High Hydrostatic Pressure Processing: Advances in the seafood sector

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Seafood sector has received huge demand worldwide due to the high nutritional qualities of fish over other meat counterparts and this has created the sector an economically important one. Value added products from fish provides us with a good alternative through which the nutritional benefits from the fish can be further utilized. But the high perishable nature of fish always reflects on product quality and its market value. Hence maintaining quality and ensuring safety of the product is of given paramount importance. Many processing and preservation techniques have been employed to preserve freshly caught fish catch for future use. Continuous efforts are being made to create safer products for consumers by conserving inherent quality attributes and also extending shelf-life in order to enhance economic returns to producers. Recent focus of food scientists and food engineers has shifted towards finding advanced technologies, for preservation of freshness and quality characteristics of the product.

In the last few decades, consumers are demanding new alternatives of fish and sea foods, which have led to more value addition and introduction of novel technologies in their production. Changing lifestyle and awareness about the nutritional qualities and healthy diet, led to the necessity of bringing more fresh and natural ready to eat foods in the market. Hence the current focus of product development shifted from traditional ones towards market-driven, health-driven and technology-driven ones, which often adds safety as well as quality characteristics. The demand for such convenient foods with higher quality and freshness, minimally processed and packaged, easy to consume

and nutritionally healthier have led to the introduction of "minimal preservation and processing technologies" (Gould, 2000).

Many minimal preservation and processing technologies covering novel thermal technologies like Ohmic heating, microwave heating, dielectric heating, infrared heating etc. and non-thermal technologies like HPP. Pulse light, pulse electric field, cold plasma, ultra sound processing etc. are being explored recently. when compared even though thermal technologies can reduce the cooking time and have direct effect on the heat and energy efficiencies (Pereira and Vicente, 2010), and regarded for volumetric forms of heating where generation of thermal energy inside the food (Cullen et al., 2012) which can sometime affect the heat labile bioactive compounds in the food. This introduces more possibilities in the minimal non thermal preservation technologies in the food sector for microbial inactivation, meeting the current global interest on more freshness, healthy and natural foods.

Non-thermal processing technologies are often effective at ambient or sub-lethal temperatures. High hydrostatic pressure/HPP, pulsed electric fields, pulsed light technology, ultrasound, ultraviolet light, cold plasma technology, oscillating magnetic field etc. are some of the advanced non thermal technologies that have the ability of inactivating spoilage microbes/ enzymes leading to the enhancement of safety and shelf life (Butz and Tauscher, 2002). In HHP and PEF a small amount of heat is generated as internal energy like adiabatic heating and resistive heating, but, they are classified as non-thermal once, as they can eliminate the use of high temperatures to inactivate the microorganisms, avoiding the deleterious effects of heat on flavor, colour and nutritive value of foods (Pereira and Vicente, 2010). Among them most extensively studied and explored non thermal process for preservation of foods appears to be HPP and PEF, which has been in commercialization for liquid food like juices, milk and other fruit derived ones.

High pressure processing (HPP) or high hydrostatic pressure processing (HHPP) is defined as an innovative processing technology which allows inactivation of pathogenic and/or spoilage microorganisms, enzymes in foods with fewer changes in texture, flavour, and colour when compared to conventional technologies. This emerging technology finds its application in the field of food preservation to extend the shelf life of food and to improve food safety of products, as a novel post packaging decontamination technology (Bajovic et. al., 2012) or cold sterilization method.

The high pressure works on the principle of microbial inactivation by protein denaturation, enzyme inactivation and cellular proteins agglomeration in addition to the changes happening in the permeability of cell membrane. Since high pressure on food does not involve in the breaking of covalent bonds, the development of undesirable flavours is eliminated and the natural qualities of the products are maintained.

This advantage of minimal effect on flavour and nutritional attributes of final products, can is usually done at ambient temperature conditions but can be used with high and low temperatures. The combined effect of high pressure with sub-zero temperature open up the unexploited potentialities for improving the kinetics of the freezing process. Also the application of pressure to food results in instantaneous and uniform transmission of the pressure throughout the product, independent of the product volume. This environment friendly, safe food preservation technique has been exploited in the area of developing newer food products which can retain the natural appearance, flavour, texture, and nutritional qualities.

The initial reports on HPP of food dated back in 1899 by Hite, who used this technology in shelf life extension of milk. Although earlier attempts of this high pressure were dated back in the 19th century, the true potential of its application in the field of food processing was put at the end of 1980's (Erkan, 2010). High pressure processed foods were first commercialized in Japan in 1992 (Murchie et. al., 2005) and now this technology has been applied to a range of foods like milk, fruit juices, jams, guacamole, oysters, fish and meat products, ready- to- eat dishes etc. and are already available in the markets of Europe, America, Japan etc. The studies on meat and fish have also shown that HPP can be a useful processing tool for such types of muscle foods (Ohshima et.al., 1993).

