GOOD AGRICULTURAL PRACTICES IN THE PRODUCTION OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN A SIMPLE RECIRCULATION SYSTEM IN URBANIZED AREAS

https://doi.org/10.56238/sevened2024.032-021

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ABSTRACT
The growth of Brazilian fish farming was due to the considerable increase in fish consumption, especially tilapia, which continues to be the most produced fish in the country, representing 65.3% of the total national aquaculture production. What was necessary was the search for the application of good agricultural practices in the production of Nile tilapia in alternative systems that produce with high density and work to reduce waste discarded in the tributaries. Thus, the study examines the implementation of biosecurity measures in simple recirculation systems, which through the biofilter reuses the same water during cultivation. These measures are necessary to ensure the health and well-being of the fish, as well as food safety. Based on a comprehensive literature review and field research, recommended practices for the installation and operation of these systems are analyzed, including the selection of suitable locations for solar incidence control, the performance of quarantine periods for monitoring clinical signs in fish lots, the regular clinical evaluation of fish, the continuous monitoring of water quality, the implementation of good management practices and the responsible use of medicines, when necessary. The results highlight the importance of these practices to prevent the introduction and spread of pathogens, as well as to promote the sustainability and economic viability of aquaculture production in urbanized environments. The dissertation contributes to the advancement of knowledge in the area and provides practical guidelines for producers and managers of Nile tilapia production systems in urban areas.

Keywords: Biosecurity. Sustainability. Recirculation.

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INTRODUCTION

Fish farming, is a branch of aquaculture that focuses on fish farming and production. Originating in Asia, this practice has spread globally and has experienced significant growth on all continents, including Brazil. Fish farming is recognized as one of the main methods of fish production worldwide, being responsible for a substantial portion of the global supply of fish for human consumption (CARVALHO, 2009).

As mentioned by Carvalho in 2009, fish farming represented 54% of fish production destined for world consumption at the time. This data highlights the importance of this sector in guaranteeing food supply, as well as in the economic development and food security of various regions of the world. Brazil, as one of the countries that has invested significantly in this area, contributes to this global panorama, expanding its production and participation in the international fish market.

According to the FAO (Food and Agriculture Organization of the United Nations) in 2020, world aquaculture demonstrated growth over the period from 2001 to 2018, with an average annual growth rate of 5.3%. This steady growth culminated in a historic milestone in 2018, when global production reached the mark of 114.5 million tons in live weight.

In parallel with the growth of aquaculture production, world fish consumption has also registered a significant increase over the decades. Between 1961 and 2017, fish consumption showed an average annual growth of 3.1%. This percentage is almost double the annual growth of the world population in the same period, which was 1.6%. In addition, the increase in fish consumption has outpaced the annual growth of other foods, such as meat, dairy products, and milk, which have grown at an average rate of 2.1% per year (FAO, 2020).

In 2018, Brazilian fish farming recorded significant growth, with an increase of 4.5% compared to the previous year, 2017. This resulted in a total production of 722,560 tons of fish. Compared to the numbers of 2014, where production was 578,800 tons, it is possible to observe a substantial growth in production over this period. Therefore, based on this survey, the fish farming production chain accumulated an expansion of approximately 24.83% in a few years, which demonstrates an expressive and continuous growth in this sector. (PEIXE BR, 2019).

The continuous growth in fish production in the country each year is related to the boost of several factors, including the emergence of new enterprises, investments in advanced technologies, improvements in management and in the production process, with this, every day more research is being developed in search of more knowledge about the proper way to produce them, with emphasis on the larviculture and nursery phases (TAVARES; DIAS et al., 2003; DANIEL, 2022).

The revenue generated by this growing fish production in 2020 was 8 billion reais, which reached 802,930 tons. More than 1 million jobs generated directly and 7 indirectly (PEIXEBR, 2021).

One of the most cultivated species in aquaculture worldwide is Nile tilapia (*Oreochromis niloticus*), due to a number of advantageous characteristics. It has rapid growth, which means it reaches a market size in a short period of time, making it a cost-effective choice for growers. In addition, its rusticity and ability to adapt to a wide range of environmental conditions make it an easy-to-manage species. In addition to being valued for its high yield index (SILVA et al., 2015).

In 2023, tilapia significantly expanded its participation in Brazilian farmed fish production, reaching the mark of 579,080 tons. This number represents a growth of 5.28% compared to the previous year. With this result, tilapia now represents 65.3% of the total national aquaculture production. In the previous year, in 2022, tilapia production in Brazil was 550,060 tons, which corresponded to 63.93% of the national total (Peixe Br 2024).

However, improper disposal of organic and inorganic waste from aquaculture can have serious consequences for the environment, including water contamination, degradation of aquatic ecosystems, and risk to human and animal health. Organic waste, such as food scraps and fish feces, can lead to eutrophication problems, resulting in decreased dissolved oxygen in the water (POERSH, 2012).

