BIOAG PROJECT FINAL REPORT

TITLE: Sustainable sanitation technique for postharvest quality and safety of organic fruits

PRINCIPAL INVESTIGATOR(S) AND COOPERATOR(S): Shyam Sablani, Karen Killinger, Barbara Rasco

KEY WORDS: *Listeria monocytogenes,* Produce safety, Ultraviolet light

ABSTRACT

We determined ultraviolet-C light inactivation kinetics of pathogenic bacteria *Listeria monocytogenes* on four organic fruit surfaces. Results show that maximum reductions of 1.6 (apple), 1.7 (pear), 0.95 (strawberry) and 0.95 (cantaloupe) log CFU/g were observed after 3.75, 11.9, 11.9, and 11.9 kJ/m^2 of UV-C doses, respectively. Findings also show that the higher roughness and microorganism interaction with fruit surface resulted in a lower inactivation rate of *L. monocytogenes* on cantaloupe and strawberry surfaces. This study showed that UV-C can reduce 0.95 to 1.7 log CFU/g *L. monocytogenes* populations on fruits depending on their surface morphology.

PROJECT DESCRIPTION

Fresh fruits are generally considered safe from pathogenic bacteria because of their high acid content. However, there are several incidents when bacterial pathogens including *Listeria monocytogenes* have been isolated in fresh and frozen fruits (Bower et al., 2003). Recent outbreaks of *Listeria* in fresh fruits have challenged the belief that pathogenic bacteria cannot grow in high-acid foods. Therefore, microbial safety during postharvest handling is one of the major concerns of the organic industry. The U.S. Food and Drug Administration (FDA) Food Safety Modernization Act now requires growers and packers of all fresh produce to adapt preventive strategies for microbial controls to minimize the risk of human pathogens.

The overall objective of this project was to determine the ultraviolet-C light inactivation kinetics of *Listeria monocytogenes* on selected organic fruit surface. A better understanding of the influence of fruit surface morphology on ultraviolet-C (UV-C 254 nm) inactivation of microorganisms will help in designing effective treatment systems.

OUTPUTS

Work Completed:

We investigated UV-C inactivation of pathogenic bacteria *L. monocytogenes* on selected organic fruit surfaces (Tables 1). As suggested by the reviewer, cantaloupe fruit was selected instead of cherries. The results indicated that it is possible to reduce up to 1.7 log CFU/g of *L. monocytogenes* on apple surfaces using 3.75 kJ/m^2 UV does, with lesser reduction (1.2 log CFU/g) on pear for similar doses. The inactivation rates were much lower for strawberries and cantaloupe which means higher level of UV-C doses will be required for inactivation of *L. monocytogenes* (Figure 1). The irregular surface morphology of strawberry and cantaloupe (Table 2) and interactions between fruit surface and *L. monocytogenes* protected microorganisms from UV-C light.

Table 1. Average logarithmic reduction levels of *Listeria monocytogenes* on selected organic fruit surfaces (N = 3)

Time (s)	UV-C dose (kJ/m^2)	*Listeria monocytogenes* reduction (Log N_0/N)			
		Apple	Pear	Strawberry	Cantaloupe
0	0	0^{a}	0^{a}	0^{a}	0^{a}
10	0.17	0.72 ± 0.15^{hi}	0.71 ± 0.03^{hij}	0.56 ± 0.06^{de}	0.33 ± 0.07^{b}
20	0.37	0.79 ± 0.15^{ij}	0.85 ± 0.28^{jkl}	0.59 ± 0.10^{def}	0.33 ± 0.10^{b}
30	0.56	0.86 ± 0.15^{jk}	0.92 ± 0.23^{klm}	0.64 ± 0.05^{efgh}	0.36 ± 0.07^{b}
40	0.66	0.83 ± 0.14^{jk}			
50	0.79	1.01 ± 0.07^{lm}			
60	1.10	1.03 ± 0.11^{lm}	0.89 ± 0.24^{jklm}	0.60 ± 0.07^{defg}	0.44 ± 0.09^{bc}
90	1.27	1.08 ± 0.14^{mn}			
120	2.02	1.12 ± 0.20^{mno}	1.03 ± 0.27^{lmno}	0.62 ± 0.12^{defgh}	0.51 ± 0.13^{cd}
180	2.33	1.16 ± 0.05^{nop}			
240	3.65	1.35 ± 0.10^{q}	1.20 ± 0.17^{opq}	0.68 ± 0.12^{fghi}	0.65 ± 0.13^{efgh}
300	3.75	1.61 ± 0.08^{s}			
360	5.30		1.26 ± 0.27^{pqr}	0.71 ± 0.11^{ghi}	0.67 ± 0.14^{efgh}
480	6.89		1.34 ± 0.33^{qr}	0.85 ± 0.09^{jk}	0.70 ± 0.04^{fghi}
600	8.82		1.46 ± 0.33^{rs}	0.85 ± 0.10^{jk}	0.84 ± 0.11^{jk}
720	10.30		1.57 ± 0.18^{s}	0.85 ± 0.08^{jk}	0.87 ± 0.11^{jk}
840	11.87		1.65 ± 0.14^{s}	0.95 ± 0.03^{kl}	0.95 ± 0.10^{kl}

