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Ultrasound technology for fish processing and preservation

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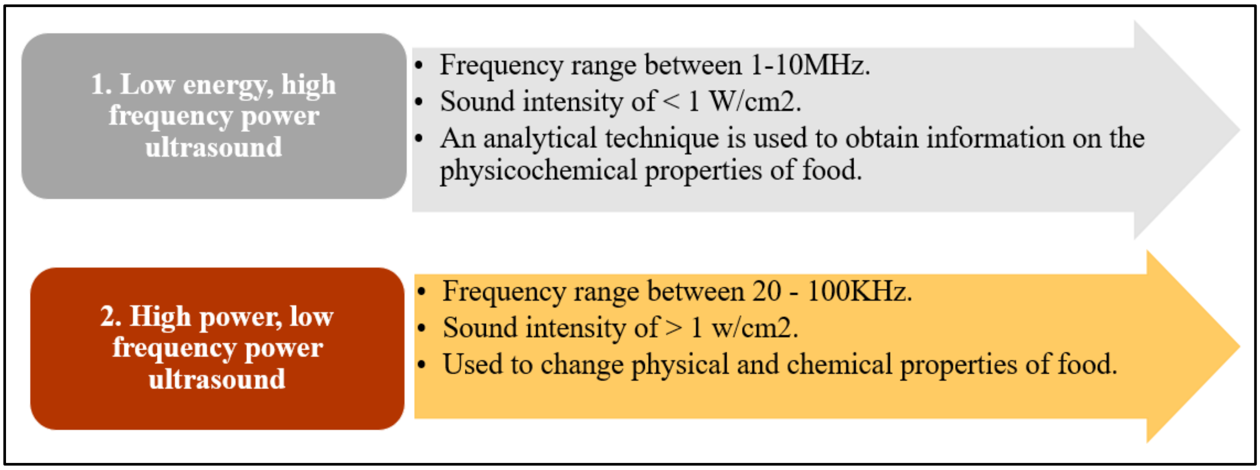
ABSTRACT:
There is an ever-increasing demand for nutritious and safe food products, with fewer changes in their nutritional and sensory characteristics. The most critical elements riding the worldwide meals enterprise in this era are wellness, safety, and convenience.Nowadays, novel types of processing methods are introduced in the production of safe and quality products.Sensory characteristics play a significant role in consumer satisfaction. Food manufacturers' goal is to develop and employ processing technologies that retain or create desirable sensory qualities or reduce undesirable changes in food due to processing. Fish and fishery products are more prone to spoilage than any other products because of high moisture content. To maintain the quality and safety of seafood, different types of processing methods are employed. Many advanced technologies have a scope to prolong the shelf life of seafood for an extended time, and one is ultrasound technology.

Introduction

Ultrasound is focused on mechanical waves at a frequency above the human hearing,i.e., above the mark of 20 MHz. Ultrasound causes compressions and depressions of the medium particles that transmit a high amount of energy to the substance when propagated through a biological framework. Ultrasound is one of the latest nonthermal technology developed to reduce processing time, increase safety, and ensure food quality. Ultrasound is used to produce beneficial food processing results, such as improved mass transfer, food protection, thermal treatment assistance, texture modulation, and food analysis.Ultrasound can be used effectively in crystallization process modification and control, liquid food degassing, inactivation of enzymes, freezing, drying, filtration, and induction of oxidation and microbial inactivation.

