Marine factory farming techniques and equipment

Jialuan Xiaoa, Yingyu Zhang
Junior students, Dalian University of Technology
aJLxiao@mail.dlut.edu.cn, 943485676@mail.dlut.edu.cn

Abstract. Marine factory farming is a short-lived but rapidly developing industry. Traditional aquaculture occupies a large area of water resources. At the same time, it has great damage to the environment and is not in line with the idea of sustainable development. Now marine resources have gradually become a hot topic. The marine factory farming industry combines a variety of emerging and traditional industries, such as machinery and automation, chemistry, biology, computer science, etc., have great development potential today. This paper discusses the technology and equipment in the process of marine factory culture from the basic situation of marine factory.

1. Summary of Marine Farming

1.1. Overview of Domestic Development
Marine factory farming, also known as facility fishery, is a kind of high-density and intensive planned production of marine biological products by combining traditional aquaculture fisheries with modern aquaculture plants and mechanical equipment. The disciplines involved in this fishery include: mechanical design and manufacturing and automation, seawater treatment chemistry, architecture, marine biology, environmental science and engineering, economics and electronic information, to realize a low-pollution, high-return, automated aquaculture industry and achieve the strategic goal of sustainable development on the basis of protecting the environment, using modern technology and equipment, and through knowledge of various disciplines such as ecology, economy, chemistry, and machinery. Marine factory farming is one of the important ways for humans to utilize marine biological resources and develop marine-related industries.

It is reported that China's marine factory farming started relatively late and can be roughly divided into three stages: The first stage is the pioneering stage (1985-1998), the second stage is the exploratory stage (1999-2006), and the third stage is the integration stage (2007-2011) [1]. The first stage was in the 1970s and 1980s, when foreign related aquaculture technology was introduced into China, and then entered the stage of exploration and attempt. With the support of the state and the development of some enterprises, the related science and technology were conquered. In the late 1990s, my country’s marine factory farming began to develop in scale, industrialization, and industrialization. As related companies continue to develop and grow, my country also basically has its own set of marine factory farming. The technical system, although not yet mature. It was not until the 1910s that China’s marine factory farming was considered to be nearly mature. Except for some inland areas such as Tibet and Inner Mongolia, marine factory farming has basically been popularized throughout the country, and the corresponding technology and equipment have been obtained. With innovation, the types of marine organisms that are cultivated are also increasing, and stable and high yields can be basically achieved throughout the year. The corresponding industrial chain and economic chain have gradually improved and grown.
Up to now, our country’s marine factory farming has achieved a certain scale, and new breakthroughs have been made year by year. My country’s marine aquaculture area and total output have reached the first place in the world. The water treatment system and related aquaculture equipment and facilities have all realized industrialized manufacturing. The core technology has also achieved national control and has achieved a certain leading position in the world. Although China’s marine industrial aquaculture has developed rapidly in recent years, compared with foreign countries, we have a considerable gap in terms of input-output ratio, high-tech level, and technology intensiveness. The environmental pollution caused by excessive offshore aquaculture cannot be underestimated.

1.2. Overview of foreign development
The world's factory farming originated in developed countries in Europe and the United States in the 1960s. Its technical basis comes from inland marine aquarium technology, automated aquarium technology and flowing water high-density aquaculture technology. The history of industrial fish farming in the world is only more than 30 years, and it has developed rapidly. According to the development process, it is divided into three stages. [2]. The three stages are quasi-industrial farming, industrial farming and modern farming.

The first stage is in the exploratory stage. Since the 1960s, Europe has begun to explore the production mode of recirculating aquaculture, but this method has not become the mainstream production method during this period. The equipment and technology required are mostly explored and used by themselves, and the degree has not reached the level of industrialization. Although aquaculture has begun to be planned, and various technologies have been adopted, such as intensive, aeration, and the output value has increased as a result, the cost is still very high.

The second stage is industrialized aquaculture. In this stage, a variety of technologies have been innovated and the corresponding equipment has been developed. Aquaculture has begun to adopt mechanical filtration, biological purification, and oxygen-enriched technologies. Marine aquaculture has basically achieved sustainability.

The third stage is modern farming, which began in the late 20th century. Due to the development of high-tech such as biology, materials, and computers, these technologies have begun to be applied to factory farming. Microorganisms such as various beneficial bacteria are used to maintain the micro-ecological system. New materials, led by nanomaterials, also appear on breeding equipment. The advent of breeding software has promoted the modernization, automation and informationization of factory farming.

