified in Objectives 2 and 3 on the quality (including color), microbial load (endogenous), and shelf life of fruit during storage (**Figure 1**).

Methods

- Three different types of wax formulations were selected: EF 100 (carnauba oil–based wax without morpholine), SF 200 (carnauba oil–based wax with morpholine), and SF 206 (vegetable oil–based wax without morpholine).
- The inhibitory activities of three different wax formulations (EF 100, SF 200, and SF 206) were tested against *Escherichia coli* O157:H7, *Listeria innocua*, and *Enterococcus faecium*, respectively. Bacterial cells were inoculated in the wax formulations and incubated for up to 60 min.
- The inhibitory activities of the wax formulations (EF 100 and SF 200) were tested on the orange skin based on three different contamination scenarios. *L. innocua* cells were inoculated on the orange skin surface before, simultaneously with, or after brush-coating the orange surface with the wax formulations.

Results to Date

- The carnauba oil-based waxes (EF 100 and SF 200) were more inhibitory to the tested bacterial cells than the vegetable oil-based wax (SF 206) (**Figure 2**).
- The carnauba oil-based wax containing morpholine (SF 200) showed the strongest antimicrobial activities among tested wax formulations (**Figure 2**).
- Gram-positive bacteria (*L. innocua* and *E. faecium*) were more susceptible to the tested wax formulations than the gram-negative bacteria (*E. coli* O157:H7) (**Figure 2**).
- *L. innocua* cells were less susceptible to SF 200 when inoculated on orange skin before the wax coating compared to cells inoculated with the wax coating (**Figure 3**).
- The inhibitory activities of EF 100 against *L. innocua* were not significantly ($p > 0.05$) affected by different inoculation scenarios (**Figure 3**).

Benefits to the Industry

The potential impact on the produce industry would be in two areas: (a) reduce the risk of cross-contamination of apples and citrus fruits during the wax coating step, and (b) reduce microbial load on the fruit surface and thus improve the safety of fruit products. The proposed approach can provide a novel process control step in augmenting the safety of the fruits. The outcome of this research will identify the food-grade formulations of compounds and extracts that can be blended with the commercial wax formulations to achieve the goals of reducing the risk of cross-contamination and improving the reduction of potential pathogens on the fruit surface, including hard-to-sanitize sections such as the calyx and stem regions of the fruit.

