Decontamination of Foods by Pulsed Ultraviolet Light

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ABSTRACT

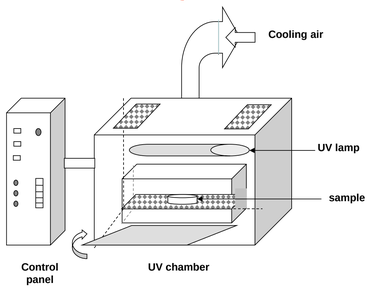
Pulsed Ultraviolet (UV)-Light is an emerging technology, which has a potential to be used for decontamination food products. The recent studies suggest pulsed UV light inactivates microorganisms not only by photo-chemical reactions, but also by other mechanisms associated with the use of high intensity pulses such as photo-thermal and photo-physical mechanisms, Microbial cells become inactive with conventional UV induced photochemical reactions have taken place, but the cell structures remain intact after UV treatment. However, pulsed UV light also damages the cell structures for some of the pulsed UV treated cells. Therefore, pulsed UV-light can be considered a powerful tool for inactivation of microorganisms on food surfaces or liquids. Many studies have demonstrated the effectiveness of pulsed UV-light on microbial loads on food surfaces. In our lab, various studies have been performed for the applications of pulsed UV-light treatment including fruits, poultry products, hard cheeses, pure water, and wastewater.

INTRODUCTION

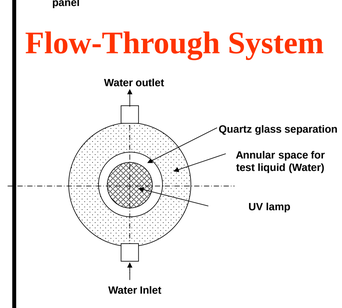
Pulsed ultraviolet (UV) light is a novel technology, which offers effective inactivation of pathogens on the food surfaces in very short periods of time. Basically, pulsed UV-light lamp produces a continual broadband spectrum from the deep UV to infrared, which are emitted as very short light pulses. These pulses involve UV-light below 400 nm, which is germicidal. Pulsed UV-light does not involve chemicals, and is safer and more efficient than conventional continuous UV-light. Pulsed UV-light may be utilized for the inactivation of microorganisms on raw and minimally-processed foods because this technology is considered to be a non-thermal for short processing times. It is also considered to be an alternative decontamination technique to irradiation. In 1999, pulsed light treatment of food was approved by FDA.

Pulsed UV-Light Systems

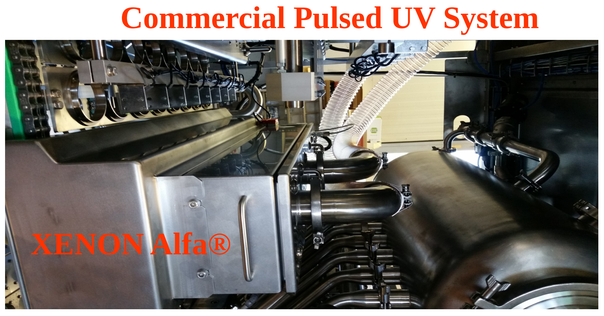
Static System



Flow-Through System



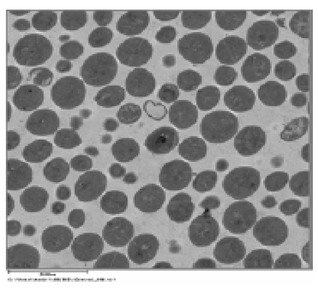
Commercial Pulsed UV System



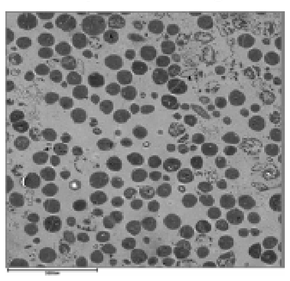
PULSED UV-LIGHT BASICS

- Electrical energy compressed into short pulses > pulsed light emitted
- Spectrum range: deep UV – infrared
- (100-1100 nm)
- Rich and efficient in the UV<400 nm (germicidal)
- Consists of short light pulses delivered by Xenon gas lamp
- Pulse duration: a few hundred microseconds
- Inactivates pathogens in very short time.
- Approved by FDA in 1999 (Federal Register, 1999).