Thus, to mitigate these impacts, it is essential to implement proper aquaculture waste management practices, including the responsible treatment and disposal of waste, monitoring water quality, and adopting sustainable production technologies.

Having alternative systems that can help reduce waste discarded in the tributaries is essential. To reconcile the increase in production with sustainability, it is essential to use production technology, which includes the water recirculation system where it is possible to produce aquatic organisms (CREPALDI et al., 2006).

The Water Recirculation System (RAS), which consists of the reuse of the same water in the system, where it will treat and maintain the water in the desired parameters (DANIEL, 2022).

The advantages that this system can offer are waste management and nutrient recycling, reduction of water consumption, easy maintenance of hygiene and disease control, biological and pollution controls carrying out the process. In addition to the possibility of being produced close to urban centers, as they require little space for operation (LIMA et al., 2015).

One of the allies of profitable production is biosecurity, these measures are essential to ensure the health and well-being of fish and to prevent the introduction and spread of pathogens in the aquaculture production environment. Producers who implement biosecurity are able to significantly reduce the risk of disease and increase the productivity and sustainability of their aquaculture operations.

Therefore, the objective of this work was to address the main aspects of biosecurity together with the recirculation system, promoting to the producer a sustainable form of production in reduced spaces.

LITERATURE REVIEW

TILAPIA-DO-NILO (*OREOCHROMIS NILOTICUS*)

On the global stage, Brazil occupies the position of fourth largest producer of tilapia, behind only China, Indonesia and Egypt. These data highlight the importance of Brazil in the world tilapia market and the significant contribution of the aquaculture sector to the national economy. In the last ten years, tilapia production in Brazil has experienced a remarkable growth, going from 285 thousand tons to 579 thousand tons. This increase represents an impressive jump of 103% in the period. The tilapia stands out as the animal protein with the highest growth in the country over this period (PEIXE BR, 2024).

This prominence in the production of this species is due to the ~~or~~ tropical and subtropical climate are conducive to the breeding of Nile tilapia, since they offer ideal temperature and light conditions for the efficient growth and reproduction of this species, thus causing it to spread to several countries. In addition, because it has excellent performance of growth and reproduction, as well as favorable sensory characteristics of fillet meat, which makes it highly appreciated in cooking. It is also worth mentioning the absence of intramuscular spines in the shape of a "Y" which enhances it as a fish for industrialization (FURUYA, 2018).

In addition, the favorable environment in Brazil offers favorable conditions for tilapia farming, including suitable climate, freshwater availability, and investments in technology and management. The growing demand has also boosted production, as tilapia is an increasingly popular option among Brazilian consumers, due to its mild flavor, affordable price, and nutritional value.

Nile tilapia's resistance to harsh conditions, its ability to grow quickly, and its ease of reproduction are additional factors that contribute to its success in aquaculture. Its versatile diet, as an omnivorous species, allows producers a wide range of food options, which provides flexibility in terms of nutritional management. These characteristics make Nile tilapia an attractive and profitable choice for commercial producers, further boosting its production (MARENGONI, 2006).

Among the exotic species that Brazil uses as a source of economy, tilapia has great competitive advantages over native ones. It is known to be a disease-resistant species. Widely used in fish farms throughout the Brazilian territory, precocious, with high productivity and good organoleptic and nutritional characteristics, such as: tasty meat, low fat content (0.9 g 100 g -1 of meat) and calories (172 kcal 100 g -1 of meat) (LIZAMA et al., 2004).

Since 2021, six out of ten farmed fish in Brazil are tilapia. Demonstrating a Brazilian growth of 12.5%, participating in 60.06%, in 2019, it represented 57% and in 2018, 54.1% of the national cultivation. With this excellent performance, the species has consolidated itself even more (PEIXEBR, 2021).

Zootechnical Indices

A careful assessment of the water resources available for cultivation is essential to determine the success of production. This involves analyzing parameters such as pH, temperature, dissolved oxygen, turbidity, nutrient levels, and the presence of chemical contaminants. Knowledge of these parameters allows producers to implement appropriate measures to maintain water quality within the ideal standards for healthy fish growth (LEIRA et.al. 2016)

Water has some variables, such as dissolved oxygen, in which values must be above 4 mg/L, lower values make the animals stressed, impairing growth (LIMA et.al., 2013).

Monitoring water quality in fish farming to ensure the well-being and healthy growth of fish is a crucial fact. Problems such as deteriorating water quality can lead to fish stress, increased susceptibility to disease, and even mortality (DANIEL, 2021).

The measurement of water parameters should be carried out regularly, preferably daily, using reliable and practical water analysis kits. Some of the important parameters that should be monitored include water turbidity, which should be monitored as it influences the growth of aquatic plants and can cause stress in the animals. In addition, the pH of the water is a critical factor as it affects the health of the fish and the effectiveness of their absorption of nutrients. Dissolved oxygen levels in the water are essential. It is also important to monitor the levels of ammonia and nitrites in the water, since high concentrations of these compounds are toxic to fish (LIMA et.al., 2013; Santos et.al 2021).

