Chapter 8

Non-thermal fish preservation techniques

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Non-thermal preservation of food

Conventional thermal processing results in some undesirable changes in food, such as loss of nutritional components that are temperature-sensitive, change in the texture of food due to heat, and changes in the organoleptic characteristics of food. Non-thermal food processing simply refers to methods where the food materials receive microbiological inactivation without the direct application of heat. They are relatively young technologies, which use mechanisms other than conventional heating to reduce or eliminate microorganisms. Hence it offers an alternative to conventional thermal processing.

1. High pressure processing

- High Pressure Processing is also known as high hydrostatic pressure (HHP) or ultra-high pressure (UHL) processing.
- It is a non-thermal, cold pasteurization technique, which generally consists of subjecting food, previously sealed in flexible and water-resistant packaging, to a high level of hydrostatic pressure (pressure transmitted by water) up to 600 MPa / 87,000 psi for a few seconds to a few minutes (1 – 20 min).
- HHP utilizes a very common medium, i.e., water, to apply the pressure on the product to be treated.
- HHP transmits isostatic pressure (100–1000 MPa) instantly to product at low temperature and might have comparable preservation effect as thermal processing through inactivating undesirable microorganisms and enzymes.
- An HPP unit consists of a pressure compartment in which food is kept and water is introduced into the chamber. Food is then pressurized using this water.

Major applications in seafood

1. Post pack lethality intervention for RTE seafood
   - *Cold post-packaging pasteurization*: For shelf-life extension, keeping freshness, maintaining higher sensorial qualities, functional properties and improving food safety.

2. Low pressure process application
    - *Mollusc shucking*: In HPP, the muscle, which is responsible for closing the shell, will not be able to contract and the oyster will open. This exposes the meat for easy extraction, resulting in a significant yield increase.
    - *Crustacean meat extraction*: In HPP, meat of crustaceans such as lobster or king crab will contract and detach from the shell, facilitating extraction with yield of almost 100 %.

2. Pulsed electric field (PEF) processing

- PEF is an efficient non-thermal food processing technique using short, high voltage pulses.
- It is used for inactivation of spoilage and pathogenic microorganisms in various food products. Electric pulses are applied for destroying harmful bacteria in food.
- Microbial inactivation is achieved by dielectric breakdown of the bacterial membranes
- Food material is placed between electrodes. The field intensity is typically 20–80 kV cm^{-1}) and the exposure time is a few milliseconds or nanoseconds.
- It enhances the shelf life of the food without quality loss.
- The PEF mechanism is called ***electroporation***. Very short electric pulses of high voltage are applied to the food. Small pores are formed in the cell membrane of the food by the electric pulses without damaging the cell compounds, such as vitamins.
- Pulsed electric field is generally used for liquid food or semi-solid food that can flow easily.

PEF device

- A typical PEF device consists of a food treatment chamber, a control system, and a pulse generator.
- The food is kept in the treatment chamber in between two electrodes generally made of stainless steel.

Applications of PEF in fisheries field

- PEF improves water holding properties of fish (submitting the fish muscle to PEF made its structure more porous)
- PEF technology improves extractive effectiveness to obtain protein from mussel (Improved extraction yield of protein)

- It can be used as a pre-treatment for drying
- PEF can be used to valorize by-products from fish processing industries.
- High-intensity PEF has been identified as an improved a method to extract calcium & chondroitin sulphate from fishbone.
- PEF has been tried for extraction of collagen from fish waste.
- PEF enzymatic-assisted extraction has been used for isolation of the abalone viscera protein.
- PEF can be used as a pre-treatment for fish waste for enhancing the yield of the extraction process.

3. Irradiation/Radiation processing

- Refers to the process by which an object is exposed to radiation (A deliberate exposure to radiation)
- Irradiation is a process of applying low levels of ionizing radiation to food material to sterilize or extend its shelf life.
- Radiation inactivates food spoilage organisms, including bacteria, moulds, and yeasts.
- It is effective in lengthening the shelf-life of fresh fruits and vegetables by controlling the normal biological changes associated with ripening, maturation, sprouting, and finally aging.
- Radiation also destroys disease-causing organisms, including parasitic worms and insect pests, that damage food in storage.
- Irradiation is harmful or noxious to humans. However, the dose for seafood pre-treatment is low, therefore making it safe for consumption. Food irradiated under approved conditions does not become radioactive.

Agri-food applications of irradiation

- *Radicidation and Radurization*: Refer to these applications of less than 10 kGy doses.
- Radurization: Application of an ionization dose sufficient to preserve the quality of food by ensuring a substantial reduction in the number of spoilage bacteria.
- Radicidation: Application to the food of a dose of ionization sufficient to reduce the specific number of viable pathogenic bacteria to a level such that they are not detectable by any known method. This term also applies to the destruction of specific parasites.

- *Radappertization*: Application of high dose (10 to 60 kGy) of ionization to food in order to reduce the number and/or activity of living microorganisms so that none (except viruses) is detectable by any recognized method. Such radio-sanitized products can then be stored for up to 2 years at room temperature in sealed plastic packaging.