Untreated *S. aureus*



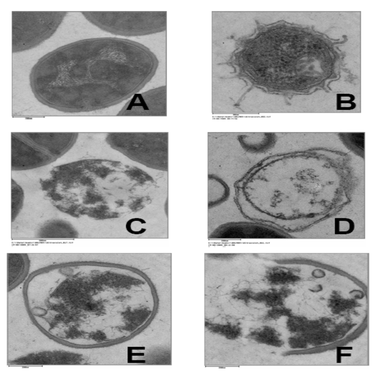
***S. aureus* after a 5-s treatment with pulsed UV-light**



INACTIVATION MODES

- **Photo-chemical effect:**
  UV-light component forms thymine dimers *(Bank et al., 1990; Jay, 1997; Miller et al., 1999)*
- **Photo-thermal effect:**
  Visible and infrared portion of the pulsed UV-light cause localized heating of the bacterial cell *(Fine and Gervais, 2004)*
- **Photo-physical effect:**
  Constant physical disturbances due to the pulses result in structural damages on cell *(Krishnamurthy et al., 2007)*

Effects of pulsed UV-light treatment on *S. aureus* after 5-s treatment with pulsed UV-light



A. untreated *S. aureus*

B. cell wall rupture

C. lack of cell wall

D. cytoplasm shrinkage and damage on cell wall

E. cytoplasm shrinkage and membrane damage

F. cell wall damage and cellular content leakage

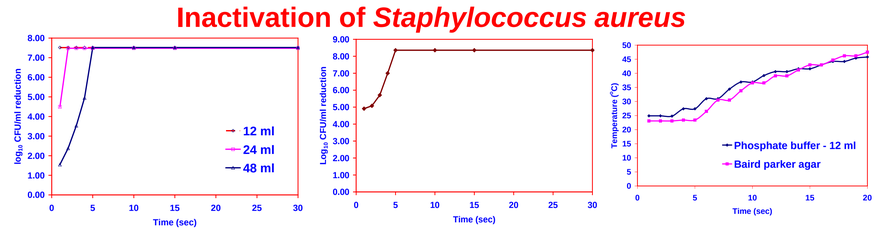
Krishnamurthy, K., S. Jun, J. Irudayaraj, and A. Demirci. Food Bioprocess Technol. 3:93–104 (2010)

ACKNOWLEDGEMNENT

The research presented here was funded in part by Penn State Experiment Station, USDA Special Research Grants, U.S. Highbush Blueberry Council, Pennsylvania Poultry Check-off Program and The Scientific and Technological Research Council of Turkey (TUBITAK).
Special thanks to XENON Corporation (Wilmington, MA) for providing technical assistance for the pulsed UV systems used for these projects.

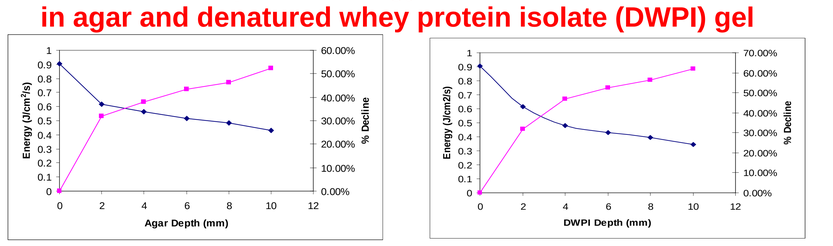
PULSED UV STUDIES AT PENN STATE

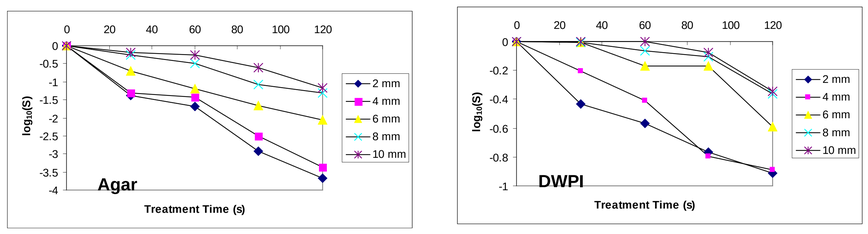
Inactivation of *Staphylococcus aureus*



Krishnamurthy, K., A. Demirci, and J. Irudayaraj. J. Food Prot.67:1027-1030 (2004)