Finally, the water temperature should be monitored, as it affects the metabolism of the fish and their growth rate. Maintaining the temperature within an adequate range is essential for the success of cultivation (Santos et.al., 2021)

Keeping water quality within optimal parameters requires not only regular monitoring, but also corrective actions when necessary, such as partial water changes, proper aeration, and adjustments to filtration systems. Proper water management is essential for the success of fish farming (CAVALCANTE et.al., 2017).

The transparency of the water, is how much the sun can enter the water, should be 30 to 45 cm, which can be observed through a Secchi disk. The desired water is more or less greenish, very transparent, favors the growth of filamentous algae and aquatic plants, which can result in a lack of oxygen. If it is too dark in color, it will result in problems with the oxygen concentration. However, tilapia, smaller readings are admissible, being limited to 10-15 cm (LIMA et.al., 2013).

For the ideal pH value in tilapia production systems, it is between 6.5 and 8. Variations greater than 2 units throughout the day can harm the life of the fish. As for the alkalinity parameter, which is the amount of calcium carbonate present in the water, it must be equal to or greater than 20 mg/L (SILVA et. Al, 2018). However, tilapia can withstand pH ranges between 5 and 9 due to their rusticity and adaptation, but they will not demonstrate their greatest growth potential (BARBOSA, 2007).

The recommended for dissolved oxygen in recirculation systems is that the concentration should be above 4 mg/L, because lower values make the animals stressed, impairing the growth of the fish, but tilapia has a very low dissolved oxygen requirement, living perfectly in waters containing up to 1.2mg/L (MACÊDO, 2004).

A characteristic that must be taken into account is carbon dioxide, as it is an oxygen limiter, the gas is produced day and night by the process of respiration, during the day the gas is consumed by phytoplankton, while at night its concentration is higher and those who consume it do the reverse process in this period. The ideal level is to be below 10mg/L (DAUDA et.al., 2018).

The ammonia that is found in the tanks comes mainly from the excretion of fish. It is broken down into nitrite and then nitrate. High values are toxic to fish (LIMA et.al., 2013).

Ammonia concentration levels above 0.20 mg/L are considered harmful to fish. If the levels of ammonia and nitrite are high (above 0.2 mg/L for ammonia and above 0.5 mg/L for nitrite), this may indicate a malfunction of the biological filter, which is responsible for converting these toxic compounds into less harmful forms. Therefore, the proposed solution is to increase the surface area of the biofilter to correct this situation and maintain water quality within the appropriate standards for fish (MARTINEZ et al., 2006; QUEIROZ and BOEIRA, 2007).

The temperature should vary according to the species produced, tilapia is an oviparous fish, adapted to living in still environments, capable of tolerating a wide range of temperatures, generally preferring waters with temperatures between 26°C and 30°C (SILVA et al., 2015). It is worth noting that sudden changes in this temperature can reduce food consumption and tolerance to handling diseases (LEIRA et.al. 2016).

In addition, it is important to contain the daily record of the mortality rate, in which the accepted is up to 10%, considering the entire fish breeding cycle.

WATER RECIRCULATION SYSTEM

Fish farming causes several environmental impacts, including water contamination, through organic waste, such as food scraps and fish feces. The repercussion of these impacts was highlighted precisely because of the significant growth of this sector. The search for sustainable ways to develop fish production are points addressed by specialists, in order to aim to reduce these conflicts. For this reason, the emphasis on the recirculation system, as it reduces the release of effluents and has proven to be very profitable (ZELAYA et.al., 2001)

The recirculation system stands out for being an ecologically correct source, offering maximum use of water, through the biofilter, the system becomes independent and recycles the water by reusing it throughout the process, in some countries such as Australia, USA, Mexico and Israel it is already widely explored for being able to increase the density of storage in smaller spaces and have greater zootechnical control (HUNDLEY et al., 2013; DANIEL, 2021).

It is worth noting that the balance of ammonia levels in the recirculation system occurs through the presence of a biofilter. These are responsible for the growth and attachment of heterotrophic bacteria. These bacteria play a role in the oxidation of ammonia, converting it to nitrite and subsequent to nitrate, which becomes a less toxic substance (DANIEL, 2021).

The ability to control and maintain water quality in aquaculture systems also allows the installation of these systems in places with water scarcity or where the cost of water is high. This is especially relevant in areas where freshwater is a limited and precious resource (KUBITZA, 2006)

Aquaculture can be adapted to operate in a variety of environments and scales, from large aquaculture farms to small systems installed in the back of the house, even in urban areas. The feasibility of these systems depends on the size of the equipment used, the amount of water available, and the investment required to establish and operate the system (LIMA, et al. 2015).

