Pulsed Ultraviolet Light as an Element of Hurdle Technology for Sanitizing Conveyor Belts

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Conveyors are widely used in the food industries to transport both loose and packaged foods through stages of processing and packaging. Loose food particles and liquid and semiliquid residues invariably come loose and collect on the belts, where they can trap and foster bacteria. This can, in turn, contaminate food being processed on that system, possibly with health-threatening strains. Because of this, conveyor systems need to be cleaned and disinfected on a daily basis; even better would be to continually treat the belts while in use to minimize transmission.

Hurdle Concept

Macroscopic particles or residue that can harbor microorganisms should be removed by physical methods, using mechanical shaking, air blowing, or rinsing to dislodge them. But to reliably disinfect the belt, killing the microorganisms with high confidence in the results, a good strategy is to a combination of techniques, sometimes called "hurdle technology"[1]. This means to use a number of a collection of different treatments that have non-overlapping natures, strengths, and weaknesses to assault the bacteria using multiple methods. The analogy is to place a series of barriers in the way of the bacteria, as hurdles are to a track runner, so that if one of them fails to effectively kill an acceptable number of bacteria, the combination of them will do so.

Originally used for meat products, the "Hurdle" concept has been extended to vegetables and fruits, and most notably to green leafy vegetables, which are often eaten fresh and raw, making them particularly susceptible to contamination. As has been noted, there is no single step in the "long chain from seed to consumption where potentially harmful microorganisms could be completely eliminated, e.g. through heating"[2]. Yet, at the same time, "A concerning trend in recent years is disease outbreaks caused by various leafy vegetable crops," particularly by common bacteria such as *E. coli*.

Leistner in 2000 stated that there existed "more than 60 potential hurdles for foods…" and that the list was "…by no means complete."[3] Alex Gonçalves[4] recognizes five classes of hurdles – *Physical Hurdles* (pressure, irradiation, and the like), *Physico-Chemical hurdles* (Salting, smoking, spices, preservatives), *Microbially-derived hurdles* (antibiotics, etc.), *Miscellaneous hurdles* (Use of Free Fatty acids, Chitosin, etc.), and *Emerging Technologies* (Ultra-High Pressure, Non-Thermo-Sonication, and other still-developing technologies).

Pulsed Light

One of the more potent sterilization methods is the use of high-intensity pulsed light from xenon flashlamps. Such lamps produce a very short, very intense pulse of light that contains wavelengths ranging from the deep ultraviolet below 200 nm through the visible to the near infrared at about one micron. The ultraviolet portion is of particular interest, since it completely overlaps the DNA absorption peaked at 260 nm. Irradiation into this band is particularly deadly to microorganisms. The ultraviolet light breaks the amino acid bonds in the DNA, which recombine “incorrectly” to form pyrimidine dimers. If enough of these form, they cause the DNA to malfunction, and overwhelm the cell’s self-repair mechanism, causing the organism to die. One advantage of the xenon flashlamp, as opposed to other sources of ultraviolet light such as LEDs, excimer lamps, and mercury lamps is that the short, intense flash of light is likely to create multiple dimers simultaneously in the same strands, making cell death more probable[5,6]. Pulsing an LED does not have the same effect. Conversely a pulsed xenon flashlamp system stores energy over time and delivers the stored energy in microseconds. This means that peak energies in the order of megawatts can be generated with pulse durations in the millisecond region. This intense peak power is able to penetrate deeper and still create significant damage. The xenon flashlamp system is also completely mercury-free, and there are no disposal problems or concerns.

System Maintenance

Applicability of any technology for a specific market segment is important and xenon Pulsed Light is no exception. To be deployable it needs to conform to norms of maintenance and handling of similar equipment. In Food and Pharmaceutical industries for example, the requirement is of wash-down and stainless steel designs where harborage of bacterial needs to be minimized. In conveyor systems the mounting of the lamp housing to eliminate any chance of broken glass plays a critical role in terms of safety.

Figure 1. Deployment into the food processing environment requires design for wash-down and clean-in–place. Stainless Design, Folded Edges and flush mount for flashlamp window is ideal.

Methods to facilitate maintenance with non-technical staff become a critical consideration when deploying the solution. The XENON flashlamp solution for example has tool-less access to service and replace the lamps.

Figure 2. Tool-less entry and easy maintenance is key to successful implementation.

Finally, XENON flashlamps are completely mercury-free, and there are no disposal problems or concerns.

