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Research and Application of Aquaponics System

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Abstract: Aquaponics is a new ecological aquaculture method, which integrates planting and aquaculture, reduces the pollution of aquaculture to the water environment, provides green organic fertilizer for vegetables, and promotes the ecological and sustainable development of aquaculture in China. Three main development trends are proposed: the construction of aquaponics system is developing towards decoupling type, the system layout is developing towards urbanization and three-dimensional, and the hardware facilities are developing towards ecological and intelligent. China's modern aquaponics technology has developed rapidly. Integrating the water quality environment collection and maintenance technology into the aquaponics system can achieve real-time monitoring and control of water quality monitoring, feed feeding, etc., eliminate the risk of diseases and pests in the aquaponics system in time, standardize the technical standards for aquaculture, optimize the fish and vegetable varieties, improve the economic benefits of the aquaponics system, and further promote the aquaponics technology.

1. Introduction

With the continuous development of society and the continuous improvement of public consumption, people's pursuit of healthy diet is also increasing. Aquatic products and green vegetables are highly praised by people because of their rich nutritional value[1], and the demand has increased year after year. The increasing demand of the society for aquatic products and green vegetables has led to the rapid development of aquaculture and vegetable planting, which accounts for an increasing proportion in agricultural production. With the development of agricultural production and technological innovation, the traditional extensive aquaculture mode has been gradually replaced by the factory and intensive aquaculture mode with higher aquaculture density[2]. However, with the increasing density of aquaculture, a large amount of wastewater from aquaculture has caused water pollution and waste of water resources[3]. With the increase of agricultural output and continuous technological innovation, a very novel joint farming system that is obviously different from the original agricultural development model -- aquaponics.

Aquaponics is a new type of compound farming system. It combines aquaculture and vegetable production, two completely different farming technologies, to achieve scientific symbiosis through

ingenious ecological design, so as to achieve the ecological symbiosis effect of fish farming without changing water without water quality problems, and vegetable farming without fertilization and normal growth. To achieve a harmonious ecological balance among animals, plants and microorganisms is a sustainable recycling and zero-emission carpet production model, and is the most effective way to effectively solve the ecological crisis[4].

This paper mainly discusses the parameters, technology, research objects and development prospects of aquaponics system.

2. Aquaponics system

Aquaponics is a compound term composed of aquaculture and hydroponics. The Food and Agriculture Organization of the United Nations defines aquaculture as the cultivation of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants; The definition of hydroponics is that plants are produced in a soilless medium, and plants obtain all nutrients needed for growth through water transportation[5]. Based on this, the Food and Agriculture Organization of the United Nations defines aquaponics as the integration of recirculating aquaculture and hydroponics in a production system[6]. Its principle is to transform the aquaculture effluent into nutrients required by plants after microbial nitrification, and the absorption of nutrients by plants can also purify the water body for aquaculture[7].

The main characteristics of aquaponics are as follows: first, high efficiency of water resources utilization. According to the statistics of the Food and Agriculture Organization of the United Nations, global agricultural production consumes 67% of available fresh water, and the proportion reaches 90% in the Middle East and North Africa. In the aquaponics system, the daily water exchange is about 0.3%~5%[8], which is a very water-saving production mode. The second is the high efficiency of nitrogen source utilization. In the general aquaculture model, only about 25% of the nitrogen source is used for fish growth, and the remaining 75% is discharged into the environment[9]. Aquaponics produces two kinds of agricultural products (fish and vegetables) from one nitrogen source (fish feed), which can sustain and high-density food production. Third, it is environmentally friendly. The aquaponics system does not use chemical fertilizers and pesticides. At present, the energy consumed by global nitrogen fertilizer production accounts for 57% of the energy required for agricultural production[9]. At the same time, the phosphate reserves on the earth are expected to decrease by half after 60 to 70 years[10]. Reducing the use of chemical fertilizers is of great significance to protect the environment. Aquaponics is expected to become one of the production methods to solve the problems of global population growth and resource shortage.

3. Water quality parameters of aquaponics system

The aquaponics system can present the environmental requirements for fish and vegetable growth. In order to further control the growth of fish and vegetable in water, it is necessary for management personnel to carefully monitor the water quality, in which water temperature, conductivity rate, pH value, nitrate and ammonia nitrogen, and dissolved oxygen content[11], water hardness[12] and other factors have a great impact on the water quality parameters for fish and vegetable growth.