Effect of Depth on Energy Dose and Inactivation in agar and denatured whey protein isolate (DWPI) gel

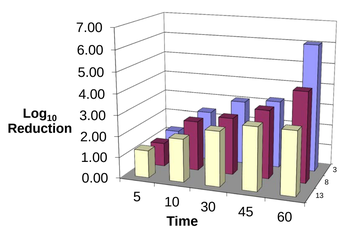




Bialka, K.L., P. N. Walker, V. M. Puri, and A. Demirci. Transactions of the ASABE. 51: 195-204 (2008)

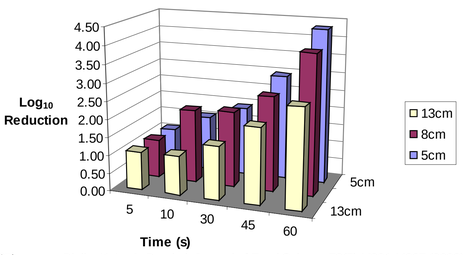
Decontamination of small fruits

Reduction of *E. coli O157:H7 on Blueberries*



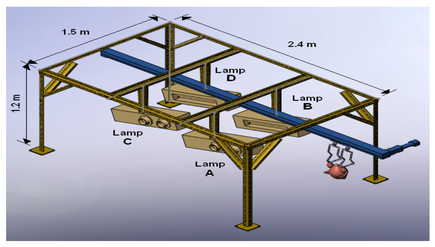
Bialka K. L., A. Demirci. Journal of Food Science 72(9): M391-M396 (2007)

Reduction of *Salmonella* on Strawberry



Bialka K. L., A. Demirci. Journal of Food Science 73(5):M201-M207 (2008)

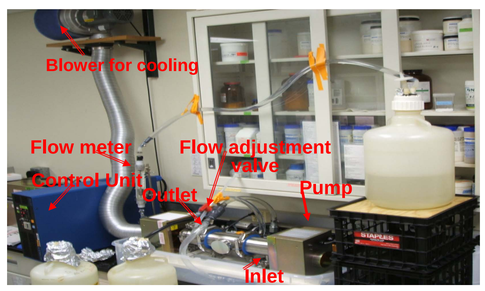
Decontamination of Poultry Carcass



Velocity (cm/min)	Log Reduction of *E. coli* (CFU/ml rinse solution)
78 (30-s)	0.87
52 (45-s)	0.96
39 (60-s)	1.00
26 (90-s)	1.17
20 (120-s)	1.31
13 (180-s)	1.43

Keklik, N. M., A. Demirci, and R. Bock. Transactions of ASABE. 54(3): 993-1000 (2011)

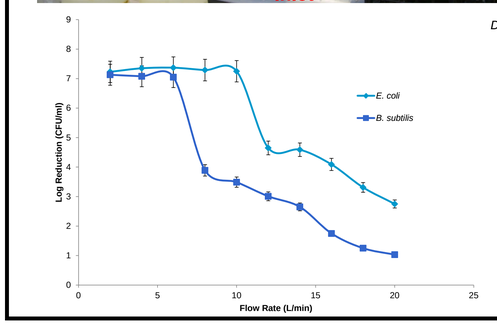
Decontamination of Pure Water and Municipal Wastewater Effluent



Pure Water

Flow rate (L/min)	*B. subtilis* (Log CFU/ml)	Growth after enrichment
0	5.5 – 6.5	Yes
2	0	No
4	0	No
6	0	No
8	0	No
10	0	No
14	0	No

Demirci, A. and K. Krishnamurthy. Ultrapure Water Journal. 24 (1): 35-40 (2006)



Municipal Wastewater Effluent

	% Removal			
	Turbidity	SS	COD	TOC
E. coli (10 L/min)	20.0	57.8	49.5	16.3
B. subtilis (6 L/min)	12.5	39.3	41.4	7.0
Raw w. water (10 L/min)	50.5	55.8	79.8	35.0