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# Occurrence of Diseases in Tilapia Culture Worldwide: Review of the Current State of the Art

## *Ocorrência de doenças na cultura da tilápia no mundo: revisão do estado da arte atual*

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**ABSTRACT:** The tilapiculture has grown substantially in the last years for the productive intensification what presupposes the increase in the frequency of occurrence of diseases and the establishment of a propitious environment to the disappointment of new pathogenic outbreaks. Aiming to contribute to the qualitative production of tilapia, the guarantee of public health and the continuous growth of tilapiculture in a sustainable way controlling and preventing the occurrence of diseases in tilapiculture A rresearch was conducted on parasitic and microbial pathogens in tilapia farming in Angola. To provide an overview of the current scenario, a preparatory study was necessary to assess the present state of tilapia farming and its sanitary conditions.The article brings an appreciation of the current state of tilapiculture and its worldwide prosecution in terms of quantitative and qualitative production, geographical distribution of production, the commercially important tilapia species, the production systems applied in tilapiculture, current vision and sanitary approach in production: most frequent diseases and pathogens, the damage caused by diseases in the sector, the forms of recognition of the presence of disease in the farm adopted by producers and the route indicated until definitive diagnosis, the solutions taken in the treatment, control and prevention of cases of diseases common to tilapiculture as well as cases of new outbreaks ending with the difficulties encountered in facing the diseases.
**Keywords:** Food-Security, Sanity, Sustainability, Tilapia Culture.

**RESUMO:** A tilapicultura tem crescido substancialmente nos últimos anos pela intensificação produtiva o que pressupõe o aumento na frequência de ocorrência de doenças causadas pelo ambiente propício à ocorrência de surtos. Visando contribuir na produção qualitativa de tilápia, na garantia da saúde pública e no contínuo crescimento da tilapicultura de forma sustentável controlando e precavendo a ocorrência de doenças na realizam-se pesquisas de agentes patogénicos parasitários e microbianos na tilapicultura em Angola e para uma visão geral do cenário atual efetuou-se um estudo preparatório referente ao atual estado da tilapicultura e sanidade. O artigo trás uma apreciação do atual estado da tilapicultura e sua prospeção mundial em termos produtivos quantitativos e qualitativos, distribuição geográfica da produção, as espécies importância comercial e potenciais, os sistemas produtivos aplicados na tilapicultura, atual visão e abordagem sanitária na produção: doenças e agentes patogénicos mais frequentes, os danos causados pelas doenças no sector, as formas de reconhecimento da presença de doença na exploração adotadas pelos produtores e a rota indicada até ao diagnóstico definitivo, as soluções tomadas no tratamento, controlo e prevenção de casos de doenças comuns à tilapicultura bem como de casos de novos surtos finalizando com as dificuldades encontradas no enfrentamento as doenças.
**Palavras-chave:** segurança alimentar, sanidade, sustentabilidade, cultivo de tilápia.

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## INTRODUCTION

Aquaculture in the last decade is the food production sector that has grown the most in productive terms worldwide and tilapiculture has achieved the greatest and fastest growth representing 10.3% of the total fish production worldwide being in second place in the world ranking of the most farmed fish species in the world (Cortés-Sánchez et al., 2021; FAO, 2020b, 2020a; Samaddar, 2022). Tilapiculture is defined as the process of growing fish of the different species of tilapia. This activity which began to be practiced in Egypt and Africa over 4000 years ago, is currently practiced in 5 of the existing six continents namely: in Africa, America, Asia, Europe and Oceania, over 170 countries from 195 countries exist, with tropical, subtropical and temperate climates predominantly in those countries considered low-middle income countries (LMICS) in the south of Africa, Asia and South America (Figure 1), Ke et al. (2012); McMurtrie et al. (2022), where in general the largest producers are the Asians. In Africa, tilapia is the most produced species representing 57.02% of aquaculture production (Figure 1), (FAO, 2020a, 2020b).

## CURRENT STATE OF TILAPICULTURE AND PRODUCTIVE PROJECTION

Already named as the "aquatic chicken" by international development agencies in the 1970s and as the fish of the 1990s in the 1990s, it is currently considered as the fish of the 21st century presenting itself as the revelation star of aquaculture (Prabu et al., 2019). The tilapia production is increasing over the last eight decades 1950-2018 reaching its maximum global production record in 2018 where production of 6,882. 202 tons and the growth perspective of this sector is global with the highest growth rate in the coming years in African countries in the range of 60% and a production projection that foresees the doubling of the global production of tilapia by 2030 in relation to its 2010 global production making it one of the leading fish and tilapiculture a key element in the future development of aquaculture and an important factor in meeting some of the UN-FAO challenges within its strategic plan for sustainable development 2020-2030 aimed at ending hunger and poverty in all its forms, achieve improved food security and nutrition, promote sustainable agriculture, ensure healthy lives, promote well-being at all ages, ensure availability and sustainable management of water and sanitation for all, ensure sustainable consumption and production patterns (FAO, 2020a, 2020b; Samaddar, 2022; United Nations, 2020).