Table 1: Dose requirement in various applications of food irradiation

Dose Level	Dose	Applications
Low	<1 kGy	▪ Inhibition of sprouting of potato, onion and other tubers ▪ Insect disinfestation in stored grain, pulses and their products, dried fruits such as dates and figs ▪ Destruction of parasites in meat and meat products
Medium	1–10 kGy	▪ Shelf-life extension of fresh meat, poultry and seafood by elimination of vegetative bacteria responsible for spoilage ▪ Elimination of pathogenic organisms from meat, seafood and poultry ▪ Treatment for quarantine purposes of fruits and vegetables
High	>10 kGy	▪ Hygienization of spices, vegetable seasonings, etc. ▪ Sterilization of food for special requirements ▪ Shelf stable foods without refrigeration

4. Ultraviolet (UV) Radiation

- A very economical non-thermal technology
- Non-heat technique for decontamination for improving both the shelf-life and safety of foodstuff.
- It is basically used to reduce the microbial load on the surface of food materials that are indirectly exposed to radiation, because of its low depth of penetration.
- UV radiation is a form of energy considered to be non-ionizing radiation having in general germicidal properties at wavelengths in the range of 200–280 nm (usually termed UV-C).
- UV irradiation has demonstrated to be effective not only in reducing microbial load but also inactivating enzymes activity in plant products.

Applications in the fisheries sector

- For food products, UV-C light technology application has been mostly confined to liquids and free-flowing foods.

- UV light is used in the fish industry to decrease the microbial load and increase the shelf life of fish, reduce the microbiological load in fish meal, disinfect working surfaces, and to sterilize the water in aquaculture and wastewater facilities.
- However, to achieve a more effective reduction in bacterial load, the studies indicate that UV light should not be used as a stand-alone strategy, but integrated with other technologies.

5. Pulsed Light (PL) Preservation

- Pulsed light (PL) is an alternative technique to continuous ultraviolet treatment for solid and liquid foods.
- PL consists of successive repetition of high-power pulses of light/short time high-peak pulses of broad-spectrum white light.
- Comparatively, PL has a thousand times strength greater than the normal UV light which is quite continuous.
- Pulsed xenon UV uses the full spectrum of ultraviolet light to disperse germ-killing energy.
- The light spectrum includes wavelengths from 180 to 1100 nm with a considerable amount of light in the short-wave UV spectrum.
- Similar to other non-thermal food processing technologies, PL also has potential in the inactivation or elimination of microbes in food.
- Specific examples of foods processed by PL include fish, vegetables, fruits, and meat.
- PL can be used alongside other novel technologies as a hurdle in the inactivation of microbes on the surfaces of foods.

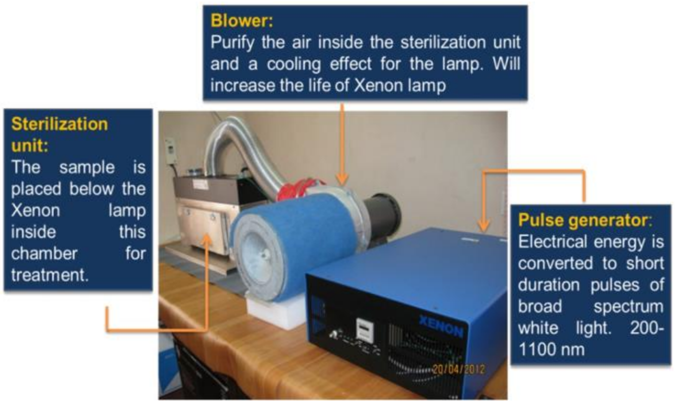

Figure 1: Pulsed Light Equipment of CIFT

6. Ultrasound (US) processing

- US is a compressional wave with a frequency of over 20 kHz.
- US is sound wave bearing certain frequency that is more than the normal human hearing frequency, which is more than 20 kHz.
- The frequency of US used in the food industry for microbial inactivation ranges from 20 kHz to 10 MHz.
- The bactericidal action of US is mainly due to the cavitation process, in which microbubbles are produced and collapsed within a liquid medium.
- During the cavitation process, the temperature can increase to as high as 5500 °C and the pressure can increase up to 100 MPa, resulting in localized microbial sterilization.
- The bactericidal mechanisms of ultrasound include breakage of cell walls, disruption and thinning of cell membranes and free radical activity due to the collapse of cavitation bubbles.

Method of application of ultrasound

- *Ultrasonic horn*: Horn is dipped in the liquid solution or juice and is treated with certain treatment frequency.
- *Ultrasonic bath*: Food material or packaged food is kept and the sound waves are generated in a bath that creates ultrasound effect and brings about desired changes in food.

Applications in the seafood industry

Freezing

- Improves freezing by better preservation of the microstructure; Requires less time and small crystal size; Improved diffusion & Rapid decrease in temperature.

Thawing

- Reduction in thawing time; Preserve colour; Inhibits lipid oxidation; Improved product quality & Reduced product dehydration.

Brining/Pickling

- Low water activity and longer shelf life; Require less sodium chloride & Uniform distribution of salt in less time.

Drying

- Intensification of mass transfer; Shorter processing time; Enhanced organoleptic properties & Increased drying rate due to less resistance.

