CREDIT SEMINAR

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Credit Seminar on:

"Application of "Minimal heat processing" for fish and fishery products"

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Application of “Minimal heat processing” for fish and fishery products

Introduction

Consumers are generally advised to increase their consumption of seafood due to the health benefits of both lean and fatty fish. It has long been well established that fish is an important source for vital nutrients, and marine omega fatty acids can reduce the risk of both heart and mental diseases. Healthy eating trends have given rise to increased demand for fish and fishery products. Global seafood market was valued at 125.2 billion U.S. dollars in 2017 and is expected to grow to 153.32 billion dollars by 2023.Fish consumption is projected to increase by 16.3%, or an additional 25 Mt, to reach 180 Mt by 2029. For seafood products, the demand for convenience is a trend that needs to be addressed by research and development. The combination of convenience and sensory quality, however, must never compromise food safety.

Thermal processing is one of the methods for achieving safe convenience fish products with an extended shelf life. But fish is very sensitive to thermal processing and will often become tough and dry when exposed to excess heat. For consumers the most important attributes of a food product are its sensory characteristics. Hence technologies that can ensure extended shelf life and food safety while maintaining optimal sensory properties are therefore of great interest. Designing such a thermal process, is challenging since the heat load required for inactivating target microorganisms may cause undesirable quality changes in the lipid and protein fraction. Reduced cooking time at a lower temperature often improves the sensory quality of fish products, though it will reduce the shelf life. New methods which focus on a rapid or minimal heating of fish products, while maintaining the safety level, are therefore vital for new developments.

What are Minimal heat processed fish products?

The category of fish products that has been exposed to a thermal process, typically to a final processing temperature from a low pasteurization at 60°C to a high pasteurization at 95°C for 10 to 30 min., with a water activity >0.85 and pH >4.6.

Why minimal heat processed food

- Diversification in diet
- Health and diet conscious
- More fish in Fresh form
- Ready-To-Cook & Ready-To-Eat

Minimal heat treated fish products

Minimal heat treated fish products includes, Hot smoked fish, Refrigerated Processed Food of Extended Durability (REPFED), Confit products etc.

Hot smoked fish

Hot smoking means curing fish by smoking at a temperature of 70-80 ^{0} C. Hot smoked fish products do not require further cooking before consumption. It is regarded as delicate food items, highly nutritious, containing unsaturated fatty acids, fat soluble vitamins etc. it can be stored upto 2-3 days at 10°c, 6-8 days at 3°c and nearly 6 months at -30°c.

Refrigerated Processed Food of Extended Durability (REPFED)

REPFED is a category of food which includes Cook-chill products and Sous vide products and are marketed as ready to eat or ready to cook products.

Cook-chill products

These products are prepared by minimal heating at temperature ≥70°c <100◦c for >2 minutes and cooled within 30 min. These products are stored at temperature of 0-3°c and have a shelf life of 5 days at 0-3°c or 24 hrs. at 5-10°c. It is recommended to reheat at 70°c minimum for not less than 2 min. and consume immediately.

Sous-vide

Sous vide is a method of Cooking in heat-stable, vacuumized pouches at precisely controlled temperatures. It is also known as low temperature long time (LTLT) cooking and helps to improves shelf-life and can enhance taste and nutrition. Sous-vide prevents the loss of aromatic volatiles and preserves moisture content, resulting in especially flavorful and nutritious food (Baldwin 2012).

Sous vide products

These products are prepared by minimal heating at temperature ≥70°c <100◦c for >2 minutes and cooled immediately. These products are stored either at a temperature of 0-3°c or at -18°c and have a shelf life of 8 weeks at -18°c, 4 weeks at 0-3°c and 12 hrs. At 5-10°c. It is recommended to reheat at 70°c minimum for not less than 2 min. and consume immediately.

Cook-freeze product

These products are prepared by minimal heating at temperature ≥70°c <100◦c for >2 minutes and cooled within 30 minutes. These products have to be stored at a temperature of -18°c and have a shelf life of 8 weeks at -18°c. Once thawed it should be consumed after heating at 70°c minimum for not less than 2 min. One of the major example for cook-freeze product is the Cook freeze shrimps exported from India. Peeled and deveined shrimps are subjected to cooking at 80-90^{o}C for 10-15 minutes. They are packed in bulk or individually and frozen by air blast freezing.

