Paper-2: Principles of the Food Processing and Preservation

Module 31: Preservation of foods by pulsed light technology

31.1 Introduction

Pulsed light (PL) technology is a non-thermal food processing technique, which involves discharge of high voltage electric pulses (upto 70 Kilovolt/cm) into the food product placed between two electrodes for few seconds. PL technique uses light energy in concentrated form and exposes the substrate to intense short bursts of light (pulses). PL processing used mainly to inactivate surface micro-organisms on foods, packaging material and equipments.PL is recognized by several names in scientific literature i.e., pulsed ultraviolet light, high intensity broad-spectrum pulsed light, pulsed light and pulsed white light.

PL includes broadspectrum wavelengths from UV to near-infrared. Thewavelength distribution ranges from 100 to 1,100 nm: UV(100ï 400 nm), visible light (400ï 700 nm), and infrared(700ï 1,100 nm). PL used for food processingapplications typically involves 1 to 20 flashes per second at anenergy density in the range of about 0.01 to 50 J cm^{-2} at thesurface.PL system can produce a peak power distribution as high as35 MW.Because of short pulseduration and cooling period between pulses, heating effects are negligible in PL technology.The FDA also has approved pulsed light for the treatment of food for surface microorganismcontrol, with the total cumulative treatment not exceeding 12.0 (J/cm^2) and the pulse duration is no longer than 2milliseconds.

31.2 Principle of the pulsed light system

PL involves the use of intense pulses of broad spectrum light for a short duration to ensure microbial inactivation on thesurface of either foods or packaging materials. PL technology involves accumulation of electromagneticenergy in a capacitor during fractionsof a second followed by its release in the form of light within ashort time (nanoseconds to milliseconds), resulting in anamplification of power with a minimum of additionalenergy consumption. Main componentsof PL system include the power supply unit, energy storage capacitor, the pulse configuration device and the lamp (Fig. 1). Energy supplied form a high voltage capacitor is stored in a high power capacitor relatively for a long period (a fraction of second) from which it is released to a specially designed xenon lamp unit within a much shorter period of time (nanoseconds or milliseconds). As the current passes through the gaschamber of the lamp unit, a short, intense burst of light isemitted thus focused on the treatment area. Xenon lamps are mostly preferred because of xenonĝs higher conversion efficiency. The microbial inactivation efficacy of pulsed light depends upon intensity (measured in Joule/cm^2) and the number of pulses delivered on the treatment area.

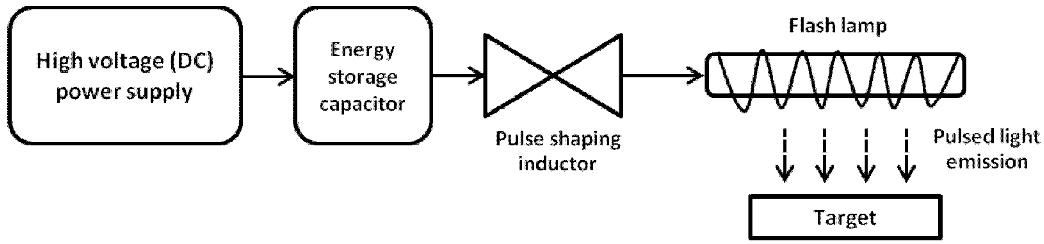

Fig. 1 Schematic representation of Pulsed light system

31.3 Mechanism of microbial inactivation by PL

The lethality of PL may be attributed to its rich broad spectrum ultraviolet content, its short duration, high peak power and the ability to regulate the pulse duration and frequency output of flash lamps. Ultraviolet portion of the Pulsed light spectrum is considered responsible for microbial inactivation by PL. Mechanisms involved in microbial inactivation by PL technology include: photochemical mechanism, photothermal mechanism and physical mechanism.

a. **Photochemical mechanism:** It states that the UV portion PL causes photochemical transformation of pyrimidine bases in the DNA of bacteria, viruses and other pathogens to form dimers. Formation of these dimers prevents DNA unzipping for replication and the organism becomes incapable of reproduction thus leading to death. Shorter wave length (100-280 nm) UV region is mainly responsible for photochemical effects.

b. **Photothermal mechanism:**The lethal effect of Pulsed light can also be due to photothermal effect. During PL treatment when energy exceeds 0.5 Joule/cm^2, bacteria can be ruptured by temporary overheating caused by absorption of all ultraviolet light from a flash lamp. This overheating of microbial cells may cause vaporization and generate a small steam flow to cause membrane destruction.

c. **Physical mechanism:**Physical mechanisms by which microbial inactivation achieved through PL processing include collapse of cell structure, enlargement of vacuoles, increased cell membrane permeability and depolarization of cell membrane.

