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Minimal Processing of Seafood by High Pressure Processing: A non-thermal processing approach

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Abstract: High-Pressure Processing (HPP) is for the seafood industry a relatively young technology that successfully evolved into one of the most engaging alternatives to conventional thermal processing. HPP has been widely applied to prolong shelf life of predominantly additive-free foods. At refrigeration, ambient or moderate heating temperature HPP inactivates pathogenic and spoilage microorganisms in foods, with fewer changes in sensorial characteristics and a better retention of micronutrients when compared to other technologies in place. HP treatments affect the main constituents of fish (proteins, lipids, and enzymes), influence its sensorial properties.

Keywords: Seafood, High Pressure Processing, non-thermal processing, Quality.

INTRODUCTION

The Indian fish processing industry need design for tomorrow in support for infrastructure in the sector. Infrastructure development in Indian fish processing industry is a contribution in future. It takes into account of local climates (e.g., humid condition does not favor cold storage in NE region of India), cultures, resource endowments and social environments. It will manifest itself through technology transfer and human resource development and commits itself to carry local jobs and new industries.

There is potential of processed seafood's and Ultra-processed seafood's in markets of Indian fish Industry. But, there is need for Minimally Processed seafood's production as far as Indian seafood industry is concerned because of following reason:

1. Changes in culinary habits of people.
2. Consumer demands for variety of convenience seafood products many of them ready-to- eat and minimally processed.
3. Domestic and International market for Chilled prepared foods (Fresh-like and Healthy foods)
4. Greater premium for retention of natural nutritional and sensory properties of seafood's.

Thermal Processing renders seafood extended shelf-life at the cost of Loss of original flavour, taste, appearance, colour, nutritional quality (Ohlsson *et al.,* 2013). Safety is weighted more than quality in thermal processing but there is balance of Quality and safety in non-thermal processing. Some of the advantages of Non-thermal processing (Campus, M., 2010) as far as High Pressure Processing is concerned–

- Increased yield from seafood especially crustaceans and Molluscs (Murchie *et al.,* 2005).
- Render foods free of pathogenic & spoilage organism
- Retain colour, flavour
- Improve shelf life
- Improve texture
- Value addition like Convenience, Healthy seafood; Natural/Fresh-like
- Energy saving
- Waste free
- Ready market
- Reduction of processing time

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Non-thermal processing technology to produce minimally processed seafood is icing on the cake. Minimal Processing means "the least possible treatment to achieve a purpose". Thepurpose is to minimally influence the quality characterstics of seafood whilst, at the same time, giving the food sufficient shelf-life during storage and distribution. In other way it means that 'preserve seafood but also retain to a greater extent their nutritional quality and sensory characteristics by reducing the reliance on heat as the main preservative action (Ohlsson *et al.,* 2013).

Codex alimentarius commission definition for Minimally Processed food suit- well to seafoods. It says:

- Those intended to be refrigerated during their shelf life to retard or prevent proliferation of undesirable micro-organism.
- Those that have an extended shelf life of >5 days.
- Foods that are heated or processed using other treatments to reduce their microbial load.
- Low acid foods (pH >4.6) and those that have high water activity (0.92).

These hurdles used in addition to heat or other treatments and refrigeration for preventing the action of undesirable micro-organisms. According to European Economic Notification, minimally processed foods are characterized by-

- A mild preservation process where product temperature during processing fall within 0 to 100ºC.
- Reliance on refrigerated storage and distribution.
- Water activity (aw) higher than 0.85.
- pH higher than 4.5.

High Pressure Processing/High Hydrostatic Pressure (HHP) / Ultra High Pressure (UHP) Processing

This technology introduced in Japan in 1990 for non-thermal decontamination of foods with minimal impact on their nutritional and sensory features (Ohlsson *et al.,* 2013).It has great potential in Indian seafood industry to reduce microbial loads. Moreover, it can stabilize ready-to-eat seafoods and cured products with demands of regulatory agency (FSSAI) satisfied.

HPP equipment has got mainly four components (Mertens, 1995):

1. Pressure vessel and its closure
2. Pressure generation system
3. Temperature control device
4. Seafood handling systems

HPP machine commercial availability:

Capacity (Litre)	NC Hyperbaric, Spain	Avure, US/Sweden
35		✓
55	✓	
100		✓
120	✓	
135	✓	
215		✓
300	✓	
300×2	✓	
320		✓
350 (400 MPa)		✓
420	✓	
687(300 MPa)		✓

In India, HPP machine is available with Central Institute of Fishery Technology, Cochin; Defense Research and Development Organization and Central Food Technology Research Institute, Mysore.