Confit

The word *confit* (pronounced "kon-FEE") derives from the French verb *confire*, which simply means to preserve. Confit consists of cooking in a fat source at low temperatures during long time, then storing it in this fat in a covered container. The temperature of the oil source is crucial, it should not be higher than 90°C, inorder to not boil water in food, and lower than 60°C, in order to tenderize the food. For fish confit, different cooking conditions (temperature/time) are recommended (60 to 65 °C/15 to 20 min) (P´erez Palacios and others 2017). Fat from vegetal (mainly olive oil) or animal origin (lard) are normally used for confit. Once cooked, the food is then packed into containers and completely submerged in the liquid, creating an impenetrable barrier and preventing any further bacterial growth. Since the justcooked food is nearly sterile as it is submerged and is cut off from any potential bacterial contamination sources, it can be thusly stored for a very long time indeed.

Microbiological safety of minimally heat processed fish and fishery products

Minimal processing often relies on the use of multiple sub-lethal stresses or processes to achieve a similar level of microbial control such as that traditionally achieved by using a single lethal stress. Most minimally processed products require refrigerated storage and distribution to maintain food safety. At low temperature, the major microbiological concern is psychrotrophic pathogens that can grow and mesophilic pathogens that survive under refrigeration and may grow during temperature abuse. Listeria monocytogenes, psychrotrophic Clostridium botulinum and psychrotrophic Bacillus cereus are of particular relevance to chilled food. In case of Clostridium botulinum, though the hazard is not very frequent but is very serious. For Listeria monocytogenes, the hazard is more frequent and serious. In case of Bacillus cereus, the food born illness is mild and self-limiting. Hence there is no reported cases of food poisoning. Among these, L. monocytogenes has been considered as a leading cause of death among foodborne bacterial pathogens(Paoli et al.2005)

The inactivation of L. monocytogenes has been suggested as a criterion for minimal heat treatment by the European Chilled Food Federation (ECFF 1996). Listeria is regarded as the most heat resistant of the non-sporulating pathogens, and other species will be more effectively heat inactivated if present (Johnston and Brown 2002; Wong et al. 2002). Codex Alimentarius recommends that the maximum contamination level for L. monocytogenes in food at consumption should be less than 100 CFU/g (Codex Alimentarius, 2009). In cases for which L. monocytogenes is selected, a 6D process is generally adequate, equivalent to 70 °C for 2 min. Incidence of Listeria species in Indian seafoods is also reported. The FDA’s risk assessment on L. monocytogenes indicates that approximately 7% of raw fish are contaminated with from 1 to 103 CFU/g and that approximately 92% are contaminated at less than 1 CFU/g. Less than 1% of raw fish are contaminated at levels greater than 103 CFU/g and <1% at levels greater than 106 CFU/g.

Thermal processes designed for a shelf life of longer than 10 days under chilled conditions require at least a 6 log inactivation (6D) of psychrotrophic non-proteolytic C. botulinum corresponding to 90°C for 10 min (European Commission 1997). In general, the recommended shelf life for products after a 70°C–2 min process is 10 days when stored below 5°C, and after a 90°C– 10 min process is 6 weeks at 5°C.

Target organisms, recommended heat inactivation parameters, and temperature storage conditions that inhibit surviving organisms to grow.

Target organism	Resistance (min.)	Treatment-6D of target organism	Eliminated or controlled	Storage conditions
Psychrotropic nonproteolytic C. botulinum type E	$D_{90°C}$ = 1.5	90°C/10 min.	Proteolytic C.botulinum type A B. cereus	<10°C <4°C
B. Cereus	$D_{100°C}$ = 1-36	100°C/48 min	Proteolytic C.botulinum type A	<10°C
L. Monocytogenes and other non-spore-forming pathogens	$D_{70°C}$ = 0.3	70°C/2 min	Proteolytic C.botulinum type A Nonproteolytic C.botulinum type E B. cereus	<10°C <3°C <4°C

Strategies to reduce the heat load

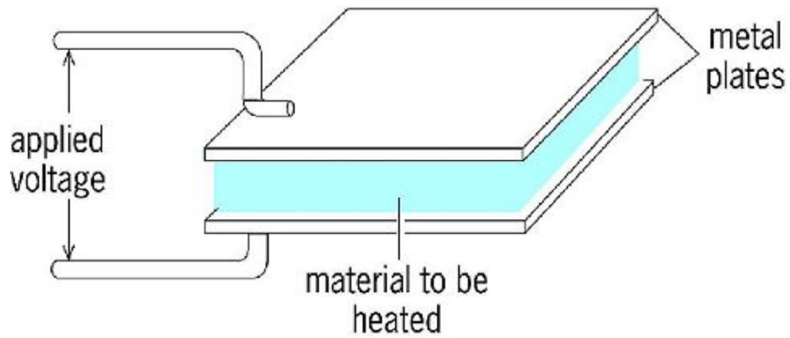
One way of reducing the thermal load is to increase the heating rate by using alternative technologies, increasing convection or conduction or targeting the specific, potentially infected product areas. Compared to traditional oven or retort processes, rapid heating methods are more suitable for continuous processing, and could lead to improved production capacity as well as product quality. In both cases, alternative technologies to conventional autoclaves, combi-steamers or water baths are used for enhanced heat transfer, thereby providing more rapid heating and avoiding unnecessarily high heat loads on part of the product. Dielectric heating, Ohmic heating, Agitated heating (Shaka technology) and surface pasteurisation are technologies that meet these approaches, and are now available for industrial applications.

