NON THERMAL PROCESSING OF FISH

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Changes in consumer's desires in the recent past, have led to the requirement for more convenient foods having supreme qualities and freshness, minimally processed and packaged, easy to consume and nutritionally healthier. 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. 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.

Thermal pasteurization and thermal sterilization 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, thermal treatments end with over processed food having 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. 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, which 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 eco-friendly, 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

Fig.: A Research model of 02 litre capacity High Pressure machine at Central Institute of Fisheries Technology, Cochin (from M/s Stansted Fluid Power Ltd, United Kingdom)

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.

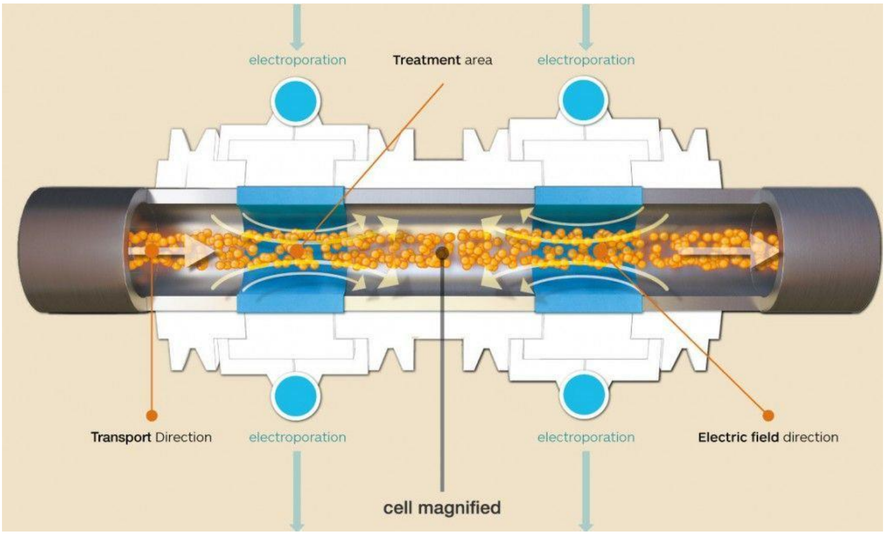
2. Pulse electric field

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)

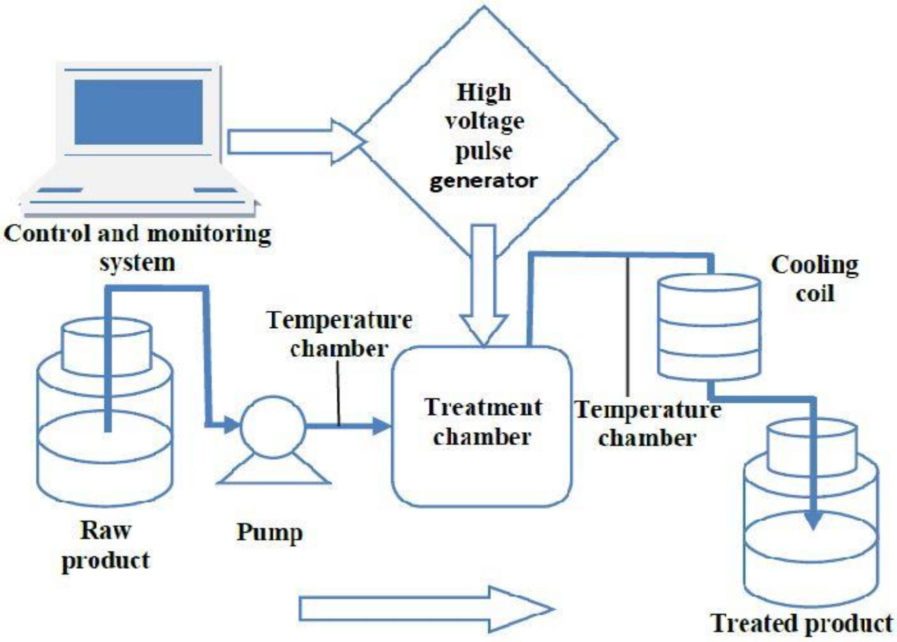


Fig.: Pulsed Electric Field Preservation

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

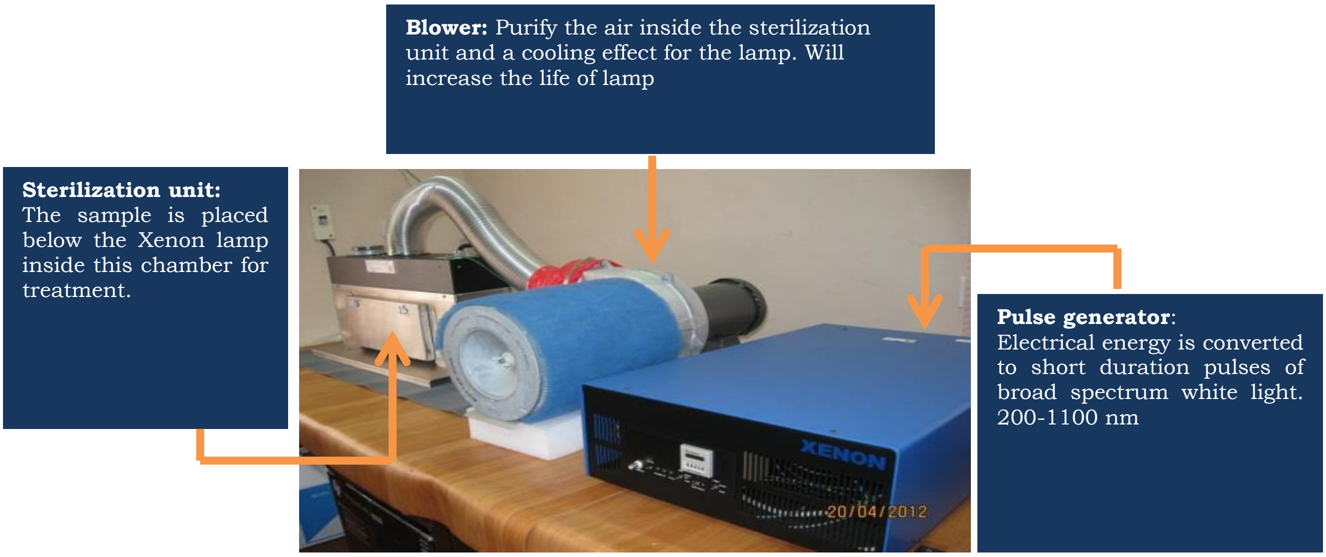
Merits

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).

Fig.: ***Applications of Irradiation***

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	Radicidation (Radiation hygienization)	Improvement of hygienic quality of frozen, materials

Packaged, frozen, ready-to-export fish can be treated before shipment. Frozen storage	Dose required: 4-6 kGy Elimination of non-spore forming pathogens such as *Salmonella, Vibrio, Listeria* etc.	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

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