Currently, tilapia is produced in most countries for self-consumption by thousands of small-scale farmers who supplement their diet with tilapia and in proportion to production, the largest consumers of tilapia are the Asians where it is also a commodity for China, Israel and Brazil who are the largest exporters of tilapia in the world marketing it to African, European and American countries FAO (2020a, 2020b); Prabu et al. (2019); Toguyeni (2004) and in these countries the tilapia production industry is not seen as an alternative to fighting hunger and poverty but as a big corporate business. In parallel to production the economic value of tilapia has grown globally where the average kilogram price increased by USD 0.5 in 2018 compared to the kilogram price in 2010, with the kilogram price increasing from USD 1.36 to USD 1.86. This global average price varied positively and negatively when evaluated by regions with appreciation above 0.5 USD in developed countries where the price increased from 3.46 to 5.72 USD/kg in a change of 2.25 USD/kg and depreciation in developing countries where the global average price of the kilogram decreased by 0.05 USD having gone from 1.98 USD/kg to 1.93 USD/kg (FAO, 2020b, 2020a). The growth and yields of tilapia farming in recent years are shown in Figure 2.

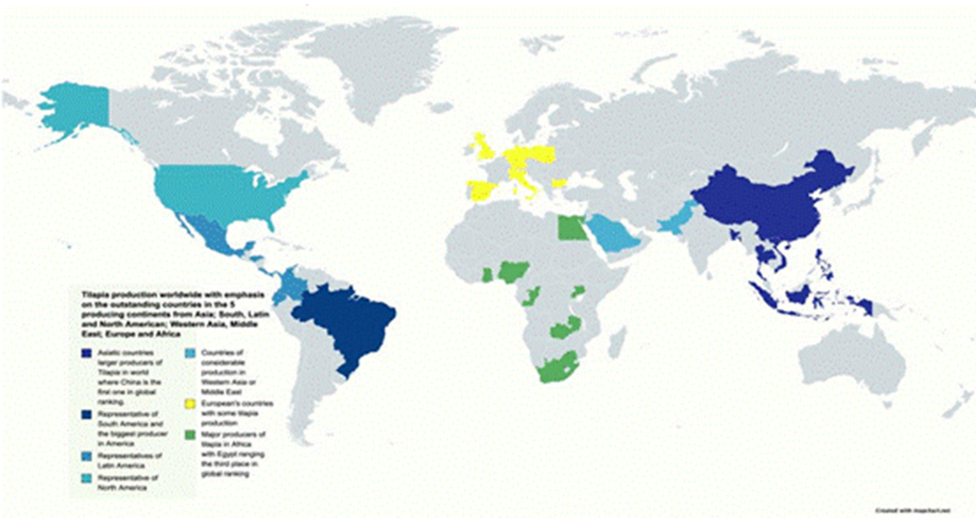


**Figure 1.** Continents with tilapia production highlighting mean countries in terms of production for each region (Cortés-Sánchez et al., 2021; FAO, 2020a, 2020b; Ke et al., 2012; McMurtrie et al., 2022; Prabu et al., 2019; Samaddar, 2022).

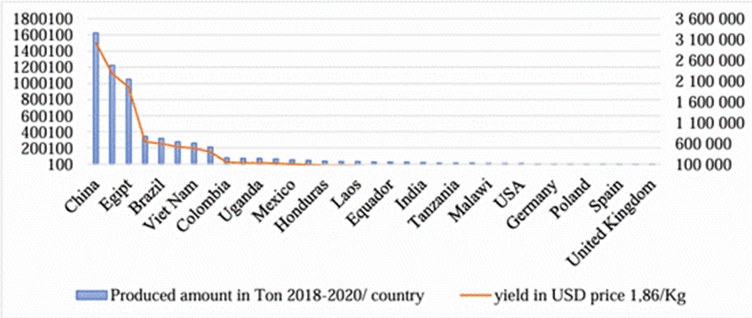


**Figure 2.** Available tilapia production record of some countries in the world in tonnes and income obtained by countries from the commercialization of tilapia at the global average value of 1.86 USD/kg in the period 2016 - 2020 (FAO, 2020a, 2020b; Garza et al., 2019; Mitiku, 2017; Moyo & Rapatsa, 2021; MPA, 2016; Prabu et al., 2019).