Different superscripts in rows and columns represent statistical significant differences between *Listeria monocytogenes* log reduction values in number of cells obtained at selected UV doses (UV treatment times) ($p < 0.05$)

Table 2: Root mean square surface roughness (R_q) and average surface roughness (R_a) values of selected fruits

Fruit	R_q (µm)	R_a (µm)
Apple[1]	30.3	25.4
Pear (D'Anjou)	40.2	32.8
Cantaloupe (Guatemala origin)	55.8	47.7
Strawberry[1]	296	287

[1]The data was obtained during first year of project

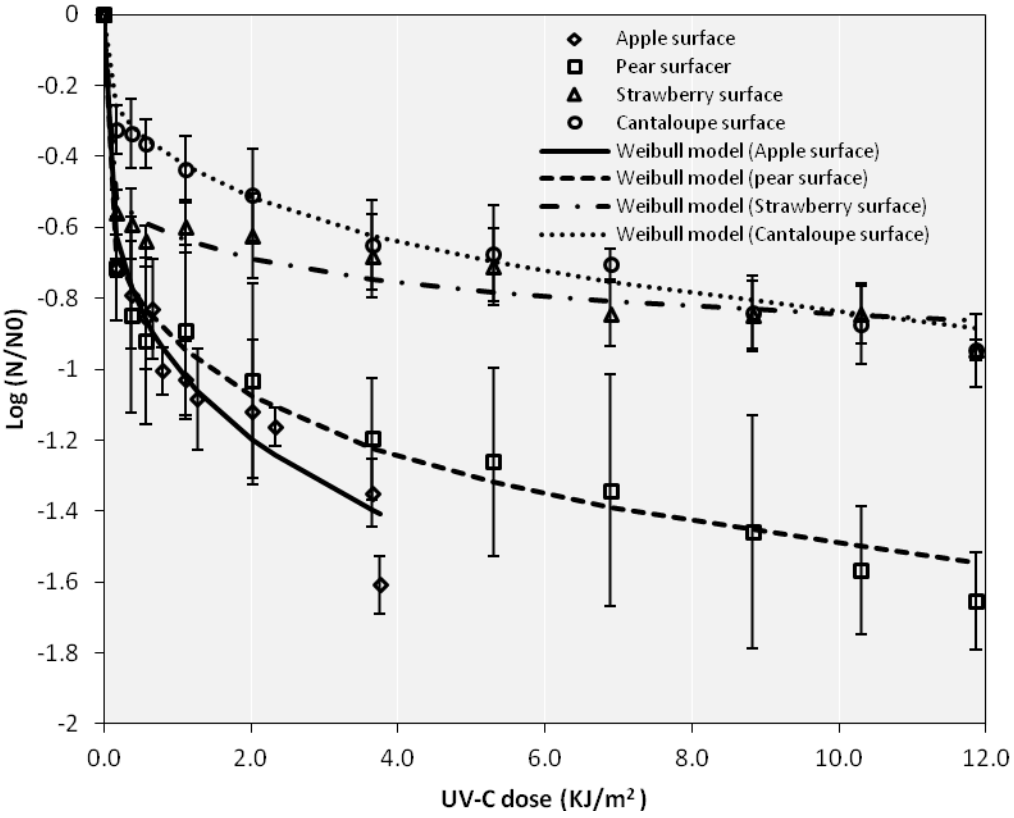

Figure 1. UV-C light inactivation of *Listeria monocytogenes* on selected organic fruits

Table3: Average and standard deviation values of surface energy parameters of selected fruits (N= 20)

Fruit surface	Contact angle (ϑ)		$\gamma_s \times 10^3$ (mN/m)	$\gamma_s^d \times 10^3$ (mN/m)	$\gamma_s^p \times 10^3$ (mN/m)	$W_a \times 10^3$ (mN/m)	$W_s \times 10^3$ (mN/m)
	Water	Diiodomethane					
Apple[1]	81.8±12.5	42.5±8.4	42.9±6.4	38.7±4.3	4.31±3.2	84.6±15	-61.2±15
Pear	96.8±7.7	38.7±5.0	40.6±2.9	40.2±2.5	0.49±0.9	64.3±9.7	-81.5±9.5
Cantaloupe	76.3±12.8	63.7±11.3	36.4±2.0	26.4±6.3	9.8±7.9	89.7±15.0	-56.1±14.6
Strawberry[1]	76.3±9.2	35.6±11	46.4±6.1	41.3±5.2	5.07±3.6	90.2±12	-55.6±11