Dielectric heating

The process of heating up material by causing dielectric motion in its molecules using alternating electric fields. All materials are made up of molecules that are composed of atoms. Polar molecules contain electric dipole moments.On exposing to an electric field, they try to align themselves in the direction of the field. When the applied field oscillates, these molecules of the material undergo rotations in order to keep themselves aligned with the field.This process is called “Dielectric Rotation”.During the dielectric rotation, as the kinetic energy of the molecules increases, the temperature of the molecules increases. When the molecules collide or come in contact with other molecules, this energy gets transferred to all parts of the material thus heating up the material.

Dielectric Heating Working

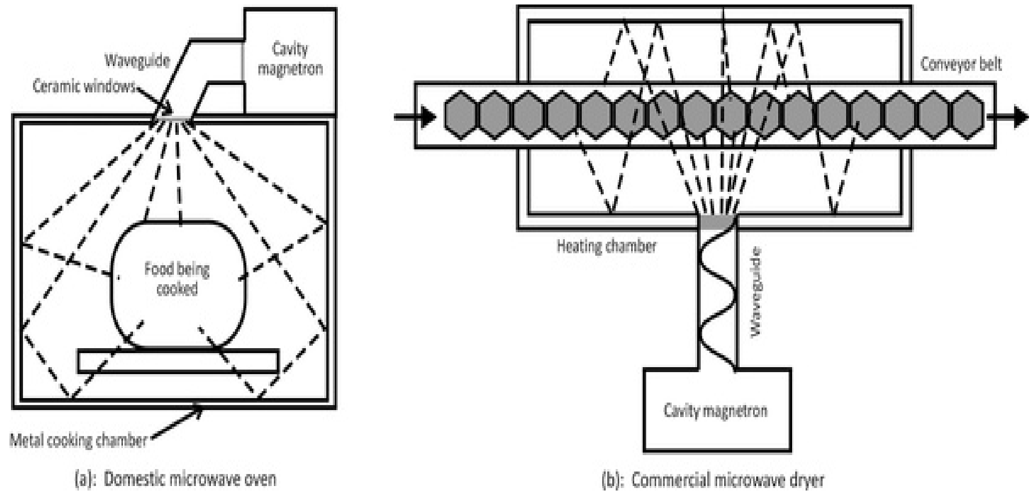
The circuit diagram of the dielectric heating system consists of two metals plates to which the electric field is applied. The material to be heated is placed in between these two metals.



There are two types of ways in which material are heating using the dielectric heating process.

A) When Microwaves are Used

Frequencies of microwave is about 300MHz-300GHz. For food applications the approved and most commonly used microwave frequencies are 2450MHz and 915MHz. (US Federal Communication Commission (FCC)). Microwave volumetric heating provides a larger penetration depth. Thus this heating is used for heating liquids, suspensions, and solids on an industrial scale. In MW heating, the waves generated by a magnetron pass via a waveguide into an oven cavity in which they essentially bounce around off the metal walls of the cavity interior causing effect on the product from many directions



Advantages of MW heating

- Reduction in the thermal processing time .
- Fresh-like taste and texture, and improves visual appeal of the food.
- Retention of nutrients .
- The use of post packaging processing helps in reducing spoilage and provide safe foods for consumers.
- Great opportunities for innovative food companies seeking to develop new food products which have not been possible due to limitation of severe heat in conventional retorting.

