

Overview of research progress on new processing technologies for aquatic products

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Abstract. China is rich in aquatic resources and the aquatic processing industry is developing rapidly, and the market potential of products produced using various aquatic raw materials is huge. The socio-economic development and the improvement of people's consumption level have put forward higher requirements for aquatic products, which further promote the technological innovation of related processing. The article classifies aquatic products into six categories: fish, shellfish, algae, crustaceans, echinoderms and cephalopods, and introduces the technological innovations and applications in freezing and preservation, sterilization, and by-product utilization in recent years, respectively, to provide reference for the continued development of aquatic products processing industry in the future.

Keywords: aquatic products, fish, shellfish, algae, crustaceans, processing technology, research progress.

1. Introduction

China's marine spatial resources, water body resources and biological resources are huge and have a vast potential for development. With the rapid socio-economic growth in China, the fisheries industry has also been fully developed. Aquatic industry in the economic, social and other aspects are closely related to China's sustainable development goals, the "People's Republic of China 2022 National Economic and Social Development Statistics Bulletin" shows that: China's 2022 annual aquatic products production of 68.69 million tons, an increase of 2.7%, the production is very rich. Most of the aquatic products contain unsaturated fatty acids, proteins, polysaccharides and other nutrients with a variety of functional ingredients. However, at present, China's aquatic processing industry still has the problems of low value-added products and high waste of by-products [1]. Therefore, it is particularly important to develop and promote new green aquatic processing technologies that are efficient, effective, and low energy consumption. In this paper, based on previous studies, aquatic products are divided into six categories: fish, shellfish, algae, crustaceans, echinoderms, and cephalopods, and the development and application of new aquatic processing technologies in China in the context of new development is summarized and concluded.

2. Fish processing technology

2.1. Freezing technology

2.1.1 Technology Introduction

Frozen processing methods are widely used in the fish processing industry for the preparation of frozen food or frozen packaged products of fish such as instant fish steaks and instant fish meat. According to the development of technology, the freezing processing process can be divided into traditional freezing technology and emerging freezing technology, and the principles, processes and applications of these two types of technology will be introduced below.

2.1.2 Traditional freezing technology

Traditional freezing methods include blast freezing, cryogenic freezing and flat contact freezing, and the basic process flow is shown in Figure 1.

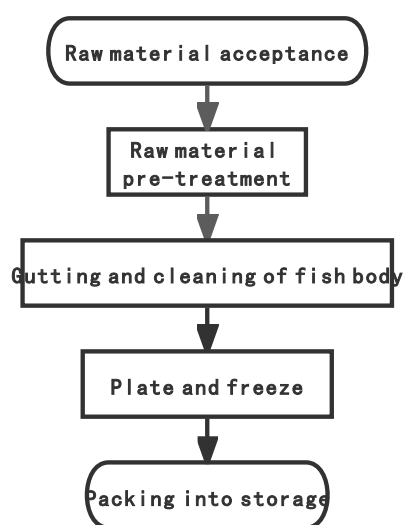


Fig. 1 Traditional fish freezing process

During the freezing process, the fish plate with raw materials is quickly put into the freezing room for quick freezing, and the sign of freezing completion is that the central temperature of the product is reduced to below -15°C . After freezing is completed, the plate is quickly removed and wrapped in ice coat. The ice coat is formed by using the low temperature of the fish product to freeze the water around the fish body. The ice-coated fish pieces are placed in a freezer at $(-18\pm 1)^{\circ}\text{C}$ for storage [2]. Due to the low thermal conductivity of food products, the freezing rate of conventional freezing techniques is usually low. Low freezing rates usually produce large, irregularly shaped and unevenly distributed ice crystals, which adversely affect fish muscle tissue. The damage caused by ice crystals to fish tissue structure during freezing and chilling may lead to problems such as decrease in tissue water content and denaturation of some proteins, reducing the nutritional and commercial value of fish products.

2.1.3 Electromagnetic assisted freezing technology

In the last decade, many research efforts have focused on food processing by electromagnetic wave freezing techniques [2, 3, 4], especially microwave methods. The potential value of using electromagnetic waves to improve freezing efficiency was also explored, especially in microwave freezing [5, 6]. Microwave-assisted freezing is based on the inherent nature of water, in which microwaves can induce dipole rotation, thus causing disturbances in ice crystal formation and growth. As mentioned above, electrical and magnetic shocks can interact with water molecules to rearrange the hydrogen bonds and make the water molecule network system stronger. However, to achieve the same effect, stronger magnetic fields are required, and electric fields have proven to be more effective in changing the conformation of the water network than magnetic fields, meaning that the effect of electromagnetic waves on water molecules comes mainly from electrical interference.

Currently, electromagnetic assisted freezing is at an early stage of development, with only a few published studies on actual food processing [7], and it is not yet fully operational in real production.

