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Review Article

DIFFERENT PULSED LIGHT SYSTEMS AND THEIR APPLICATION IN FOODS: A REVIEW

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Abstract: Preservation of food is a challengeable task, because there are several techniques for food preservation in which foods are subjected to very high temperature which leads to the effect of food quality, nutrients etc. So, there is a need for technology which preserves the food without affecting the food quality. Nutrients and mainly maintains the texture. Hence pulse light technology is the ultimate solution for not only preservation of food but also it achieves microbial decontamination. The present review article gives detailed information about various pulse light system and their application in foods.
Keywords: Pulse light technology, pulse light systems, microbial decontamination.

Introduction

Pulsed light technology is a innovative non thermal technology, it is a process of sterilization and purification of foods by using high intensity light pulses within a short duration of time. The term pulsed light is known since from the year 1980 and the application of pulsed light technology in foods is approved by food and drug administration in the year 1996(luigi palmeiri and domenico cacace).

The pulsed light technology and pulsed electric field are similar; the main difference is that the electric pulse (in PEF) are converted into the pulses of light for microbial in activation by using a flash lamp containing XE gas. The pulsed light operates under a wavelength of 180nm-1100nm, which includes UV, VISIBLE and IR, the spectrum of sunlight and pulsedlight are similar, where the UV radiation in sunlight spectrum is purified by the earth's atmosphere. The visible light has a wavelength of 400-700nm and the UV light, X=180-400nm. The UV light is again sub divided into UV-A, UV-B, UV-C having wavelengths in the range of 315-415nm, 280-315nm, 280-315nm and 180-280nm respectively. The UV Light is responsible for the bacterial inactivation in foods and now a day an efficient technique of sterilization as developed for treating packaging films (cerly, 1977).

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Conversion of electric current into pulsed light

The low power, low voltage, low AC continuous electric current is converted into low power, high voltage and low DC continuous current by using an electrical energy converter. The current from the converter is passed into the electrical storage, which is capacitor. The capacitor supplies large amount of current (pai and zhang, 1995). This is passed through pulse forming switches in order to obtain, high power, high voltageDC, pulsed electric field.

Now the pulsed electric current is passed through the inert flash lamps in order to obtain the high power pulsed light. This power pulsed light is applied to foods for microbial decontamination. The mechanism behind the conversion of electric pulses to light pulses is that, the pulsed electrical energy which is delivered by the switches to the flash lamp containing XE gas will convert in to light pulses, as soon as the current which is associated with the pulsed electrical energy will pass through the gas transfer the energy to the XE atoms, such that the XE atoms are excited to higher energy levels, after that the XE atoms reach lower energy states by giving off energy in the form of light pulses.

Mechanism of microbial inactivation using Pulse light

The high intensity light pulses within a short duration of time able to inactivate the micro-organisms in food to different extents based on the dosage or fluence. There are several theories or mechanisms which explains the microbial inactivation in foods (Barbosa-canovas etal.2000). there are two effects which are responsible for the microbial inactivation, the first one is the photochemical effect, which is due to the effect, which is due to the second one is the photo thermal effect, due to the energy dissipation of the light pulses when absorbed by the surface of food material.

The photochemical effect of pulsed light is due to the presence of UV-light, which acts directly on the DNA cells of the micro-organisms (Earkas,1997). The DNA ofcells, which is responsible for the cell reproduction absorbs the UV-light through the conjugated double system(Jay,1996) present in the DNA, the absorbed energy, breaks the alignment of double bonds which cause (or) develops rearrangement in the DNA, which leads to the disruption of the DNA cells. There will be activation of electronic and photochemical reactions which can prevent the DNA reproduction, due to the formation of pyrimidine and thymine dimmers (hariharan and gerutti, 1997: franlin et al.,1985).

According to Friedberg, 1985, the molecules of DNA show a great capability to modification and damage, due to the presence of some self –repairing enzymes, but the application (or) exposure of food substances to pulsed light showed the absence (or) death of

such enzymes but the application of continuous UV light to food stuffs showed the presence of self-repairing enzymes in foods, so that there will be birth of microorganisms(Block,1991).

The inactivation effect of pulsed light is very effective when it was compared with that of continuous light. In a study of comparison betweenpulsed light and continuous light it was 7 logs of aspergillus Niger spores when it was exposed to few light pulses, but it was totally different in the case of continuous light, there was only 3-5logs of inactivation evenby using light of high energy and time duration (Dunnet.,1995).