Disadvantages of MW heating

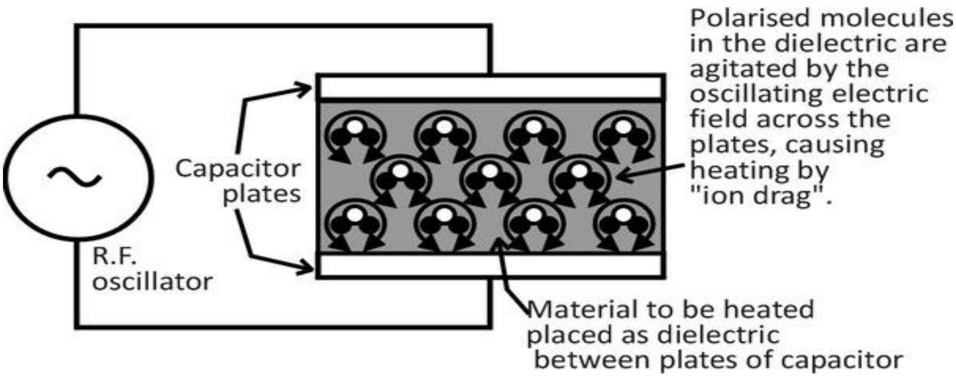
- Less uniform field distribution , hence the occurrence of hot spots and cold spots takes place in food.
- The microwaves cannot penetrate into the food up to 1.5 inches. So, it also important to maintain the shape and size of the food, in order to avoid uneven cooking.

Example of scientific studies of minimal heated fish products using microwave

Fish products	Thermal conditions	Objectives of experiments	References
Salmon (Oncorhynchus keta) caviar, Sturgeon (Acipenser transmontanus) caviar	Varying time at 915 MHz (20 °C to 80 °C)	Determination of dielectric constant, loss factor and power penetration	Al Holy et al. 2005
Shrimps (Penaeus sp.)	300 to 3,000 MHz (to 70 °C)	Determination of dielectric properties	Tanaka et al. 1999
Oysters (Crassostrea virginica)	915 and 2,500 MHz	Determination of dielectric properties	Hu and Mallikarjunan 2005
Sea bass (Dicentrarchus Labrax, Linnaeus, 1758)	16 min at 2,450 MHz	Chilled storage at 2 °C for approximately 15 days	Turkkan et al. 2010
Rainbow trout (Oncorhynchus mykiss)	13 min at 2,450 MHz	Determination of composition of mineral contents	Gokoglu et al. 2004

B) When Radio Frequency are Used

RF Heating works at relatively low frequencies compared to microwave, the wavelengths are much longer. Radiofrequency is a part of the electromagnetic spectrum with frequency in the range of 3KHz-300 MHz. For RF heating, an operating frequency of 27.12 MHz is most commonly used. RF heating technology works with wavelengths 1000 to 10,000 times longer allowing for very uniform heat with large or bulky material. This ability to reach deep inside a material and generate heat uniformly and instantly is one of the primary benefits of RF heating.



Advantages

- Uses lower frequencies than microwave, resulting in longer penetration depths that helps to process bulk food materials that have larger dimensions.
- Uniform field distributions
- Rapid volumetric heating

Disadvantages

- Equipment and operating cost

  RF heating equipment is more expensive and operating cost is higher than conventional convection, radiation or steam heating systems

Example of scientific studies of minimaly heated fish products using radiofrequency

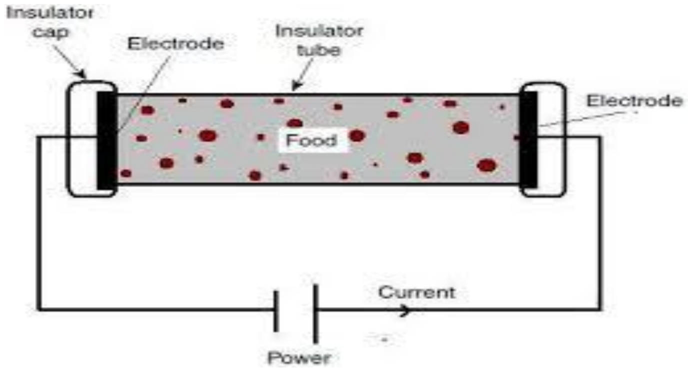
Fish products	Thermal conditions	Objectives of experiments	References
Salmon (Oncorhynchus keta) caviar, Sturgeon (Acipenser transmontanus) caviar	Varying time at 27 MHz (20 °C to 80 °C)	Determination of dielectric constant, loss factor and power penetration	Al Holy et al. 2005
Alaska pink Salmon (Oncornynchus gorbuscha) fillets	Varying from 27 to 1,800 MHz (20 °C to 120 °C)	Determination of dielectric properties	Wang et al. 2008

Ohmic heating

Ohmic heating is also called as Joule heating, electrical resistance heating, or electroconductive heating. It is a heating technology that can ensure uniform, rapid heating, microbiologically safety and high quality foods. AC of voltage and frequency ranges from 120-240V and 50-60Hz are used. Ohmic heating volumetrically heats the entire mass of the food material, thus the resulting product is of far greater quality. It is possible to process large foods that would be difficult to process using conventional heat exchangers.

