RESEARCH REGARDING THE EQUIPMENT USED IN WATER TREATMENT PROCESSES OF RECIRCULATING AQUACULTURE SYSTEMS

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ABSTRACT

Modern aquaculture technologies are made with the help of recirculation systems, which require the use of innovative and high-performance solutions for the treatment of recirculated water. Aquaculture recirculation is essentially a technology for growing and developing fish or other aquatic organisms by reusing water for more intensive fish production. The technology is based on the use of mechanical and biological filters, and this ecological method can be implemented for any species cultivated in aquaculture, such as fish, shrimp, mussels, etc. The scientific paper presents a brief summary of the control and solution of the main problems faced by water recirculation systems.

INTRODUCTION

Aquatic products have become an essential necessity in the global food market. It is estimated to be worth about $ 250 billion [10]. Due to economic benefits and excessive demand, research and development projects have been launched on the implementation of water recirculation systems for fish farming. The increase in food demand is due to the large number of human population and the rising standard of living that have influenced the aquaculture industry to expand its production capacity to meet current requirements [17].

According to FAO (2019), aquaculture production has grown steadily to an average of 4.8% per year, from 2010 to 2017. In 2017, aquaculture contributed 46.4% of total world fisheries production, which is the equivalent of 80.1 million metric tons (valued at USD 23.8 billion). It is estimated that this share will reach 52% in 2025, which is equivalent to 102 million tonnes of production. This indicated that the aquaculture sector will be the main driver of the world's fish supply [9].

Research and development of recirculation systems has been going on for several decades and efforts are being made to improve and optimize these new technologies for raising fish in a controlled environment. There are many alternative technologies for each process and operation. The selection of a particular technology depends on the fish species raised, the location, the infrastructure, the expertise in production management and other factors shown in Figure 1.

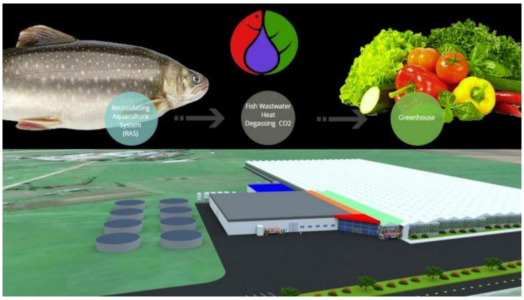

Fig. 1. Innovative aquaponic solution [22].

The interest in RAS is due to major global concerns that require immediate resolution, such as water resources and limited land, to fill this gap by using this equipment. The main objective of the researchers is to solve the problem of deteriorating water quality during treatment processes in the system, when they are not properly controlled. Water quality problems in SARs have been associated with low levels of metabolites of fish waste and vegetable waste from culture water [20]. Due to the projected water shortage, limited area for aquaculture [8] and increasingly stringent environmental regulations, RAS has become more important for aquaculture activities. Repeated attempts to promote these systems on a commercial scale have increased dramatically in the last decade, although there are few such systems, fish production is on the rise. The main benefits of recirculation systems are highlighted by the fact that land and water requirements are reduced; the necessary cost of producing fish species is reduced by reducing the use of electricity to maintain a temperature specific to water conditions [3,7].

The operation of a fish farm under limited water quality conditions can reduce the profitability of fish production, as water quality problems can be fatal [19]. The most common phenomenon is the damage caused by infection with various diseases of fish health, causing a decrease in intensive growth and accelerating the risk of their total loss. The most common water quality problems in RAS can be caused by temperature fluctuations (high or low), waste caused by metabolite concentrations, gas supersaturation, measured levels of dissolved ozone and the presence of certain cleaning chemicals in the water [1].

