Chapter 12

Advanced fish processing technologies

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In the last few decades' consumers are demanding new alternatives of foods having supreme qualities and freshness, minimally processed and packaged, easy to consume and nutritionally healthier, which have led to more value addition and introduction of novel food products. Changing life style and the awareness about the nutrition and healthy diet, led to the necessity of bringing more fresh and natural, ready to eat foods in the market. So, the focus of product development has moved from traditional ones towards market-driven, health-driven and technology-driven products, which often adds safety as well as quality characteristics. Thermal pasteurization and thermal sterilization are the most common processing operations widely employed for processing and preservation of food (Barbosa-Canovas and Bermudez-Aguirre, 2011). But these conventional operations are designed to focus on the vital thermal treatments responsible for microbial inactivation and reduction of enzyme activity, which assures consumer's required safety and shelf life of product. However, despite its benefits such processes end up with loss of natural freshness and quality and consequently affect its functional and organoleptic properties. Often thermal processing ends with the reduction of nutrient content and formation of cooked off flavours in the products. Hence, the focus of food scientists and engineers have been directed towards alternative technologies or minimal processing and preservation technologies that are environment friendly, low in cost and able to preserve fresh quality attributes of the food.

Recent years have introduced many novel thermal and non-thermal technologies like ohmic heating, microwave heating, dielectric heating, infrared heating, HPP, Pulse light, pulse electric field, cold plasma etc. for the preservation of food without losing the quality and shelf life of the products. These technologies can overcome the excessive cooking times and have direct implications on both heat and energy efficiency (Pereira and Vicente, 2010).

Thermal Technologies

1. Microwave heating:

Microwaves are electromagnetic waves of frequencies varying from 300 MHz to 300 GHz; smaller frequency waves having high penetration power. The principle is that microwaves produces frictional heat and it is strongly penetrable. So the food inside and outside is heated simultaneously along with a rise in temperature. It is another emerging technique extensively used in the food industry for heating, cooking, pasteurization, sterilization and drying. The major advantage with regard to microwave sterilized foods is that they can be stored at ambient temperatures and re-heated in the common household microwave prior to consumption. These products do not require refrigeration thereby cutting down the cost for food processors and distributors, as well as saving valuable refrigerator/freezer space for consumers. Since the heat is produced directly in the food, the thermal processing time is sharply reduced. Microwave sterilization technique guarantees better color, texture and other sensory attributes to the foods in comparison to those that are conventionally retorted simultaneously meeting microbial safety requirements.

Principle: Food containing water is a good absorber of microwave energy. Water exist as dipolar contains both positive and negative charges and the microwaves excites and polarized the water molecules in the food. The water molecules get pulled back and forth at a rate of 2.5 billion times/sec by the electric fields. This rapid motion between water molecules creates friction and hence generates heat.

2. Infrared heating:

Infrared energy is a form of electromagnetic energy. It is transmitted as a wave, which penetrates the food, and is then converted to heat. Infrared radiation is classified as the region of wavelength between visible light (0.38 to 0.78μm) and microwaves (1 to 1000 mm). In Far Infra-Red (FIR) heating, heat is supplied to food by electromagnetic radiation from the FIR heaters. The rate of energy transfers between the heater and the food depends on the temperature difference between the heater and the food. The FIR energy emitted from the heater passes through air and is absorbed by the food; the energy is then converted into heat by interaction with molecules in the food. Heat passes throughout the food from the surface layer by conduction. The related process of near-infrared radiation (NIR) heating is based on the same principle, using the appropriate wavelength. On the other hand, in conventional heating, heat is mainly supplied to the surface of the food by convection from circulating hot air and products of combustion. The difference of heating mechanism between IR and conventional heating makes the difference in cost and quality of the products. The features of IR heating for food processing are as follows:

• The efficient heat transfer to the food reduces the processing time and energy costs.

• The air in the equipment is not heated, and consequently the ambient temperature could be kept at normal levels.

• It is possible to design compact and automatic constructions with high controllability and safety.

• Exact heating control is required, because there is danger of overheating owing to the rapid heating rates.