2.2. Pulsed Electric Field Technology (PEF)

2.2.1 Technology principle

In order to meet the market demand for fish products with higher nutritional value, better color, and better morphology, food companies and academia are conducting relevant new technology development. Pulsed electric field technology is a new non-thermal food sterilization

technology that can induce modification of meat and fish tissues and improve the ability to extract high value-added compounds from fish products.

Pulsed electric field treatment treats semi-solid, liquid raw materials with higher electric field strength (20-80kV/cm), shorter pulse width (0-100 μ s) and higher pulse frequency (0-2000Hz) to kill microorganisms. Under the action of pulsed electric field, the morphological structure, cell wall membrane, and biochemical reactions of microorganisms are subjected to different degrees of change, which affects the original physiological functions of microorganisms and causes their destruction or irreversible changes [8].

2.2.2 Process flow

In a pulsed electric field system, fish food can be placed in an intermittent treatment chamber or be continuously pumped through the treatment chamber. The treatment chamber contains pulsed electric field containers, pressurization devices and auxiliary equipment. The treated food products pass through the aseptic system for final product packaging or are sent to storage tanks. Figure 2 shows a flow chart of the extraction of hydrophilic compounds from fish tails using pulsed electric field technology.

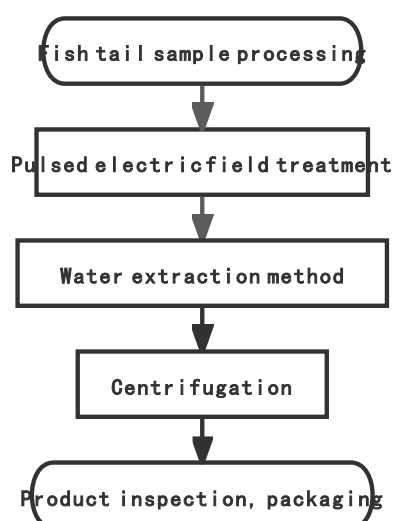


Fig. 2 Flow chart of fish tail treatment by pulsed electric field technology

2.2.3 Technical characteristics

Pulsed electric field technology, as a non-thermal cell membrane permeation method, is characterized by low energy consumption, continuous operation, short processing time, a new green and non-polluting process with broad development prospects in the fish processing industry, is cost-effective, and is in line with the concept of sustainable development [9-10]. Also, this technology can be performed at room temperature or slightly above ambient temperature and minimizes energy loss due to food heating [11].

However, the complex equipment circuitry and high system cost of the pulsed electric field technology are the primary problems in promoting this technology. Also, this technique may lead to disruption of cell membranes of fish products and leakage of intracellular contents, which may result in loss of cellular metabolic activity.

3. Shellfish processing technology

For shellfish processing, according to the difference of processing degree, it can be mainly divided into four process stages: pretreatment, purification, deep processing and by-product processing.

3.1. Shellfish ultrasonic cleaning pretreatment

Pre-treatment of shellfish is an important treatment process for shellfish after harvesting, which mainly includes shell cleaning and impurity separation, i.e. removing other substances attached to the outer surface of shells, such as mucus, seaweed, mud and sand. The traditional manual cleaning process cannot effectively remove the deep dirt, resulting in poor cleaning effect and low efficiency. In order to improve the cleaning efficiency of shellfish, the Institute of Fisheries Machinery and Instruments of the Chinese Academy of Fisheries Sciences conducted theoretical innovation and practical exploration to apply ultrasonic cleaning technology to the shellfish pretreatment process [12, 13, 14].

3.1.1 Technology principle

Ultrasonic cleaning technology, mainly using ultrasonic cavitation in the liquid, the acceleration effect and the direct flow into the action on the tightly attached, so that the attached layer is dispersed, emulsified, separated and then achieved the effect of removal [15], in the deep cleaning at the same time, the research team also took into account the warming effect generated by ultrasound and the effect on the activity of shellfish and process improvement [16].

3.1.2 Process flow

In terms of process flow, the ultrasonic cleaning process for oysters by Jingfeng Zhang's team [17] is shown in Figure 3 as an example.

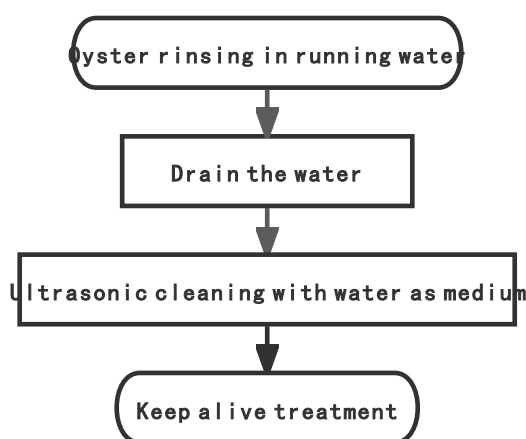


Fig. 3 shellfish ultrasonic cleaning process

The shellfish were rinsed under running tap water for about 1 min. After rinsing, the shellfish were washed with filter paper to dry the surface water and left for 2 min. The mass of shellfish before and after rinsing was recorded separately, and the specific gravity of impurities removed by rinsing was calculated. After the rinsed shellfish were grouped according to the experimental design and put into a glass container using indirect cleaning in ultrasonic equipment, the medium was water. The water temperature change was monitored in real time during the cleaning process. The environmental conditions were controlled constant during the experimental process, and the ultrasonic cleaning frequency, time for single factor analysis control experiment to determine the optimal cleaning combination [17].

