International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

Pulse Light Technology and Dense Phase CO_2(Non-Thermal Food Preservative Techniques)

Blassi Kaur T, *Grewal Singh G, *Pratibha
Punjab Agricultural University,
Ludhiana, Punjab

ABSTRACT

Loss of organoleptic, nutritional quality as well as several other undesirable changes in food when preserved using thermal techniques lead to increase in demand of non-thermal food preservative techniques which called in for novel as well as effective technologies giving rise to Pulsed light technology and Dense phase CO_2technology.Liquid foods are generally processed by thermal pasteurization techniques, which can destroy heat-sensitive nutrients and sensory attributes. These both are basically for liquid foods. Dense phase carbon dioxide (DPCD) inactivate certain microorganisms in liquid foods at low temperatures to avoid the thermal effects of traditional pasteurization. Pulsed light technologynot only decontaminates the food or packaging but also maintains its texture, nutrients etc. The germicidal effect was found to be due to photochemical and photothermal effect. The following paper is a compilation of reports on the mechanism of action of the technologies and their recent applications.

KEYWORS:

Pulse light technology, Ultraviolet light, Photochemical effect, Photothermal effect, applications, Dense phase CO_2, treatment system, microbial inactivation, applications.

PULSE LIGHT TECHNOLOGY- INTRODUCTION

Also known as pulse pure technology, is a rapid & effective purification and sterilization technique which make use of high power & short duration light pulses emitted by inert gas flash lamps. It is 2,000 times more intense than sunlight. Its inactivation efficiency depends upon intensity and number of pulses delivered. Technique is used mainly to inactivate surface micro-organisms on foods, packaging material and equipment. It uses light energy in concentrated form and exposes the substrate to intense short bursts of light (pulses). Typically for food processing about one to twenty flashes per second are applied.

Principle

It is the non-thermal method of food preservation that involves the generation of pulsed light with gradually increasing from low to high energy and then releasing the highly concentrated energy as broad spectrum bursts, to ensure microbial decontamination on the surface of foods and packaging foods. Within fraction of second, the electromagnetic energy gets stored in the capacitor and is then released in the form of light within a billionth of a second, which results in power amplification and minimum additional energy consumption. The inactivation efficacy of pulsed light depends upon intensity (measured in Joule/cm-2) and the number of pulses delivered.

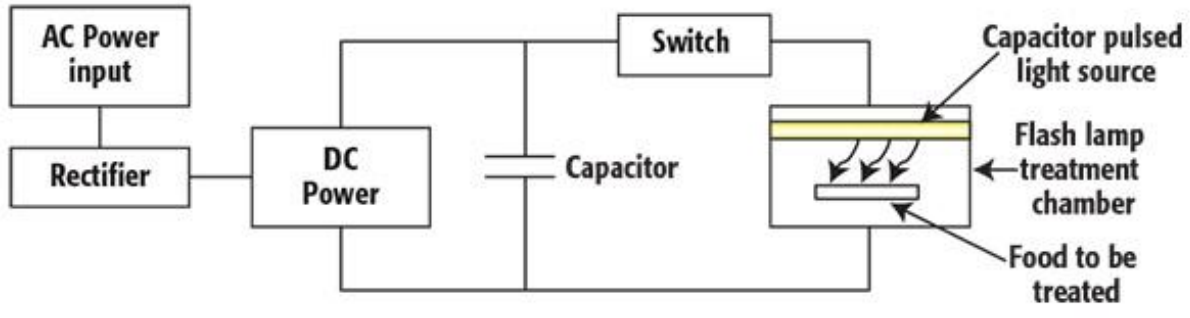

FIG-1

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

MECHANISM OF MICROBIAL INACTIVATION

The lethality of Pulsed Light 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. Mechanisms that have been proposed to explain the lethality of pulsed light treatment are related to ultraviolet (UV) part of the spectrum which include photochemical and photothermal effect.

PHOTOCHEMICAL EFFECT

The primary target cell of pulsed light in photochemical mechanism is nucleic acid as DNA is the target cell for these ultraviolet wavelengths. Ultraviolet light absorbed by the conjugated carbon-carbon double bonds in proteins and nucleic acids induces the antimicrobial effect as it changes the DNA and RNA structures. Ultraviolet irradiation usually generates thymine dimers in large quantity, cytosine dimers in low quantity and mixed dimers at an intermediate level. These dimers inhibit the formation of new DNA chains in the process of cell replication resulting in the chologenic death of affected microorganisms by ultraviolet.