Aquaculture recirculation systems are intensive systems, which are based on feed formulated to provide all the nutritional requirements for cultivated organisms. A RAS consists of a self-cleaning-conditioning system, which the water reuses for fish culture. This paper will present the advantages of recirculated wastewater treatment systems. [2]

MATERIAL AND METHOD

The basic principles of recirculation systems refer to water treatment technology, which continuously removes waste products and regenerates the optimal water quality for fish. The water in the fish tank flows through a mechanical filter and is then sent to a biological filter, before being aerated, then removing the carbon dioxide and finally the water is returned purified in the fish tank shown in Figure 2. Several other applications can be added, such as pure oxygen oxygenation, ultraviolet light disinfection or ozone disinfection, automatic pH adjustment, heat exchange, denitrification, etc., depending on the exact requirements. [18]

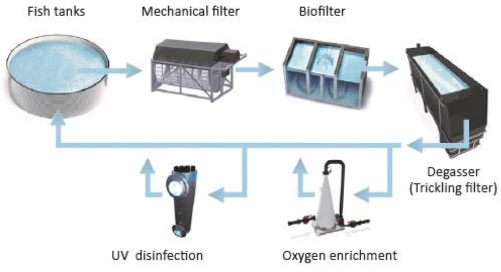

Fig.2. Basic principle of a recirculation system [18]

In the recirculating aquaculture system (RAS), metabolites, food waste, the biological body and other proteins of cultivated species cannot be broken down over time, leading to an increase in ammonia, nitrite nitrogen and other substances harmful to fish, which can pollute the water environment and can cause toxic effects, causing a large number of animal deaths [14]. In this sense, during the process of industrial aquaculture, the traditional way of water treatment is replaced by the application of biological purification technology. The biofilter is the basic component of RAS, being used most often. Biological treatments are composed of biological bacteria that convert TAN (total ammoniacal nitrogen) and nitrate into nitrogen gas to achieve complete water purification. Despite the widespread application of treatments, both nitrification and denitrification suffer from certain deficiencies. [5]

The removal of ammonia takes place through a biological filtration process that is done in two stages: (1) ammonia is oxidized by Nitrosomonas bacteria and transformed into nitrites, which are very toxic and (2) nitrites are oxidized by another category of autotrophic bacteria Nitrobacter and converted to nitrates. The two oxidation processes are followed by a denitrification process, which leads to the conversion of nitrates to nitrogen gas. [17]

Denitrification can be performed either by chemical or biological means. The second possibility is the use of aquatic plants for which nitrate is a source of food to obtain agriculture in urban areas, due to this aquaponic system. Figure 3 shows a recirculation system that simultaneously ensures the growth of fish and plants (usually vegetables) using a single input: fish feed. The fish component of the aquaponic recirculation system provides food (nitrates) for the horticultural biomass and the plants contribute by denitrification to the purification of the recirculated water in the aquaculture basins. [1,4]

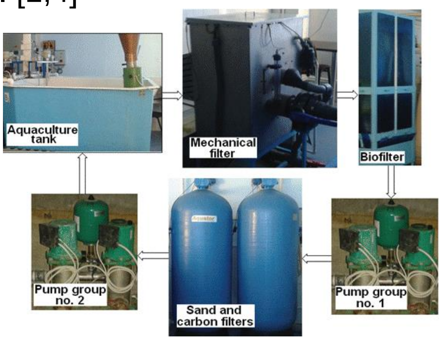

Fig.3. Technological structure of the recirculation system [4]

Electrochemical disinfection is recommended because the damage to bacterial cells is more severe than that caused by pure chemical disinfection with chlorine. Low turbidity improves the efficiency of electrolysis, and on the other hand accentuates the bactericidal effect of the ultraviolet lamp. During the intensive fish farming experiment, the turbidity of the aquaculture water fluctuates slightly, the bactericidal effect of microelectrolysis combined with ultraviolet rays, the recirculating system remains unaffected shown in Figure 4. Compared to the removal of TAN and nitrites, less time is needed to inactivate microorganisms during the process of electrolysis combined with UV light. [21]