1.3. Future trends
In the future, recirculating aquaculture is still an advanced development direction of marine factory farming. In the coming period of time, in the new productivity, the two methods of temperature controlled flowing water aquaculture and circulating aquaculture will still appear as the main forms of land-based factory farming, but the proportion of circulating aquaculture will continue to increase [3]. Simultaneously, the industrial structure will continue to develop and upgrade. Among them, sustainable development is a long-lasting concept in the future. How to develop green, healthy, safe and high-efficiency factory farming is a top priority in the future.

In addition, the importance of marine resources continues to increase in this century, and aquaculture fisheries are also part of the ocean. Corresponding technologies such as energy saving and emission reduction and intelligent control will also increase investment. All in all, the future mainstream development direction of marine factory farming is the direction of pollution-free intelligent circulating aquaculture system, which affects various industries related to it.

2. Marine factory farming technology

2.1. Recirculating aquaculture technology
Industrialized circulating aquaculture represents the development direction of advanced productivity in
the aquaculture industry, and is also one of the important development directions for future fishery development [4]. Traditional open aquaculture, such as tidal flat aquaculture and cage aquaculture, have associated environmental pollution and pests and diseases. The consequences of these problems will adversely affect the development of marine aquaculture and limit its sustainable development in the future. The advantages of recirculating aquaculture are outstanding: good working conditions, high production efficiency, 2-6 times reduction in the breeding cycle, 20-80 times higher yield per unit area than high-yield ponds, and 120-1600 times less water consumption for aquaculture [5]. The aquaculture water circulation technology is mainly divided into the following two parts: water treatment technology and water disinfection technology.

Fig.1. Circulating aquaculture technology process

2.1.1. Water treatment technology.
Water treatment technology mainly uses physical or biological filtration to remove residual bait, biological manure and other nitrogen-containing harmful substances in aquaculture water. This step is the most core step in circulating aquaculture, and it is also the reason why it can save water resources. Additionally, it can also maintain high-quality and stable water quality conditions in the water body, making the water quality artificially close to nature, so as to shorten the breeding cycle of seedlings and greatly improve production efficiency. Combined with reasonable and scientific artificial breeding, this method can achieve high-yield, stable, hygienic and high-quality breeding effects.

Water treatment technology is divided into three methods: physical treatment, chemical treatment and biological treatment. Physical treatment is the removal of solid waste in sewage through physical or mechanical separation. Common methods include adsorption, filtration, centrifugal separation, magnetic separation, precipitation, and air flotation. Among the solid wastes, the organic matter content is relatively high, which is the main source of water pollution. In marine factory farming, we generally put physical treatment as the first step in order to remove these large suspended particles in time.

Chemical treatment is the second step of the water treatment process. There are many methods for sewage treatment chemical methods, such as coagulation, neutralization, oxidation-reduction, electrodialysis, extraction, etc., but for the wastewater in the breeding process, the methods that can be used are limited (The types of various elements and ions in the water are too complex, and at the same time, the impact on the cultured organisms needs to be considered). At present, more methods such as coagulation and redox are used. Chemical treatment mainly removes heavy metal salts and harmful organic matter in water.

The third is the biological treatment method, which mainly uses the metabolic capacity of microorganisms to degrade and transform the harmful and toxic substances in the aquaculture wastewater into harmless substances. A large amount of ammonia nitrogen and nitrite will be produced during the breeding process, and microorganisms can degrade them well. Biological treatment is mainly divided into two types: anaerobic biological treatment and aerobic biological treatment. For the water produced by aquaculture, we generally have two treatment methods. ①Using heterogeneous bacteria to decompose organic matter such as feces and residual bait in the aquaculture water. Decompose the
macromolecular organic matter into inorganic matter, such as decomposing protein into amino acids, and finally into nitrogen and nitrogen, and carbohydrates into carbon dioxide and water.  Using nitrosating bacteria and nitrifying bacteria to convert the more toxic ammonia nitrogen and nitrite into non-toxic nitrate nitrogen. [6] Biological treatment mainly uses biological filter and water purifier equipment in the breeding process.

2.1.2. Water disinfection technology.
The methods of water disinfection are mainly divided into chemical disinfection and physical disinfection. There are roughly the following methods: chlorine disinfection, chlorine dioxide disinfection, ozone disinfection, ultraviolet disinfection, sodium hypochlorite disinfection. For aquaculture water bodies, disinfection is mainly aimed at pathogenic bacteria and pathogens in the water body. The chlorine-containing substances contained in the chemical disinfection method have an impact on the cultured organisms. Marine factory farming generally adopts physical disinfection methods, and the more commonly used ones are Ultraviolet rays and ozone disinfection methods. Ultraviolet rays damage bacteria's DNA by changing the protein structure in the cell nucleus and destroy their reproductive capacity. Ozone disinfection uses the strong oxidizing power of ozone to destroy the cell structure of bacteria.