Type of ultrasound frequencies used in food industry

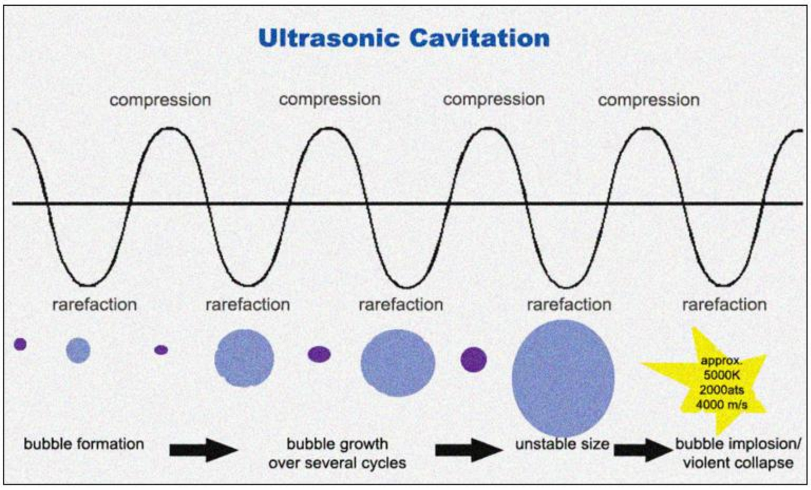


Action mechanism of ultrasound technology

The primary mechanism by which ultrasound works on foods is acoustic Cavitation.Acoustic Cavitationis the process of bubble generation, growth, and the application of ultrasound causes eventual collapseinto food systems. The bubbles oscillate and collapse as ultrasound waves spread, causing a thermal, mechanical, and chemical effect. Collapse friction, turbulence, and shear stresses are mechanical effects, while the chemical effects include free radical generation.

Effects in the cavitation zone create extremely high temperatures (5,000 K) and pressures (1,000 atm).Locally induced alternating positive and negative pressures cause expansion or compression of the content, resulting in changes in the food system, depending on the ultrasound's frequency.Depending on the strength of the ultrasound, locally induced alternating positive and negative pressures cause expansion or compression of the material, which causes changes in the food system. Ultrasound induces water hydrolysis within the oscillating bubbles, leading to the creation of free radicals H+ and OH that can be caught in specific chemical reactions,e.g., free radicals be scavenged by amino acids of the enzymes involved in structure stability, substrate binding, or catalytic functions.

Bubbles formed in liquid foods are classified into two groups based on their structure: (1) stable cavitation bubbles are known as non-linear, forming large bubble clouds of equilibrium size during pressure cycles. (2) The inner (transient) cavitation bubbles are classified as non-stable, quickly collapsing and disintegrating into smaller bubbles.



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Application of ultrasound in fish processing and preservation

The processing of whole fish for human consumption requires immediate and meticulous care to preserve its nutritional quality. Fish are supposed to be kept at low temperatures to slow the spoilage rate, and subsequent processing follows. However, the deterioration of a commodity before it reaches the market is not unusual. It can lead to a substantial loss of fish resources, requiring quicker and more efficient processing approaches. Simultaneously, the demand for healthier, organic products that do not use high chemicals or preservatives. The objective was to develop an ultrasound-based system to minimize processing times, such as washing, freezing, thawing, dehydration, and inactivation of microbial inactive. Ultrasound is a well-established preservation method used in many food production areas, such as pre-and post-harvest fresh vegetables and fruits, cheese production, and frozen seafood.

1. Freezing and crystallization

Freezing of fish is one of the best suitable methods for the preservation for a long duration. During freezing all free water get freeze and form ice crystals. The crystallization process should be fast; either it will createa large crystal size, which can degrade the final products' quality. Initial nucleation followed by crystallization is the main steps involved in the freezing of seafood. Ultrasound plays a crucial role in the creation of crystals. Incorporation of ultrasound leads to nucleation sites' development in the medium increases both the nucleation rate and crystal growth rate. Whereas in conventional freezing, issues such as non-uniform crystal growth and destruction of the cell structure. Conventional cooling also offers much faster seeding when ultrasound is applied, thus reducing the freezing time. Ultrasound ranging from 20 kHz to 100 kHz is beneficial in the crystallization process.

2. Thawing of fish

To preserve consistency, the thawing process of frozen seafood is of great importance. There should be little impact on the texture of the product if the thawing process is done correctly. As a rule, the thawing process should be carried out as quickly as possible to prevent microbial off-products from rising and preserving the food's sensory characteristics. Furthermore, unwarranted heating of seafood, excessive drip loss, and dehydration should be avoided by the thawing process. A prolonged and costly process can cause chemical and physical changes in the thawing of frozen food products. Therefore, rapid thawing at low temperatures is necessary to preserve a good quality of seafood, and excessive dehydration must be avoided. The relaxation mechanism work showed that when applying a frequency in the ice crystals relaxation frequency range in the food, frozen fish could absorb more acoustic energy. The thawing method was also faster than the process using only conductive heating at this relaxation frequency. It is believed that acoustic thawing is a powerful technology in the food industry if the acoustic intensity and frequencies are optimum.The conventional thawing method, such as air thawing, water thawing, and vacuum thawing, is prolonged and costly.Adequate frequency is essential for food thawing. The greater frequencies will be attenuated, and the lower frequencies will induce Cavitation. Using ultrasound-assisted thawing at 1.5 kHz and 60 W took 70% less time than using water immersion thawing from -29 to -1 ° C.