3.2. Shellfish biological decontamination method

3.2.1 Introduction of technology

Purification is to send the pretreated shellfish into the special purification tank to reduce the enriched sediment and heavy metals and other pollutants in the body through the shellfish's own normal feeding and metabolic activities, with the aim of obtaining safe and healthy edible

shellfish. Biological metabolic purification technology has become a research hotspot in recent years by virtue of its advantages of being natural, non-toxic and not easy to produce secondary pollution. Biological decontamination method refers to mixing beneficial microbial flora, thus inhibiting the growth and reproduction of harmful bacteria, or feeding baits that can promote the discharge of contaminants to contaminated shellfish through the food chain to accelerate shellfish metabolism and achieve the purpose of reducing contaminants in the organism [18].

3.2.2 Process flow

Ye Ting [19] et al. used the macroalgae lobelia to purify Portuguese oysters with the following process: oysters were purified, 20 mg/L of chitosan and 10 kg of fresh lobelia were added to the temporary water body, and oysters were sampled for heavy metal content. The results showed that the contents of Cu, Cd and Pb in the oysters were lower than the detection limits after 14 d of purification.

3.2.3 Technical characteristics

The biological purification method has the advantages of low cost and wide range of adaptation, while both ecological and regenerative, will not cause secondary pollution, and is suitable for large-scale shellfish purification production in factories.

3.3. Shellfish functional component extraction technology

At present, in addition to some of the freshly sold products in China's shellfish market, most of them will be further processed into pickled products and dried products, most of them use traditional hot air drying, and some of them use cold air and freeze-drying, but due to high processing costs, they are only suitable for high-grade shellfish production. In recent years, researchers have continued to deepen the research and processing of marine farmed shellfish to help make full use of shellfish nutrients and improve the utilization rate of shellfish resources. Shellfish deep processing mainly revolves around the extraction technology of shellfish proteins, sugars and other functional substances [20].

3.3.1 Technology Principle

The production of bioactive peptides by enzymatic digestion is the more common method nowadays. Experimental analysis shows that the selection of enzymes corresponding to the decomposition of active peptides, followed by separation and purification using ultrafiltration and chromatography systems, can obtain a more pure one or a concentration of antioxidant peptides, and the determination of their molecular composition by gas chromatography-mass spectrometry, and the detection of active peptide conformation is important for the study of their antioxidant mechanism and physiological activity [21].

3.3.2 Technical characteristics

Enzymatic digestion is a way to prepare shellfish active peptides by exogenous enzyme or endogenous enzyme pathway. The shellfish bioactive peptide prepared by enzymatic digestion has the advantages of milder reaction conditions, better controllability of reaction, more adequate exposure of bioactive groups and better reproducibility of reaction, which has become one of the main methods for the preparation of shellfish active peptides. The disadvantage of the enzymatic method is that the separation and purification of the products is difficult, making it only applicable to a small range of target substances preparation [21].

4. Algae processing technology

Currently, the overall processing process of edible seaweeds can be divided into four stages: drying of raw materials, sterilization of products, deodorization of algae and extraction of functional substances [22].

4.1. Ultrasonic-IR radiation composite algae drying technology

Drying technology, is to reduce the water activity in raw materials by different physicochemical methods to inhibit the growth of microorganisms in them, oxidation reactions, etc., thus extending the shelf life of food and reducing the loss of nutrients. The most common techniques for drying edible algae are hot air drying, solar drying and spray drying. These drying methods have different drawbacks, but flexible application of their combinations can alleviate these problems, and the combination of one of the more applied techniques, ultrasound-infrared radiation composite algae drying, will be presented next [23].

4.1.1 Technology principle

Ultrasonic pretreatment: when algal raw materials are subjected to ultrasonic treatment, they are repeatedly compressed and stretched, causing the material to continuously contract and expand, forming a sponge-like structure [24]. When the force generated by this structural effect is greater than the internal moisture surface tension, the moisture is easily transferred through the microtubules during drying. Low-frequency ultrasonic treatment changes the structure of edible algae through the "pore effect" and "degassing effect", thus improving the drying efficiency [25].

Infrared radiation drying: Due to the penetrating nature of infrared radiation, its energy is first concentrated inside the material, and when the algae molecules and atoms absorb the infrared irradiation energy, it will cause the particle motion to increase and the molecular vibration energy level to change, resulting in an increase in the internal temperature of the material. At the same time, due to the continuous evaporation of water to absorb heat leads to a decrease in the external temperature, forming an internal high and external low temperature gradient [26]. In addition, the internal water content of most tissues in algae is higher than the epidermal water content, forming a moisture gradient consistent with the temperature gradient. Under the combined effect of the internal high and external low temperature and humidity gradients, infrared radiation drying can greatly enhance the drying rate of materials [27].