Water Recirculation System Infrastructure

According to MARTINS et al., (2010, 2011) in this system, the water is continuously recirculated through different components that aim to maintain water quality and the well-being of the fish. The components mentioned include decanters, mechanical and biological filters. Decanters are responsible for separating and removing heavier solid materials from the water, such as feed scraps and fish feces, through the decanting process.

The assembly of the recirculation system for mechanical-biological filters involves several steps to ensure its proper functioning. Initially, it is essential to prepare the bottom of the system by choosing a non-corrosive substrate such as plastic, fiberglass, ceramics, or rocks. This substrate is placed at the bottom of the system, serving as a filtering medium and providing porosity for bacterial colonization. Then, a protective screen, such as a shade screen, is added over the substrate, in order to protect the fine pebble that will be inserted later. The fine pebble is then introduced over this screen, functioning as another filter medium to trap smaller particles in the water. To protect the layer of coarse sand that will follow, a suitable protective screen, such as an organza screen, is included over the fine pebble. Next, coarse sand is added over this screen to complete the mechanical filtration system (LIMA et. al., 2015).

After completing these steps, the mechanical filtration system is ready, with the substrate, fine pebble and coarse sand in their proper positions. Finally, the recirculation system is activated and the water passes through the entire filtration system, being purified and ready to be reintroduced into the fish farming environment.

Mechanical filters act to remove smaller solid particles from water, ensuring its clarity and purity. Biological filters, on the other hand, are essential for controlling water quality. They provide an environment conducive to the growth of nitrifying bacteria, such as Nitrosomonas and Nitrobacter, which cycle nitrogen. Nitrosomonas convert ammonia (from feces and food scraps) into nitrite, while Nitrobacter converts nitrite into nitrate, a less toxic form of nitrogen (MARTINS et al., 2010, 2011).

In this system, oxygen is the main limiting factor for measuring water quality. However, it can be easily controlled with the use of aeration and oxygenation (LOBÃO et.al. 2018). Because bacterial metabolism requires oxygen, it is necessary for air to be supplied to the biofilter. In this way, as the water passes through the filter, it is continuously oxygenated, while carbon dioxide is removed. In this type of system, the use of biofilm is necessary. Because the metabolism of bacteria needs oxygen. This will happen with the passage of water through the filter, in which it will be oxygenated and carbon dioxide will be removed (EDING et al, 2006).

In this way, the water recirculation system allows the maintenance of ideal environmental conditions for the fish, minimizing the accumulation of toxic waste in the water and ensuring the health and proper growth of the animals. This is an effective method to optimize water use and reduce the environmental impacts of intensive aquaculture (MARTINS et al., 2010, 2011).

However, the Peixe Br (2021) highlights some disadvantages associated with the water recirculation system in aquaculture. Among these disadvantages are the constant need for energy for the circulation of the system and aeration, the high initial investment cost for the acquisition of equipment, pumps and filters, in addition to the requirement of labor for the daily monitoring of the system.

Despite these challenges, the significant advantages and benefits of the water recirculation system are highlighted. This system has a low water demand compared to other forms of farming, which contributes to the conservation of this essential resource. In addition, it reduces the discharge of effluents into the environment, minimizing negative impacts on aquatic ecosystems. Another benefit is the possibility of installing the system in urban areas, close to commercial and market areas, due to its spatial efficiency and the ability to recycle and reuse water, which can be an advantage in terms of logistics and access to consumer markets (SCHNEIDER et al., 2010).

These advantages underscore the importance and feasibility of the water recirculation system in aquaculture, especially in contexts where the conservation of natural resources and the reduction of environmental impact are priorities. Although it presents challenges, the system offers effective solutions to address issues related to sustainability and the development of the aquaculture industry.

The high density of fish is the characteristic of many water recirculation systems, which directly influences the choice of the species to be used. The species must be tolerant of high stocking densities and frequent management (HUNDLEY et al., 2013). The main freshwater species produced in this system are tilapia, African catfish, eels and trout. As marine species, sole and sea bass (MARTINS et al., 2010).

Silva *et.al.* (2015), highlights that the popularity of Nile tilapia is due to its advantageous characteristics such as fast growth, rusticity, ease of management, high yield and excellent quality meat, these attributes make it an attractive choice for producers around the world.

BIOSECURITY

According to Sesti (2005), the term "biosecurity" derives from the English word "Biosecurity" and is intrinsically related to animal health. Within this context, a biosecurity plan is established that must contain flexible standards, risk management, and preventive veterinary medicine practices to ensure the health and well-being of animals.

According to Santos et.al (2021), biosecurity in fish farming is structured actions to contain the introduction and dissemination of pathogens in the aquaculture production environment.