3. Ohmic heating (OH):

Ohmic heating (also called Joule heating, electrical resistance heating, direct electrical resistance heating, electroheating, or electroconductive heating) is considered an advanced technique for continuous processing of particulate food products. Ohmic heating is defined as a process wherein electric current is passed through materials with the primary purpose of heating the object. During ohmic heating, heating occurs in the form of internal energy transformation (from electric to thermal) within the material. Therefore, it can be explained as an internal thermal energy generation technology and it enables the material to heat at extremely rapid rates from a few seconds to a few minutes. Ohmic heating have a large number of actual and potential future applications, including its use in blanching, evaporation, dehydration, fermentation, extraction, sterilization, pasteurization and heating of foods. The microbial inactivation due to ohmic heating can be explained by the presence of electric field. The additional effect of ohmic treatment may be its low frequency (usually 50 Hz to 60 Hz), which allows cell walls to build up charges and form pores. As a main consequence of this effect, the D value observed for the microbial inactivation under ohmic heating is reduced when compared to traditional heating methods.

The OH system allows for the production of new, high-added-value, shelf stable products with a quality previously unattainable with alternative sterilization techniques, especially for particulate foods. Its major advantages are:

- Continuous production without heat transfer surfaces
- Rapid and uniform treatment of liquid and solid phases with minimal heat damages and nutrient losses (e.g., unlike microwave heating, which has a finite penetration depth into solid materials)
- Ideal process for shear-sensitive products because of low flow velocity
- Optimization of capital investment and product safety as a result of high solids loading
- Reduced fouling when compared to conventional heating
- Better and simpler process control with reduced maintenance costs
- Environmentally friendly system

Some of the disadvantages accounting for OH are the higher initial operational costs and the lack of information or validation procedures for this technology.

4. Radio frequency (RF) dielectric heating:

RF dielectric heating is a heating technology that allows for rapid, uniform heating throughout a medium. This technology generates heat energy within the product and throughout its mass simultaneously due to the frictional interactions of polar dielectric molecules rotating in response to an externally applied AC electric field.RF dielectric heating offers several advantages over conventional heating methods in food application, including saving energy by increasing heat efficiency; achieving rapid and even heating; reducing checking, the uneven stresses in the product as a result of evening the product moisture profile; avoiding pollution, as there are no by-products of combustion; increasing production without an increase in overall plant length; saving floor space, as efficient heat transfer results in faster product transfer and reduced oven length; and automatically compensating for variations in product moisture. In addition, this technology can be easily adapted during implementation to be compatible with automated production batch or continuous-flow processing

The novel thermal technologies for the inactivation of microorganism and reduction of enzyme activity, has resulted in making safe product with extended shelf life than its raw counterparts. But despite its substantial benefits, these treatments end with significant changes that can alter its sensorial attributes like flavor, colour, texture and nutrient content (Barbosa-Canovas and Bermudez-Aguirre, 2011). The introduction of non-thermal technologies in food processing opens a new era of minimally processed food with high nutritive value, retains the fresh attributes of the product without compromising the safety and quality.

Non thermal technologies

Many novel non thermal technologies like high pressure processing, pulsed light, pulsed electric field, ultrasound, irradiation etc. find application in preservation of food and is in the line of commercialization. Among all non-thermal technologies, HPP offers promising possibilities for the processing and preservation especially in meat, poultry and seafood.

1. High pressure Processing (HPP)

Application of very high pressures (100-900 MPa) for the preservation of food substance with or without the addition of heat, to achieve microbial inactivation or to alter the food attributes in order to achieve consumer-desired qualities. This technology is also known as high hydrostatic pressure processing or ultra-high pressure processing. HPP retains food quality, maintains natural freshness, and extends microbiological shelf life of the product. This technology is now recognized by the USFDA for RTE foods. The processing can be conducted at ambient or refrigerated temperature eliminating thermal effects and cooked off flavors and thus highly beneficial for heat sensitive products.

The first line of HPP was demonstrated in 1899 by Bert H Hite, as a possible food preservation process at West Virginia Agricultural Experimental Station (Hoover et al., 1989; Knorr, 1999). In 1992, commercialized high pressure processed products (high acid products including apple, strawberry, and pineapple jams) were marketed in Japan and since after 1992 High pressure processed foods are available in the markets of Japan (Suzuki, 2002) and in Europe and in the United States since 1996 (Knorr, 1999). Other, commercially available high pressure processed products in Australia, Europe and the U.S. include juices, tomato salsa, smoothies, fruit & vegetable purees, and ready to eat meals.