4.1.2 Process flow

The basic process flow of this technology is shown in Figure 4.

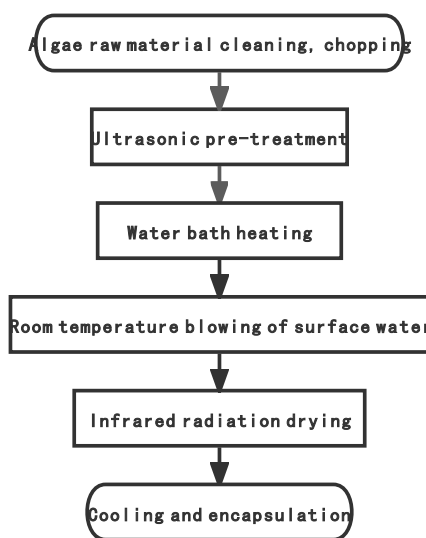


Fig. 4 Ultrasonic-IR radiation composite algae drying technology

4.1.3 Technical characteristics

In a study by Tekin's team [28], it was found that vacuum ultrasonic treatment (USV) was able to improve algae dehydration and reduce drying time by 1 hour. In addition, USV treatment

could produce more phenolic compounds in the product compared to non-ultrasonic treatment. Early studies have demonstrated the effectiveness of ultrasonic treatment for some seafood products, but the application in edible algae is still in the early stages of development.

Infrared radiation technology has low energy loss and high controllability of the action process. From the raw material point of view, most algae have a high absorption of IR radiation and can save energy. In addition, infrared radiation heating causes less loss of change in the food material, which facilitates the improvement of product quality. Moreover, infrared radiation is a simultaneous heating process inside and outside the material, the heat and mass transfer direction is the same, the heating is more uniform and local overheating is avoided. Lee et al [29] compared infrared drying with freezing and hot air drying and found that infrared dried samples had higher phenolic content and better antioxidant activity. Infrared drying reduced the drying time of kelp by 57% compared to hot air drying [26].

4.2. Radiofrequency algae sterilization technology

4.2.1 Technology Principle

Radiofrequency sterilization (RF) refers to the use of electromagnetic waves (1-300 MHz) to generate heat to heat liquid, solid, and semi-solid raw materials to inactivate the microorganisms contained therein. The principle of RF heating can be divided into two parts: ionic conduction and dipole rotation. Ionic conduction, i.e. positively charged ions in algal raw materials move in the direction of the electric field, negatively charged ions move in the opposite direction and continuously change their direction of motion with the alternating electric field. In this process, the ions collide with other molecules and the hydrogen bonds of water molecules break prompting the conversion of ionic kinetic energy into thermal energy to heat the raw material [29]. And dipole rotation is the use of water molecules as a representative polar molecules in algae raw materials, according to the polar molecular dipole characteristics, the food is in the radio frequency alternating electric field, its internal polar molecules will be rearranged due to the change in the direction of the electric field, and this arrangement in the alternating electric field at a frequency of more than millions of times per second, resulting in intermolecular friction a lot of heat generation [30].

4.2.2 Process flow

The RF sterilization process flow is: raw material pretreatment, initial disinfection by immersion in sodium hypochlorite solution, product color protection treatment, followed by 20 min sterilization using an RF processor (6 kW, 27 MHz, plate spacing 20 mm) [31].

4.2.3 Technical characteristics

RF heating sterilization compared to traditional methods such as autoclaving, autoclaving, etc., has the characteristics of high efficiency, high degree of nutrient retention, and better maintenance of food color, flavor and other sensory qualities. RF heating is faster and more uniform than microwave heating, allowing for deeper internal heating of the sample. Moreover, RF heaters are relatively simple to configure and have a large loading cavity volume, while being easy to operate and handling a larger volume of raw materials in a single pass [32].

However, this technique has limitations and the most concerned issue in RF heating is the variation of dielectric properties leading to uneven heating of food materials. Also the penetration energy of the irradiated electron beam is low, resulting in higher irradiation doses required for spore inactivation, which may lead to consumer concerns about food safety [33]. RF heating also has problems such as incomplete pathogen inactivation, and the corresponding testing standards need to be improved.

4.3. Microencapsulated algae deodorization technology

The fishy taste of volatile components in edible algae can seriously affect the sensory experience of consumers and limit the development of the edible algae industry. Current

deodorization techniques mainly include the acid-base salt method [34] and autoclaving method [35]. Although these techniques have a certain deodorization effect, they are detrimental to the proteins and vitamins in algae, thus affecting the nutritional value of edible algae. To better solve the problem of fishy odor removal from algal material, microencapsulation is an efficient technique.