7. Cold Plasma (CP) Technology

- Plasma: Fourth state of matter after solid, liquid, and gas.
- When the energy of gases crosses a certain value, it results in the ionization of gas molecules. Ionization of gas molecules gives rise to plasma.
- Two types

  -Thermal plasma

  -*Cold plasma* (non-thermal)
- Cold plasma is a non-thermal treatment that works in the temperature range 25–65° C.
- Cold plasma has high antimicrobial activity and efficient enzyme inactivation capacity.
- The composition of the plasma reactive species largely depends on the composition of gas which is ionized.
- The gases commonly used for the generation of plasma include argon, helium, oxygen, nitrogen and air.

Cold plasma generation

- The gases are subjected to any of the types of energy like thermal, electrical, magnetic field, etc., to generate plasma containing positive ions, negative ions, and reactive species like ozone and singlet oxygen.
- Methods

  -Radio frequency plasma

  -Dielectric barrier discharges

  -Gliding arc discharge

  -Microwave

  -Corona discharges
- Cold plasma is an ionized gas generated through gas ionization under corona discharge, dielectric barrier discharge, microwaves or radiofrequency waves.

Advantages & Applications

- Reduction of the microbial load in food or on the surface of food. All kinds of microbes are said to be inactivated by cold plasma technology, including viruses, fungi, and bacteria.
- Enhance the physical and chemical properties of food constituents like lipids and proteins.
- Sterilization of food processing equipments.
- Inactivation of food spoilage enzymes.

- Treatment of food packaging material. Cold plasma can serve for in-package sterilization.
- Treatment of wastewater.
- Cold plasma is produced at near ambient temperature and does not depend on high temperature for microbial inactivation.
- Since the temperature used is ambient, there are no chances of thermal damage to heat-sensitive food material.
- It has continually been referred to as an eco-friendly technique since, besides having minimal changes on the food matrix, its application does not result to the generation of toxic residuals/wastes.

8. Ozone treatment

- Ozone is a colorless gas with a typical odor.
- It contains three molecules of oxygen and is chemically written as O_3. It is formed when molecular oxygen (O_2) combines with singlet O.
- Ozone is a very reactive gas, and it is very much unstable and cannot be stored and needs to be produced on the spot when needed.
- Ozone is extensively employed as an effective antibacterial against many bacteria in food. Due to its high oxidizing potential and the ability to attack cellular components, ozone has broad-spectrum of disinfection.
- Ozone treatment is a chemical method of food decontamination that involves exposing contaminated foodstuffs (fruits, vegetables, beverages, spices, herbs, meat, fish, and so on) to ozone in aqueous and/or gaseous phases.

Effect of ozone on microbes

- Ozone alters the permeability of cells by damaging the microbial cell membranes.
- Ozone is also known to damage the structure of proteins, leading to the malfunctioning of microbial enzymes, which affects the metabolic activity and finally results in microbial cell death.
- Chemical composition, pH, additives, temperature, initial bacteria population, and ozone contact time with food and food surface type are factors determining the efficiency of ozone treatment on microbial reduction in seafoods

Other methods

Acidic Electrolyte Water

- Electrolyte water (EW) is made from water without the addition of any hazardous chemicals except sodium chloride.
- EW is known as either a sanitizer (EW containing HOCl, an acidic electrolyte water) or a cleaner (EW containing NaOH, an alkaline electrolyte water.
- The simplicity of EW production and application is the foremost reason for its popularity.
- In numerous fields such as medical sterilization, agriculture, food sanitation and livestock management, EW is gaining attention because of its antimicrobial properties.

Dense phase carbon dioxide (DPCD)

- DPCD processing utilizes the liquefied carbon dioxide and performs at mild temperature and relatively low pressure, about one tenth of the pressures for HHP.
- It is applied to cold pasteurize and extend the shelf life of product without heating.
- Carbon dioxide is a nontoxic, non-flammable and low-cost gas; in the supercritical state, the fluid CO_2 rapidly penetrate porous materials due to its low viscosity ($3–7 \times 10^{-5}$ Pas) and surface tension. This penetration is accompanied with pH decrease, bicarbonate ion generation and cell disruption, which contribute to the microbial and enzyme inactivation.

High voltage electrical discharge (HVED) processing

- Different from PEF in electrode geometry, shape of pulses and mode of actions, HVED generally consists a needle electrode and a grounded one (normally flat geometry) or wire plane.
- Though the advantages of PEF and HVED are promising, the release of metals from the corrosion or migration of electrode materials should be concerned and investigated in the future applications.

Conclusion

The demand from consumer for safe and nutritious food products has promoted the rapid development of non-conventional processing technologies. With non-thermal treatments, consumers get high quality, healthy, and safe food products. But there are two sides of the coin: with advantages come some disadvantages as well. If food is exposed for a longer period or treated at a higher intensity, these non-thermal technologies may lead to some undesirable changes in food, such as oxidation of lipids and loss of colour and flavour. But these technologies have many advantages compared to thermal processing. After overcoming the limitations properly in a planned manner, non-thermal technologies will have a broader scope for development and commercialization in food processing industries.