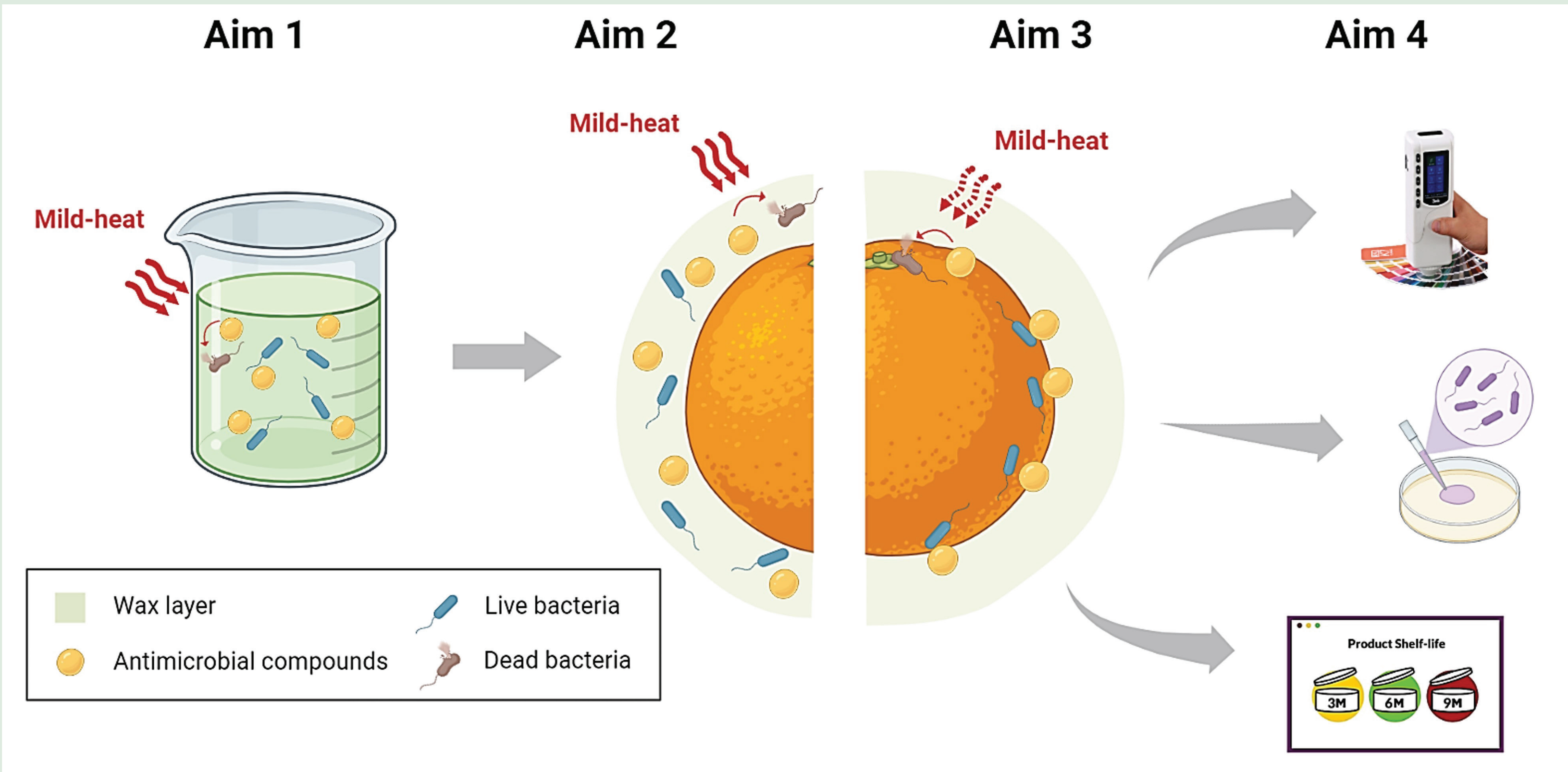

Figure 1. A schematic diagram of the wax coating project.

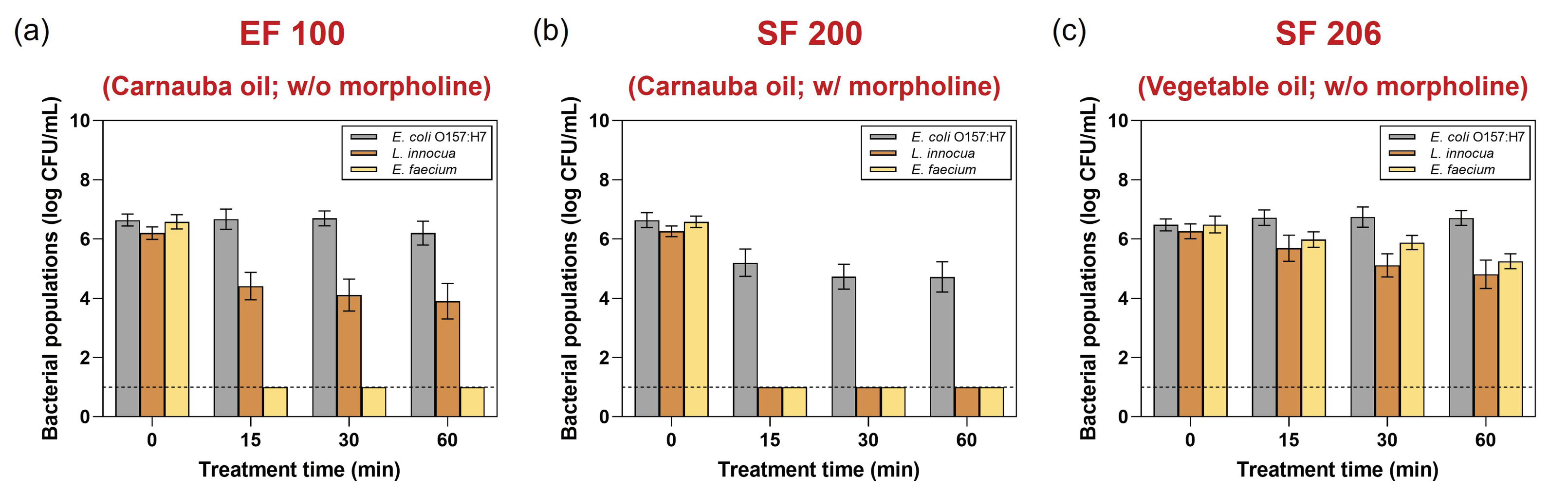

Figure 2. Inhibitory activities of the wax formulations. Bacterial cells (*Escherichia coli* O157:H7, *Listeria innocua*, and *Enterococcus faecium*) were inoculated in (a) carnauba oil-based wax without morpholine (EF 100), (b) carnauba oil-based wax with morpholine (SF 200), or (c) vegetable oil-based wax without morpholine (SF 206)