4.3.1 Technical Principle

Microencapsulation technology refers to the encapsulation of solid, liquid or gaseous substances by forming semi-permeable or hermetically sealed fine particles using polymeric materials [36]. Microcapsules are usually spherical in shape and some are complex or irregular in shape [37]. Microencapsulation technology can mask the fishy odor of edible algae.

4.3.2 Process flow

Liu et al [38] used microcapsules to encapsulate the algae and the process is shown in Figure 5.

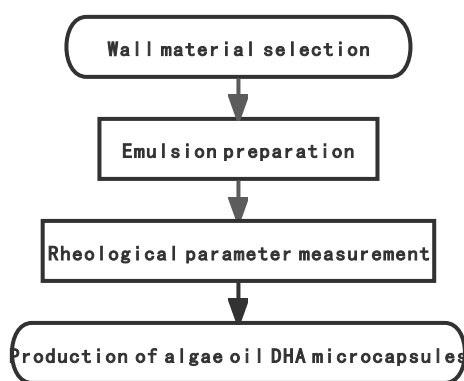


Fig. 5 Microencapsulated algae deodorization technology process

For raw material selection, DHA microalgae oil, gum Arabic (GA), whey protein isolate (WPI-90), and EPS-producing strain *L. paracasei* were used. microcapsule production process was performed at 25 °C, followed by water bath cooling to 5 °C. The EPS producing strains were added to the emulsions separately to produce microalgae oil microcapsules, followed by rheological parameter measurements. Finally, microalgae oil DHA microcapsules were produced and the emulsions were spray dried using 180 °C inlet and outlet temperatures, respectively [38].

4.3.3 Technical characteristics

The deodorization effect of microencapsulation technology is better compared with the traditional process of adding acid and alkaline salts, while basically not losing the nutrients such as DHA in algae. At the same time for the algae natural color protection effect is better. However, the production of microencapsulation requires the use of equipment such as spray dryers, and the production cost is relatively high [38, 39].

5. Crustacean processing technology

China is rich in crustacean aquatic resources, mainly shrimp and crab. The following is mainly introduced in recent years crustacean aquatic products anhydrous preservation, sterilization technology, by-product comprehensive utilization of technology.

5.1. Anesthesia method without water preservation technology

Currently applied to the shrimp processing of live transport methods, can be divided into two categories of water preservation and anhydrous preservation. The waterless preservation technology is more innovative than the traditional water preservation technology, to the more widely used anesthesia method as an example. Anesthesia is a method to reduce the response of live shrimp to external environmental stimuli through anesthetic drugs or environmental stress to reduce their metabolic rate to improve survival rate preservation methods, divided into chemical anesthesia and physical anesthesia method [40].

The principle of chemical anesthesia is the use of anesthetics to inhibit the cerebral cortex so that the loss of tactile sensation in shrimp, and then act on the basal ganglia and cerebellum, and finally act on the spinal cord to complete the overall anesthesia. Common chemical anesthetics include carbon dioxide, eugenol, 2-phenoxyethanol, etc. The anesthetic effect, usage, dose, and target of use vary among anesthetics [41].

Physical anesthesia methods inhibit the nervous system of shrimp with the help of physical stimuli, thus reducing the intensity of their response to external stimuli. Common methods include hypothermic anesthesia, electric current anesthesia, and salt solution anesthesia. Compared with chemical anesthesia methods, physical anesthesia methods are safer and more acceptable to consumers [42].

5.2. Ozone non-thermal sterilization technology

5.2.1 Technology Principle

Ozone is an effective sterilization, decolorization and deodorization of high-efficiency residue-free disinfectant. Its antibacterial effect is mainly reflected in its own strong oxidation, and ozone in water can be generated by redox reactions with high reactive superoxide anion radicals, hydroxyl radicals, which destroy harmful microbial cell walls, cell membranes and nucleic acid substances and lead to cell lysis and death [43].

5.2.2 Process flow

Xuanwei [44] used the ozone method for the treatment of Chinese shrimp samples, and the process flow is shown in Figure 6.

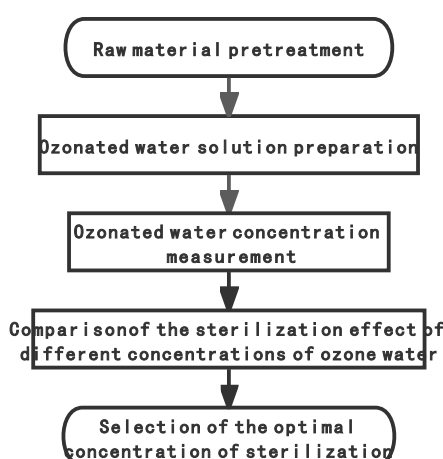


Fig. 6 Ozone method shrimp sterilization process flow

5.2.3 Technical characteristics

The use of ozone for the treatment of aquatic products can effectively sterilize, inhibit bacteria and extend the shelf life of the product, but it can have some negative effects on sensory attributes such as flavor and color of the food. Studies have shown that the sensory score of shrimp treated with ozonated water decreases with increasing action time at the same ozone

concentration. Wei Ya et al. compared ozonated water with other sterilization methods and found that the color of shrimp had a tendency to become lighter after different treatments, but ozonated water treatment had the least effect on the product color [45].