3. Drying / Dehydration

Drying/dehydration of fish under sunlight is a typical traditional process, but it has the main problem of retaining internal moisture. Furthermore, fluctuations in environmental conditions and direct exposure to sunlight affect the color, taste, and nutritional value of food items. Using the technology of ultrasonic osmotic dehydration to increase the rate of dehydration. Therefore, the oxidation risk has decreased. The color, taste, and nutritional value remain unchanged by the use of ultrasound.Power ultrasound also improves heat and mass transfer phenomena in drying processes. To increase drying effectiveness, US-assisted dehydration has been combined with other types of dehydration, including convective, osmotic, vacuum, and freeze-drying. To overcome the surface tension for dehydration purposes, ultrasound-assisted osmotic dehydrationrelies on the sponge effect, cavitation effect, and induced mechanical changes in fish. As the ultrasound wave passes through solid with high intensity, it causes alternating expansion and compression (called sponge effect). The force created by the sponge effect forms a microscopic channel. It acts as a preferred channel for the external diffusion of water molecules, increasing moisture's efficient diffusiveness. Ultrasound is used in both these processes to boost the drying rate and decrease the drying temperature.

4. Meat tenderization

Meat tenderness is one of the significant indicators for assessing the quality of meat products. Factors that affect fish tenderness are muscle fiber properties, myofibrillary protein properties, and intramuscular connective tissue properties. The ultrasonically aided tenderization of meat is based on cavitation concepts. Meat tenderness induces the collapse of cavitation bubbles. Such falling bubbles create very high temperatures locally and pressure and micro-streaming, which happens with high shear forces. These effects can speed up the flow of enzymes and increase enzymes' mass transfer, thus improving enzymes' catalytic ability. Intense shear forces are generated by ultrasonic Cavitation.The muscle fiber properties associated with muscle tenderness, the properties of myofibrillar proteins, and intramuscular connective tissue properties were primarily affected by ultrasound tenderization to achieve the goal of improving muscle tenderness. Two techniques are used to perform power ultrasound, a useful tenderization method

- Muscle cells are split, and myofibrils are separated by ultrasonic Cavitation
- Increasing the rate of enzymatic reactions by using biochemical effects.

5. Ultrasonic emulsification

In the development of many formulated foods, emulsification is the most important process. Emulsifying properties are valuable functional features that play an important role in producing fish protein hydrolysate, fish protein concentrate, emulsified surimi gel, and many other products. In most food emulsions, proteins are the components that dominate.

Emulsions are dispersions of two or more immiscible liquids. Food emulsions may contain oil in the form of water(O/W) or water in oil (W/O). Protein emulsifying action is the protein's ability to create emulsions and stabilize the emulsion that has been freshly formed. Ultrasonics is a comparatively cheaper emulsion forming method with a noticeable effect on emulsion droplets' size and shape. As with microemulsion formation, unless the mixing is random, the process requires an energy input through mechanical agitation or ultrasonic agitation to allow small droplets to form. Highly intensive ultrasound supplies the power needed to disperse a liquid phase (dispersed phase) in small droplets in a second phase (continuous phase). In the dispersing zone, imploding cavitation bubbles cause intensive shock waves in the surrounding liquid and result in liquid jets of high liquid velocity. An ultrasound can reasonably achieve a mean droplet size below 1 micron (micro-emulsion).

6. Ultrasonic assisted cell extraction

Monitoring the composition and physicochemical properties of food during processing and storage is essential for producing high-performance, quality, and stable food products. Different classes of compounds, such as aromas, polyphenols, organic substances, and minerals, have efficiently been extracted from various matrices using the ultrasound.

A significant application of high-pressure ultrasound is to facilitate the process of extraction from fish (e.g., protein, polysaccharides) and bioactive ingredients (e.g., antioxidants). HPU's action is due to Cavitation, which generates high shear forces and microbubbles.

The mechanical effects facilitate greater penetration of the solvent into the cells, improving the transfer and the cavitation effect, which causes the cell walls to break and release their contents into the medium. Therefore, with this technology, higher yields are obtained in less time with lower processing temperatures. Some scientists were able to extract collagen, gelatin, and volatile compound from different fish skin.