3.1 Water temperature

Water temperature is one of the most important factors for the growth of aquaponics. On the one hand, water temperature directly affects the body temperature of fish, and the body temperature of fish directly affects the moldy activity of body cells and their metabolism, thus affecting the growth and food intake of fish; On the other hand, water temperature has a great impact on the occurrence of

fish diseases, and indirectly affects the changes of other water quality parameters. The research shows that fish are very sensitive to the change of water temperature, and the drastic change of water temperature will cause a large death of fish[13].

3.2 Conductivity

Conductivity is an important index to measure the purity of water. Impurity water can conduct electricity. The higher the content of impurities, the better the conductivity. The content of acidity and alkalinity in water directly affects the conductivity. The conductivity suitable for the growth of fish and vegetables is generally below 1000 us/cm. If it is too high or too low, it will affect the water quality, thus affecting the growth of fish and vegetables[14].

3.3 pH value

PH is an indicator of the acidity and alkalinity of water. The research shows that the growth of fish and vegetables, the decomposition of fish excrement and feed residues and the water exchange of aquaponics system will directly cause the change of pH. For fish, it is most suitable to grow in a neutral or alkaline environment with pH of 7~8.5. If the pH is too low, it is easy to cause fish infection; If the pH is too high, it is easy to corrode fish gills, hinder fish respiration and affect fish growth. For vegetables, the optimum pH is 6~7. A high pH will lead to the lack of trace elements in vegetables and affect the growth of vegetables[15]. Therefore, it is very necessary to monitor the pH of aquaponics water.

3.4 Dissolved oxygen

Dissolved oxygen is the key factor to measure the quality of water quality. The level of dissolved oxygen directly affects the growth of fish and the reproduction of microorganisms. Research shows that plants need a higher level of dissolved oxygen content, usually more than 3 mg/L, and fish need a dissolved oxygen concentration of more than 5 mg/L. If the dissolved oxygen in water is insufficient, it will lead to the gradual death of vegetable roots and the reduction of fish production[16]. Therefore, it is very necessary to monitor the dissolved oxygen in water and know whether the dissolved oxygen is within the appropriate range.

3.5 Ammonia nitrogen and nitrate content

The content of ammonia nitrogen and nitrate is an important indicator of water quality. The main component of fish excreta is ammonia nitrogen. Organic matters such as feed residues are decomposed into nitrite by bacteria and fungi, and nitrite is converted into nitrate by specific nitrifying bacteria. Ammonia nitrogen and nitrate are the main inorganic forms in the water body. On the one hand, they can be directly or indirectly converted into nutrients needed by vegetables. On the other hand, the excessive accumulation of ammonia nitrogen and nitrate is toxic to fish. In the aquaponics system, for fish, the ideal range of ammonia nitrogen is 0~2mh/L, the appropriate range of nitrite dissolution is 0~1mg/L, and the nitrate should be kept below 90mg/L, which will not cause biological health threats in the system[16]. Therefore, it is very important for the growth of aquaponics to monitor the concentration of ammonia nitrogen and nitrate in the symbiotic water of fish and vegetables in real time and properly control them to keep them within a reasonable range.

3.6 Water hardness

There are two main types of hardness: general hardness (GH) and carbonate hardness (KH). Generally, hardness is basically the amount of calcium (Ca^{2+}), magnesium (Mg^{2+}) and less iron (Fe^{+}) ions in water. Both $Ca^{2+}$and Mg^{2+}ions are essential nutrients for plants. When water flows through hydroponic components, they are absorbed by plants. Calcium in water can prevent fish from losing other salts and make them healthier. Carbonate hardness, also known as alkalinity, is an indicator of water buffering capacity. Carbonate hardness is the total amount of carbonate (CO2-) and bicarbonate (HCO-) dissolved in water. It is also measured in milligrams of CaCO per liter. The higher the concentration of KH in water, the longer the effect of KH as pH buffer to maintain the stability of the system to resist acidification caused by nitrification process. Therefore, it is very important to monitor the carbonate hardness in water, and it also affects the pH value[17].

4. Selection of fish and vegetable in aquaponics system

4.1 Selection of fish

The choice of fish in the aquaponics system is very diverse. The aquaponics system in China mainly focuses on the cultivation of tilapia, carp, grass carp and ornamental fish. According to the climate difference between the south and the north, select the appropriate breeding species. Most farmers give priority to economic fish. For example, the temperature difference in the four seasons in northern China is relatively large and the temperature is not stable, and most of them are carp, tilapia and other economic fish; The temperature in the south is relatively high and the precipitation is relatively abundant, and the culture of bass and loach is the main[18].