HPP in fish and fish products

In fish and fishery products, due to its perishability and safety concerns scope for a detailed investigation on their amenability to HPP has been increasing. Although the sensitivity of microorganisms like both spoilage and pathogenic, can be exploited for shelf life extension and also their hygienization in fresh fish. So application of high pressure can not only destroy spoilage bacteria and inactivate enzymes that affect the quality of fish, it helps to display better qualities like nutrition retention, fresh flavour, improved taste and texture, when compared with traditionally processed products. The technology has led

to innovative processing methods and many products have been commercialized in different parts of the world especially Japan, Europe and American markets. The regulatory agencies (USFDA) have accepted the preservation method using high pressure for the pasteurization of food products. However, in India HPP is still a novel and potential technology especially for solid based foods and hence having huge research potential in the current areas.

The effect of pressure on fish and seafood for microbial inactivation and shelf life extension has been extensively studied. High pressure has been found to inhibit the formation of putrefactive compounds and maintains the hardness of fish muscles during storage, thereby ensuring higher sensory quality. High pressure (HP) processing helps in shucking the raw meat without cooking, to remove meat from the rigid shell of crustaceans and molluscs easily without losing the natural texture and appearance.

Many research has been done in the area of shucking of live clam, oysters and mussels. Live oysters subjected to moderate pressures of 240–350 MPa for 3 min help to open up the oysters without knife and thus have developed as an alternative to the laborious and costly hand shucking process in the oyster industry (Morrissey, 2002). Similar, reports showed an optimum shucking pressure range of 240 to 275 MPa resulted in minimum changes to pacific oyster (He et al., 2002). Mussel meat is usually consumed as raw, blanched or cooked and the meat removal from the shell is done by steaming or dipping the whole mussel in boiling water. This process leads to the loss of structure, moisture reduction, protein degradation and loss of juiciness, resulting in rubbery texture. Thus, a more efficient means of meat removal can be achieved without changing the size and shape of the meat and at same time the nutritional qualities are retained.

Various other fields of applications of high pressure are pressure – freezing and thawing, preservation at subzero temperatures under non frozen conditions, in addition to its potential in developing many novel texturized products. HPP has received increased attention in recent years as a possible way of improving functional properties of muscle proteins and also a powerful tool for protein and enzyme modulation studies (Mozhaev et.al., 1996). Wide application of this technology has dealt as a result of protein denaturation, textural alterations, gelation, greater flavour and colour retention, and enzyme modifications. So this technology has shown its potential in seafood industry for the production of surimi, kamaboko or other minced products. The response of food products to HPP is complex in nature and is being affected by the product characteristics (pH, water activity) and processing parameters (pressure intensity, duration of pressurization, temperature etc.) (Sequeira-Munoz et.al., 2006).

Now the focus is on enhancing textural and functional quality of fish mince by the application of HPP for the development of new and improved products. The application of pressure will

also minimise protein denaturation, increase nutritional and sensorial quality and maintain inherent properties which can be best lose in traditional pasteurisation process. Fish proteins with increased gel strength, softer gels and higher water retention can be well produced by application of pressure. High pressure processed products will create a new demand for raw or fresh like products and command a niche in the world food markets. Also the conventional process of restructuring depends on hot set binding of extracted myofibrillar proteins with the combined effect of salt, phosphate and mechanical action and the new trend has shifted towards non thermal/ cold setting of restructured products. Because in restructured products binding can be achieved through the formation of gels that set thermally (heat set) or chemically (cold set). In cold setting of restructured products, high pressure technology promises many value added products which can offer fresh like qualities.

High pressure processing machine -Research model 2L capacity (FPG 7100:9/2C, Stansted Fluid Power Ltd. Essex, UK)

CIFT High pressure equipment is an iso- lab model designed by Stansted Fluid Power Ltd., UK having cylindrical pressure chamber of 2L capacity with 570 mm X 70 mm length and diameter. The chamber is filled with pressure transmitting fluid consisting of distilled water (100%) or 30% propylene glycol. Process temperature of pressure transmitting fluid inside the chamber can be monitored through T-type thermocouple.

An increase of 2–4°C in the transmitting fluid occurs with ramp rate, which is brought down to the set temperature by the cooling system of the machine (Ever Cool, Type EPIALT-7 .5). Holding time/ dwell time does not add pressure come-up or release time. An average come up time of 60-70s and a decompression time of 72s was noticed for seafood processing. Adiabatic compression was observed in pressure transmitting fluid which causes a raise in temperature at a rate of 3–4°C for every 100 MPa increase in pressure.