Later there was a growing interest in the area of seafood safety that led seafood processors to explore high pressure technology in product development and extension of shelf life. This technology was utilized in the area of extending shelf life of product mainly be destroying the spoilage and pathogenic microorganisms (Toepfl et. al., 2006) and also used as an alternative thermal treatment to packaged food materials. This non thermal preservation technique could also showed many benefits like complete separation of meat from shells of clams, crabs, lobsters, and oysters providing high yield of product without any mechanical damage. HPP could open up the new eras of product development and product improvements in all segments of meat and fish industry. Another advent is pressure assisted freezing and thawing, which finds its unique application in food industry especially in product development and product quality improvement (Urrutia et.al. 2007). Since HPP has minimal detrimental impact on thermally labile bioactive compounds the technology is becoming a topic of major interest for cosmetic, nutraceutical and pharmaceutical industry.

During the time HPP has turned to be an explored technologies and today it is a commercial reality. HPP products find its place in the world food market with high quality and high value addition. Today the use of high pressure (300-700 MPa) for commercial application comes in vessels ranging 35-420L capacity which had given an annual production of >150,000 tons (Wan et. al., 2009). Regulatory agencies like FDA has approved HPP as substitute to pasteurization but in February, 2009, a combination of pressure with heat called as PATS (Pressure assisted thermal sterilization) found to be effective instead of conventional sterilization (NCFST, 2009).

The basic principles that govern the high pressure effect on the behaviour of foods are (i) Pascal's Isostatic principle and (ii) Le Chatelier's principle.

According to Pascal's isostatic principle high pressure acts uniformly and instantly throughout the sample, independently of the size and shape of the food product (Smelt,1998). A uniform pressure will be applied to the product from all direction, thereby the product will not get damage and return to its original shape on the release of pressure. The fundamental principle of physico-chemical changes occurring during HPP follow the Le Chatelier's principle, which states that ‘when a system at equilibrium is disturbed, the system then respond in a way that tends to minimizes the disturbance’. So at high pressure any reactions like change in conformation, or transition of phase that is accompanied by a volume decrease will be favored, while inhibit those reactions involving an increase in volume (Lopez-Malo et. al., 2000).

Mechanism of Pressure Treatment

Each processing cycle in HPP consists of an initial pressurization period where the pressure builds up and the processing operation can be done either with or without the application of heat. The packaged product should be in flexible or semi flexible pouch, that can sustain very high pressures. The product is then submerged into a pressure transmitting fluid, where water is commonly used. Other liquids like ethanol or glycol, castor oil, silicone oil etc. can also use in various combinations with water or use separately. This fluid is able to protect the inner vessel from being corroded and fluid is selected based on the manufacture’s specification. During the pressure processing adiabatic heating occurs and the product gets heated up. The temperature increase due to adiabatic heating depends on the type of fluid, pressurization rate, temperature and pressure.

Once the process starts, the hydraulic fluid is pressurized with a pump and the generated pressure is transmitted into the packaged food uniformly from all sides. Since this processing is independent of size and geometry of foods, also acts instantaneously there by the total processing time can be reduced. The process is suitably applied for liquid foods and to liquid foods, having a certain amount of moisture content. The transmitted pressure is uniform and simultaneously applied from all directions so that food retained its structure even at high pressures. Once the pressure is build up to the desired level the product is held at this pressure for a few minutes and then decompression or pressure release takes place. Once there is a fall in pressure the product temperature falls below that of the initial product temperature.

Major Advantages of the Technology

1. HPP does not involve in breaking covalent bonds which prevents the development of unpleasant flavours to the product and maintains the natural freshness and quality.
2. High pressure is able to modify the palatability and functional properties by inducing denaturation and muscle protein gelation.
3. Process can be carried out at ambient temperatures, that helps in reducing the thermal energy used during conventional processing.
4. High pressure processing is isostatic in nature, equally applied to all particles of food, with no particle escapes.

5. Since high pressure is not time-mass dependent, pressure acts instantaneously thereby reducing the processing time.
6. This non thermal technology is independent of size and geometry of the food.
7. The process is ecofriendly, with no waste and requires only electric energy.