5.3. Subcritical fluid-Antarctic krill oil extraction technology

5.3.1 Technology principle

The subcritical oil extraction technology selects subcritical fluid as extractant, in a closed oxygen-free, low-pressure vessel, based on the principle of similar solubility of organic substances, through the molecular diffusion of the extracted material and extractant in the immersion process, so that the solid material lipid-soluble components are transferred to the liquid extractant, and later the extractant is separated from the target components by evaporation under reduced pressure. The subcritical state refers to a form that exists relative to the supercritical state with relatively mild extraction conditions [46]. Among them, butane and propane are two liquid media widely used for shrimp oil extraction [47].

5.3.2 Process flow

Sun Dewei et al. used subcritical butane separation to prepare Antarctic krill oil, and gas chromatography mass spectrometry was used to detect the volatile components of Antarctic krill oil prepared by the new process, the steps of which are shown in Figure 7 [48].

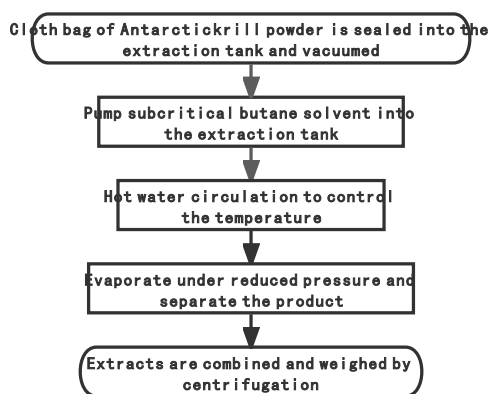


Fig. 7 Antarctic krill oil preparation process by subcritical butane separation

5.3.3 Technical characteristics

This technology has the characteristics of economy, low pollution and better preservation of the biological activity of Antarctic krill oil. At the same time, the subcritical fluid extraction technology has the advantages of low working pressure, relatively low working temperature, high overall efficiency, and relatively low overall investment and operating costs.

5.3.4 Applications

Subcritical fluid extraction technology is a new type of green extraction and separation technology, and there are studies on its initial application to the extraction and purification of highly bioactive oils, proteins and other nutrients in aquatic raw materials, which can overcome the shortcomings of traditional extraction technology with large solvent residues and difficult to remove. At present, most of the crustacean subcritical extraction technology applications are still in the laboratory stage, and in the future, the yield should be improved and technical problems such as easy quality deterioration of extracts in large-scale production should be overcome [49].

6. Echinoderm processing technology

6.1. Vacuum freeze-drying technology for sea cucumbers

6.1.1 Technical principle

Vacuum freeze-drying is to freeze the materials first, and then remove the water directly under vacuum. This method can maintain the original active ingredients and properties of the materials and effectively inhibit the growth and reproduction of microorganisms, which is especially suitable for the dehydration of seafood with special tissue structure such as sea cucumbers, and can reduce the moisture content of sea cucumbers to less than 5% and reduce the loss of nutrients and physiological active substances of sea cucumbers [50, 51, 52].

6.1.2 Process flow

Yang Qing [53] performed vacuum freeze-drying of sea cucumbers to obtain ready-to-eat sea cucumber freeze-dried flakes, and the process flow is shown in Figure 8.

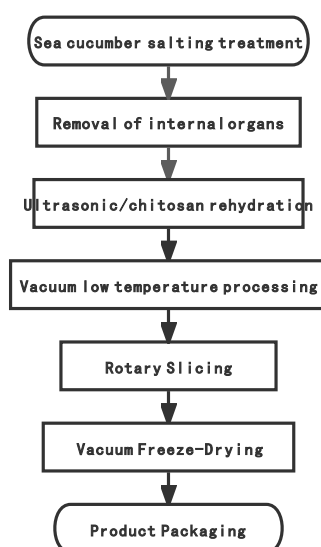


Fig. 8 Process of preparing ready-to-eat products by vacuum freeze-drying technology for sea cucumbers

The optimal lyophilization process conditions were obtained by experimental optimization: lyophilization time of 32 h, sublimation temperature of 25 °C, and ice crystal temperature of -29 °C.

6.1.3 Technical characteristics

The use of vacuum freeze-drying technology can make the material dehydration more thorough and effectively retain the original nutrients and physiological active substances of sea cucumbers, and after freeze-drying, sea cucumbers are rehydrated for consumption, not only the time is short, but also the taste after rehydration is not significantly different compared with that before freeze-drying. Meanwhile, this method can also inhibit the effect of bacteria and enzymes, thus effectively extending the shelf life of sea cucumber products, which is conducive to the long-term preservation, transportation and sales of the products. However, the relatively high acquisition and operation costs of vacuum freeze-drying apparatus and equipment seriously restrict the wide application of this method in the processing of sea cucumber products [54, 55].