PHOTOTHERMAL EFFECT

With a fluency exceeding 0.5 Joule/cm2, the disinfection is achieved through a rupture of bacteria during their temporary overheating caused by absorption of all ultraviolet light from a flash lamp. This hypothesis become evident by when they showed electron-microscope photographs of flashed *Aspergillus niger* spores presenting severe deformation and rupture. The ruptured top of spore become evident of an escape of an overheated content of the spore, which became empty after such an internal ‘‘explosion’’ and ‘‘evacuation’’ of its content took place during the light pulse.

Other effects on the cells include, collapse of cell structure, enlargement of vacuoles as found in some microbial studies. Antimicrobial effects are also manifested due to changes in ion flow, increased cell membrane permeability and depolarization of cell membrane.

FACTORS AFFECTING THE MICROBIAL INACTIVATION BY PULSED LIGHT

Type of micro-organism

Optical properties of cells, for example their degree of scattering and absorption of light are important. The incident beam of light undergoes refraction due to difference in the optical density between the substrate and the surrounding air.

Interaction between light and the substrate or between light and the microbial cells (micro-organism)

For transparent and colored food materials, refraction is particularly relevant, whereas for opaque food materials, reflection is the prevailing phenomenon. 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 result into scattering. In the case of biological tissues, absorption and scattering are the most relevant types of light–substrate interaction.

The distance from the light source

As the distance from light source and depth of the substrate increases, the absorption and scattering diminishes. This is because the light intensity decreases as it travels through the substrate.

Design of pulsed light system

Pulsed-light equipment may vary from manufacturer to manufacturer. The system of pulsed light consists of several common components.

A high voltage power supply: provides electrical power to the storage capacitor

A storage capacitor: which stores electrical energy for the flash lamp

A pulse-forming network: determines the pulse shape and spectrum characteristics

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

The gas discharge flash lamp

A trigger signal: which initiates discharging of the electrical energy to the flash lamp, which is the key element of a pulsed light unit.

The flash lamp is the important element of any Pulsed light unit that converts 45% to 50% of the input electrical energy to pulsed radiant energy. This is filled with an inert gas such as xenon or krypton. Pulsed light systems can be of either batch or continuous type depending on the usage.

APPLICATIONS

Pulsed light treatment given to eggs for surface decontamination

Eggs and egg-based products were frequently associated with salmonellosis outbreaks caused by *Salmonella Enteritidis* in the United States of America (U.S.A.), as well as in the European

Shelf-life extension and inactivation of *Listeria monocytogenes* on ready to eat cooked meat products using pulsed light

Listeria monocytogenes is responsible for severe foodborne disease outbreak. It tripled the shelf-life of ham as compared to conventional ready-to-eat (RTE) products. 2.1 Joule/ cm2 adversely affected the sensory quality of bologna slices.

Pulsed light treatment for decontamination of chicken from food pathogens

High-power pulsed light of 1,000 pulses, treatment duration 200 seconds and total ultraviolet light dose 5.4 Joule/cm2 was found to reduce viability of *Salmonella typhimurium* and *Listeriamonocytogenes* inoculated on the surface of chicken by 2-2.4 log10 (N/N0) colony-forming units (CFU)/ ml.

Pulsed light treatment for freshly cut mushroom

Fresh slices of mushrooms were exposed to pulsed light treatment by flashing at 4.8, 12 and 28 Joules/cm2 and it was found to increase the shelf life by 2-3 days in comparison to untreated samples. The native microflora reduction ranged from 0.6-2.2 log after 15 days of refrigeration.

Continuous flow pulsed light system for bacterial inactivation in fruit juices and milk

Apple juice (pH of 3.49) and orange juice (pH of 3.78) were inoculated with gram positive (*Listeria innocua*) and gram negative (*Escherichia coli*) bacteria. These were then subjected to continuous pulsed light system. Xenon-flash lamp emitting light in the range of 100-110 nanometer (nm) and with the flashes at constant frequency of 3 Hertz and lasting for 360 microseconds (μs) was used. It was concluded that the lethal effect of pulsed light processing depends on the type of microorganism and the absorption properties of the liquid food. Continuous flow pulsed light technique was also used for inactivation of *Staphylococcus aureus* in milk and has a potential in treatment of milk pathogens.