Application in marine Products

- Used to extend shelf life of products
- Develop new gel based products with desired sensory attributes and mouth-feel
- Used in shell fish processing for 100% removal of meat from shells
- Reduces the microbial risks during raw sea food consumption
- Inactivates vegetative micro-organism and reduces the bacterial contamination and the pathogens
- Modify functional properties of the food material
- HPP in combination with salting and smoking helps to extend the shelf life
- Pressure assisted thermal processing used for development of shelf stable ready to eat products
- Pressure assisted freezing and thawing helps in retaining the microstructure and reduces drip loss in fish products

High Pressure Processing Facility at ICAR-CIFT

A Research model of 2 litre capacity High Pressure machine from M/s Stansted Fluid Power Ltd, United Kingdom at Central Institute of Fisheries Technology, Cochin.

Seafood is a highly perishable commodity and technologies like high pressure processing are essential to increase the market value of some high value fishes. High pressure processing has now experiencing a growing demand in the global market. A lot of researches have been carried out on HPP from the past decade. Further studies on the effects of this technology on the textural and functional modification, biochemical characteristics and microbial kinetics of fish and shellfishes are necessary. The effectiveness of high pressure on microbial and enzyme inactivation, while maintaining optimal product quality is a crucial factor for the commercialization of this technology. HP processing offers many advantages over conventional processing methods known to seafood. This is exemplified by the success of HP-processed oysters in USA by Motivatit Seafood, Goose Point Oysters and Joey Oysters. However, as HP processing becomes more widely available, initial capital costs may be reduced, making technology accessible to more producers. In addition, the commercialization of the technology for other foods may provide encouragement for seafood processors, by allaying apprehension regarding the use of this novel technology and demonstrating consumer acceptance of HP-processed products.

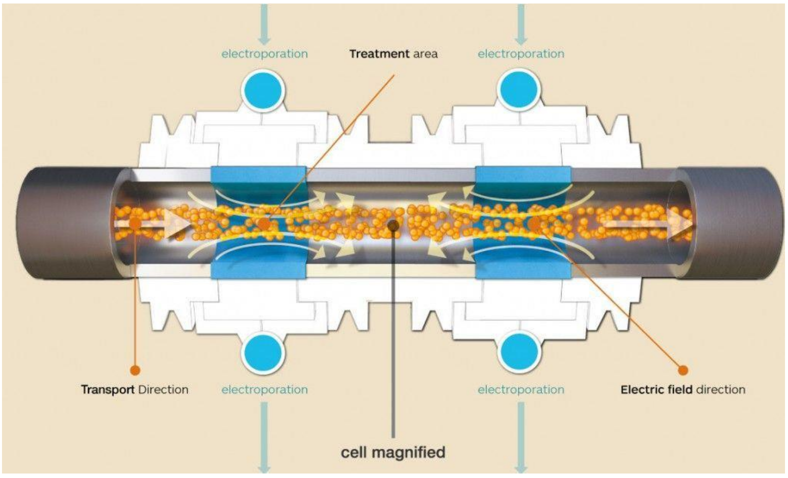
2. Pulse electric field

Pulsed electric field processing is a non-thermal food preservation technique used mainly for inactivation of microbes. PEF technology is the application of short pulses of high electric fields with duration of micro- to milliseconds and intensity in the order of 10-80 kV/cm in order to preserve the food. The processing time is calculated by multiplying the number of pulses times with effective pulse duration. The process is based on pulsed electrical currents delivered to a product placed between a set of electrodes and the distance between electrodes is termed as the treatment gap of the PEF chamber. The applied high voltage results in an electric field that causes microbial inactivation.