6.2. Extraction technology of sea cucumber polysaccharides by salt analysis and extraction

6.2.1 Technical principle

Sea cucumber polysaccharide is one of the main efficacy components in the body wall of sea cucumber, accounting for more than 6% of the dry base, and it also exists in the internal organs and gonads. Compared with the traditional acid-alcohol precipitation method, which only targets one or two active substances [56], it can extract a variety of functional substances in the sample together, with mild reaction conditions and low operational difficulties, among which the double aqueous phase extraction technique formed by hydrophilic low molecular organic substances and inorganic salts has the advantages of easy continuous operation, low solvent cost and high recovery [57].

6.2.2 Process flow

Chen Deling [58] et al. used this technique to extract sea cucumber polysaccharides, and the operation steps are shown in Figure 9.

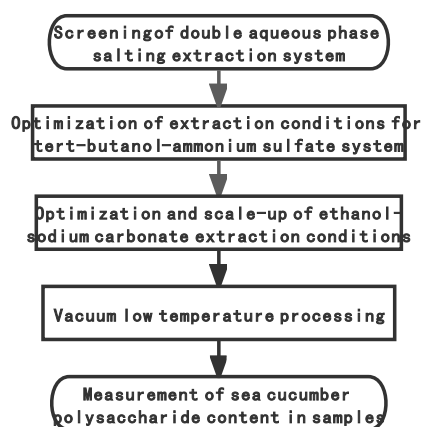


Fig. 9 Extraction process of sea cucumber polysaccharide by salt extraction

6.2.3 Technical characteristics

The extraction method of salinization can separate a variety of active ingredients in sea cucumber processing by-products simultaneously, and the extraction rate is high, which is suitable for industrial production. However, a large amount of organic solvents and inorganic salts will be used in the operation process, which makes the production cost relatively high and the subsequent removal of solvents and inorganic salts is complicated.

6.3. Sea urchin yellow solid beverage processing technology

6.3.1 Technology principle

On the basis of the lyophilized powder of sea urchin yellow, its inherent physicochemical properties are used to develop it into a solid beverage, which retains its bioactive molecules and unique flavor to the maximum extent. Xue Fang's team [59] optimized the processing of sea urchin yellow solid beverage, and the results showed that the optimal addition amounts were 0.1% xanthan gum, 0.15% CMC, and 0.1% guar gum.

6.3.2 Process flow

The processing technology flow of sea urchin yellow solid beverage is shown in Figure 10.

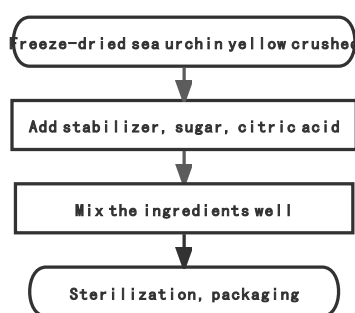


Fig. 10 Sea urchin yellow solid beverage processing technology flow

6.3.3 Technical characteristics

The technology required for the production of sea urchin yellow solid beverage is simple, time-consuming and fast yielding, with relatively low investment in production equipment and relatively simple production process, which is an emerging industry with low production input, high yield and wide demand, with good application prospects and will promote the development of marine economy [60].

7. Cephalopod processing technology

About 700 species of cephalopods exist, including squid and octopus, most of which are edible. 21 century, China's cephalopod processing industry has developed rapidly and has become a major component of the domestic aquatic industry. With the progress of biotechnology and the exploitation of marine resources, squid processing research has been gradually deepened, and the production and types of processed products have been increasing, while squid has become a hot spot for functional food development and is highly favored [61]. The current status of squid food processing and by-product utilization technology is described below.

7.1. Squid freezing technology

7.1.1 Technology principle

Frozen squid is the main raw material for the production of various squid products, and to ensure the quality, squid must be frozen quickly on board after catching. Due to the actual production conditions, the main squid production mode in China is ocean squid fishing and freezing on board, and then transported back to China for subsequent processing. The larger squid are cut into head, torso, tentacles and other parts and then frozen in pieces; the smaller squid are frozen whole [62].

7.1.2 Process flow

The squid freezing process is shown in Figure 11.

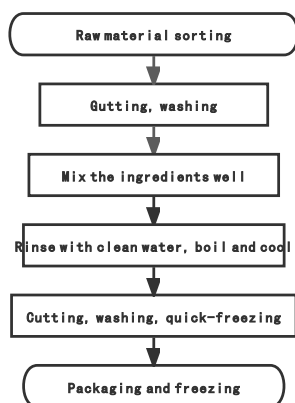


Fig. 11 Squid freezing process

7.1.3 Technical characteristics

This method changes the mode of exporting in the form of raw materials, and the processing process is simpler and has better economic benefits, which is suitable for processing and treating large quantities of fresh squid. However, in the actual fishing process of current fisheries, squid sometimes cannot be frozen or processed in time because of the busy fishing operation and other problems, which will lead to the reduction of product quality. Pretreatment of squid such as gut removal and scalding and bleaching as soon as possible after harvesting can effectively extend the shelf life of squid products [63].