2.2. Temperature control technology

![Fig.2. Schematic diagram of factory circulating water temperature control system](image)

As one of the core technologies of marine factory farming, temperature control technology has a great influence on the results of aquaculture. The purpose of controlling the temperature of the aquaculture water is: 1. Constant temperature in all seasons, to provide a suitable living and production environment for aquaculture of marine organisms, 2. If necessary, the temperature can be adjusted according to market needs to achieve the purpose of controlling production.

2.2.1. Traditional temperature control technology.
Traditional temperature control methods are mainly coal-fired, oil-fired, and electric-fired boiler heating methods. However, these temperature control technologies have common drawbacks. First of all, they are not environmentally friendly. Whether it is coal, oil or natural gas, or electric heating, the essence is It must rely on the consumption of fossil energy, and it will definitely pollute the environment. Secondly, the energy efficiency of this method is not high and it is not economical.
2.2.2. Heat pump temperature control technology

![Heat pump principle diagram](from Baidu Encyclopedia)

Heat pump temperature control technology mainly includes the following forms of heat pumps: air source heat pumps, ground source heat pumps and sea water source heat pumps. Each heat pump has different forms of advantages and disadvantages, cost and application scenarios. A heat pump is a device that transfers heat energy from a low-temperature heat source to a high-temperature heat source, using soil, groundwater, air, etc. as low-temperature heat sources to achieve cooling and heating. Compared with traditional fossil fuel boiler devices, heat pumps have the advantages of economy, energy saving, and high efficiency. Fossil fuel boilers can only convert 50% to 90% of fuel heat energy into heat to produce hot water. The heat pump can absorb 2-6 kWh of heat from the environment for every 1 kWh of electric energy consumed, which saves more than 40% of energy compared to oil or gas boilers. [8]

2.3. Oxygenation technology/Aeration

The aeration of the aquaculture water body is generally realized by an aerator. In layman's terms, the principle of aeration technology is to dissolve more oxygen in the water body. Generally, we usually use three methods to achieve this:

1) The motor drives the mechanical parts of the aerator to agitate the water body and promote the exchange of dissolved oxygen in the water body and the atmosphere;
2) Spray the water body into the atmosphere in the form of fine droplets to increase the contact area to increase oxygen;
3) The air is sent into the microporous tube by the blower, and the microporous tube releases the gas in the form of small bubbles at the bottom of the pool.

For the above-mentioned aeration technology, the third is often more economical and practical, because related studies have shown that this method of negative pressure inhalation and conversion into bubbles can very well activate the water body, which has great benefits for long-term factory farming, and also more conducive to achieving sustainable development.

2.4. Ecological control technology

2.4.1. Ecological environment restoration technology.

In the process of factory farming, pollutants such as nutrients, heavy metals, organics, etc. will be produced. If the environment is not repaired in time and sea pollution is treated, these substances will seriously affect the renewable capacity of the aquaculture water environment and the quality of the aquaculture products. And production, so timely ecological restoration of the aquaculture water body is necessary.

Regarding organic matter and heavy metals, it has been mentioned in the article above, that is, part of the recycled water treatment process can be removed, but physical and chemical methods will inevitably affect the ecosystem. Therefore, a more suitable way is ecological environment restoration technology. In order to avoid causing excessive impact on the environment, ecosystem restoration techniques are often bioremediation-based methods. At present, the ecological restoration technologies
that can be used in mariculture mainly include ecological floating bed restoration, macroalgae restoration and artificial wetland restoration. [9]

The ecological floating bed restoration technology is based on the principle of soilless cultivation technology, polymer materials are used as the substrate, and the surface soilless planting technology that combines agronomy and ecological engineering is used. This technology can purify the nutrients in the water, and it is also useful for heavy metals and antibiotics. A certain absorption effect, its mechanism of action is mainly the absorption of pollutants by plants and the biochemical effect of plant rhizosphere microorganisms [10]

Macroalgae restoration, is the use of macroalgae to restore the ecosystem. Large algae can not only improve the environment, absorb nutrients, and effectively reduce organic pollution, it can also benefit from it. These residual bait and feces of the system are the nutrients for large seaweeds. These nutrients guarantee the growth rate of large seaweeds. In the restoration of marine aquaculture, the commonly used macroalgae include kelp, asparagus, Gracilaria, seaweed, Ulva vulgaris, Kappa algae, Red algae, etc. [11] However, the artificial wetland restoration technology is rarely used in factory farming, so I won't go into details here.