Many experiments use light pulses in the range of ultraviolet because of its lower wavelength responsible for higher energy levels (Barbosa-canvosa et. ,2000: morgar, 1989) and there was an interesting study which was conducted by Wekhof et al, 2001 which shows the difference of microbial inactivation with and without UV-C. The *Aspergillus niger* spores were inoculated on polyethyleneterthalate (PET) surface and it was treated with without UV-C, it was observed that the PET surface exposed t the pulses without UV-C was three to five times less effective compared to that of UV-C, depending on dosage (or) fluence of treatment.

Photo thermal mechanism

The photo thermal mechanism of pulsed light is due to the rise of temperature of food stuffs, due to the absorption of light pulses and dissipation of absorbed pulses into heat by the surface. There will be rapid heating of microbial cells, because the cells absorb more amount of pulsed light energy when compared to the surrounding medium, sometimes at higher dosage there are temperatures which can reach upto 130°C, which are sufficient enough for the excess heating and disruption of cells, which leads to the death of micro-organisms.

In an experiment carried by wekhof, 2001. They observed the increase of temperature of E. coli cells on a polymeric surface. The surface was exposed to different treatment levels (fluence rates) and there is no raise of temperature until the threshold limit of fluence is exceeded, after crossing the threshold limit there is an enormous increase of temperature higher than 120°C, but there is no effect for the polymeric surface. The same study (wekhof, 2001) also involves the exposure of aspergillus spores on PET surface to light pulses and for different values of spectral distribution and different values of fluence rate, found that there is no increase in temperature upto fluence of 10-30kj/$cm^2$and the photo thermal activity was observed at higher fluence values around 50-60kj/cm^2. It was also observed that, under low fluence values the microbial inactivation (80-90%) is due to the photochemical effect of UV-C.

Application of pulsed light technology to foods

Food powders:

Type of food	Fluence(j/cm^2)	No. of pulses (per second)	Pulse duration	Micro-organism	Reduction (log reduction)
Wheat flour	**31.2**	**64**	**-**	***Saccharomyces cerevisiae***	**0.7**
Black pepper	**31.2**	**64**	**-**	***Saccharomyces cerevisiae***	**2.93**

Fine & Geravis, 2004

Fruit juices

Type of food	Fluence(j/cm^2)	No. of pulses	Pulse duration	Micro-organism	Reduction (log reduction)
Apple juice	**1.8-5.5**	**3**	**360 µs**	***E.Coli.*** ***L. innocua.***	**4** **2.98**
Orange juice	**1.8-5.5**	**3**	**360 µs**	***E.Coli.*** ***L. innocua.***	**2.90** **0.93**

Pataro *et al.,* 2011

Egg surface decontamination

Type of food	Fluence(j/cm^2)	No. of pulses	Pulse duration	Micro-organism	Reduction(log reduction)
Eggs (unwashed)	**2.1-10.5**	**-**	**-**	***salmonella***	**3.6**
Eggs (washed)	**2.1-10.5**	**-**	**-**	***salmonella***	**1.8**

(Lasagabster *et al.,* 2011)

Mushrooms

Type of food	Fluence(j/cm^2)	No. of pulses	Pulse duration	Micro-organism	Reduction (log reduction)
Mushrooms	**4.8,12,28**	**-**	**-**	***microflora***	**(shelf life extension)**

Decontamination of packaging material

Type of food Material	Fluence(j/cm^2)	No. of pulses	Pulse duration	Micro-organism	Reduction (log reduction)

Paper-polyethylene	**0.244-0.977**	**-**	**-**	***Aspergillus niger***	**2.7**

abida *et al.,* 2014

Application on food processing equipment

Type of food Material	Fluence(j/cm^2)	No. of pulses	Pulse duration	Micro-organism	Reduction (log reduction)
Stainless steel	**3**	**-**	**-**	***E.coli***	**6.5**

abida *et al.,* 2014

DIFFERENT PULSED LIGHT SYSTEMS TO FOODS

Pulsed system for bacterial inactivation of food surfaces:

Ina study conducted by elmnasser et al., 2007 in order to see the effect of pulsed light on the decontamination of listeria monocytogenes Scott A, listeria monocytogenes CNL, pseudomonas fluorescens MF37 and photo bacterium phosphoreum SF680. The pulsed light system used in this study consists of a generator in order to generate light pulses is of RDT350 model from La Calhene USA. The apparatus consists of mainly three components, they are power source, energy storage capacitor & treatment chamber. The treatment chamber is of 250cm diameter and there are 8 xenon lamps arranged on the periphery of the chamber, the distance between the samples & the xenon lamps was 13.5cm and were generating a fluence of 1.5J/cm^2 during 300µs per flash. The wavelength of the emitted light is between 200-1200nm.