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Effect of HPP on Protein:

In general, covalent bonding is not affected by pressure processing, with the exception of sulphydryl groups and thiol-disulphide interchange reaction. Primary structure of large molecule is minimally affected by pressure. Hydrogen bond formation is stabilized by HPP, along with the breaking of ions, as this leads to a decrease in volume. HPP modifies secondary, tertiary and quaternary structure of proteins (Kato *et al.,* 2002).

Small molecules like vitamins, flavor compounds allow preservation of nutritional value and sensory appeal (Linton *et al.,* 2002).

Effect of HPP on micro-organisms:

Microbe's cells got inactivated in HPP due to combination of certain factors (Simpson RK and Gilmour A, 1997) like

- Changes in cell membranes and cell wall.
- Changes in proteins an enzyme-mediated cellular function.

It has been said for microbial inactivation by HPP that there is a little correlation between gram types rather shapes of bacteria has to play role in HPP inactivation mechanism. For example, *Staphylococcus aureus* (cocci) is more resistant to pressure but rod-shaped pathogenic bacteria like *Escherichia coli*, *Pseudomonas aeroginosa*, *Listeria monocytogens*do change their morphology under HPP (Ludwig H. and Schreck Ch., 1997). It has been also proposed that *Escherichia coli* otherwise, insensitive to bacteriocins of *Lactobacillus* (lack of specific receptors)isvery sensitive to nisin when pressurized (Kalchayanand *et al.,* 1994).

Effect of HPP on colour of the seafood muscle:

It has been reported that Yellow fin tuna chunks subjected to high pressure (250 MPa) with a holding time of 5 min. at 25°C has shown whitening effect due to myoglobin denaturation and/or to haem displacement /release (Carlez, 1995). The pressure processing of cured meat or white meat is unlikely to cause problems in this respect.

There is report that seabream (*Sparusauratus*) after HPP application showed increase in lightness (L*) and yellowness (b*) values along with decrease in redness (a*)(Amanatidouet al., 2000, Chevalier *et al.,* 2001, Hurtado *et al.,* 2000 and Oshima *et al.,* 1993)but work on cold-smoked dolphin fish report revealed that there is increment in all three parameters (L*,a*,b*)(Go`mez-Estaca J. *et al.,* 2007). Some authors suggested that there is minimal effect on the anthocyanin after HPP treatment.

Effect of HPP on endogenous enzymes:

In general, HPP inactivates enzymes (Butz P. and Tauscher B., 2002). It has been observed that little or no changes in connective tissue (Suzuki A. *et al.,* 1993) as consequence of pressure treatment. Desmin is known Calpain substrate and HPP treatments of seabream muscle at 300 Mpa and 400 Mpa results in reduced degradation of desmin correlated with decreased water holding capacity (Campus M. *et al.,* 2010).

Release of Cathepsin from the lysosymes due to pressure induced membrane damage and inactivation of the released enzymes by high pressure has been reported (Ohmori T. *et al.,* 1991). It has been seen that Cathepsin'C' is inactivated in fish by HPP but HPP has no effect in bovine Cathepsin 'C' because of poikilothermic nature of fish (Low PS. and Somero GN., 1974). (In cold environment enzyme tend to have more flexible structure).

Affect of HPP on texture:

1. Pre-rigor treatment for a few minute at 100-200 MPa induces meat tenderization (Ohmori T. *et al.,* 1991 andElgasim EA. and Kennick WH., 1980).
2. 'Puncture Test' – Report says there is a decrease in "strength values"(Ashie INA. and Simpson BK., 1996) decrease in elasticity of muscle but the same has been maintained in storage(Campus M. *et al.,* 2010).
3. Reduced degradation of cytoskeletal proteins (assayed by western blotting) due to blockade of proteolytic activity by HPP.
4. High pressure can affect molecular interactions (hydrogen bonds, hydrophobic interactions and electrostatic bonds) and protein conformation leading to protein denaturation, aggregation or gelation(Messens W. *et al*., 1997).
5. Texturizing effects of HPP have been used to increase the gel strength of uncooked surimi by two to threefold by making protein substrates more accessible to transglutaminase, which increases intermolecular cross-link formationand gel strength (Ashie IN. and Lanier TC., 1999).

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6. 100-500MPa for 10 min. at 0°C has been shown to give greater breaking strength in gels of fish surimi (Okazaki E. *et al.*, 1997).