2.4.2. Variety co-cultivation technology.
In the breeding process, if conditions permit, if multiple species of marine organisms can be used for co-cultivation, and if the combination is reasonable, a stable symbiosis or dependence relationship can be formed, which is conducive to material circulation, and is useful for promoting the development of productivity and using water space.

In addition, in order to curb the spread of diseases and promote the production of breeding organisms, carnivorous natural enemies of this organism can be put in place. In this method, when the number of aquaculture organisms is controlled within an appropriate range, the yield will be significantly increased, and the spread of diseases will also be better controlled, but this method is not common in factory farming.

2.4.3. Disease control technology.
The emergence of aquaculture biological diseases will often seriously affect the production and quality of aquaculture, and have a major impact on the economic development of the aquaculture industry. In addition to the indirect biological control mentioned above, there are mainly two kinds of disease control technologies.

1) Clean and disinfect the breeding pond regularly 2) Launch biopharmaceuticals

In the first method, except for regular cleaning of sludge and removing garbage, there is also a disinfection method of splashing lime slurry. This disinfection method is not only cheap, but also has a significant disinfection effect, and it will not have much impact on the quality of aquatic products. [12]

3. Marine factory farming equipment

3.1. Breeding pond
Traditional factory farming ponds are mostly made of concrete, plastic, bricks and tiles. With the advancing of the times, material science and technology continue to develop. Now factory farming ponds have begun to use polymer materials and composite materials for breeding tanks, such as fiberglass, canvas, etc.

In the inside of the breeding pond, a layer of special breeding paint is usually applied. The main components of this coating are polymer synthetic resin, pigments, emulsions and other additives, which can form a dense coating inside the breeding pond to isolate the breeding The pond and water body prevent the pond body from being corroded by sea water and seawater microorganisms and attached organisms. It has the advantages of acid resistance, alkali resistance, and easy cleaning. And it has been widely used in marine factory farming.

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3.2. Aeration equipment

The aeration equipment mainly consists of aerators and aeration pumps. The role of aerators in marine factory farming is:

1) Increase the oxygen content in the breeding water to ensure the normal survival of the breeding organisms;
2) Promote the escape of harmful gases in aquaculture waters, such as hydrogen sulfide, nitrogen, methane, etc.;
3) Inhibit the reproduction of anaerobic microorganisms in the water and prevent diseases.

The types of aeration equipment are as follows: impeller aerators, waterwheel aerators, jet aerators, suction aerators, water jet aerators, microporous aerators, etc.

The use of aerators generally depends on the size of the aquaculture pond, water quality, and environment. For marine industrial aquaculture, the practicality of water jet aerators is not very high. Generally, other moderate power and applicable water depths are used.

The microporous aeration facility uses Roots blowers to send air into the air pipeline, and the air pipeline sends the air into the microporous tube. The microporous tube disperses the air into the water in the form of microbubbles, and the microbubbles float upward from the bottom of the pool. Fully dissolve oxygen into the water, and the formed water stream rotates and flows up and down, bringing the oxygen-rich water from the upper layer to the bottom layer, and at the same time promoting the diffusion of oxygen-rich water around the microporous tube to achieve uniform oxygen increase in the pool water. [13] Due to its working principle, the microporous aerator has a much greater increase in the dissolved oxygen at the bottom than other aerators. At the same time, the overall dissolved oxygen level has also been improved. It has a very good effect on the breeding species that inhabit the bottom. This kind of aerators are widely used in factory farming.

At present, most aerators have been automated, and related intelligent control technologies are gradually developing. However, due to the high energy consumption of most existing aerators, the current development direction of aerators is energy saving, The direction of development of intelligence and low risk, the front direction is the aerator of microporous aeration technology and the aerator of a variety of aeration technologies.

3.3. Baiting equipment

Since the development of my country’s aquatic products industry is somewhat lagging behind that of foreign countries, the automation of my country’s feeding equipment is also slightly behind. At the beginning of this century, my country began to increase research and development and investment in feeding machines. So far, Chinese baiting machines have been basically automated, and the output can basically meet domestic demand.

Indoor factory-made bait machines are generally used for factory fish farming and greenhouse fish farming. This kind of bait machine throws a small amount of feed at a time, but it is very uniform and accurate. Generally, the spraying area is 0.8 to 1.2 square meters. [14]Feed is a variable cost in aquaculture, usually accounting for about 65% of the cost of aquaculture. [15] Therefore, reasonable feeding of bait can not only improve the economic benefits of breeding, but also avoid water pollution caused by excessive feeding, which is a problem that must be considered.