When developing a biosecurity plan, it is essential to identify potential hazards, which may include pathogens such as viruses, bacteria, and parasites, among others, that are specific to the species being farmed. There is also a need to carry out a risk assessment, examining risk factors and critical control points. During this stage, it is essential to carefully analyze the possible routes of introduction and dissemination of pathogens in the population, as well as their consequences. It is also worth mentioning that these measures within a fish farming system aim to protect the health of the fish and ensure the sanitary quality of the system, thus preventing the occurrence of diseases and maintaining the sustainability of aquaculture production. (SANTOS et.al, 2021).

To reduce the negative environmental impacts caused by the production systems of fish, shrimp and other aquatic organisms, Good Management Practices (BPM) (DE QUEIROZ, 2002) are recommended.

The Good Sanitary Monitoring Practices (BPMS) protocol for the recirculation system, as described by De Queiroz et al. (2017), covers a series of procedures aimed at ensuring the health and well-being of farmed fish. This includes installing the system in locations that allow solar incidence control and carrying out a quarantine period in cultivation tanks isolated from the main recirculation system. During this period, the behavior of the fish is observed and any clinical signs of disease are monitored, even if the fish have a provenance considered reliable.

In addition, the protocol involves a detailed clinical evaluation of the fish, considering their general condition, such as behavior, mucosal color, mucus production, appearance of the gills, weight and length. Possible macroscopic alterations are observed, such as deformities in the body, skin and gill infections, and the presence of ectoparasites, among other symptoms (KUBITZA, 2006).

According to Zanolo (2021), adopting strict biosecurity measures is essential to ensure health and efficiency in aquaculture production. Among the recommended practices, the purchase of fingerlings that are free or have low sanitary pressure stands out, as the acquisition of healthy fingerlings is crucial to prevent the introduction of diseases into the cultivation system. Additionally, the adequacy of crop densities is essential, since maintaining an adequate density of fish prevents stress and the spread of disease, promoting a more balanced and sustainable environment.

Carrying out preventive diagnoses is equally important, as the early detection of possible health problems in fish allows for rapid interventions, minimizing negative impacts. In addition, cleaning and disinfection programs of structures significantly reduce the presence of pathogens, ensuring safer facilities. (VIANNA et. al., 2019).

Water quality management is another vital aspect, as controlling parameters such as dissolved oxygen, temperature, pH, and ammonia is essential for fish health. Preventive vaccination is an effective tool for protecting fish against specific diseases, and the use of good quality feed ensures a balanced diet, promoting healthy fish growth and improving their resistance to disease. (FIGUEIREDO et.al., 2020).

The entry of people into the fish farming area, as well as the handling of inputs, can represent a significant risk of disease introduction, especially when these individuals transit through other fish or animal farms that share potential infectious agents in common. Therefore, it is crucial to implement strict preventive measures to minimize the possibility of contamination. All visits must be scheduled in advance, allowing for stricter control over who enters the production areas and the implementation of appropriate security measures. It is recommended that visitors and service providers respect a minimum period of 24 hours since their last visit to other fish production areas, helping to reduce the risk of transmission of pathogens that may be inadvertently carried (BARCELLOS, 2022).

In addition to prior scheduling, it is essential that all visitors undergo disinfection procedures before entering the premises, including washing and disinfecting footwear, clothing, and hands. The use of personal protective equipment (PPE), such as boots, lab coats, and gloves, should be mandatory for everyone entering the production area. Implementing an access control system to monitor and record the entry and exit of people makes it easier to track in case of disease outbreaks. It is also essential to provide guidance and training to visitors and staff on proper biosecurity practices and the importance of these measures in disease prevention (SOUZA, 2021)

That is why the installation of sinks with water, soap and other hygiene items are essential for hand washing and equipment. Regular disinfection, whether with alcohol, iodized alcohol, or other disinfectants, helps reduce the risk of contamination. In addition, the use of appropriate clothing, such as shoe covers, caps, and masks, is essential to prevent the entry of contaminating agents into the facilities. Replacing personal clothes with sterile clothes is an even more effective measure to minimize the risk of cross-contamination

Regarding inputs, it is important to ensure that all, such as feed and medicines, are purchased from reliable suppliers who follow strict safety and hygiene standards. Inputs should be stored in appropriate places, away from production areas, to avoid cross-contamination, in addition to being stored suspended on the floor to avoid humidity. Regular inspections of inputs are necessary to detect any sign of contamination or deterioration (SANTOS et.al., 2020).

In relation to the disinfection of utensils and equipment, it is common to use liquid household bleach is 3% to 6%, with the proportion of 10 ml per liter of water is adequate for effective disinfection. Similarly, granular bleach (HTH pool chlorine) is effective and can be used at a rate of 200 mg per liter of water. After disinfection, it is important to rinse the utensils thoroughly under running water to remove any residue from the disinfectant. In addition, the use of high temperatures, above 75 ºC, is also effective in destroying microorganisms, being another option to ensure the complete hygiene of equipment and utensils in fish farming (BARCELLOS, 2022).