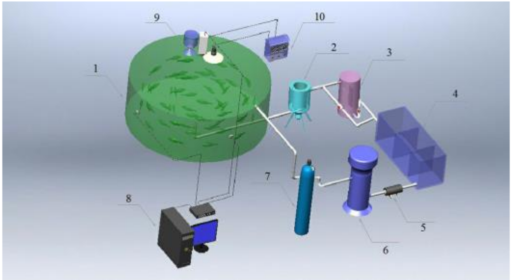

Fig. 4. The recirculating aquaculture system which is based on electrolysis combined with ultraviolet light [21]

RESULTS AND DISCUSSIONS

Suspended particles or solids are the source of most water quality problems, as they have a significant impact on all other RAS components, so their management is fundamental to good system performance [11]. A biofilter is directly affected if the suspended solid particles are not effectively removed from the treatment loop, it becomes clogged, decreasing the specific surface area (SSA) and thus the amount and viability of nitrifying bacteria. Moreover, as the concentration of solid particles increases in the system, the water parameters change and these changes are the causes of the stress of farmed fish, preventing their intensive growth performance due to susceptibility to changing situations [15]. At the same time, the inadequate removal of particles or solids creates competition between both heterotrophic and autotrophic bacteria, influencing the increase in ammonia levels in water. In addition to the biofilter, other equipment, such as auxiliary devices and ozone pumps, are also adversely affected.

Mechanical filtration of wastewater from fish tanks has proven to be the only practical solution for disposing of organic waste. Currently, all fish farms use this method of recirculating water from fish tanks with the help of a microscreen equipped with a drum-type filter between 40-100 microns, ensuring the total removal of particles. The principle of operation of the drumfilter consists in the recirculation of water through the filter elements of the drum which is exerted by a driving force (Fig.5). The solid bodies are caught by the filter elements and raised in the reverse washing area by the rotation of the drum. The water from the rinsing nozzles is sprayed from the outside of the filter elements, and the rejected organic material is sent by them to the sludge tray. The sludge flows along with the wastewater by gravity from the filter, thus freeing the basin in which the fish are located from the existing residues. [6]

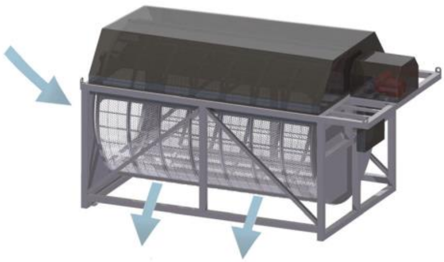

Fig. 5. Drumfilter [6]

The finest particles of organic matter pass through the mechanical filter together with compounds dissolved in phosphate and nitrogen. Phosphate has no toxic effect on fish production, but a nitrogen compound, such as free ammonia (NH3), is toxic to fish and must be converted to nitrate which is harmless. The biofilter is a biological process performed by bacteria. Heterotrophic bacteria oxidize organic matter, consuming oxygen and producing carbon dioxide, ammonia and sludge, while nitrification is performed by nitrifying bacteria, removing ammonia from water and turning it into nitrites and nitrates. Biofilters are usually constructed using circular plastic shapes (Fig.6), where bacteria accumulate on their surface in the form of biofilm. Biofilters used in recirculation systems can be designed as fixed bed filters or mobile bed filters. [16] All biofilters used today in recirculation systems function as submerged units. In the fixed bed filter, the plastic is fixed and does not move as the water flows. In the mobile bed filter, the plastic material moves in the water inside the biofilter by a current created by pumping it into the air. [13]

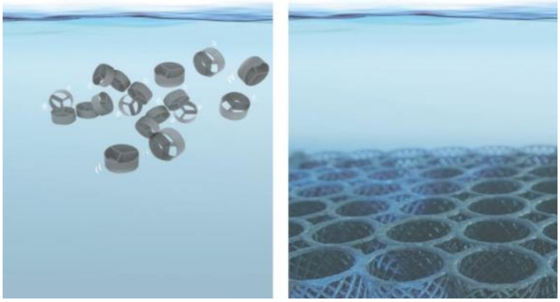

Fig. 6. Biofilter [18]

Accumulated carbon dioxide (CO2) and free nitrogen (N2) are harmful substances to fish, which must be removed from the water. Under anaerobic conditions, and especially in salt water systems, hydrogen sulfide (H2S) is also produced. Hydrogen sulfide is deadly to fish, even in low concentrations. The removal of these gases is called degassing, aeration or pickling and can be done both in fish tanks and separately before the water reaches the tanks back (Fig.7).