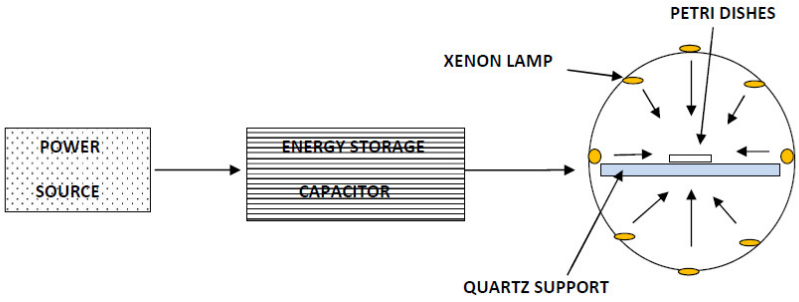

Figure 1: Schematic diagram of light treatment system.

Bench top pulsed light system for decontamination:

In the world there are only two companies manufacturing pulsed light systems in the world they are steri beams systems in Germany and xenon corporation in USA (wekhof 2000, Lyager 2007). The following basic pulsed light system consists of treatment chamber and control module. The treatment chamber is made of stainless steel and there is a sample shelf

in order to hold the target samples (either inoculated petre dishes or micro-organisms). The sample shelf is flexible such that it can be adjusted in order to set the required distance between, lamp house and target. The lamp house is located at the top center and it consists of xenon gas. The lamp house consists of to lamps (Jun et al., 2003).

The control module & light source is connected by the control cable, such that the electric electric current can be modulated in order to have specific pulse repetition rate, pulse width & peak power. By using the techniques of pulse power generation we can get peak power (lamot et al., 2003), Hancock et al., 2004). A bench top pulsed light system for microbial decontamination in foods as follows.

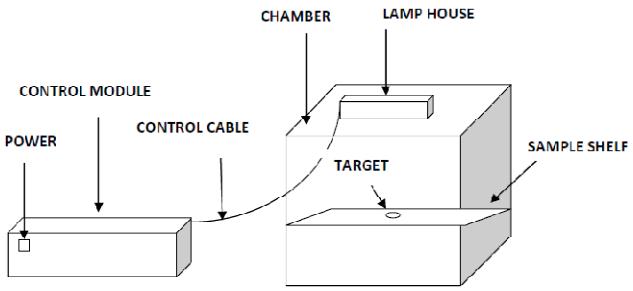

Figure 2: Schematic diagram of a bench top pulsed light system

Pulsed light system for pumpable foods (fruit juices):

A pulsed light system was developed by Dunn et., al 1988, and it was patented as a system for sterilization of pumpable foods such as fruit juices. The samples which is to be treated is passed through space present between the inner cylinder and outer cylinder. The inner cylinder contains the flash lamps which are responsible for decontamination and the surface of the outer cylinder is made of highly reflective material in order to allow maximum light through the food. The flow rate of the sample is maintained by the circulation pump at the bottom based on the frequency, delivering required no. of pulses to the product.

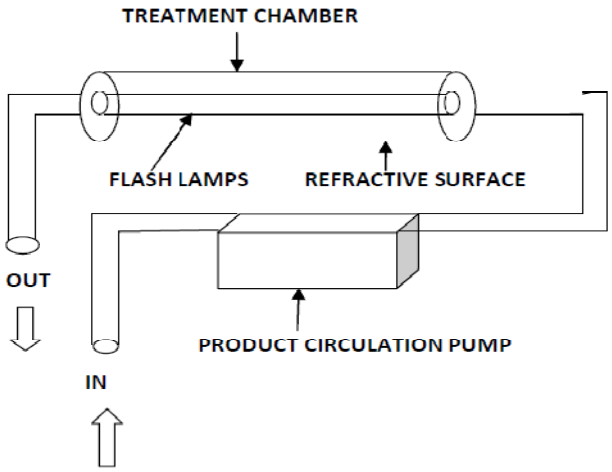

Figure 3: Schematic diagram of pulsed light system for pumpable foods (fruit juices).