When available, additional tests should be performed, such as hematological and parasitological parameters, to assess the health status and stress level of the fish. These tests provide valuable information about the health of the fish, including blood cell counts, biochemical profiling, and parasitological analysis of tissue samples. Hematological parameters, such as blood cell count and hemoglobin dosage, can provide additional information about the overall health of fish, identifying potential signs of infection or inflammation (DE QUEIROZ et al., 2017).

In cases of need for veterinary treatment, it is important to use medicines responsibly and according to the guidelines of a qualified professional, in order to avoid medicine residues in fish and the environment (SANTOS et.al., 2021)

It is worth noting that the professional should not only focus on the recognition of parasites and/or pathogens, but also on the knowledge of the facilities and the quality of the water in the cultivation (MARTINS, 2004).

Inadequate water quality conditions can have significant impacts on the development and health of aquatic organisms, compromising the success of production. Water quality in fish farming is crucial to ensure the growth, reproduction, health, and survival of fish. Water serves as the environment where fish live, feed, breathe, and eliminate waste. Therefore, it is essential that the water characteristics are adequate to meet the physiological needs of the fish (LEIRA et.al. 2016).

Management measures such as aeration, population density control, partial water exchanges, regular monitoring of water quality, and responsible use of inputs are essential to ensure optimal environmental conditions in fish farms. By controlling and maintaining water quality, producers can maximize productivity, minimize disease risks, and ensure the sustainability of their aquaculture operations (LEIRA et.al. 2016; FERREIRA ET AL., 2005; ALVES DE OLIVEIRA, 2001).

For this reason, MARTINS (2004) highlights the importance of sanitary measures in fish farming. To ensure the effectiveness of sanitary measures in aquaculture, it is crucial that several factors are properly coordinated. In addition to the implementation of good management practices that includes regular cleaning of tanks, proper feeding and control of population density, which can help reduce the risk of disease and improve the health of the fish. It is crucial for aquaculture enterprise owners to be aware of the importance of sanitary management and the relevant aspects to ensure the safety of the food produced. The presence of trained professionals in the area of animal health and sanitary management is essential. Maintaining water quality in ponds is essential to prevent contamination of fish by pathogens. This involves regularly monitoring parameters such as pH, temperature, ammonia, dissolved oxygen, and the presence of chemical contaminants.

Sanitary management

Parasitic and bacterial infections represent one of the main causes of economic losses in Brazilian fish farming. Fish affected by these agents show a number of signs of abnormal behavior, including lethargy, anorexia, loss of balance, grouping at the surface of the water or water entrance, agitated breathing, excessive mucus production, erosion of the skin and/or fins, inflamed or pale gills, inflamed abdomen, bloody fluid, swollen and stiffened anus, exophthalmos, apathy, isolation from the school and, eventually, death (SCHALCH et al., 2009).

These outbreaks that can cause mortality are due to the stress resulting from management, routine transport of fish, high stocking density, poor water quality. To avoid losses, fish farming processes need attention (TAVARES-DIAS *et.al.,* 2014).

To prevent diseases from becoming limiting factors for increasing productivity and causing significant economic losses, it is essential to implement constant prophylactic management in fish farming. This involves preventive measures, such as regular monitoring of fish health, water quality control, maintaining good management and hygiene practices, and, when necessary, using appropriate therapeutic treatments. Preventive management is essential to minimize the impact of diseases on aquaculture production and ensure the economic sustainability of the activity for fish farmers (TAVARES-DIAS *et.al*., 2014).

In order to reduce the number of diseases, the use of antibiotics for the prevention and treatment of bacterial infections is common in fish farms (CABELLO et al., 2013). The use of prophylactic or therapeutic antibiotics can affect the natural bacterial population by increasing the ability to produce antibiotic-resistant bacteria or environmental resistance genes. Bacterial resistance to bacteria is considered one of the most important threats to human health and affects the effectiveness of treatment of various infections worldwide (HOSSAIN et al., 2020; WHO, 2018).

On the other hand, according to Melo (2015), vaccination practices are a laborious technique and stressful for fish, in addition to requiring qualified labor for the service. This makes it impractical to completely eliminate the use of these drugs in the sector, since according to Smith (2012) antibiotics continue to be an effective treatment for diseases in intensive fish farming.

Fish farmers resort to antibiotics, either by preventive or therapeutic methods, in order to reduce the incidence and spread of bacterial infections. Generally, antimicrobials are used in two situations: prophylactically, through treatments via immersion bath or incorporated into the feed; and therapeutically, for the treatment of bacterial infections (Ali et al., 2016). In Brazil, only two antimicrobials are approved for use in fish farming: oxytetracycline and florfenicol (National Union of Animal Health Products Industry - SINDAN, 2018).