Aeration is the process of pumping air into water through which gases are removed from the turbulent contact between water and air bubbles. A more efficient method involves a degasser that uses a drainage filtration system. In a degasser, the water flows through a distribution plate with holes and is then thrown down through a fixed plastic support divided into columns. The gases are removed from the water by contact with the plastic medium and the contact between the two is maximized by the turbulence on the distribution plate and the washing process. [6]

Fig.7. Aeration system [6]

Fish and most other aquatic animals depend on dissolved oxygen for respiration for their survival. Therefore, an RAS system must monitor and regulate the level of oxygen saturation in the water. When leaving the pool, the water saturation level is usually reduced to 70%, and the level is further reduced depending on the biofilter and degasser used. Aeration can stabilize the saturation level to over 90%.

In any case, it is preferable to add pure oxygen so that the water entering the fish tanks is supersaturated to have enough oxygen available for a high and stable growth of the fish. There are several different methods for making super-saturated water (oxygen content reaching 200-300%), either by high pressure in the oxygen cones or under lower pressure in the oxygen platforms. Oxygen cones use more energy (electricity) than platforms. On the other hand, the cones use only a part of the circulating water, while the platform is used as part of the whole recirculation flow. Regardless of the method used, the process must be controlled with oxygen measurement (Fig.8) [12].

Fig. 8. Oxygen cone for dissolving pure oxygen at high pressure and a sensor for measuring the oxygen saturated on of the water [18]

Bacteria, viruses, fungi and small parasites can be killed / removed from the water by ultraviolet (UV) disinfection. UV disinfection is more efficient if the water is previously filtered both mechanically and biologically (Fig.9). [18]

Fig. 9. UV water treatment system [18]

Ozone treatment can be used to destroy unwanted organisms in the fish pond to be subsequently trapped by mechanical or biological filters. Ozone treatment breaks down micro-particles into molecular structures that will bind together and form larger particles, which can then be removed. Ozone treatment is also called "water polishing" because it makes the water clearer, reducing the amount of suspended solids and pathogenic microorganisms.

Ozone overdose can cause serious injury to fish. Excessive use of ozone can also be detrimental to recirculation system operators. Therefore, proper dosing, adequate ventilation and careful monitoring are essential for positive and safe results. In many cases, UV lighting is a good and safe alternative to ozone. [18]

CONCLUSIONS

The recirculation technology of aquaculture systems offers some significant advantages over other existing aquaculture methods.

The cultivation of fish in a terrestrial, closed and controlled environment reduces the risk of their contamination with diseases. Antibiotics or disease treatments are not involved in a normal production process, so the fish produced is healthier.

The movement of water in growth tanks allows growers to constantly capitalize on fish, which in some fish species results in a more natural composition of fats and tissues. Another benefit of recirculating aquaculture systems is that due to its advanced filtration capabilities it significantly reduces water pollution from feed, feces and chemical waste, making it a much more sustainable alternative to other aquaculture methods.

In terms of efficiency and productivity, RAS allows continuous harvesting throughout the year, and fish grow to commercial size faster compared to other aquaculture methods.

Faster growth usually means a better conversion of feed for fish meal and, in general, a lower impact on the entire production chain and production costs, thanks to full control of water temperature and the capacity of aquaculture systems. recirculation to maintain optimal levels of oxygen and carbon dioxide.

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