7. Enzyme inactivation

In biotechnology and related fields, enzymes are vital tools because of their catalytic nature. Consequently, for centuries, they have been commonly used in food production and processing, but fish preservation at low temperatures can cause quality issues due to enzyme action. After capturing fish, proper beheading and degutting should be performed either digestive enzymes can reduce fish's shelf life.A practical method for improving the stability, shelf-life, and qualityof fish is the enzymes' inactivation. Depending on the sensitivity of the ultrasound, ultrasound power is used to increase or inactivate enzymatic activity. Cavitation and acoustic streaming are generated by ultrasonic shock waves in the liquid medium, creating enough mechanical, thermal, and chemical effects to inactivate enzymes.

Some enzymes are responsible for the enzymatic browning in crustaceans resulting in decreased sensory quality. Polyphenol oxidase (PPO) and peroxidase are specifically the enzymes involved in enzymatic browning (POD). Heat treatment is commonly used in the food industry to remove enzymes. Although PPO is very heat-sensitive, POD is heat-resistant. Full inactivation of POD by heat treatment would also result in the loss of heat-resistant substances and decrease the product's nutritional value. Ultrasonication cavitation cause changes in the microstructure of cells and produces free radical, which help inactive enzymes.

8. Desensitization

More than 170 kinds of food can cause allergic reactions; 90% of the occurrence is primarily due to allergic proteins in milk, eggs, soybeans, shellfish, fish, nuts, peanuts, and wheat. The majority of food allergens were water-soluble glycoproteins with molecular weights ranging from 10 to 70 kDa, stable for treatment with protein hydrolysis, heat, and acid. It is understood that ultrasound modification of proteins is based on cavitation effects induced by the bursting of bubbles that release an instantaneous amount of energy. In addition, the hydrogen bond and van der waals interactions in the polypeptide may be disturbed by intense agitation induced by microfluidics, thus altering the conformational structure of the native protein/allergen. Seafood is a rich source of protein, and its protein consists of various types of allergic compounds that may not be suitable for some people. Troponin is the primary allergen that is found in both fish and shrimp. Troponin is a 34-38 kDa protein with an alpha-helical coil secondary protein structure. The epitope consists of amino acids, namely glutamic acid, arginine, serine tyrosine, and phenylalanine, which shows an allergic reaction in some consumers.High-intensity ultrasound (HIU) can oxidize cysteine, methionine, and lysine troponin and induces free radical degradation of troponin via protein fragments. In polypeptide chains, the rapid formation and collapse of bubbles can break both hydrogen bonds and interactions with van der Waals. The application of ultrasound affects the enzyme's secondary and tertiary structure and contributes to losing their biological function.

9. Microbial inactivation

Thermal pasteurization and sterilization are two standard procedures for inactivating microorganisms in food products by using heat. However, these treatments' efficacy requires long-term exposure to elevated treatment temperatures, leading to decreased nutritional and sensory quality of food and impair its functional properties. Many attempts have been made to develop alternate food safety and sanitation procedures to reduce unwanted heat effects.In particular, high-pressure ultrasound has shown many advantages over heat pasteurization, such as reducing the loss of taste,even homogeneity, and substantial savings in energy. Microbial inactivation of ultrasound treatment accounts for acoustic cavitations. Cavitation is the creation, growth, and breakdown of gas bubbles in liquid media that can generate mechanical energy on a localized basis. By causing significant damage to the cell wall, Cavitation will destroy cell structure and functional components up to the point of cell lysis.Gram-negative bacteria are more susceptible to ultrasound effects than Gram-negative bacteria. This distinction is possibly attributable to the fact that due to the cross-over of peptidoglycan and teichoic acid, gram-positive has a thicker and more stable cell wall, which renders these bacteria less prone to ultrasound.

Conclusion

Ultrasound is used in science and food technology to research foodstuffs' composition and detect contamination by foreign materials in foods. Not much research has been done on fish processing ultrasound technologies. Still, much potential research is needed to develop industrial-automated ultrasound systems to help minimize labor, prices, resources and ensure full production of high-value and healthy food products.Ultrasound is an innovative technology called green technology as it saves a lot of energy and maximizes efficiency, being non-toxic and eco-friendly.