Oxytetracycline is widely used to treat bacterial infections in fish (RIGOS; TROISI, 2005). This substance has bacteriostatic action, inhibiting protein synthesis in bacteria (RIGOS; NEMGAS; ALEXIS, 2006). Administered in doses ranging from 50 to 125 mg/kg, for a period of 7 to 10 days (MARQUES, 2018). Excessive or inappropriate use of this antimicrobial can result in adverse effects on fish organisms and the promotion of bacterial resistance (MARSHALL; LEVY, 2011).

Florfenicol, considered an antimicrobial of critical importance for the control of diseases in fish, is indicated for the treatment of *S. agalactiae*. It demonstrates a wide range of action and is often administered through feed, in doses that usually range from 10 to 20 mg/kg, for a period of 10 days (ARMSTRONG et al., 2005).

Antimicrobial resistance presents substantial challenges to animal health and welfare. The ability of resistant bacteria to spread between humans, animals and the environment transcends borders, making it a global concern in terms of public and animal health (MARTINS, 2004). The indiscriminate and inappropriate use of medicines has been identified as one of the main drivers of the emergence of resistant strains, negatively impacting not only the balance of ecosystems, but also the health and safety of the general population (DA SILVA et al., 2022).

Even so, productions are susceptible to diseases, especially of bacterial origin, which are the cause of economic losses in tilapia cultivation, especially *Streptococcus agalactiae*. This bacterium can be found in the internal organs of tilapia, such as the kidneys, liver, intestine, heart, brain, and spleen (CAI et al., 2004; LIM AND WEBSTER, 2006).

The presence of these bacteria in the internal organs can lead to the development of bacterial diseases that affect the health and well-being of tilapia, resulting in significant losses in aquaculture production. This disease can manifest itself in several ways, including systemic infections, infections of specific organs and skin lesions, among others (SILVA, 2008).

Streptococcus is a gram-positive bacterium that represents a significant concern in aquaculture, affecting a variety of hosts, including fish. This bacterium, often associated with high morbidity and mortality rates, demonstrates remarkable adaptability to different environments, also including freshwater (JOHRI et al., 2006; EVANS et al., 2002).

Among the fish species affected by *S. agalactiae*, Nile tilapia (*Oreochromis niloticus*) is particularly susceptible. These infections can lead to serious impacts on fish health, resulting in significant losses in production and aquaculture as a whole. Given the severity of infections caused by *Streptococcus agalactiae*, it is crucial to implement effective control and prevention measures, including appropriate management practices, regular health monitoring, and, when appropriate, the use of vaccines to protect fish against this pathogenic bacterium (EVANS et al., 2002; EVANS et al., 2004).

Vaccination is recognized as the most effective procedure for immunization against a variety of pathogens in aquaculture. It works by activating the acquired immune response and generating memory cells through the introduction of antigens into the fish's bodies (SECOMBES AND BELMONTE, 2016).

In aquaculture, there are three main routes of vaccine administration: oral, immersion, or intraperitoneal/intramuscular injectable (Dadar et al., 2017; Derome et al., 2016). The choice of vaccine administration route depends on several factors, including the characteristics of the target pathogen, the natural route of infection, the type of vaccine (live or inactivated), the state of immune memory and the immune system of the fish, the production cycle, the production system, management practices, nutrition, cost-effectiveness, and environmental conditions, such as water temperature (ASSEFA AND ABUNNA, 2018; DADAR ET AL., 2017).

Oral vaccination, performed by administering the vaccine in the feed, has been shown to be an effective approach in protecting against *Streptococcus agalactiae* in Nile tilapia (MELO et.al., 2015). According to Firdaus-Nawi et al. (2012), oral vaccination offers several advantages, including reduced labor costs, needle and syringe expenses, and minimizing stress on fish during the vaccination process.

However, it is important to recognize that oral vaccination can induce immunity mainly in the mucosa of the gastrointestinal tract, providing local protection (MELO et.al., 2015). Studies, such as that by Rombout et al. (1986), who investigated oral vaccination in carp (*Cyprinus carpio*), observed that this form of vaccination may result in less pronounced immunity in the circulatory or systemic system.

In addition, as mentioned by Evensen (2009), orally vaccinated fish may have a shorter protection period compared to other forms of administration, such as injection or immersion. This means that the immunity conferred by oral vaccination may be short-lived compared to other forms of vaccination.

Despite these considerations, oral vaccination is still a viable strategy to protect fish against *S. agalactiae*, especially in aquaculture systems where oral administration is more practical and cost-effective. However, it is important to regularly monitor the effectiveness of oral vaccination and consider other vaccination options, depending on the specific needs of each production system and growing conditions (MELO et.al., 2015).

The aforementioned studies, by Evans et al. (2004) and Longhi et al. (2012), indicate that the vaccine administered by immersion bath proved to be less effective in protecting against *Streptococcus agalactiae* in Nile tilapia compared to other forms of vaccination.