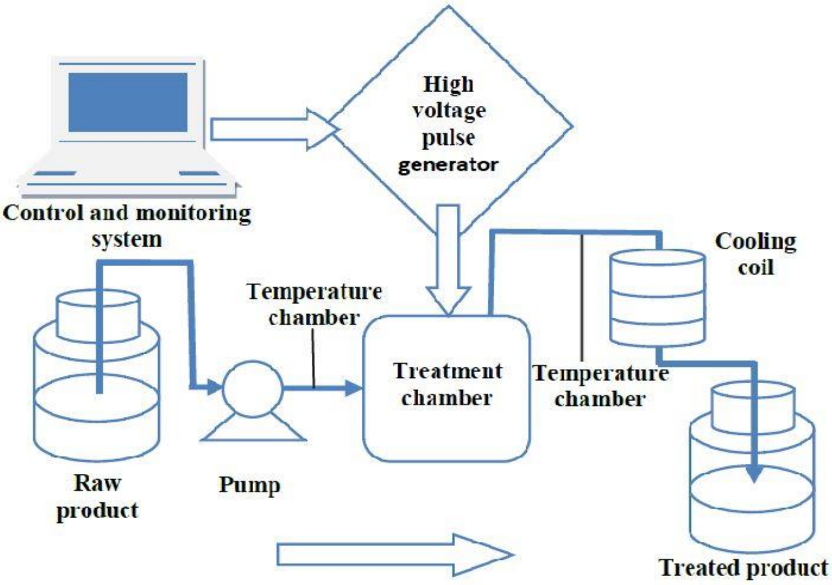
The pulsed electric field induces poration of cell membranes and thereby the cell membranes of microorganisms, plant or animal tissue are permeable. This process of electroporation is suitable for use in a broad range of food processes and bioprocesses using low levels of energy. PEF technology has many advantageous in comparison to heat treatments, because it kills microorganisms and at the same time maintains the original color, flavor, texture, and nutritional value of the unprocessed food. It is suitable for preserving liquid and semi-liquid foods removing micro-organisms and producing functional constituents. Most PEF studies have focused on PEF treatments effects on the microbial inactivation in milk, milk products, egg products, juice and other liquid foods.

Working

PEF technology is based on a pulsing power delivered to the product placed between a set of electrodes confining the treatment gap of the PEF chamber. The equipment consists of a high voltage pulse generator and a treatment chamber with a suitable fluid handling system and necessary monitoring and controlling devices. Food product is placed in the treatment chamber, either in a static or continuous design, where two electrodes are connected together with a nonconductive material to avoid electrical flow from one to the other. Generated high voltage electrical pulses are applied to the electrodes, which then conduct the high intensity electrical pulse to the product placed between the two electrodes. The food product experiences a force per unit charge, the so-called electric field, which is responsible for the irreversible cell membrane breakdown in microorganisms. This leads to dielectric breakdown of the microbial cell membranes and to interaction with the charged molecules of food. Hence, PEF technology has been suggested for the pasteurization of foods such as juices, soups, and other liquid based products.



(Source i3 foods)



Pulsed Electric Field Preservation

Pulsed electric field can be applied in fishes fresh and frozen fish dried, brined or marinated fish. Mass transport processes, such as moisture transport and removal, are improved by the electroporation of fish tissue, resulting in enhanced drying, brining and marinating of fish. The required field strength for cell disintegration of fish is 1.0 – 3.0 kV/cm and the energy delivery is 3 – 10 kJ/kg. The applied pulsed electric field leads to cell disintegration in tissue, enhancing product quality and production processes. It also helps in inactivation of parasites such as nematodes. PEF processing enhances mass transport, processes during extraction, pressing, drying, brining and marinating processes. PEF technology speeds up drying of food products, minimizing processing times and energy consumption. The process can be applied to fruits, vegetables, potatoes and meat. Enhancement of extraction processes is also an advantage of electroporation. Extraction and pressing yields are increased, for example for fruit juice, vegetable oil and algae oil and protein. PEF technology speeds up freezing of food products, allowing a reduction of processing times and energy consumption. The cell disintegration increases the freezing rates.

Cellular water flows easily out of the cell and ice nucleation outside the cell starts. As smaller ice molecules are formed, product quality of frozen food is improved. (www. pulsemaster).