Decontamination of food powders using pulsed ultraviolet (UV) light

Food powders were decontaminated using pulsed ultraviolet (UV) light and the treatment parameters were optimized. 58 Joule/cm2 of pulsed light was required for *Saccharomyces cerevisiae* decontamination and reducing the microbial load by 7 log.

Decontamination of packaging material

Paper-polyethylene was artificially inoculated with spores such as *Cladosporium herbarum, Aspergillus niger, Aspergillusrepens* and *Aspergillus cinnamomeus* and then exposed to pulsed light with fluency ranging from 0.244 to 0.977 Joule/cm2.

Application on food processing equipment

Pulsed ultraviolet (UV) light treatment was studied for its applicability in decontamination of the stainless steel surface contacting meat from *Listeria monocytogenes* and *Escherichia coli* O157:H7. A four lamp batch scale apparatus which generated 3 Joule/cm2 with an input voltage of 3000 Volts was used.

Pulsed light field technology in combination with other non-thermal processing technologies

The non-thermal technologies studied were, ultra-violet light (5.3 Joule/cm2), high intensity pulsed light (3.3 Joule/cm2), pulsed electric field processing (34 kilovolt/cm, 18 Hertz, 93 microsecond) and manothermosonication (5 bar, 43oC, 750 Watt, 20 kilohertz). Experimented on a blend of apple and cranberry juice and the efficacy of the combination of technologies was determined on the basis of quality attributes such as odor and flavor.

Mitigation of allergen using pulsed ultraviolet light

Peanut allergy is a severe Immunoglobin E mediated reactions with food. Peanut allergy can be prevented by complete avoidance. Pulsed ultraviolet light treatment of soy extracts has found to decrease the levels of soy allergens.

ADVANTAGES AND DISADVANTAGES

Advantages

The intensity of light that lasts for only a second is 20,000 times brighter than sunlight, but there is no thermal effect, so quality and nutrient content are retained. The xenon-flash lamps used in pulsed light treatment are more eco-friendly than the mercury vapor lamps used in ultraviolet (UV) treatment. Pulsed white light is not strictly a non-thermal, but the thermal action, due to its very short duration, it doesn't show much adverse effect on the nutrients.

Disadvantages

A possible problem of this preservation method is that folds or fissures in the food may protect microbes from being exposed to the pulsed light. There might be some strains of micro-organisms which are resistant to the pulsed light treatment, for example *Listeria monocytogenes*. This technique for decontamination of micro-organisms is useful mostly in case of liquid foods and surface of solid foods and hence limiting its application.

DENSE PHASE CARBON DIOXIDE PROCESSING OF LIQUID FOODS (DPCD)

Dense phase carbon dioxide (DPCD) also known as cold pasteurization, is a non-thermal treatment of liquid foods or liquid model solutions in which food is contacted with pressurized sub- or supercritical CO_2 for a period of time in a batch, semi-batch or continuous manner. CO_2 used in this process is not only a powerful solvent for a wide range of compounds of interest in food processing, but is relatively inert, inexpensive, nontoxic, nonflammable, recyclable and readily available in high purity leaving no residue when removed after the process. Combined with these aspects the importance of CO_2 solubility as critical factor for CO_2 bactericidal proper action has been also investigated recently. The CO_2 pressure can range from 7.0 to 40.0 MPa. Process temperature can range from 20 to 60 °C.

DPCD Treatment System

Three types of treatment systems are used:

1. **Batch type:** Both CO_2 and treatment solution are stationary in a container during treatment. Treatment time can range from about 120 to 140 min.
2. **Semi-continuous type:** Continuous flow of CO_2 throughout the chamber while liquid food is stationary. Treatment time can range from about 120 to 140 min.
3. **Continuous type:** Flow of both CO_2 and the liquid food takes place. Treatment time can range from about 3 to 9 min.

BATCH TREATMENT SYSTEM

Principle: A typical batch system mainly has a CO_2 gas cylinder, a pressure regulator, a

Pressure vessel, a water bath or heater, and a CO_2 release valve. The sample is placed into the pressure vessel and temperature is set to the desired value. Then, CO_2 is introduced into the vessel until sample is saturated at

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

the desired pressure and temperature. The sample is left in the vessel for a period of time and then CO_2 outlet valve is operated to release the gas. Some systems contain an agitator to decrease the time to saturate the sample with CO_2.