Affect of HPP on Lipid oxidation

1. HPP promotes lipid oxidation. More rapid increase in the values of thiobarbituric acid reactive substances (TBARS) has been seen after HPP processing (Cheah P. B. and Ledward D.A., 1996).
2. Release of non-haem iron and membrane damage to catalyse lipid oxidation (Orlien V. *et al.*, 2000).
3. Denatured forms of proteins play an important role in catalyzing lipid oxidation (Cheah P.B. and Ledward D.A. (1996, 1997).

Oil sardine treatment alone with HPP upto500MPa showed minimal oxidation, it was concluded that oxidation of fish oil was accelerated by pressure treatment in the presence of fish muscle (Wada S., 1992) and it could be related to the catalyzing power of metal ions present in fish meat.

Lipid oxidation limits the usefulness of this technology for meat-based products unless oxygen-free packaging is used or antioxidants are added. However, oxidation of lipids is a key event for the development of aroma components in dry-cured products finds potential scope in the industry (Toldra` F. and Flores M., 1998).

Seafood intended to be processed with HPP with or without packaging to pressures between 40 and 1000 MPa (1-20 min) having application of physics principle like:

Le Chatelier's Principle

"When a system at equilibrium is disturbed the system responds in a way that tends to minimize the disturbance".

It applies to all physical processes.

Isostatic Principle

"Pressure is instantaneously and uniformly transmitted throughout a sample under pressure whether the sample is in direct contact with the pressure medium or hermetically sealed in a flexible package that transmits pressure".

Simply put in terms of HPP, application of pressure shifts the equilibrium to the state that occupies the smallest volume. Hence, pressure favours reactions accompanied by a decrease in a volume, and *vice versa* (Gross M. and Jaenicke R., 1994, and Heremans K., 1982). That is why probably HPP has the little effect on food product with below 40% moisture content. In concern with seafood, high hydrostatic pressure (400-600 MPa depending on the product) put usually under vacuum in a flexible package through pressure-transmitting liquid (Jime´nez-Colmenero F. and Borderias A.J., 2003). The pressure transfer is instantaneously and uniformly (Delgado AHC.,2003) and the unique part of the process is the independence of the product to be processed and the equipment size and geometry because the pressure transmission is not mass/time dependent, thus minimizing the treatment time and facilitating the scale-up from laboratory findings to commercial applications.

HPP has shown great potential, spreading throughout the world almost exponentially since 2000 especially in meat and vegetables industries. Scope of HPP in seafood-industrial applications:

1. Optimization of HPP conditions to inactivate target micro-organisms for each product and commercial presentation.
2. New packaging systems and combination with natural antimicrobial substances to enhance the shelf-life extension.
3. Development of new seafood products based on cold gelification of starches
4. 100% removal of meat from the shells and for reducing the microbial risks during raw seafood consumption.
5. Marination and impregnation of desired flavors and colors in seafood's.
6. Pressure assisted freezing and pressure assisted thawing - to retain the microstructure and reduce drip loss.
7. HPP induces the gelation in surimi (increase in gel strength of uncooked surimi by 2-3 folds by making protein substrate more accessible to transglutaminase, which increases cross-link formation and gel-strength).

HP freezing and thawing

HP freezing at low or subzero temperatures produces phase transitions in fish. Pressure shift freezing (PSF) generates uniform ice crystals when pressure is released, thus inducing super cooling and instant uniform ice crystal nucleation

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throughout the sample depth (Cheftel, *et al.*, 2000) if the fish muscle is cooled just above the freezing point. PSF may result in a better preserved texture of some foods, due to the formation of small ice crystals during fast nucleation (Truong *et al*., 2015). However, ice nucleation and ice crystal growth largely depend on the heat removal rate. PSF studies were conducted on turbot (Chevalier *et al*. 2000), sea bass (Tironi,*et al.,* 2007), and Atlantic salmon (Zhu, *et al*., 2003) showing the superiority of texture obtained by PSF compared to conventional freezing.

CONCLUSION

High Thermal Processing of seafood's meets the demand of natural and minimal processing- avoids chemical addition or high temperature. HPP is Environment friendly technology- no by-products, uses less energy. NTP method improves microbial safety and extends shelf life. HPP Method is not sufficiently effective on its own in inactivating microorganisms and enzymes at intensities that reduce sensory and nutritional quality. Combination with 'hurdles' is required to result in sufficient shelf-life and product safety at minimal loss of fresh food quality. The future perspectives of HPP applications in fish are strongly connected with trends in consumers' preferences that go with the capacity to further reduce fish allergen-city, reduce salts, and obtain products with improved functionality and clean labels. HPP Equipment cost (though coming down) still is a major limiting step. Process documentation, verification procedures need to be worked out for government approval to assure safety (adequate processing).

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