3. Pulse Light technology

Pulse light technology is one such explored Non thermal technology in the food industry, especially for decontamination of food surfaces and food packages. This technique works by applying high-voltage, high-current short electrical pulse to the inert gas in the lamp, which results in strong collision between electrons and gas molecules cause excitation of the latter, which then emit an intense, very short light pulse to decontaminate and sterilize foods (Palmieri & Cacace, 2005). Usually short pulses of light one to twenty flashes per second is used in food industry. The term light is generally used to mean radiations having wavelength ranging from 180 to 1100 nm, which includes ultraviolet rays (UV 180–400 nm, roughly subdivided into UV-A, 315–400 nm; UV-B, 280–315 nm; UV-C, 180–280 nm); visible light (400–700 nm) and infrared rays (IR 700–1100 nm) (Palmieri and Cacace, 2005). This technology can be used for the rapid inactivation of microorganisms on food surfaces, equipments and food packaging materials (Dunn et al., 1995). The effect on microorganisms is mostly due to the photochemical action of the ultra violet part of the light spectrum that causes thymine dimerization in the DNA chain preventing replication and ultimately leading to cell death (Gomez-Lopez et al., 2007).

The principle involved in generating high intensity light is that a gradual increase of low to moderate power energy can be released in highly concentrated bursts of more powerful energy. The key component of a Pulse Light unit is a flash lamp filled with an inert gas. A high-voltage, high-current electrical pulse is applied to the inert gas in the lamp, and the strong collision between electrons and gas molecules cause excitation of the latter, which then emit an intense, very short light pulse. It is generally accepted that UV plays a critical role in microbial inactivation. So pulsed light is a modified and claimed improved version of delivering UV-C to bodies. The classical UV-C treatment works in a continuous mode, called continuous-wave (CW) UV light. Inactivation of microorganisms with CW-UV systems is achieved by using low-pressure mercury lamps designed to produce energy at 254 nm (monochromatic light), called germicidal light (Bintsis et al., 2000). More recently, medium-pressure UV lamps have been used because of their much higher germicidal UV power per unit length. Medium-pressure UV lamps emit a polychromatic output, including germicidal wavelengths from 200 to 300 nm (Bolton & Linden, 2003). Pulse Light treatment of foods has been approved by the FDA (1996) under the code 21CFR179.41. The treatment is most effective on smooth, nonreflecting surfaces or in liquids that are free of suspended particulates. In surface treatments, rough surfaces hinder inactivation due to cell hiding.

Generation of Pulsed Light

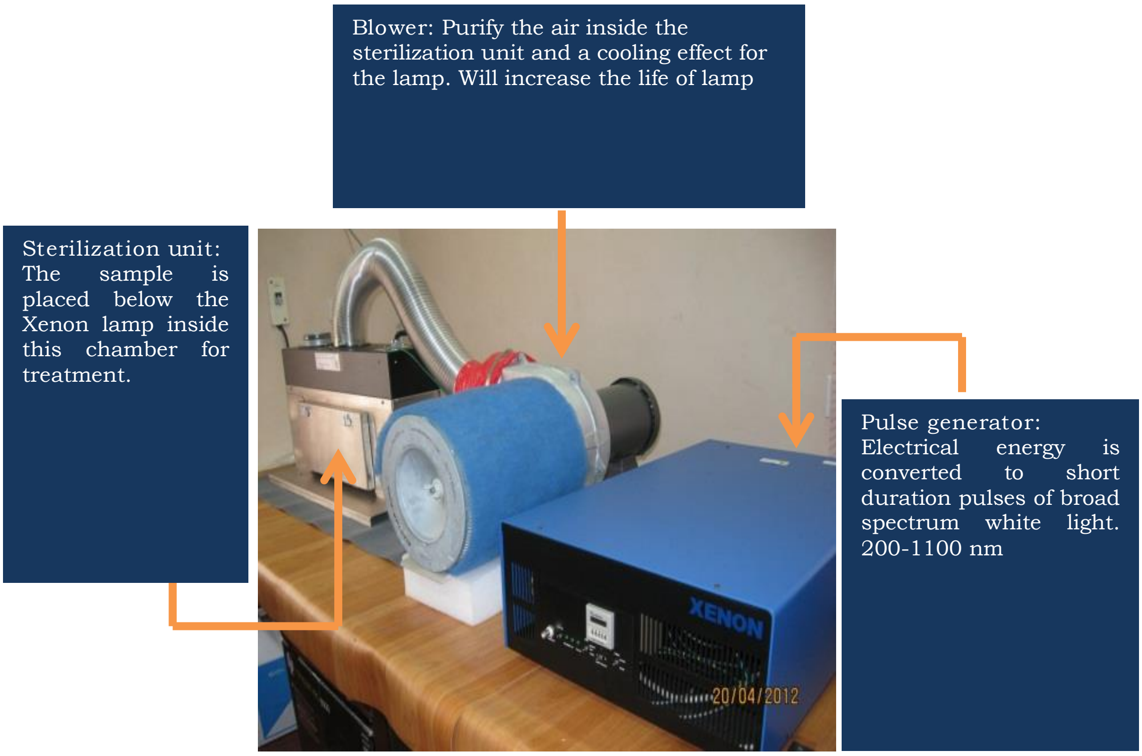
Light can be emitted from different sources by different mechanisms, due to the spontaneous transition of some atoms from an excited state to a condition of lower energy. Light can be delivered either continuously or in the form of pulses. (Palmieri and Cacace, 2005). Pulsed light works with Xenon lamps that can produce several flashes per second. During the pulse treatment the spectrum produced is 20000 times brighter than sunlight at the surface of the earth (Dunn et al., 1995). Electromagnetic energy is accumulated in a capacitor during fractions of a second and then released in the form of light within a short time (nanoseconds to milliseconds), resulting in an amplification of power with a minimum of additional energy consumption. As the current passes through the gas chamber of the lamp unit, a short, intense burst of light is emitted. The light produced by the lamp includes broad-spectrum wavelengths from UV to near infrared. The wavelength distribution ranges from 100 to 1,100 nm.