Similar to the productive level and market price, tilapiculture has also been growing in the production systems used. The production methods adopted vary from country to country and various systems and means of production have been used according to the country's production level, existing legislation on availability and use of water and land resources, environmental factors in the country, climatic conditions, innovation, accessibility, technological availability, skilled labour, level of knowledge, food availability, financing and production support. Thus, based on the above factors, tilapia has been produced using the systems shown in Table 1.

Food, nutritional, employment and income need in the world only tend to increase with the growth of global population density and the worsening of environmental conditions that make the food production process difficult and tilapiculture presents itself as the food sector in the opposite direction of the general scenario.

Since tilapicultura produces meat of high protein value besides being a source of employment and an important element for rural development and the generation of livelihood and income for families mainly in developing countries.

The development of new strains or the introduction of GIFT (Genetically Improved Farmed Tilapia) tilapia that have better records in terms of production, health and physical, nutritional quality is also the trend for the coming years (Samaddar, 2022).

Normally, it is cultivated for human food as well as for feeding carnivorous fish species that are cultured such as sea bass, mud snail in India, while quo in Brazil the possibilities in the treatment of burns to improve the healing process of burns is studied in Brazil (De Miranda, 2018).

## TILAPIA SPECIES PRODUCED IN TILAPICULTURE WORLDWIDE

Originating from Africa, tilapia corresponds to a family of freshwater fish composed of 112 species and subspecies grouped into three genera according to their parental behaviour: genus Tilapia, genus Sarotherodon and genus Oreochromis (Machimbirike et al., 2019; Prabu et al., 2019). Of these existing varieties, in current tilapiculture only 23 species are bred and species of the genus Oreochromis are the most cultivated because they tolerate better high stocking densities, grow faster, disease resistance, are adapted to captivity, accept balanced diets, and have good quality meat and therefore are well accepted in the market Cortés-Sánchez et al. (2021) and among the 23 species bred, only 10 species are commercially important worldwide in which the following stand out in order of highest production in Tables 2, 3, 4 and 5: These species which have a productive potential, together contributed less than 1% of the total world tilapia production. and the predominant species in terms of production and world distribution is Oreochromis niloticus (Albuquerque et al., 2015.; Machimbirike et al., 2019; Prabu et al., 2019; Samaddar, 2022).

**Table 1.** Systems used for tilapia production worldwide, their classification according different criteria presented in bibliography (Prabu et al., 2019; Sagua, 1987; Samaddar, 2022).

| Criteria for classifying tilapicultura production systems | Stock density or produced quantity / year | Production facilities | Water supply technology | Number and type of species cultivated |
|---|---|---|---|---|
| Criteria for classifying tilapicultura production systems | Extensive<br>4 -10 /m$^3$ 400kg/ha/year | Earthen ponds | Open or continuous | Monoculture |
| | Semi-Intensive<br>10-50/m$^3$ 10 t/ha/year | Cages | Semi closed without recirculation | Polyculture |
| | Intensive<br>50 -200/m$^3$ 90 kg/m$^3$/year | Concrete or other material tanks | Closed with recirculation | Aquaponics |
| | | | | Integrated |

**Table 2.** Ten tilapia species commercially produced worldwide in order of importance.

| Species | Common name |
|---|---|
| *Oreochromis niloticus* and its variety GIFT | Nile tilapia |
| *Oreochromis sp.* | |
| *Oreochromis urolepsis hornorum* | Wami |
| Hybrid of the crossing of *Oreochromis niloticus x Oreochromis aureus* | Blue tilapia |
| *Oreochromis aureus* suitable for countries with low temperature and rapid temperature changes during seasons. | -* |
| *Oreochromis mossambicus* good for brackish waters in extensive monoculture systems. | - |
| Hybrid of Oreochromis *niloticus x Oreochromis mossambicus* suitable for brackish waters. | Red tilapia |
| *Tilapia Zillii* | - |
| *Coptodon rendalli* | - |
| Hybrid of *Oreochromis aureus x Oreochromis mossambicus* | - |
| Hybrid of *Oreochromis mossambicus x Oreochromis hornorum* | - |
| *No common name founded | |

**Table 3.** Six tilapia species commercially potentials in scale of importance.

| |
|---|
| *Oreochromis shiranus* |
| *Oreochromis macrochir* |
| *Oreochromis andersonii* |
| *Oreochromis tanganicae* |
| *Oreochromis hornorum* |
| *Oreochromis angolensis* |

**Table 4.** Tilapia species that still known in tilapiculture (Machimbirike et al., 2019)

| |
|---|
| *Tilapia amphimelas* |
| *Tilapia esculenta* |
| *Tilapia variabilis* |
| *Hoplochromis sp.* |

## DISEASES IN TILAPICULTURE

With the growth, expansion and intensification of aquaculture production, biosecurity becomes an important consideration as aquatic animal diseases are one of the most serious constraints to the expansion and sustainable development of aquaculture (FAO, 2020a, 2020b). Intensification can cause chronic stress that adversely impacts fish physiology resulting in reduced growth and resilience to disease. Increasing stocking density and production levels often occur with insufficient clean water, leading to deterioration in water quality, including dissolved oxygen, hydrogen potential (pH) and ammonia, which in turn negatively impacts fish growth and health and leaves them more susceptible to disease (McMurtrie et al., 2022).