31.4 Factors affecting the microbial inactivation by pulsed light

a. **Type of microorganism:**Optical properties of cells viz. degree of scattering and absorption of light influence the effect of PL on them. Some microorganisms with efficient DNA repair mechanisms are resistant to pulsed light.

b. **Interaction between light and the substrate:**The composition of the food sample and its surface integrity (rough, smooth) effect the absorption of the PL. Specular or diffused reflection can occur depending on the smoothness or roughness of the surface of the material respectively. For translucent materials, some part of the incident light interacts with the internal structures and causes multiple internal reflections, redirections which decrease the PL effect.

c. **The distance from the light source:**As the distance from light source and depth of the substrate increases, the absorption and scattering diminishes leading to decreased PL effect.

d. **Design of pulsed light system:**Proper PL system design with minimal energy losses and maximum efficiency is necessary to achieve effective microbial inactivation.

31.5Applications of PL technology

a. **Liquid foods:**Increasing the amount of solids will diminish the intensityof penetration of the PL i.e. in aqueous solutions, the lower the transparency,the less effective the PL treatment. Liquid foods with high UV absorbance mustbe treated as a thin layer in order to increase PL effectiveness. With increase in the number of UV absorbing components in the liquid foods, the effectiveness of PL decreases. The effectiveness of PL in liquid mediums could be increased by minimizing the sample depth, reducingdistance between PL source and the sample and/or increasing the treatmenttime.

b. **Solid foods:**Surface topography of solid foods influences the PL effects. PL treatment of solid foods with relatively simple surfaces leads to high levels of microbial inactivation.On complex surfaces like meat etc. PL treatment is not much effective. Part of the radiations of pulsed light spectrum may be absorbed by food constituents on rough surfaces leading to reduction in effectiveness of PL.

c. **Food powders:**Composition and the colour of the powders influence the effectiveness of PL treatment. Coloured powders will absorb more PL and this will reduce its effectiveness. However, thermal effects occurring due to absorption of PL may result in microbial reduction in powders.

d. **Application of PL for decontaminating food processing equipment:**Pulsed light treatment is highly suitable for its applicability in decontamination of the food process equipment surfaces. The type of food product in contact with the equipment surface and the time between contamination and intense pulse treatment decide the effectiveness of the microbial inactivation on surfaces. Surface topography of food contact surfaces also has a complex influence on the efficacy of PL treatments.Microbial inactivation decreased in the smoothest finish dueto its highly hydrophobic and reflective nature that leads tocell clustering.

31.6Merits and limitations of the PL technology

a. **Merits:**

- Inactivation of microbes by PL is a very fast process
- Consumption of energy is very less in this process
- No toxic chemicals or harmful residues are obtained during PL treatment
- Nutritional and sensory qualities of the food are minimally affected

b. **Limitations**

- PL has low penetration power compared to ionizing radiations which limits its microbicidal action.
- Control on food heating is not achieved yet during PL treatment which again limits its applications to certain heat sensitive foods.
- Food powders absorb PL thus leads to undesirable colour alterations.
- Surface topography of the food samples and contact surfaces create shadow effects which reduce the PL efficacy.
- Foods with rough or uneven surfaces, crevices, or pores are unsuitable for PL as it could not reach those inner places due to multiple reflections and shadow effects.
- PL is not an adequate technology for cereals, grains, and spices as they are opaque and absorb PL thus reduce its efficacy.

31.7 Suggested readings

1. Koutchma, T., Forney, L. J. and Moraru, C. I. (2010). Ultraviolet light in food technology: principles and applications. CRC Press, Boca Raton.
2. Elmnasser, N., Guillou, S., Leroi, F., Orange, N., Bakhrouf, A. and Federighi, M. (2007). Pulsed-light system as a novel food decontamination technology: a review. Canadian Journal of Microbiology, 53(7): 813-821.
3. Oms-Oliu, G., Martín-Belloso, O. and Soliva-Fortuny, R. (2010). Pulsed light treatments for food preservation - A review. Food and Bioprocess Technology, 3(1): 13-23.