Merits and Demerits

Merits: The inactivation of microbes by Pulse Light is very fast process and cause rapid disinfection in a very short period. It is a green technology as the consumption of energy is very less during its application. Pulse Light has been proven as a safe technology for living being and their environment without producing harmful residuals, chemicals and toxic by-products in the treated foods. It does not affect the nutritional and sensory quality of the products. The concerns of ionized radicals and radioactive by-products in foods by consumers are removed in Pulse Light due to its nonionizing spectrum (Dunn et al.1995).

Demerits: Pulse Light application in meat industry has some constraints as the low penetration power and chances of lipid oxidation (Fine & Gervais, 2004). To get the desired outcome, the packaging materials showing high penetration of light should be used while treating the packed food by this method. The limited control of food heating still remains the main concern in Pulse Light technology. Sample heating is perhaps the most important limiting factor of this technology for practical applications (Gomez-Lopez et al., 2007).

Pulsed Light Equipment at CIFT



4. Ultrasound processing

The application of ultrasound in food processing has been stared as another area in non-thermal approaches, which exploits the preservative effect of the high intensity sound waves. The preservative effect is by the inactivation of microbes and spoilage enzyme by mechanical actions. Mechanism is that when propagates through biological structures, Ultrasonic cavitation produces shear forces, which causes mechanical cell breakage and allows material transfer from cell into solvents. Cavitation causes particle size reduction thereby increases the surface area in contact when extracting a compounds.

The technology finds its application in the field of extraction of proteins, lipids and their functional modifications, emulsification, viscosity improvement, homogenization and improvement of dispersion stability in liquid foods (Mohd. Adzahan and Benchamaporn, 2007). So this technology is utilized in the field of processing, preservation and extraction, which makes use of physical and chemical phenomena that are fundamentally different from conventional extraction, processing or preservation techniques.

In food industry, the application of ultrasound can be divided based on range of frequency:

- *Low power ultrasound:* Uses a small power level that the waves cause no physical and chemical alteration in the properties of the material through which it passes. This property is being utilized for non-invasive analysis and monitoring of various food materials during processing and storage, to ensure quality and safety.
- *High power ultrasound*: Uses high energy [high power, high intensity] ultrasound of 20 and 500 kHz. It causes disruptive and enforce effect on the physical, mechanical, or biochemical properties of foods. These effects are promising in food processing, preservation and safety.