Globally, a trend in aquaculture is that previously unreported pathogens causing new and unknown diseases emerge and spread rapidly causing increased production losses approximately every 3 to 5 years, in addition to endemic diseases in each region with local losses and impacts (FAO, 2020a, 2020b). Such diseases are mostly caused by viruses but globally in several occurrences the etiological agents reported have been bacteria, parasites and fungi (FAO, 2020a, 2020b). Like any production system, tilapia farming is susceptible to disease.

Tilapia has long been considered a disease-resistant species because of its high tolerance to a wide temperature range, its survival in different salinities and environmental conditions considered adverse and its lower climatic and environmental requirements compared to other farmed fish species. Currently, this knowledge is held as an outdated belief because recent studies point out that the disappointment of intensive tilapia production has made it more susceptible to disease-causing microorganisms McMurtrie et al. (2022) and all other factors related to the emergence of diseases.

Disease is a condition in living organisms in which normal physiological functions are impaired by changes in body systems and typically manifested by distinct signs and symptoms. As in all animals in a cultured environment, for the emergence of a disease in tilapiculture there must be the interaction of several factors related and integrated in the pathogenic triad presented in Figure 3.

In tilapia as in every animal the diseases are classified based on the origin of the disease into two major groups infectious and non-infectious which in turn aggregate different diseases that are given specific names based on the causative agent of the same as presented in Table 5, being the infectious diseases that constitute the greatest challenging problems for tilapicultura, public health and food safety (Abdelsalam et al., 2023; Journal of environmental science and technology, 2020; Rahman Md Ashikur et al., 2019).

## FREQUENCY OF DISEASE OCCURRENCE IN TILAPIA PRODUCTION

In recent times, tilapia farming has been burdened with diseases and other problems caused by viruses, bacteria, parasitic fungi and other unidentified or emerging pathogens Bondad-Reantaso et al. (2005) although recording and reporting of occurrences has been a problem for some of the major producers such as Asian countries that under-report disease occurrences as well as African countries that do not report due to lack of material technical conditions, information, training and technical assistance. Bacterial infections are common in tilapicultura in Egypt that several cases arise mixed infections where more than one infectious agent co-infect the fish (Abdelsalam et al., 2023).

With intensification and increase in production the incidence of diseases has also increased in a directly proportional reaction (Ali et al., 2020).

Despite insufficiency in statistical data, publications indicate that in Asian countries such as Thailand, where intensification is established and on a large scale, outbreaks of unknown diseases occur annually with mortalities above 50% (Dong et al., 2015).

## MAIN DISEASES REPORTED

The diseases reported in tilapiculture are mainly those of infectious origin among which are viral, bacterial, parasitic and fungal infectious diseases in which most dermal diseases are caused by the parasitic bacteria and fungi. In turn, bacterial diseases in tilapia are classified into septicaemia bacterial diseases, localized skin diseases and chronic granulomatous diseases (Junior et al., 2020; Leira et al., 2016). The diseases recorded in tilapiculture are shown in Table 6.

## PATHOGENS INVOLVED IN THE OCCURRENCE OF SUCH DISEASES

In tilapiculture, tilapias have been affected by different pathogens many already identified some of which are part of their natural microbiota such as some bacteria (Machimbirike et al., 2019). The main agents implicated in reported cases of disease in tilapia are presented in Table 7.

**Table 5.** Global geographic distribution of tilapia production by species in (FAO, 2020a, 2020b; Holčík, 1991; McMurtrie et al., 2022; Moyo & Rapatsa, 2021)