Continuous flow pulsed light system:

The fruit juice which was inoculated is prestirred and passed through the food grade tygon tube placed between two quartz tubes of inner diameter 1 mm and 0.5 mm wall thickness which were placed 1.9 cm below the quartz window. The central axis of the quartz tubes is aligned with the axis of the xenon lamp such that there is maximum energy absorption. Out of the total length of the tubes only 20 cm is exposed to the light source and the remaining portion of the tube including the connection of tubing's between the two quartz tubes are covered with aluminum foil in order to block or prevent from the exposure of UV-light. There is an external refrigerated system consisting of water-ethylene glycol which is kept at a temperature of 10°C. The purpose of the external cooling system is, for cooling the product after pulsed light treatment and also cooling of air in the sterilization chamber. The sample, here the fruit juice before entering and after leaving the chamber is cooled by submerging stainless steel tubes in water bath.

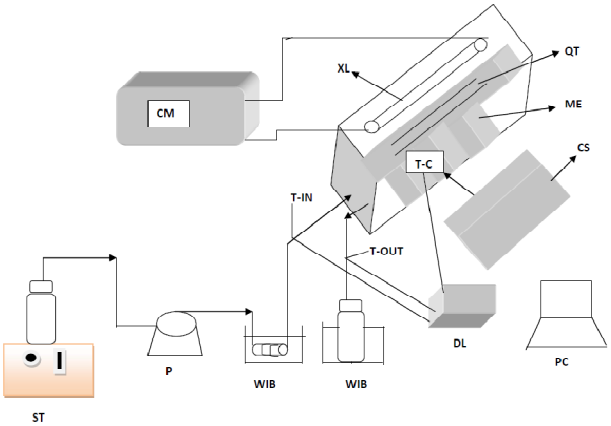

Figure 4: schematic diagram of continuous flow pulsed light system.

US: untreated sample; **ST**: stirrer; **P**: pump; **WIB**: water-ice bath, **SC**: sterilization chamber, **XL**: xenon lamp, **QT**: quartz tubes; **ME**: metal enclosure; **CS**: cooling system; **CM**: control module, **T-IN**, **T-OUT&T-C** are thermocouples, **TS**: treated sample, **DL**: data logger, **PC**: computer.

Intense pulsed light system for sea foods:

In a study conducted by Chan-ick cheigh et al., 2013, they developed lab scale intense pulse light system for decontamination of micro-organisms in solid foods and sea foods. The system consists of major components like power supply, controller, treatment chamber and cooling blower. The maximum voltage generated by the electricity was 50KV. An input voltage of 220-V AC supply source at 25A was rectified and it is transformed to a maximum voltage of 50KV. The energy generated is stored by using resonant charging, whenever there is need of energy a thyratron switch was used for delivering the energy. The intense pulses are generated by a quartz lamp in which the xenon gas is filled at a pressure of 450 Torr. The length of the lamp is 145 mm and the outer diameter of the lamp is 7.14 mm. The wavelength of the emitted light is around 200-1100 nm which ranges from UV-C to IR.

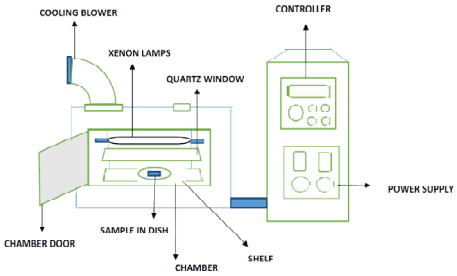

Figure 5: Schematic diagram of intense pulsed light system.

Pulsed light system for standardization of methods for dosage (UV dosage):

The apparatus with which UV disinfestation experiments were carried are collimated beam. The term collimated refers to physics, which means, a beam of light having low divergence, such that the beam radius does not under significant changes during propagation through longer distances. The use of collimated beam was first reported by Qualls and Johnson in the year 1993 for carrying the experiments using UV light. The apparatus shown in this study (Bolton et al., 2003) consists of different components like shutter, window, power supply, collimating tube, platform, stirring, lamp.