7.2. Squid skin collagen extraction technology

7.2.1 Introduction to the technology

Squid skin accounts for about 10% of the total weight of squid and is rich in collagen. The squid skin collagen extraction techniques mainly include hot water extraction method, acid extraction method and enzyme extraction method [64].

7.2.2 Process flow of compound enzyme method

Cai Jinxiu et al. used a complex enzymatic method to prepare squid skin collagen antifreeze peptide, and the results showed that the optimal enzymatic conditions: substrate concentration of 4% and enzyme addition of 4 000 U-g-1, first by alkaline protease at pH=8, 50 °C for 2 h, and after inactivation by papain at pH=6, 45 °C for 3 h. The steps were as follows [65].

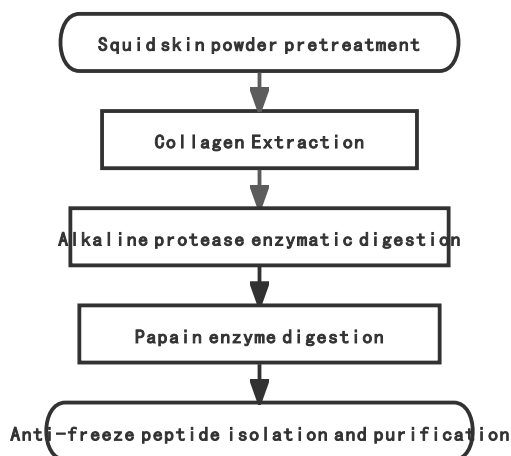


Fig. 12 Preparation of squid skin collagen antifreeze peptide by complex enzyme method

7.2.3 Applications

In practice, enzymatic extraction or combined acid-enzyme extraction is often used. The enzymatic product of squid skin collagen has good emulsification, solubility and processability. Also the enzymatic digest is rich in active peptides, which have physiological functions such as lowering blood pressure and antioxidant.

7.3. Comprehensive utilization of squid ink

Squid ink is rich in active ingredients such as polysaccharides, peptides and melanin. Among them, melanin can enhance the radiation resistance of organisms, and has a variety of physiological effects such as antioxidant and immunity improvement. Polysaccharides have antiseptic and preservative effects, as well as antioxidant and antibacterial properties [66].

7.3.1 Extraction process of ink polysaccharides

Yang Lizhi [67] studied the isolation and purification of polysaccharides from the ink of the South Sea kris squid, and the polysaccharide separation was carried out by the aqueous extraction and alcoholic precipitation method, the steps of which are shown in Figure 13.

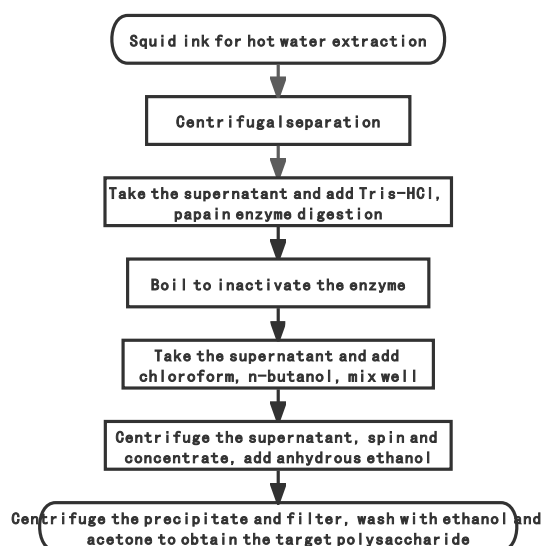


Fig. 13 Iris squid ink polysaccharide isolation and purification process

The crude polysaccharide yield of 0.91% and polysaccharide content of 9.8% were obtained for the optimal process conditions of Iris squid ink polysaccharide [68, 69, 70].

8. Conclusion

This paper summarizes the principles, processes, and characteristics and applications of emerging technologies for freezing, sterilization, functional substance extraction, deodorization, and anhydrous preservation of fish, shellfish, algae, crustaceans, echinoderms, and cephalopods. In recent years, the development of a variety of new processing technologies in the field of aquatic products, the refinement and improvement of processes, and the upgrading of production equipment have led to a complete industrial chain in China's aquatic processing industry, but many technologies are still in the laboratory stage of small-scale production, and processes suitable for larger-scale production are being improved and optimized. At the same time, the extraction of functional substances in aquatic products has become an emerging industry hotspot, and it is foreseeable that more aquatic raw material health products will be developed and produced in the future.

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