| Geographical distribution of tilapia´s production by species | | |
|---|---|---|
| **Region** | **Country** | **Species produced** |
| **Africa** | South Africa | *O. niloticus* |
| | Botswana | *O. niloticus* |
| | Egypt | *O. niloticus* |
| | Ghana | *O. niloticus* |
| | Laos | *O. niloticus* |
| | Malawi | *Lepterodon; Rendalli; O. shirany* |
| | Mozambique | *O. mossambicus* |
| | Nigeria | Tilápias nei* |
| | Uganda | *O. niloticus* |
| | Zambia | *O. niloticus; O. tanganicae*; T. da cabeça vermelha; T. estreita; T. malhada |
| | Zimbabwe | *O. niloticus* |
| | Angola | *O. niloticus?* |
| | Namibia | *O. niloticus?* |
| **America** | Brazil | *O. niloticus; Cicla spp* |
| | Colombia | *T. nei; O. niloticus* |
| | Mexico | *T. nei; O. niloticus* |
| | Ecuador | *O.niloticus* |
| | USA | *O.niloticus* |
| | Honduras | *O. niloticus* |
| **Asia** | China | *O.niloticus;* T. Azul |
| | Indonesia | *O. niloticus; O. mozambicus* |
| | Bangladesh | T. nei |
| | Philippines | *O. niloticus*; T. nei |
| | Vietnam | T. nei |
| | Thailand | *O. niloticus; O. mossambicus* |
| | Taiwan | T. nei |
| | Myanmar | T. nei |
| | Malaysia | T. nei; *O. niloticus* |
| | Lao | *O. niloticus* |
| | India | *O. niloticus; O. mossambicus*; T. red |
| **Europe** | German | *O. niloticus* |
| | Switzerland | *O. niloticus* |
| | Poland | *O. niloticus; O. aureus; O. mossambicus* |
| | Italy | *O. niloticus?* |
| | Spain | *O. niloticus?* |
| | Bulgaria | *O. niloticus?* |
| | United Kingdom | *O. niloticus; O. mossambicus; T. zillii* |
| **Oceania** | Indonesia | *O. niloticus; O. mossambicus* |

? - Uncertainty or the information about the specie (s) produced in the country is not feasible. *nei - an ASFIS nomination for species item representing a group of miscellaneous tilapias or other freshwater fishes.

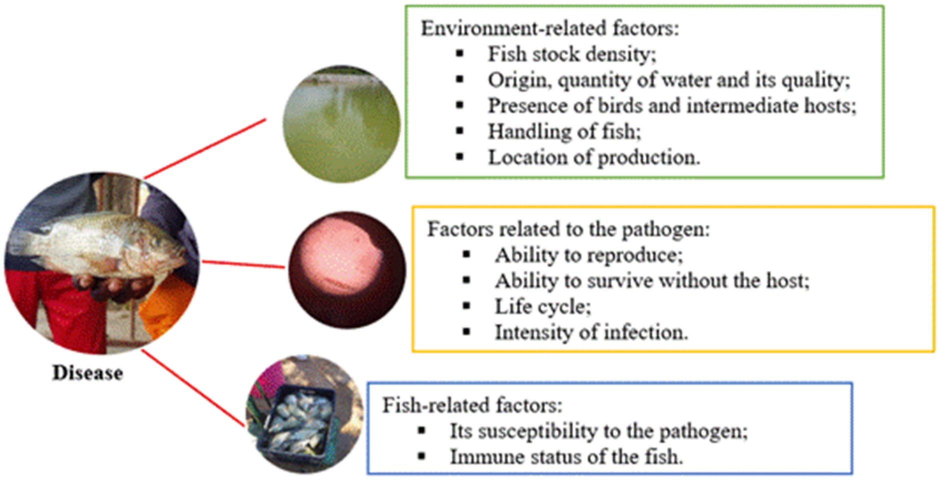


**Figure 3.** Schematic representation of the pathogenic triad. The point of convergence of the unbalanced conditions of these three elements is the manifestation of the disease.

## IMPACT OF DISEASE ON TILAPIA PRODUCTION

Diseases are currently the first limitation in tilapiculture in developed countries and the second in developing countries only behind food shortages due to food insufficiency that promotes competitiveness between food consumption in fish production and human food consumption, preventing growth and economic and social sustainability of production and the country through direct losses in productivity, increased operating costs and indirectly through trade restrictions (Bondad-Reantaso et al., 2005). The impacts are felt through the expenses necessary to treat the disease once it is installed in production, the loss of dead fish that will reduce the volume of production and consequently affect the financial income to be obtained at the end of the production cycle, which in turn may become a social problem by leading to the loss of jobs in the sector due to low productivity. Diseases in tilapiculture limit productivity and sustainability with impacts on food security, food confidence, job stability and human health. Acute bacterial diseases for example cause massive deaths in a short time as in the case of streptococcosis which leads to considerable morbidity and mortalities worldwide with excessive economic losses which in 2008 form evaluated at over $250 million (Abdelsalam et al., 2023; Zamri-Saad et al., 2014). The major negative impact of the diseases is the threat to food security and public health that they pose since tilapia can become a potential source of disease to humans.