Extensive research on the effect of high pressure on the quality attributes like pH, colour, browning index, total soluble solids content, total phenolics, ascorbic acid content, antioxidant activity, sensory characteristics, spoilage causing enzymes (polyphenol oxidase and/or peroxidase and/or pectin methyl esterase), microorganism (aerobic mesophiles, psychrotrophs, coliforms, latic acid bacteria, yeast and mold) of fish, shrimp, shell fishes, molluscs and fruits like mango, litchi etc. has been done.

Work on high pressure induced inactivation of spoilage causing enzymes and microorganisms have been modelled and the developed kinetics will help for designing the technology adoption at industrial level. Some works on the effect of pressure processing on fish mince and mince based products like fish sausage, ham, smoked tuna, shrimp analogue etc. have been carried out and compared against the conventional heat treatments. When analyzed the effect of pressure in replacing the conventional method of sausage development, High pressure could possibly replace it with an enhanced quality and form softer and glossier gels with bubble-free surface than heat-induced ones. At higher pressures (like above 400 MPa) denaturation of myofibrillar protein creates the required consistency and texture to the products with increased shelf life. But textural modification was achieved at 250 MPa in 10 min, when microbial transglutaminase enzyme was used along with high pressure and so that enzyme addition could drastically reduce the optimized pressure in mince products.

The research works carried out focused on to

i. Employ shelf-life extension of the products by destruction of pathogens & spoilage organisms

ii. Reduces the microbial risks during raw seafood consumption

iii. Inactivation of oxidative endogenous enzymes before storage and processing of fish products

iv. Employ little effect on low molecular compounds like flavour compounds, vitamins and pigments.

v. Develop new gel based products with desired sensory attributes and mouth-feel

vi. Modify palatability and functional properties by inducing denaturation and muscle protein gelation

vii. Application in shellfish processing for 100% removal of meat from shells

viii. As an alternative to the conventional heat treatments for processing of various value added foods

Based on the studies carried out the optimized pressure ranges and dwell time of various products is shown below.

Product	Optimised Pressure and Dwell Time
HL Indian white Prawn	250 MPa, 6 Min
PUD Prawn	250 MPa, 6 Min
Tiger Prawn	435 MPa, 5 Min
RTC Prawn	235 MPa, 5 Min
Yellow fin tuna	200 MPa, 5 Min
Litchi juice	300 MPa, 5 Min
Mango Pulp	600 MPa, 10 Min
Fish Gel	400 MPa, 20 Min
Fish sausage	560 MPa, 15 Min
Marinated Tilapia	300 MPa, 5 Min
Restructured sausage	200 MPa 15 Min

