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Pulsed light improves food safety, quality

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Ultraviolet wavelengths have significant antimicrobial effects



As seen on the salmon to the left above, pathogens can grow on food even at refrigeration temperatures. Photo by Rick Griffiths, Virginia Tech.

The number of reported foodborne illnesses associated with bacterial enteropathogens continues to rise in both Europe and North America, despite significant advances toward a better understanding of bacterial transmission and pathogenicity in foods, implementation of good manufacturing practices, mandatory HACCP risk management systems, and other quality assurance schemes.

Contamination of both unprocessed and processed foods with pathogenic microorganisms is an international concern, and any method of reducing or eliminating the contamination will reduce the risk of disease. Both intrinsic and extrinsic microorganisms and enzymes are responsible for the loss of fish and shellfish quality after harvest. Since many seafood products are transported over large distances, the ability to increase shelf life by two or three days can have an important economic impact.

Outdated food safety ideas

In years past, it was thought that properly refrigerated foods would remain safe since pathogenic bacteria could not grow at refrigeration temperatures. Microbial growth was thought necessary to produce either a sufficient number of cells or enough toxin to cause illness.

Since then, we have learned that several pathogens, such as *Listeria monocytogenes*, can grow well at refrigeration temperatures. We also know that some pathogens can cause illness even when only a few cells are ingested. With sufficient time at refrigeration temperatures, several types of psychrotrophic bacteria, yeast, and mold can grow to levels sufficient to cause spoilage.

Pseudomonas sp. are among the most common spoilage agents of refrigerated foods. During growth, these bacteria produce proteases and lipases that can catalyze reactions resulting in the degradation of protein and fat. The consequence of these reactions is the formation of peptides and fatty acids with undesirable flavors and odors. Also, some bacteria produce enzymes capable of converting amino acids into toxic amines.

Pulsed light

Many of the pathogens and spoilage organisms are surface contaminants, so a process which reduces surface contamination may both increase safety and extend shelf life. One technology that has this potential is high-intensity pulsed light.

Pulsed light treatments depend on rapid, intense, magnified flashes of light or electrical energy from a capacitor. High-power xenon lamps pulse for about 0.1 to 3 millionths of a second, with a peak emission at 400 to 500 nm, and contain wavelengths of ultraviolet through near-infrared at about 20,000 times the intensity of light at sea level. The lamps emit light containing some ultraviolet wavelengths absent in sunlight.

For modest energy input of three joules (J), this results in peak power dissipation of approximately 35 mW. Unlike gamma irradiation, ionization of small molecules does not occur with pulsed light because the wavelengths are too long.

Beyond UV

According to Dr. Dallas Hoover, the antimicrobial effects of pulsed light are significantly greater than those of nonpulsed or continuous-wave conventional UV irradiation. For example, a single flash at 0.5 to 1.0 J per square centimeter will eliminate populations of approximately 100,000 vegetative bacteria, bacterial endospores, or fungal conidiospores per square centimeter.

Pulsed light appears to kill all types of bacteria and eukaryotic microorganisms with equal effectiveness. Reductions of 7 to 9 log₁₀ colony-forming units per square centimeter are possible with multiple pulses at 1-5 J per square centimeter per flash. The susceptibility of microorganisms to pulsed light disinfection depends on the strain, growth medium, stage of culture, and ability of the organisms to repair injury.

There are some requirements for the application of pulsed-light processing. Light must be able to penetrate the packaging material to reach the food surface. If the product has an irregular surface, the light is blocked and the process loses effectiveness. However, reductions in bacterial population of 1-3 log₁₀ cycles have been achieved in products with rough surfaces.

Effects on microorganisms

The effects of pulsed light on bacterial populations that cause illness in humans, including *Escherichia coli* (serotype O157:H7), *Listeria monocytogenes* (serotype 4b), *Salmonella enteritidis*, *Pseudomonas aeruginosa*, *Bacillus cereus*,



Pulsed light can be used to treat the surface spoilage that sometimes develops in packaged seafood dips and spreads. Photo by Rick Griffiths.

and *Staphylococcus aureus*, have been investigated by several researchers (references available from author). Results showed that as few as 64 light pulses of one microsecond reduced *E. coli* populations by three \log_{10} cycles and *L. monocytogenes* by two \log_{10} cycles. When 200 light pulses were applied, the inactivation ranged 2-6 \log_{10} cycles.

A two-log reduction in *L. monocytogenes* on a ready-to-eat-product can be a significant reduction, since the U.S. Food and Drug Administration established a zero defect action level for the organism. In clean processing facilities, *L. monocytogenes* contamination usually averages 50 colony-forming unit per gram. Processing plants with minimal or unacceptable sanitary operations can have products containing *L. monocytogenes* populations of 100 to 10,000 colony-forming unit per gram.

Consequently, a 2- \log_{10} cycle reduction of the microorganism in a plant employing high sanitary standards may eliminate all of the contamination. Hence, large reductions in a specific microbial pathogen are not always required to place high-quality, safe products into the marketplace.

Fungal spores of *Aspergillus niger* were subjected to pulsed light for varying treatment times and at varied distances from the light source. The optimum process resulted in a 4.93 log₁₀ reduction. Pulsed light treatments on *Saccharomyces cerevisiae* caused an increase in the concentration of eluded proteins and structural changes in the cells indicative of cell membrane damage. The study did not include a determination on the effects of varying processes on cell reductions.

Effects on enzymes

Only limited research has been reported on the effects of pulsed light on enzyme activity, but results appear promising. Two enzymes, alpha-amylase and neutral proteinase, were treated in pulsed light up to 40 flashes. Irrespective of the intervals of pulsed light, treatment of alpha-amylase with 40 flashes decreased its activity by 71 percent compared with the untreated controls. The activity decrease was 59 percent with a treatment of only 10 flashes. Activity effects of pulsed light on neutral proteinase were similar to those of alpha-amylase.

Applications in seafood industry

Studies in the author's laboratory at Virginia Tech in Blacksburg, Virginia, USA, have shown that the shelf life of various fish could be extended two to four days depending upon the species. Sea trout had the lowest shelf life extension, while hybrid bass had the highest.

Since pulsed light is a surface treatment, the technology can be best employed where surface contamination of pathogenic and spoilage microorganisms predominates. Hot-smoked fish sometimes spoil due to the growth of surface microorganisms and may have postprocessing contamination with *L. monocytogenes*.

Pulsed light could be a cost-effective control method for both microbial issues. Other applications include using pulsed light to treat packaged seafood pates, dips, and spreads, since surface spoilage usually dominates in these products.

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