## IDENTIFICATION OF DISEASES IN TILAPIA PRODUCTION UNITS

The identification of diseases in farms follows a diagnostic protocol with staged practices that range from the simplest to the most complex until a precise and definitive diagnosis of the disease-causing agent is reached. In general, producers, researchers and specialists cooperate in the diagnosis of diseases and adopt the diagnostic protocol recommended by FAO and ANACA in which diseases are diagnosed at 3 different and complementary levels:

I. The first level with application of the most traditional method which is fish inspection and environmental examination. this involves the observation of the different clinical signs in random apparently infected and non-infected live animals, also evaluating the signs and lesions in fish killed by the disease for presumptive diagnosis, the most common general clinical signs are: presence of abdominal red spots on the fish, exophthalmos, corneal opacity, ulcerations on the skin, inflamed operculum, erosion of the tail and fins, superficial swimming, injuries on the top of the head (Abdelsalam et al., 2023). However, mixed infections may underlie different clinical signs and are responsible for the difficulties in diagnostic regimes so reliance solely on diagnosis based on this method may mask the identity of the real causative agent as well as lead to definitive misdiagnosis. For confirmation of presumptive diagnosis, various techniques have been developed in identification of bacterial, fungal and parasitic pathogens Abdelsalam et al., (2023) then move to the second level which is laboratory analysis divided into 2 groups: screening analysis and advanced analysis.

II. Screening laboratory analysis with parasitological, microbiological (bacteriology, mycology) and histopathology observation in which samples of internal and external secretions and tissues of the fish collected and brought to the laboratory alive are treated and observed microscopically to identify the pathogen. In parasitology direct observation of the smear of skin mucus, gills and the intestinal tissue is used to identify parasites located in these parts of the fish body. Coprology is also used for identification of early parasitic forms in fish faeces.

**Table 6.** Viral, bacterial, parasitic and fungal diseases reported in tilapiculture (Abdelsalam et al., 2021, 2023; Atyah et al., 2010; Fayaz & BhatI, 2023; M. Gamal et al., 2022; S. A. Gamal et al., 2023; Guan et al., 2022; Jansen et al., 2019; Journal of environmental science and technology, 2020; Junior et al., 2020; Mitiku, 2017; Nicholson et al., 2020; Prabu et al., 2019; Rahman Md Ashikur et al., 2019; Teles, 2013; Thomas et al., 2014).

| Origin | Disease | Symptomatology | Mortality rates |
|---|---|---|---|
| **Viral** | Viral disease of Nile Tilapia Or Tilapia syncytial hepatitis virus | Viral disease of Nile Tilapia Detachment of scales, haemorrhagic marks, open sores, noisy scales and dark discolouration. Clinical manifestation varies according to the central organ affected e.g. in Israel affected fish show signs denoting problems in the brain, in Ecuador and Colombia it appears that the target organ is the liver (Environ. Sci. Technol. 2020). Pathognomonic symptom is ascites and histological observations shows hepatocellular lipoprotein accumulation, necrosis and syncytia formation with necrosis of gastrointestinal mucosa | Up to 90% in farmed fish |
| | Infectious pancreatic necrosis | Tilapia show little or no specific clinical signs serving mainly as carriers of the virus. | Up to 90% in fry and fingerlings |
| | Viral Nervous Necrosis | Affects Tilapia larvae | From 20% - to 100% |
| | Tilapia Larval Encephalitis | Characterised by spinning syndrome and severe mortalities. | Above 90% |
| | Infectious necrosis of spleen and kidney | Affects mainly adult female ovaries, fertilised eggs, larvae and fry. Survivors and moribund individuals exhibit lethargy, pallor of the gills and distension of the coelomic cavity caused by coelomic ascitic fluid. | Around 50 -75% |
| | Bohle´s disease | Affects mainly young fish. Infected fish show gyratory swimming behaviour which led to the name of the disease being Tilapia gyratory syndrome. | 100% |
| **Bacterial** | *Aeromonas septicaemia* | The disease may manifest itself as hyperacute, acute or very subacute and chronic. With characteristic signs of septicaemia such as haemorrhages in the gills, around the year and in internal organs, abscesses and ulcers in chronic cases. | More than 50% |
| | Septicaemia by pseudomonas | Externally haemorrhagic lesions are observed on the skin and at the base of the fins. Internally there is an accumulation of ascitic fluid in the peritoneum, haemorrhages with petechiae in the gills, kidneys, liver and in the lumen of the intestinal submucosa. | High |
| | Furunculosis by Aeromonas | The clinical manifestation of furunculosis can also occur in hyperacute, acute, subacute and chronic form with signs such as alteration in the colouration of the fish which become darker and die quickly, the fish become lethargic, stop eating, appearance of skin lesions and furuncles. The fish may show exophthalmos and bloody secretions in the year and nasal passages. | Up to 98% |
| | Columnariosis | The causative micro-organism infects the whole body from the skin, gills and internal organs. Whitish patches on the skin of the fish give way to rapid deterioration of the affected site with ulcerations, eroded fins and the fish gulps at the surface. | High |
| | Edwardsielloses | Small localised lesions in the posterolateral region of the affected fish, abscesses in the muscles and caudal peduncle which on increasing in size fill with gas and become necrotic. Bleeding of the skin around the mouth, pale gills, exophthalmos and open lesions on the head may occur if *E. ictaluri* is the agent involved. Internally, the kidneys and spleen are swollen, necrotic areas in the liver, accumulation of bloody ascitic fluid in the peritoneum and haemorrhages on the inner wall of the muscles. Fish larger than 15 cm may show no external symptoms. | Massive mortalities |
| | Vibriosis | Infected fish become inactive, with loss of appetite. The common clinical manifestation for all forms of vibrioses in fish are typical of a haemorrhagic septicaemia which may present in subacute, hyperacute and chronic forms. Affected fish show haemorrhage at the base of the fins, around the year and mouth; skin discolouration, necrotic lesions in the muscles and when these reach the skin they give rise to ulcers, exophthalmos and corneal opacity. Internally, the liver appears pale and occasionally the intestine may be filled with a viscous fluid. | May reach 100% |
| | Yersiniosis | The disease manifests clinically in hyperacute, acute and chronic form. External symptoms are inflammation and erosion of the jaw and palate, reddening of the mouth and throat caused by subcutaneous haemorrhage, darkening of the skin, appearance of haemorrhages at the base of the fins, bilateral exophthalmos and lethargy. | Considerable |
| | Streptococcosis | Exophthalmos, abdominal distension, haemorrhages in eyes, opercula and at base of fins, darkening of skin and erratic swimming. Internally, one finds damage to the liver, kidneys, spleen and intestines with accumulation of ascitic fluid in the abdominal cavity. | 73,3% |
| | Staphylococcosis | The disease presents with exophthalmos, swelling and caudal ulcers. Splenomegaly. With diffuse white nodules in the gills, liver, gonads, stomach and intestines. | 60-70% |