Mussels

Fish ham

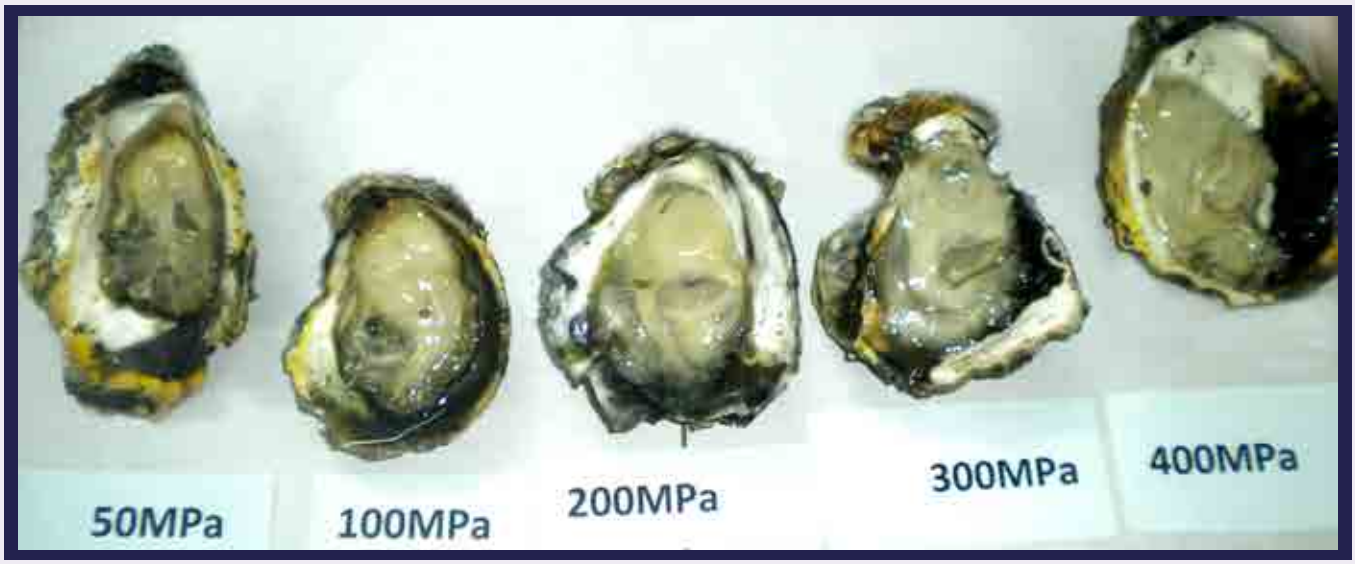
Indian white shrimp

Lobsters

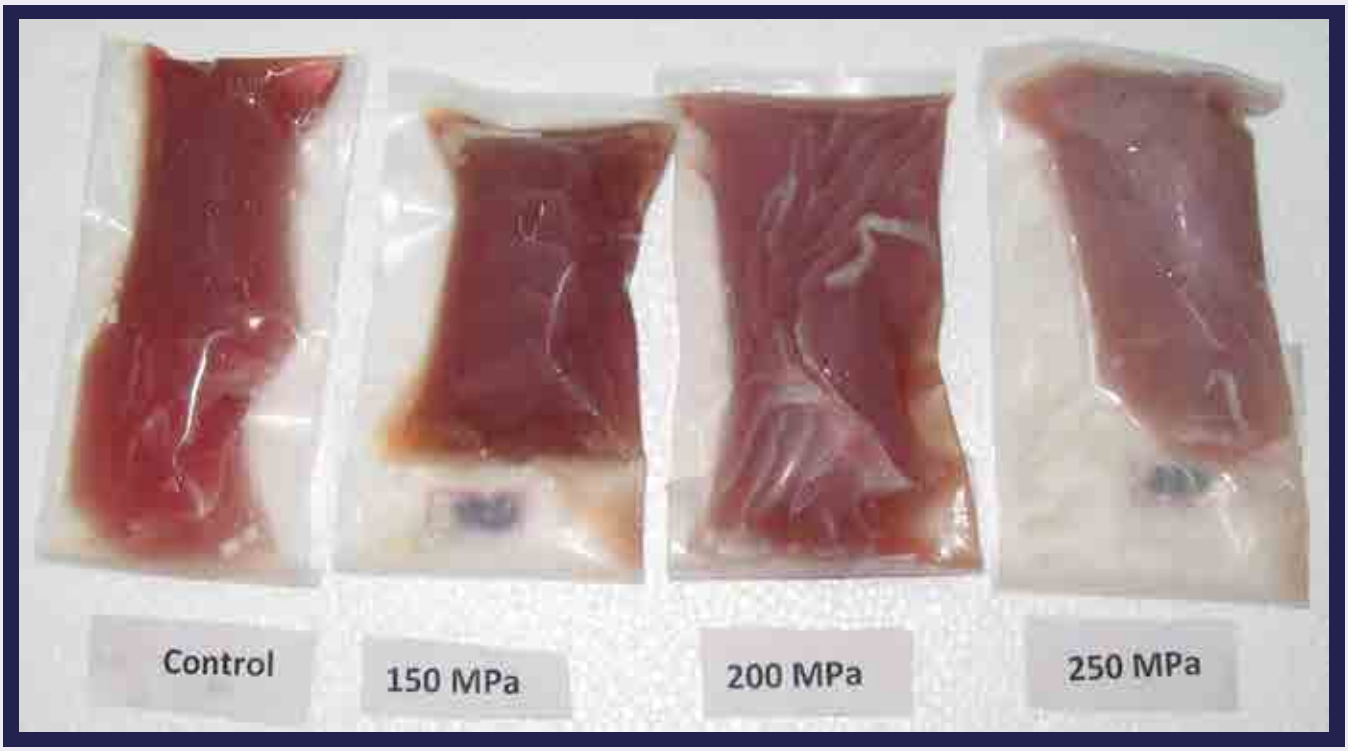
Surimi balls

Fish sausage

Crab Claws



Oysters



Tuna meat

Conclusions: Consumers awareness and concern on nutritional quality and safety of food in turn affects its market value. Hence emphasis is shifted towards developing novel products and technologies for future. Large varieties of fish-based products have been introduced in our market and are having huge demand like other meat counterparts. In many products the fish mince either cooked or uncooked is used with different formulation and the concern for safety and quality is gaining importance. The application of modern processing and preservation techniques in developing such formulated products in food industry has evolved to greater significance.

In India it is worthwhile to give more attention to the development of such formulated products and advanced technologies. There is unlimited scope for design and fabrication of such convenient products by technological interventions which causes physical, chemical or functional modification.

Advanced researches have been conducted in the application of high pressure on various fields of food processing especially in fruit and fruit juices, milk and milk products, soups, sauces and smoothies, vegetables and meat and seafoods. In Indian context the application of high pressure, as a means of non-thermal preservation techniques, has emerged recently and its application on fish and other meat is in nascent stage. This technique can be used as an alternative to conventional heating treatments for the development of various products with a minimum quality loss and extended shelf life.