[1]The data was obtained during first year of the project

where γ_S = surface energy (mN/m), γ_S^d = Dispersion component of the surface energy of the solid (mN/m), γ_S^p = Polar component of the surface energy of the solid (mN/m), W_a = Reversible work of adhesion (mN/m), W_s = Spreading coefficient (mN/m)

Our research demonstrated that UV-C is effective in reducing microorganisms population up to 3 log CFU/g depending up on types of microorganism and fruit surface morphology. The UV-C technology is safe, cost effective and commercially well developed. This technology is being used for sanitization of bottled water, packaging materials, conveyor belts, filling equipment and working surfaces. The implementation of UV-C system on packaging line for sanitization of fruits surface will require minimal capital and operating investment. The system will require installation of UV-C lamps over fruit conveyor belts. The number of lamps required will depends on doses needed to inactivate target pathogens, fruit surface properties and the speed at which fruit moves through conveying system. Washington Potato Co. is using UV-C based system for decontamination of potato surfaces. The company recently received approval from the WA State Department of Agriculture to use UV-C for decontamination of organic products (http://www.foodquality.com/details/article/807877/Give_UVC_a_Tumble_to_Eliminate_Bacteria.html?tzcheck=1). The company is using UV-C based treatments on an increasing basis for organic processing of their own private-label stock items and those manufactured on a contract basis for other processors, wherever approved by their customer.

- Publications, Handouts, Other Text & Web Products:

Conference Presentations:

Adhikari, A., Sablani, S. S., Killinger, K., Syamaladevi, R. M., and Gray, P. (2014). Ultraviolet-C light inactivation of *Listeria monocytogenes* on organic fruits, International Association for Food Protection, Indianapolis, Indiana, August 03-06.

Peer-reviewed publications:

Syamaladevi, R. M., Adhikari, A., Lupien, S. L., Dugan, F., Bhunia, K., Dhingra, A., and Sablani, S. S. (2015) Ultraviolet-C Light Inactivation of *Penicillium expansum* on Fruit Surfaces, Food Control 50: 297-303

Adhikari, A., Syamaladevi, R. M., Killinger, K., and Sablani, S. S., (2014). Fruit surface morphology influence on Ultraviolet-C Light inactivation Kinetics of *E. coli: O157 H7* and *Listeria monocytogenes* (In preparation)

- Outreach & Education Activities:

The potential uses of UV-C technology for fruit sanitization and the results of our study were discussed with growers at the grower's meetings, Good Agricultural Practices (GAPs) and Hazard Analysis and Critical Control Points (HACCP) workshops. The grower's meetings were organized in several Louisiana state counties between March and April, 2014. The GAPs workshops were organized at New Orleans, LA (May 28, 2014), Puyallup (February 08 and March 02, 2013) and Bellingham, WA, and HACCP workshop was conducted at Ellensburg (March 11-13, 2013). These workshops were attended by more than 60 participants. The experimental protocols developed and knowledge generated through this project will be used as teaching material in the course 'Thermal and Nonthermal Processing of Foods' to be offered in Fall 2015.

- **IMPACTS:**

Short-Term: *Listeria monocytogenes* can be reduced on organic fruits up to 1.7 log CFU/g using UV-C light. The fruit surface morphology and properties affected efficacy of UV-C light for inactivation of *Listeria monocytogenes*.

Intermediate-Term: The information acquired can be used to design UV-C doses for sanitization of organic fruit surface thus increasing the microbial safety and extending the postharvest shelf-life of organic produce.

Long-Term: The improved microbial safety and extended postharvest life of organic produce will provide economic incentives to Washington organic agriculture industry. The research findings and new methods developed by this project may also lead to more environmentally-sound food handling methods and improved consumer health and safety throughout the nation.

ADDITIONAL FUNDING APPLIED FOR / SECURED:

Ultraviolet light (UV-C) treatment for improving safety of red raspberries, National Processed Raspberry Council, $31,455 (Sablani, Killinger, and Ganjyal), 2014-2016

GRADUATE STUDENTS FUNDED:

This project has supported doctoral student and postdoctoral fellow: (1) Poonam Bajaj and Kanishka Bhunia, Biological Systems Engineering, (2) Achyut Adhikari in School of Food Science.

RECOMMENDATIONS FOR FUTURE RESEARCH:

Our research demonstrated that fruit surface morphology and surface integrity have significant influence on efficacy of UV-C treatment. In general, UV-C alone is effective in reducing microorganism population up to 3 log CFU/g depending up on types of microorganism and fruit surface characteristics. A combination of UV-C with other technologies such as electrolyzed water rinse and natural antimicrobial sprays needs to be investigated to achieve a 4-6 log CFU/g reduction of microorganisms on fresh produce as recommended by USDA.