In general, automatic bait-dropping machines can be divided into: traditional bait-dropping machines and intelligent bait-dropping machines. The traditional bait machine refers to a fixed pattern, in a fixed area, a fixed time, imitating artificial methods for bait. Although it is automated, it is actually a pseudo-automation. In many aspects, this traditional bait machine It cannot be adjusted according to the changes in the breeding pond, and there are still big defects in use.

The intelligent bait feeder is a bait feeder as the core device, which integrates a variety of sensors, monitoring systems, pneumatic lift pumps and other devices. It is actually a system. First, the water quality monitoring system obtains various water quality parameters in the aquaculture water, and then passes The built-in computer makes the bait decision. The content of the decision includes whether to
bait, the location, amount, area, and duration of bait, and finally the bait operation is completed through the mechanical part.

3.4 Water quality treatment equipment

3.4.1 Microfilter:
Microfilter, also known as rotary grid machine or drum grid, is a screen filtering device used to trap solid particles in liquid and realize solid-liquid separation. The working principle of the microfilter is basically the same, all through the rotating centrifugal force of different sizes of screens, under the lower hydraulic resistance, has a higher flow rate, so as to achieve interception of suspended solids, and at the same time through the force of backwashing water it can clean the screen and keep the machine in good condition. In marine factory farming, two types of microfilters are often used, drum microfilters and crawler microfilters.

Rotary drum microfilter is a rotating drum screen filter device. It filters through a rotating stainless steel drum. It has a built-in pressurized water pump and sewage pipe. The whole equipment is driven by an external motor to drive gears.

Rotary drum microfilter is more widely used today. It has better decontamination ability and can effectively remove most pollutants. However, there are still many shortcomings: large area, high energy consumption, and high water consumption. Not economical enough for the breeding industry.

The crawler type microfilter uses filter cloth to filter, and has built-in ultrasonic vibration device, water pump, backwash device, and sewage pipeline. Because of the existence of the ultrasonic vibration device, the pressure of the water pump only needs to be small to achieve effective decontamination. Compared with the drum type micro filter, the crawler type is lighter and simpler, with low energy consumption and low cost, but the current popularity is still not high.

3.4.2 Protein skimmer:
Protein separator, also known as foam separator, is a machine that removes protein and other organic matter. The working principle is the surface tension of bubbles.

First, the water to be treated enters the contact chamber, and the oxygenation equipment of the water protein separator generates a large number of microbubbles. During the movement of the contact chamber, these bubbles gather suspended, dissolved and undissolved protein particles in the water on the surface of the bubbles. Finally, the bubbles accumulate upward into the sewage collection chamber and gradually settle, and then are discharged through the sewage pipe.

The protein removal efficiency of the protein skimmer is actually far lower than the theoretical value, which can only reach 30-50%, and its decontamination ability is far from excellent. In the process of marine factory farming, in order to make the protein separator more effective, it is often used with an ozone machine. This is because ozone has strong oxidizing properties and can quickly react with the proteins in the wastewater, especially reducing proteins. In addition, ozone can also kill viruses and germs in the water, oxidize harmful nitrogen-containing inorganic salts into nitrates that are harmless to breeding organisms, and can also increase the dissolved oxygen concentration in the water, without side effects like other disinfectants. But this also has disadvantages, that is, it oxidizes most of the elements
in the water, and the disappearance of trace elements is likely to cause the decline of water quality. At the same time, these trace elements are also necessary for some marine life, such as manganese, iron, etc.

3.4.3. Biological purification pond.

The main function of the biological filter is to remove the ammonia nitrogen in the water. Biofilm method is the most economical and effective method to remove ammonia nitrogen in aquaculture water. [16] The principle of the biological purification tank is to form a biofilm through the adsorption of microorganisms. The organic matter in the aquaculture water is directly synthesized by the microorganisms. In addition to the nitrification of ammonia nitrogen and nitrite, the equipment can also increase oxygen. To achieve the purpose of purifying water bodies and improving productivity.

4. Conclusions

The main technologies and equipment of seawater factory aquaculture are as described above, of which the key technologies are oxygenation technology and temperature control technology, and the key equipment is water treatment equipment. The future mainstream development direction of marine factory farming is the direction of pollution-free intelligent circulating aquaculture system. The water treatment process is the core of the system and will not change in the short term. In the next few years, the main breakthrough direction of the industry is that unless there is a breakthrough in the technical level, it will focus on the improvement of energy consumption, energy power, materials, and intelligent control of breeding equipment. Nowadays, marine resources are the focus of the world, and they are bound to be valued. Marine factory farming will usher in an opportunity for development. Whether it can successfully break through the core technology and complete the industrial upgrade and diversification of the industrial structure is the key to its ability to seize the opportunity and develop rapidly.

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