In the study by Evans et al. (2004), where only an immersion bath with the vaccine was used, there was no statistically significant difference in survival between the vaccinated fish and the control group. The study conducted by Longhi et al. (2012), where two immersion baths with the vaccine were applied, with an interval of 25 days between them, observed a greater protective effect compared to the control group. However, this protection was similar to that observed in the group of fish submitted to only one bath. In addition, due to the high mortality rate recorded in all fish groups (approximately 43%), the authors concluded that the immersion bath has low efficacy in protecting against *S. agalactiae* in Nile tilapia.

Injectable vaccination has been shown to be the most effective. According to Klesius et al. (2000), intraperitoneal vaccination with inactivated *Streptococcus* cells significantly reduced mortality in tilapia infected with this bacterium, preventing the appearance of symptoms such as erratic swimming and hemorrhagic exophthalmos.

Intraperitoneal vaccination using inactivated *Aeromonas hydrophila* cells in tilapia achieved significant protection in the weeks following vaccination (RUANGPAN et al., 1986).

Injectable vaccination has some significant advantages over other methods of vaccine administration. Because it is administered in small quantities, directly into the fish's body (intraperitoneal or intramuscular), and often accompanied by adjuvants, this form of vaccination can provide a longer period of protection (immunization). In addition, it allows the inoculation of antigens from different pathogens in a single vaccine, known as a multivalent vaccine (DADAR et al., 2017).

However, it is important to highlight that vaccination by injection may not be suitable for the initial phase of the life cycle of fish, such as post-larvae and fingerlings, whose immune system is still developing. This is because administering the vaccine by injection can cause stress in the fish, leading to a reduction in feeding and even tissue injury (ASSEFA AND ABUNNA, 2018; LILLEHAUG, 2014).

However, it is important to recognize that vaccination through individual injections is a laborious and stressful technique for fish. This is because it requires the removal of the fish from the water and their anesthesia before administering the vaccine. In addition, this approach may not be economically viable in large-scale crops, and is generally reserved for high-value fish, breeding and ornamental fish (MELO et.al., 2015).

In addition to vaccination and the use of antibiotics, fish farming has as an ally the use of common salt, in addition to being a low-cost option, also reducing the need for other chemotherapy drugs, providing ideal health conditions for fish and increasing the safety of the production system and consumers (CHAGAS et al., 2012; SILVA et al., 2009).

The mucus produced by fish plays a key role in protecting against salt loss and osmotic regulation of the body, as well as acting as a barrier against overhydration. The stimulation of mucus production, facilitated by the use of salt, also contributes to reducing the chances of secondary infections caused by fungi and bacteria. Therefore, the use of salt can be an effective strategy to promote the health and well-being of fish in intensive fish farms, helping to prevent health problems and minimize negative impacts on production (MELO et.al., 2015).

The use of salt is effective in controlling some ectoparasites (SCHALCH et al., 2009; SILVA et al., 2009), minimizes osmoregulatory stress during transport (KUBITZA, 2007; URBINATI; Carneiro, 2004, 2006) and during management, in addition to preventing methemoglobinemia, known as brown blood disease (FRANCIS-FLOYD, 1995). In addition, the use of common salt decreases the parasite load of *Piscinoodinium pillulare* after transport.

In recirculating systems, fish often face water with a high amount of suspended solids, which can result in the proliferation of parasites, bacteria and fungi. In addition, due to high stocking densities and continuous exposure to stressors such as variations in water quality parameters, fish can lose salts more quickly. Maintaining a constant salinity of around 20g/L helps mitigate problems with parasites and fungi, reduces irritation of the gill epithelium, and minimizes excessive loss of salts by fish (RECOLAST, 2017)

In this same system, toxic concentrations of nitrite can occur. Applying salt to water can mitigate the toxic potential of nitrite to fish. Chloride ions, when present in adequate amounts in water, bind to nitrite receptors in fish gill cells, preventing the absorption of this toxic compound (KUBITZA, 2007).

FINAL CONSIDERATIONS

In conclusion, the implementation of good agricultural practices in the production of Nile tilapia in simple recirculation systems in urbanized areas is crucial to ensure the sustainability and economic success of this activity. The emphasis on biosecurity plays a key role in this context, as it makes it possible to prevent the introduction and spread of pathogens, ensuring the health and well-being of fish, as well as food safety.

By prioritizing biosecurity, producers can minimize disease risks and increase the efficiency of the recirculation system, resulting in healthier and more productive production. This is especially relevant in urban environments, where environmental and health challenges can be more intense due to proximity to residential and industrial areas.

It is also important to ensure that suppliers are reliable for the best results, and to be aware of the signs that fish may present throughout the cultivation cycles, in order to make appropriate decisions when necessary. Seeking guidance is essential for the success of the producer in this venture.

Therefore, investing in biosecurity measures, such as proper system installation, quarantines, regular water quality monitoring, and implementing proper management practices, is essential to ensure successful production in simple recirculation systems in urban areas. These measures not only protect the health of fish but also contribute to the economic viability and long-term sustainability of aquaculture in urbanized environments.

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