SEMI-CONTINUOUS TREATMENT SYSTEM

Principle: It was developed using a cylindrical filter to micro-bubble CO_2 entering into the pressure vessel. The inactivation of enzymes using a micropore filter was 3 times more than without using it. CO_2 is increased from 0.4 to 0.92 mol/L in the sample at 25 MPa and 35°C.

CONTINUOUS TREATMENT SYSTEM

Principle: It is very effective in inactivating microorganisms. In this system, liquid CO_2 and a saline solution were pumped through a vessel. Liquid CO_2 was changed to gas using an evaporator and then dispersed into the saline solution from a stainless steel mesh filter with 10μm pore size. The micro-bubbles of CO_2 moved upward while dissolving into the solution. Then, the solution saturated with CO_2 was passed through a heater to reach the desired temperature. Another coil with a heater was used to adjust the residence time.

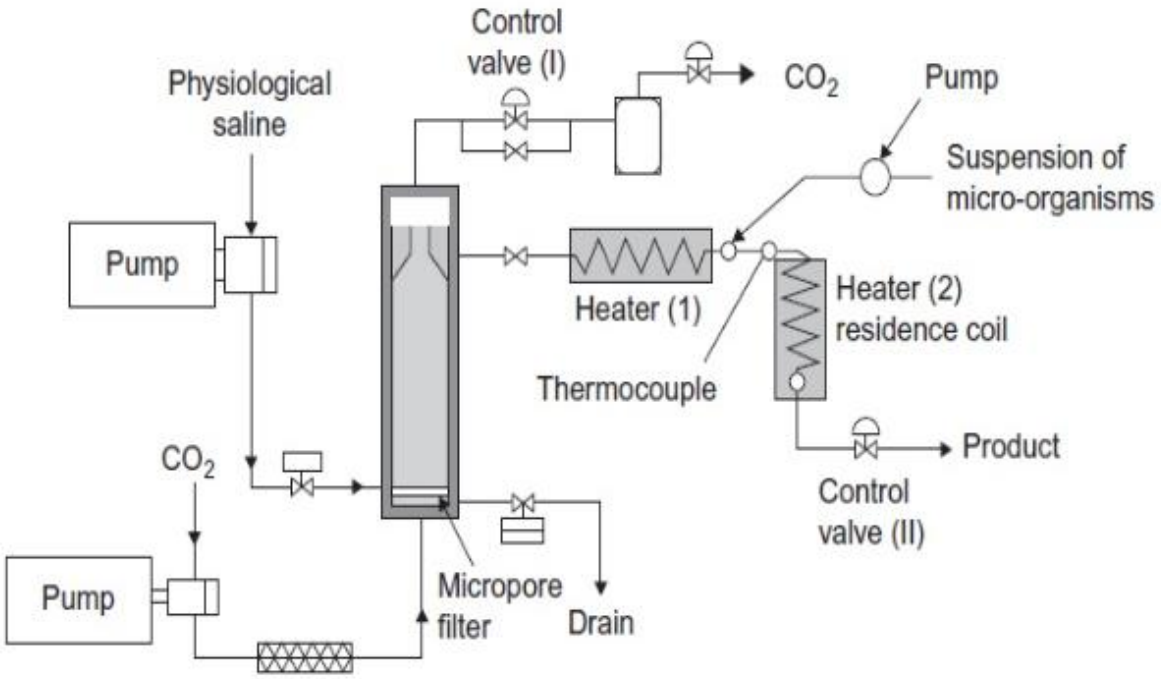

FIG-2

MECHANISM OF MICROBIAL INACTIVATION

Different researchers proposed different mechanism of inactivation of microorganisms. Some of them are:

1. pH lowering effect
2. Inhibitory effect of CO_2 and bicarbonate ion
3. Physical disruption of cells
4. Modification of cell membrane and disruption of cellular components.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

pH lowering effect

CO_2 can lower the pH when dissolved in aqueous part of a food by forming carbonic acid, which further dissociates to give bicarbonate, carbonate and H^+ ions lowering extracellular pH. The internal pH of microbial cells has the largest effect on their destruction.