4.2 Selection of plant

Leaf plants and fruit plants are the main cultivated plants in the aquaponics system. The aquaponics system in western countries mainly focuses on the cultivation of basil, tomato and salad vegetables, which is inseparable from the western diet habits, and the plant varieties are relatively simple. The aquaponics system in China has a rich variety of cultivated plants, including cabbage, celery, oilseed, water spinach, broccoli, eggplant, taro and other vegetables. In recent years, it has also begun to cultivate herbs, flowers, etc[18]. Some studies have found that more attention to hydroponic vegetable production may bring higher profits than the fully integrated aquaponics system[19].

5. Technical points of aquaponics systemtem

In a complete aquaponics system, the growth environment of vegetables and fish is in water. In order to understand the growth of fish and vegetables and maintain a suitable water quality environment, it is necessary to measure and control the water quality parameters. The water quality of aquaponics is a comprehensive reflection of various water quality parameters. The quality of water quality directly affects the growth of fish and vegetable. The collected water quality parameters are transmitted to the background for storage and processing from the water quality environment, and finally the command is sent to control the equipment for environmental maintenance. The whole process includes several necessary technologies.

5.1 Water quality collection equipment

Water quality monitoring node is mainly used to monitor water quality. Water temperature,

conductivity, pH value, dissolved oxygen, ammonia nitrogen, nitrate and water hardness affect the parameters of fish and vegetable water quality. Select the corresponding water quality sensor to collect the data information of water quality environment. For the monitoring of water temperature, since most of the sensors on the market include the function of measuring temperature, in order to save costs, it is not necessary to select a separate temperature sensor.

5.2 Communication protocol

At present, the water quality sensor mainly transmits data through RS485 serial port, and its communication protocol is the standard Modbus-RTU communication protocol. The format of each byte in RTU mode is 8-bit binary. Each 8-bit byte in the message contains 2 hexadecimal characters. Each byte includes 1 start bit, 8 data bits, 1 parity bit and 1 stop bit. The default check mode is even check. If no check is used, there are 2 stop bits[20].

5.3 Wireless communication technology

In the design of the monitoring and control system for aquaponics water quality environment, the water quality monitoring node and the equipment control node need to communicate with the embedded gateway. Due to the large water area, it is not convenient to lay the line, so the system uses wireless communication technology.

Wireless communication technology is mainly divided into short distance and long distance. Among them, the representative technologies of short distance communication include ZigBee and WiFi, and the representative technologies of long distance communication include LoRa, GPRS, NB-IOT, etc.

Although short range wireless technologies such as ZigBee and WiFi have some advantages in ad hoc networks, the limited transmission distance leads to the problem of small coverage, and the latter is also limited by the high cost of operators, which is not conducive to large-scale use and deployment.

Based on the characteristics of the detection of aquaculture water data, that is, the data quantity of the monitored factors is small, so the data transmission rate is not high. However, due to the distance between the aquaculture pond and the aquaculture pond is usually far, the data collection nodes are widely distributed and scattered, requiring a large coverage area. In wireless communication technology, LoRa is in line with the characteristics of the system in terms of transmission distance, that is, the amount of data that can be transmitted in a single transmission process is small and the transmission distance is long. Therefore, LoRa is ideal for the application scenario of aquaculture pond water monitoring[21].

5.4 Water quality and environment maintenance equipment

The core of aquaponics technology is the circulation between fish, vegetable and microorganism, which is usually realized by pumping pump and mixing pump; The regulation of dissolved oxygen is usually achieved by controlling the oxygen pump; The water temperature is regulated by controlling the heater and cooler; Generally, the fish feeder is used to put the feed in the storage tank and throw the food through the rotation of the internal motor. These can only be achieved by transmitting instructions to the control terminal through wireless communication to switch the equipment on and off.

