# Waxing of whole produce and its involvement in and impact on microbial food safety


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## Project funding dates

January 1, 2021 – December 31, 2022

## Acknowledgements

We thank our industrial collaborators for providing the wax samples and citrus fruits.



## Summary

After harvest, many fresh fruits and vegetables are washed and waxed in order to prevent premature rotting and to extend shelf life. Over the past decade, the influence of commercially available waxes on fruit and vegetable quality has been investigated and reviewed, however, there is a need for a more systematic evaluation of the impact of waxing on microbial food safety. This project aims to fill these knowledge gaps by conducting in-lab and pilot plant studies using a citrus model. The results of this project will be used to support individual packinghouse food safety plans and facilitate auditor evaluations.


## Objectives

1. Evaluate the microbial and chemical properties of currently available citrus waxes and determine the potential for human pathogens to survive in these waxes under simulated packinghouse storage conditions.
2. Investigate the behavior of *Listeria monocytogenes (LM)* and *Salmonella* inoculated onto citrus fruit surfaces when storage waxes are subsequently applied and fruit is stored.
3. Characterize and evaluate the pathogen control efficacy of different finishing waxes, the heated drying steps, and subsequent storage by conducting in-lab and pilot-scale packinghouse trials.

## Methods

Commercially available citrus storage and finishing waxes were obtained from industry partners and the pH and background microbiota were determined. The survival of 5-strain cocktails of *Salmonella* and *LM* inoculated into the waxes were determined during storage at 4 and 22°C. Lemons will be inoculated with the same pathogen cocktails, storage waxes will be applied, and then microbial populations will be monitored under conditions that mimic degreening or commercial storage. The impact of applying finishing waxes combined with a heated drying step on microbial populations will be evaluated under laboratory and pilot packinghouse conditions with both lemons and oranges. Surrogate microorganism *Enterococcus faecium* NRRL 2354 will be used for the pilot plant study.

## Results to Date

Four storage waxes and 15 finishing waxes were obtained from major wax suppliers. **Figure 1** shows the pH values of these waxes. Aerobic plate counts were below the limit of detection for all but two storage waxes (2.5 and 3.2 Log CFU/ml) and one finishing wax (5.6 Log CFU/ml). Storage waxes (**Figure 2**) and finishing waxes (**Figures 3 and 4**) were inoculated with *LM* and *Salmonella* at 6 Log CFU/ml and subsequently stored at 4 and 22°C for 24 h. Populations of *Salmonella* declined more rapidly than *LM* regardless of storage temperature. Greater population reductions were noted at 22°C than at 4°C.

## Benefits to the Industry

The Preventive Controls for Human Food Rule and the Produce Safety Rule mandate that the food industry implement efficient preventive controls against identified hazards (e.g., *Salmonella* and *LM* for tree fruit). In recent years, the numbers of audits that the fresh fruit and vegetable packinghouses need to handle have increased. For many of the packinghouses, as well as for the auditors, very limited information is available about the food safety risks associated with waxing, a common step widely used by packinghouses. Results from this project will address this critical need for the fresh produce industry facilitating risk assessments and strengthening food safety plans.

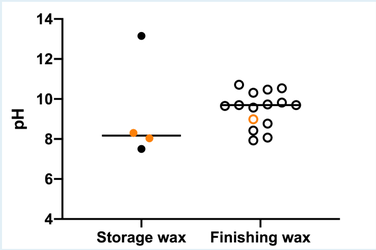


**Figure 1**.pH values of citrus storage and finishing waxes. Dots in orange color represent waxes that contained background flora. Dots in black color represent waxes in which no background flora were detected (limit of detection is 1 CFU/ml).

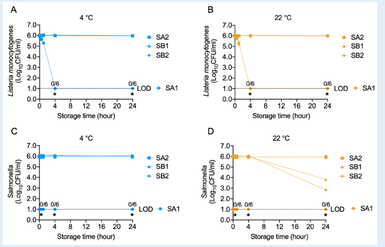


**Figure 2**. Survival of *Listeria monocytogenes* (A, B) and *Salmonella* (C, D) in citrus storage waxes. SA: storage wax from company A; SB: storage waxes from company B; LOD is limit of detection by plating; * represents surviving cells that fell below the limit of detection; #/#: numbers of samples that were positive after enrichment/total numbers of samples tested.

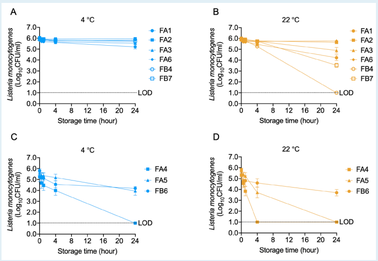


**Figure 3**. Survival of *L. monocytogenes* in citrus group 1 (A, B) and group 2 (C, D) finishing waxes. FA: finishing waxes from company A; FB: finishing waxes from company B; LOD is limit of detection. Group 1 includes finishing waxes where the reduction of *L. monocytogenes* after 24 h of storage at 4°C was less or equal to 1 Log CFU/ml. Group 2 includes finishing waxes where the reduction of *L. monocytogenes* after 24 h of storage at 4°C was greater than 1 Log CFU/ml.

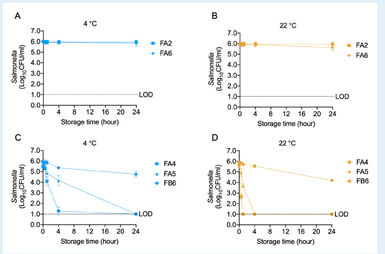


**Figure 4**. Survival of *Salmonella* in group 1 (A, B) and group 2 (C, D) finishing waxes. FA: finishing waxes from company A; FB: finishing wax from company B; LOD is limit of detection. Group 1 includes finishing waxes where the reduction of *Salmonella* after 24 h of storage at 4°C was less or equal to 1 Log CFU/ml. Group 2 includes finishing waxes where the reduction of *Salmonella* after 24 h of storage at 4 °C was greater than 1 Log CFU/ml.