| Origin | Disease | Symptomatology | Mortality rates |
|---|---|---|---|
| **Fungal** | Saproleniosis | The external manifestations involve the formation of cotton-like plaques of fungus, the infected fish become detached and swim isolated around the corners of the tank near the surface breathing slowly, with reduced appetite and bumping into hard substrates. Ulcerations and sloughing off of fins are also observed. | High |
| | Aspergillomycosis | Paleness of gills, anaemia, low growth rate, hepatoma and death | High |
| **Parasitic** | Ichtiophiiriasis White spot disease (Ich) | Small white spots on the body surface and on the gills of infested fish, formation of a mucous mass on the body surface, microscopic lesions which favour the formation of hyperproduction of mucus, lethargy, superficial swimming on the edges of the fishponds, accelerated respiratory movements and mouth-watering degeneration of the caudal fin, diffuse haemorrhagic spots. | High |
| | Trichodinase | Infested fish do not show specific clinical signs, lethargy is observed erratic and superficial swimming, whitish and irregular lesions on the surface of the body and head. Hyper production of mucus, whitish areas and pallor in the gills suggesting necrosis. | High in severe infestations |
| | Chilodonellosis | Depigmentation of the skin, hyperproduction of mucus, loss of appetite, breathing at the water surface, ulceration of the skin with micro-haemorrhages, loss of scales and lesions on the gills. | High in severe infestations |
| | Ichthiobodosis | Lethargy, loss of appetite, dyspnoea, erratic swimming and rubbing of the body on the edges and bottom of the fishponds, alteration in the colouration of the body surface, excessive amount of mucus, haemorrhagic foci, loss of scales and ulcerative lesions. | High in severe infestations |
| | Hexamitosis | Presence of lip tumours, unilateral exophthalmos, muscular ulcers and blister formation in the skin, haemorrhage in the head and eyes, internally there are granulomas in the liver and spleen and anaemia in haematological examinations. | High in severe infestations |
| | Coccidiosis (Eimeria spp.) | White nodular areas in the stomach due to inflammation of the intestines, dysentery and darkening of the colour of the fish body. | High in severe infestations |
| | Trypanosomiasis | Severe haemolysis, loss of RBCs leading to an anaemic room, cell destruction, altered haematopoietic tissue, lethargy, impaired gill tissue, gill oedema, lamellar fusion and tissue necrosis. | High in severe infestations |
| | Datilogyrosis | Significantly infested fish show inappetence and body weight loss. The clinical manifestation presents with erratic swimming, lethargy, hypersecretion of mucus all over the body and on the gills, fish concentrate on the surface or at the water inlets of the nurseries for a long time, constant opening of the operculum, irritation and exfoliation of the body surface. The gills may also exhibit a slimy, whitish appearance. | Variable depending on the age of the infested fishes and degree of infestation. |
| | Gyrodactylosis | The behaviour of the fish and clinical manifestation is similar to datilogirosis in that significantly infested fish exhibit inappetence and body weight loss. The clinical manifestation presents with erratic swimming, lethargy, hypersecretion of mucus all over the body and on the gills, fish concentrate on the surface or in the water inlets of the ponds for a long time, constant opening of the operculum, irritation and exfoliation of the body surface. The gills may also exhibit a slimy, whitish appearance. | Variable depending on the age of the infested fishes and degree of infestation. |
| | Ciclidogirosis (Tilapia gill worm) | Skin irritation, erratic swimming, scratching of the body on fixed substrates. The mortality rate caused by them varies according to the production stage of the fish (fry, juveniles or adults) and the stage of the disease: acute or chronic. | Variable depending on the age of the infested fishes and degree of infestation. |
| | Clinostomiasis | Presence of yellow grape-like punctures on the gills and their subcutaneous muscles causing destruction of the gills associated with signs of asphyxia. | High in severe infestations |
| | Diplostomiasis (*Posthodiplostomum cutícola*; *Dilpostomum spathicum*) | Presence of multiple black spots scattered all over the fish body especially on the scales, unilateral or bilateral central opacity, emaciation and death by cessation of food consumption. | High in severe infestations |
| | Diphilobotriasis | Infested fish float on the water surface with the head tilted to one side. Infested fish die when the larva migrates into the heart and the carcasses of freshly killed fish may appear with an S- or C-shaped body. | High in severe infestations |
| | Acanthocephaliases (*Neochinorhynchus rutili*; *Acanthogyrus* sp.) | Inappetence, lack of weight gain and/or weight loss, inflammation of the intestinal mucosa. | High in severe infestations |
| | Argulosis | Stress, irritation and itching lead to behavioural changes in the fish manifested as repeated rubbing against substrate or other fish, jumping out of the water, forming smaller schools or remaining on the margins of the culture pond and anorexia. Fish with high infestation rates show anaemia, and focal haemorrhagic inflammatory lesions and hyperpigmentation at the base of the fins and in the gill chambers, the preferred sites of the parasites. Lethargy, weakness, skin lesions and mortality may occur. | High in heavy infestations |
| | Ergasilosis | Asphyxia in heavy gill infections, hyperproduction of serosanguinous mucus and high mortality occurs when infestation rate is high. | High in heavy infestations |
| | Lamprognaeoses (*Lamprogna monodi*) | Anorexia, apathy and point-like haemorrhages in the body and alterations in the respiratory system, they lose their sense of direction and crash against the pond walls, stay on the pond surface, may clump at the water inlet due to infestation of the gills and body surface. The fish may die from altered gill functions caused by the parasite. | High in heavy infestations |
| | Lerniosis anchor worm infestation | Skin irritation with excessive mucus secretion, abnormal swimming behaviors, scale detachment and presence of focal haemorrhagic granulomatous ulcers. Asphyxia in heavy gill infestations. Excessive blood-tinged gill mucus and the white adult female are seen attached to the gill filaments | High in heavy infestations |