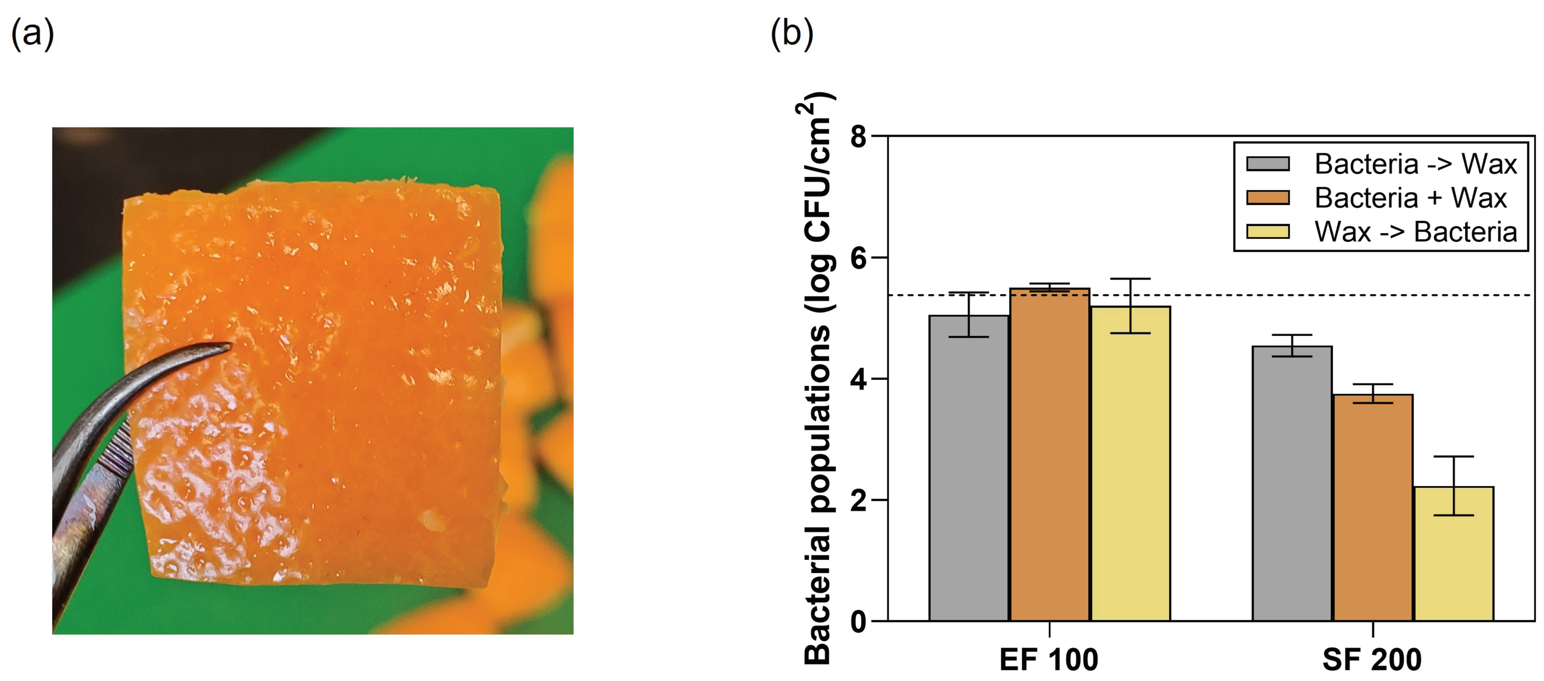

Figure 3. Inoculation test performed on the orange skin: (a) An image of the orange skin coupon ($2 \times 2\ cm^2$) and (b) inhibitory activities of EF 100 and SF 200 against *L. innocua* as influenced by different inoculation scenarios. *L. innocua* cells were inoculated on the orange skin surface before, simultaneously with, or after brush-coating the orange surface with the wax formulations.