The shutters are used for the regulation of UV dosage during the experiments and also to regulate the time of exposure factor in the UV dosage calculation during the experiments. The accuracy of the shutter plays an important role during the delivery of short

dosages (repeatable dosage). The window is used because the energy output of many UV lamps is temperature sensitive, so the enclosure of the lamp must be thermally stable. The power plays an important role in the constant generation of UV light continuously for one or two hours. A constant voltage power source is used in order to avoid fluctuations. The purpose of using collimated beam was to provide uniform parallel beam of light on the exposed area. The platform used is for keeping the samples (in petri plates), such that the platform must be stable physically and thermally (Morowitz 1950). In order to attain the equal dosage to all micro-organisms stirring is required. The lamps used must be in such a way that they should not emit radiations below 200nm. The system shown in the following process is a continuous UV treatment system and can be used as a pulsed light system by using a pulse generator.

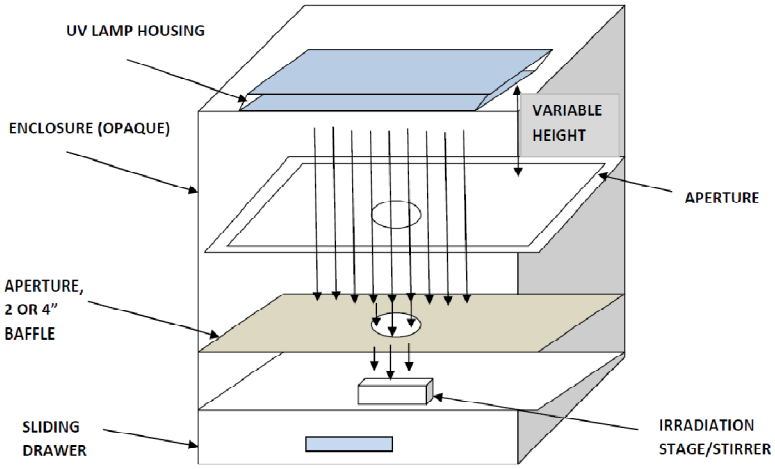

Figure 6: schematic diagram of UV bench scale set up.

Generalized pulsed system for foods:

So we have seen several pulsed light systems which are applied in food processing and we can generalize the pulse light system by its components such that a basic pulsed light system consists of components like high voltage (DC) power supply, energy storage capacitor, for storage and discharging of energy, an pulse shaping inductor for obtaining the pulses of desired shapes, flash lamp mainly containing xenon gas inorder to generate high intensity light pulses for microbial inactivation and finally the target food on which the pulsed light has to be applied.

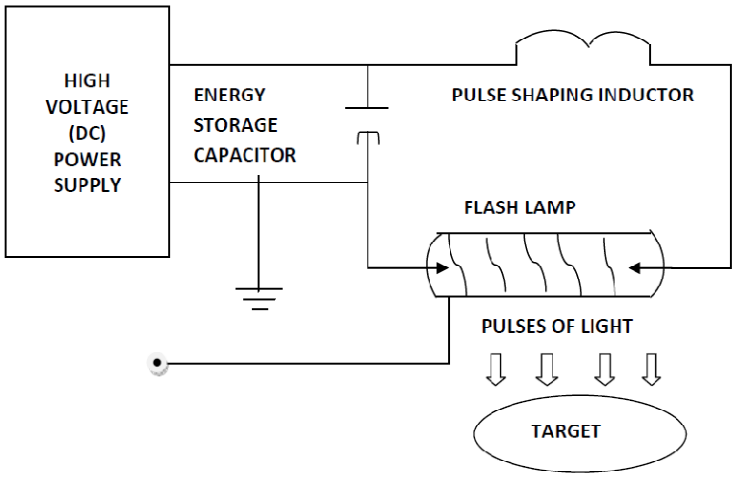

Figure 7: schematic diagram of basic pulsed light system.

Conclusion

Pulsed light system is a costly preservation technique besides having many advantages. It is very efficient process for the surface decontamination of foods, so finally it can be concluded that pulse light technology is a good substitute for conventional and thermal preservation systems and also the commercialization of the technique is possible only when there is a pulsed light system which is economical and affordable.

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