5.5 Water quality monitoring platform

In view of the need for intelligent management in aquaculture, it is necessary to develop a water

quality monitoring platform to facilitate farmers to better grasp the quality of aquaculture water. The platform needs to cover water quality collection sensor equipment management, user management, dynamic monitoring data management, data query and other functions. The database stores various water body data from remote transmission, so that the platform can call the data next. The core part of the platform is the data display interface, which realizes the dynamic display of water temperature, conductivity, pH value, dissolved oxygen, ammonia nitrogen, nitrate, water hardness and other key factors of the water body. This interface factor is real-time follow-up and update based on the water quality data transmitted by the water quality data acquisition unit through the wireless transmission module, so as to facilitate the fish pond management personnel to accurately grasp the actual situation of the water body and improve their ability to accurately judge the water quality. In addition, there should be equipment information management and sensor status management to realize the operation of adding, deleting, modifying and checking equipment information and the remaining life status of the sensor can be modified. The framework diagram of the aquaponics system is shown in Figure 1.

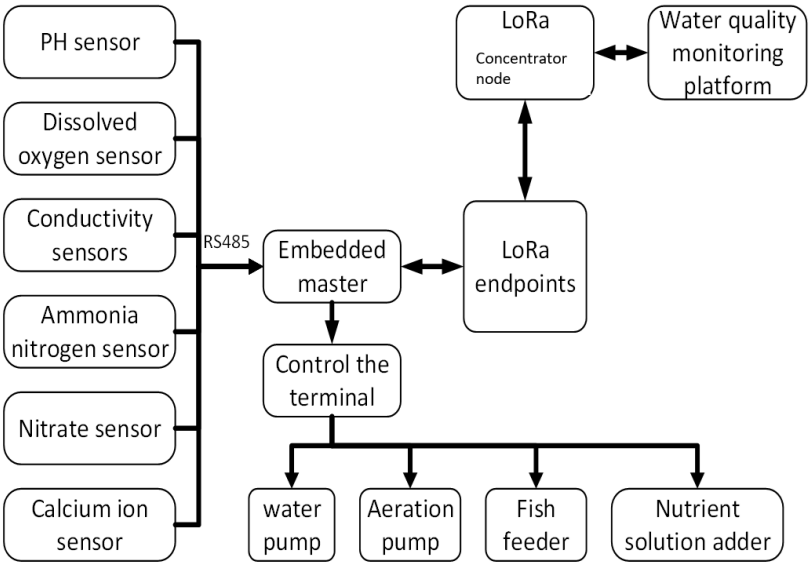

Figure 1: Framework diagram of aquaponics system

6. Development prospect of aquaponics system

6.1 Integrate artificial intelligence technology to realize comprehensive monitoring

With the development of artificial intelligence technology, farmers can use the Internet of Things, sensors and automation technology to build an ecological aquaponics aquaculture system, develop integrated computer control systems according to the characteristics of their own plants and cultivated fish, purchase intelligent facilities, and further improve the intelligent level of aquaponics technology. For example, farmers can purchase an intelligent management system to monitor the oxygen content, ammonia nitrogen and other indicators of water quality in real time, as well as the growth of microorganisms and algae. Once the content of impurities in water quality is found to be too high, the aquaculture user can open the automatic water change valve, carry out water circulation according to the water quality of each aquaculture unit, and monitor the water temperature, water quality, etc. In addition, farmers can also use the computer intelligent control system to carry out intelligent feeding, automatic water spraying and water quality control, reduce labor input, scientifically control the amount of fish feed, timely discover the potential disease and pest risk of fish through water quality detection, scientifically control the lighting time, comprehensively promote the

transformation of aquaponics technology to intelligent, and improve the income of farmers.

6.2 Select breeding objects to improve the survival rate of fish and vegetables

Cultivated plants should be combined with factors such as farmed animals and market demand to ensure that farmed animals and cultivated plants can be sold smoothly and that farmers can quickly return funds, which is also an important guarantee for optimizing aquaponics technology. For example, farmers should give priority to plants with relatively developed roots, such as leafy vegetables as water spinach, lettuce and water celery, which can quickly grow roots in the water, absorb nitrogen, phosphorus and other nutrients in the water to the maximum extent, and promote plant growth. At the same time, farmers should carefully choose fish and try to choose fish with strong disease resistance, short growth cycle and strong adaptability. For example, many local farmers choose to breed loach, which is resistant to low temperature and hunger, suitable for high-density cultivation, and has a relatively short growth cycle. It has both edible and medicinal value, and is relatively popular with consumers. In addition, the farmers should also pay attention to disease prevention and control, install pest prevention and disinfestation equipment in the greenhouse, add microorganisms and algae in the water according to the water quality monitoring data, and use pure natural agents to adjust the water quality, ensure the health of fish and vegetables, and reduce the damage to the microbial environment.