$CO_2 + H_2O \longleftrightarrow H_2CO_3$

$H_2CO_3 + H^+HCO_3 \longleftrightarrow$

$HCO_3 + H^+CO_2 \longleftrightarrow$

Inhibitory effect of CO_2 and bicarbonate ion

At low pH, protein bound arginine may interact with CO_2 to form a bicarbonate complex, inactivating the enzymes. Complete inactivation of alkali protease at 35 °C, 15 MPa was done by pH lowering by dissolved CO_2 and lipase was done by sorption of CO_2 into the enzyme molecules. Another proposed mechanism is precipitation of intracellular carbonate Ca^{+2}, Mg^{+2} from bicarbonate which causes a lethal change to the botanical system.

Physical disruption of cells

Inactivation of *E. coli* cells was done at 50.7 MPa in less than 5 min by bursting due to the rapid pressure release and expansion of CO_2 within the cell. Indication of cell rupture can be observed by measuring the total protein concentration in the supernatant of DPCD treated samples. Morphological changes caused by DPCD may differ based on the treatment conditions, gas release rate, or the type of microorganism.

Modification of cell membrane and disruption of cellular components

This concept is based on hydrophilicity and solvent characteristics of CO_2. It was observed that the extraction of intracellular substances such as phospholipids is a possible mechanism of microbial inactivation. It was also proposed that diffused and accumulated CO_2 increases fluidity of the membrane due to the order loss of the lipid chains also called the "anesthesia effect," and this causes an increase in permeability which causes disruption.

DPCP FOOD APPLICATIONS AND EFFECT ON QUALITY

Some applications of dense phase CO_2 and its effect on food have been summarized below:

Table 1.DPCP food applications and effect on quality

S.No.	FOOD	FINDINGS
1.	Orange juice	Improvement of physical & nutritional quality attributes like color, ascorbic acid retention & stability.
2.	Carrot juice	Cloud retention
3.	Beer	Aroma and flavor retention in pasteurized beer
4.	Mandarin juice	Improvement of cloud formation, color, titratable acidity
5.	Coconut water based beverage	Improvement in shelf life for 9 weeks under refrigerated storage
6.	Milk	increase in lipolytic activity under storage, casein production, lowering of pH.

ADVANTAGES AND DISADVANTAGES

Advantages

- Retention of antioxidants, phytochemicals and organoleptic attributes such as taste, color and appearance
- Beneficial for heat sensitive compounds
- Retention of vitamin-C

Disadvantages

- Operational cost is high
- Greenhouse effect of CO_2.

CONCLUSION

Increasing demand of these non-thermal processes is the result of demand for foods with high nutritional value, fresh characteristics.Sensory attributes as a result of such processing are well preserved and of extended shelf life.

The pulsed light processing is a new concept and has many applications in the food industry as a non-thermal technique of food preservation. While developing the applications of pulsed light processing, it is to be taken into consideration that the food to be processed, the microbial type and load affect the efficacy of the treatment. Though with some limitations, if complemented with other processing techniques this technology can help in better food preservation with minimal effects on the food quality. The DPCD cold pasteurization technology is a cost-efficient, environment friendly and reliable method to preserve the quality of liquid food. Further, several batch, semi-continuous, and continuous systems have been developed for DPCD applications. However, the applicability of this technology in industrial scale has not been widely spread due to several challenges.

REFERENCES

- http://www.foodtech portal.eu/index.php?title=Special:PdfPrint&page=Pulsed+light+for+microbial+inactivation
- www.slideshare.net/mobile/asutoshmohapatra963/dense-phase-carbon-dioxide-core-nonthermal -technology-for-food-processing
- www.slideshare.net/mobile/keerthana37a/pulsed-light-system-as-a-novel-food-decontamination
- Pulsed light technology: a novel method for food preservation- Abida, J., Rayees, B. and Masoodi, F. A.
- Dense phase carbon dioxide processing of liquid foods: a review Murat O. Balabana, Giovanna Ferrentinob-December 2012 article.
- Dense Phase Carbon Dioxide Processing of Liquid Foods: a Review Murat O. Balabana, Giovanna Ferrentinob
- Ferrentino G, Balaban MO, Ferrari G, Poletto M. 2010. Food treatment with high pressure carbon dioxide. Part II. Inactivation of *S.cerevisiae* modeled by Peleg kinetics expressed as a function of CO2 solubility. J Supercritical Fl. 52:151-160.
- Cold Pasteurization of Liquid Foods using Dense Phase Carbon Dioxide Joyner JJ and DhineshKumar V.