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Flashlamp Spectrum

Another advantage of the xenon flashlamp is that its broadband output contributes to sterilization by other, still not fully understood, light-activated methods. One of these possible mechanisms is the breakdown of cell walls by short-wave visible light at about 405 nm[7,8]. Whatever the actual mechanism, it has been demonstrated that irradiating surfaces with longer wavelength light in addition to deep ultraviolet significantly increases the lethality of the treatment[9]. The output of ultraviolet LEDs and excimer lamps, while not as narrow in wavelength as lasers, are still essentially monochromatic, and do not exhibit these multi-wavelength effects. Some UV LED systems, in fact, have started adding extra LEDs working at a longer wavelength, but still only provide two wavelengths instead of a continuum.

System Integration

The Pulsed Light irradiation can be retrofitted to systems already in use, will not interfere or interact with many other of the "hurdle" treatments, and does not create activated species or unwanted chemical changes. One of the important aspects of this technology is its low temperature properties. This is significant in food processing where sanitization of the product is required but the product is frozen or fresh and potential "cooking' must be avoided and the food flavor or nutritional value unaltered. This low temperature characteristics comes about because the pulse ON time is thousand times shorter than the OFF time typically and thermal inertia of the materials does not allow for any significant temperature increase.

Process Validation

The successful deployment of XENON flashlamp solutions will require validation to the specific process parameters like conveyor width and speed. Once this is known however, the technology is scalable by the addition of multiple flashlamp systems to scale with faster throughput demands.

Figure 3. Pull away design are best solutions for mounting and servicing in confined areas.

Typical conveyor solutions which keep cycling through multiple times a day, the Pulsed Light treatment has a cumulative benefit, so that repeated use of it on a moving belt itself will, in time, irradiate the entire length of the belt. Repeated exposures of the same portions of the belt will work to eliminate any residual organisms, as well as attacking new ones deposited since the last exposure.

In conclusion, xenon flashlamp technology for the treatment of conveyors is an ideal hurdle technology for the Food and Pharmaceutical industries. They are effective in continual reduction in bio-burden associated with the conveyor and can be a straight forward retrofit of the technology to existing lines. Their non-

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contact, chemical-free and low temperature properties mean that the conveyed products are minimally affected. The process is scalable to cope with different process requirements in terms of speed and width. It is worth mentioning that although this paper discusses treatment of conveyor belts with pulsed light, the use of Pulsed light in the treatment of food is an FDA approved process.

Figure 4. A complete conveyor treatment solution including power electronics panel and lamp housing.

References

1. Lothar Leistner and Leon G.M. Gorris "Food Preservation by Hurdle Technology" *Trends in Food Science and Technology* **6** (2) 41-46 (February 1995)
2. Lars Mogren et al. "The Hurdle Approach – A Holistic Concept for Controlling Food Safety Risks Associated with Pathogenic Bacterial Contamination of Leafy Green Vegetables – A Review" *Frontiers in Microbiology* **9** Article 1965 (August 2018)
3. Lothar Leistner "Basic Aspects of Food Preservation by Hurdle Technology" *International Journal of Food Microbiology* **55** (1-3) pp. 181-186 (2000)
4. Alex Gonçalves et al. "Hurdle Technology in the Food Industry" Chapter 3 (pp. 147-210) in *Food Engineering* Brendan C. Siegler (ed) Nova Press (2011)
5. Cheigh, C. I., Hwang, H. J., & Chung, M. S. "Intense pulsed light (IPL) and UV-C treatments for inactivating Listeria monocytogenes on solid medium and seafoods" *Food Research International* **54** (1) 745-752 (2013)
6. Bohrerova, Z., Shemer, H., Lantis, R., Impellitteri, C. A., & Linden, K. G. "Comparative disinfection efficiency of pulsed and continuous-wave UV irradiation technologies" *Water research* **42** (12), 2975- 2982 (2008)
7. Murdoch, Lynne E., Michelle Maclean, Endarko Endarko, Scott J. MacGregor, and John G. Anderson. "Bactericidal effects of 405 nm light exposure demonstrated by inactivation of Escherichia, Salmonella, Shigella, Listeria, and Mycobacterium species in liquid suspensions and on exposed surfaces" *The Scientific World Journal* 2012 (2012)
8. McKenzie, K., Maclean, M., Grant, M. H., Ramakrishnan, P., MacGregor, S. J., & Anderson, J. G. "The effects of 405 nm light on bacterial membrane integrity determined by salt and bile tolerance assays, leakage of UV-absorbing material and SYTOX green labelling" *Microbiology* **162** (9) 1680-1688 (2016)
9. Woodling, S. E., & Moraru, C. I. "Effect of spectral range in surface inactivation of Listeria innocua using broad-spectrum pulsed light" *Journal of Food Protection* **70** (4) 909-916 (2007)

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