6.3 Standardize technical standards and improve the technical level of farmers

The aquaponics technology is a new ecological aquaculture technology in China. Many farmers lack the experience of aquaponics cultivation, and the cultivation technology is not standardized. This will not only affect the production of vegetables and fish, but also easily lead to diseases and pests. Therefore, the technical personnel should further standardize the cultivation technology of farmers, improve the cultivation and cultivation level of farmers, and steadily increase the production of vegetables and fish. For example, for some places where there is a need, the relevant departments at the grass-roots level should shoulder the responsibility of training, organize technical personnel to go to the front line for guidance and research, help them select breeding varieties, debug intelligent production facilities, explain the key technologies of aquaponics ecological breeding, and provide on-site guidance to let them truly master the aquaponics technology.

For example, for the aquaponics mode in the pond, the vegetable planting area should be reasonably calculated according to the pond area, the number of floating baskets and the amount of fish seedlings should be calculated, and the number of vegetables and fish should be scientifically controlled to avoid the excessive cultivation density affecting the yield. Cultivate the scientific breeding awareness of farmers, help them build an intelligent aquaponics ecological breeding system, and improve the vegetable yield and fish quality.

6.4 The government should increase support to optimize the aquaponics market

The government should actively promote the aquaponics model, based on the development foundation of local agriculture and aquaculture, actively support farmers to set up farming cooperatives, provide technical support for their contact with agricultural and fishery experts for aquaponics aquaculture, and also set up corresponding special funds to give aquaponics farmers certain financial subsidies, and encourage more farmers to participate in aquaponics aquaculture. For example, the government can organize agricultural and fishery experts to form technical groups, regularly go to the countryside to teach farmers aquaponics technology, support farmers to set up cooperatives, promote the commercialization of traditional aquaculture, improve the market

competitiveness of farmers, and realize the sharing of aquaculture technology and resources. Cooperatives can raise funds to establish breeding bases to alleviate the pressure of individual funds. The government helps to contact intelligent equipment, high-quality fish fry, scientific research institutes, universities and experts in this field to guide farmers and solve their technical problems. In addition, the government should also actively seek customers for breeding agencies, contact local large hotels, travel agencies and agricultural product processing enterprises to cooperate with farmers, promote local green organic fish and vegetable products, solve marketing problems, and open up multiple sales channels, which can not only enrich the local people's dining tables, but also increase the added value of fish and vegetable, increase the economic benefits of farmers, and promote the large-scale development of local aquaponics, Improve the development level of agriculture and aquaculture.

6.5 Develop new ways of agricultural tourism and improve the economic benefits of farmers

Agricultural tourism is a new agricultural development mode, providing a new development channel for aquaponics technology. Farmers can build aquaponics as a new selling point for agricultural tourism, attracting surrounding consumers to visit and shop. For example, farmers can hold popular science lectures and small experiments, provide new ways of parent-child sightseeing and tourism, and explain key technologies of aquaponics, ecological and environmental protection production methods, and intelligent equipment to children; Parents can lead their children to try to understand various vegetables and fish, work with farmers, create an opportunity for urban children to be close to nature, and provide more opportunities for farmers to increase their income.

In addition, farmers can set up aquaponics ecological restaurants, and tourists can also pick them on the farm, open up new sales channels, further promote aquaponics technology, let more consumers know the fish and vegetables grown by aquaponics technology, create a good brand image, and promote the long-term development of aquaponics. In addition, farmers can cooperate with the government to open new media publicity channels, and use local WeChat official account, group purchase account, Tiktok and other platforms to promote fish vegetable symbiotic agricultural tourism, so that more citizens can understand this new, green and ecological breeding technology, and help farmers to steadily increase their income[18].

7. Conclusion

This paper is a comprehensive study of aquaponics system. This paper introduces the water quality parameters needed to collect for the growth of fish and vegetables in the aquaponics system, screens out the factors such as water temperature, conductivity, pH value, dissolved oxygen, ammonia nitrogen, nitrate and water hardness, and makes a simple study. These water quality parameters have an important impact on the research of aquaponics system.

The selection of fish and plants is an essential part of the aquaponics system. Therefore, understanding the growth of fish and vegetables and maintaining a suitable water quality environment will directly affect the growth of fish and vegetables. The technology used in the whole process of collection, transmission, storage, processing and control can reflect the gradual intellectualization of aquaponics system to achieve scientific collaborative symbiosis. The current development prospect of aquaponics technology is studied. The current research on aquaponics system has great development space.

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