Principle of ohmic heating

Ohmic heating is based on the passage of alternating electrical current (AC) through a body such as a liquid-particulate food system which serves as an electrical resistance in which heat is generated.



Advantages

- Heating takes place volumetrically.
- Product does not experience a large temperature gradient within itself.
- It results in minimal mechanical damage and better nutrients and vitamin retention.
- High energy efficiency because 90% of the electrical energy is converted into heat

Disadvantages

- High installation cost
- Can not apply for all the food
- Leaching of electrode material into the food systems

Example of scientific studies of minimally heated fish products using ohmic heating

Products	Thermal conditions	Objectives of experiments	References
Sausage	Ohmic heating of 75 °C for 30 s	Determine OH effects on *Listeria monocytogenes* inactivation and changes in quality and sensory attributes	*P. Inmanee, et al. 2019*
Fish steaks	71.88°C, 5.75 min; (voltage 75 V)	The effect of OH on quality para-meters of fresh fish steaks.	Kumar v., et al. 2014
Shrimps (Pandalus Borelias)	72°C, 1150 V m−1 to 1725 V m−1	Application of ohmic heating of cold water shrimp and brine mixtures	Pedersen SJ,et al., 2016
Shrimps (Pandalus Borelias)	72°C ,(15 A, 0–250 V, 50 Hz)	The potential of ohmic heating as an alternative to steam for heat processing shrimps	Lascorz, D., et al., 2016
Alaska pollock surimi	80 °C at frequencies from 55 Hz to 20 KHz	Determination of electrical Conductivity and Physical Properties	Pongviratchai ,et al.,2007

Agitated heat processing

Agitated heating can enhance heat flows rates through forced convection in liquid and semiliquid foods. Through improved heat flow rates, agitated heating can minimize non-uniform temperature zones, overprocessing, and undesirable quality changes. Thermal process experts have studied various types of rotary agitation mechanisms, such as end-over-end or axial rotations. More recently, reciprocating mode of agitation was extensively studied.

Shaka technology

The Shaka technology applies back and forth agitation during the retorting to process the food faster through improved thermal transfer; 90 percent faster depending on the package and food. Faster processing through Shaka technology improves the taste, texture, appearance, and nutritional quality of food. A wide range of products from low-viscosity fish soup to highly viscous baby foods can be successfully processed. Shaka technology is feasible for both mild heat pasteurisation and sterilization.

Example of scientific studies of minimally heated fish products using agitated heating

Products	Thermal conditions	Objectives of experiments	References
Fish soup	62°C, 65°C and 68°C for 11.5, 6.8 and 5.5 min processing in agitating mode(80-100 SPM)	Comparison of bacterial inactivation with novel agitating retort and static retort after mild heat treatments	Ates et al. 2014
Fish-based artificial food	59°C,64°Cand 69°C (7 min. To 37.5 min.)	The effect of food matrix rheology and fat content on thermal inactivation of Listeria monocytogenes in the Shaka agitated retor	Verheyen et al, 2021

Advantages

- Improve heat transfer
- Reduce process time
- Minimize heat damage

Disadvantages

- Shaking, rotating etc. will make the fish fall apart.

Surface Pasteurisation

The thermal load required for pasteurisation will negatively affect most fish products with respect to sensory quality. At certain stages of the production chain, however, reducing the bacterial load through targeting the surface may be an option. The amount of heat needed to kill 100 bacteria on 1 cm2 is 15 million times less than that required to cook the surface to a depth equal to the length of a bacteria (Morgan et al. 1996). Based on this, surface pasteurisation appears to be a sound approach. Even so, there are a number of complicating elements, of which most are related to the target area, namely the surface.

Fish muscle interior is sterile immediately after slaughter. Hence, the initial post process bacterial load is exterior, and may be targeted as such. When production involves, e.g. the baking or frying of non-packaged products immediately before the packaging step, a surface heating step may be used to inactivate any recontamination on the product’s surface.The process comprises, heating the product surface to at least 80^{o}C, for 20 to 30 seconds, without causing any substantial change in colour and internal core temperature of the product.

Conclusion

Need for the production of safe high quality food that is nutritionally superior and easy to prepare.Meeting the three consumer mega-trends of convenience, health and sensory enjoyment are vital for a products success in today’s market. Benefits of Minimal heat processed fish products are, it assure the sensory quality, assure the nutritional quality and assure the microbial safety. The main challenges with respect to minimal heat processed fish products are, difficulties in maintenance of cold chain, comparatively low shelf life and high expensive.

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