5. Irradiation

Irradiation is the process of applying low levels of radiation to any food material to sterilize or extend its shelf life. It is a physical method that involves exposing the prepackaged or bulk foodstuffs to gamma rays, x-rays, or electrons. Foods is generally irradiated with gamma radiation from a radioisotope source, or with electrons or x-rays generated using an electron accelerator (Barbosa-Canovas et al., 1998). These rays have high penetration power and thus can treat foods for the purpose of preservation and quality improvement. During exposure of food the amount of ionizing radiation absorbed is termed 'radiation absorbed dose' (rad) and is measured in units of rads or Grays. A strictly regulated process of dosimetry is used to measure the exact dose of radiation absorbed by the food. One Gray is equal to one joule of energy absorption per kilogram of a material. Irradiation has been approved for the microbial disinfestations of various food products in the US (USFDA, 1998). A number of countries have marketed irradiated products worldwide. Irradiation has the potential to enhance food safety for fresh foods that will be consumed raw and for raw foods that require further processing. Food irradiation mainly is done by the radioactive element cobalt-60 as the source of high energy gamma rays. Gamma rays are electromagnetic waves or photons emitted from the nucleus of an atom. These gamma rays have energy to dislodge electrons from food molecules, and to convert them into ions which are electrically charged. However, the rays do not have enough energy to dislodge the neutrons in the nuclei of these molecules and hence they are not capable of inducing radioactivity in the treated food. The radiation dose varies depending on the thickness moisture, and characteristics of the foods. External factors, such as temperature, the presence or absence of oxygen, and subsequent storage conditions, also influence the effectiveness of radiation (Doyle, 1990).

In general, irradiation of food does not significantly affect the protein, lipid, and carbohydrate quality. Minerals are stable to food irradiation. The overall chemical changes in food due to irradiation are relatively minor and hence there is little change in the nutritional quality.

Irradiation of moist food under frozen condition and in the absence of oxygen significantly decreases the overall chemical yields by about 80%; So the cumulative effects of irradiating to a dose of 50 kGy at −30°C is essentially equivalent to a dose of 10 kGy at room or chilled temperature. A dose of 1-10 kGy can control food-borne parasites responsible for diseases such as trichinosis. A minimum dose of 0.15 kGy can prevent development of insect infestation in dried fish. Irradiation is considered as a phytosanitary measure often obligatory if certain agricultural commodities are to be exported. The unique feature of radiation decontamination is that it can be performed in packaged foods even when the food is in a frozen state.

Table I gives details of irradiation processes for seafood.

Table 1: Radiation processes of seafoods (Source: Venugopal, Protech 2013-Pg28)

Treatment and storage temperature	Radiation process	Benefits
-10° to -20°C Packaged, frozen, ready-to-export fish can be treated before shipment. Frozen storage	Radicidation (Radiation hygienization) Dose required: 4-6 kGy Elimination of non-spore forming pathogens such as *Salmonella, Vibrio, Listeria* etc.	Improvement of hygienic quality of frozen, materials for export such as frozen shrimp, cuttlefish, squid, finfish, fillets, and IQF items.
15° to 30°C Ambient storage	Radiation disinfestation Dose required < 1 kGy Elimination of eggs and larvae of insects.	Dry products free from spoilage due to insects, from dried fishery products including fish meal and feed for aquaculture. Inactivation of *Salmonella* spp. and other pathogens
-1°to +3°C (Post-irradiation storage: under ice).	Radurization (Radiation pasteurization for shelf life extension) Dose: 1-3 kGy Reduction of initial microbial content by 1 to 2 log cycles. Specific reduction of spoilage causing organisms.	Extends chilled shelf life of fresh marine and freshwater fishery products two to three times. Additional benefit includes reduction of non-spore forming pathogens

6.Cold Plasma Technology

Recently, plasma technology has emerged as a potential preservation technique in food industry for exploring its preservation and shelf-life extension potentials. This technology has the feasibility of being energy efficient, short processing duration and operational at reasonable temperatures. The application of plasma technology in seafood sector, include direct application in fresh and dried products as well as indirect application of plasma activated water and seafood industry wastewater purification. However, this technology is globally less explored in the seafood sector. The atmospheric cold plasma has been demonstrated to be effective in reducing microbial and enzymatic actions in various vegetables, beverages and meat products. But the application for control of pathogenic and spoilage bacteria in fish products has got meager attention, especially the studies reported in value added fishery products are very rare. However, few studies conducted in plasma application in seafoods viz., fresh and dried products widen the application potential of plasma technology in the sector. However, a few disadvantages reported in these investigations viz., effect of plasma in oxidizing the products have to be addressed. Comprehensive investigations are required in this regard for efficient exploration of this technology to deliver safe and stable seafood in the supply chain in a cost-effective way.

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