III. In bacteriology tissue samples are selected from the fish and grown mainly on agar for isolation, evaluation of phenotypic and serological characteristics of the pathogen (Cortés-Sánchez et al., 2021).

IV. For fungi tissue swabs are observed microscopically and subsequent tissue culture, microscopic visualization and identification of sexual or asexual reproductive stages (Gamal et al., 2022).

V. The third level involves the advanced analyses with molecular diagnostic techniques using electron microscopic observation, molecular biology and immunology for the identification of the pathogen. These analyses are more accurate and faster than the traditional screening methods applied in the initial two levels. Therefore, they allow tilapia farmers and aqua pathologists to design effective strategies for disease control in tilapiculture farms and enable the use of appropriate medication and consequently prevent the occurrence of farm resistance (Abdelsalam et al., 2023).

The three levels of disease identification in production units and tilapia presented, have wide application in disease diagnosis and detention but are not applied to the same extent everywhere. Each country applies one of the levels or a combination of two or all three jointly according to material, technical and professional capacities and availability of resources (Bondad-Reantaso et al., 2005).

**Table 7.** Main etiological agents related to cases of disease in tilapiculture and their classification (Cortés-Sánchez et al., 2021; do Espírito Santo et al., s. f.; Jansen et al., 2019; Prabu et al., 2019; Suebsing et al., 2015; Zamri-Saad et al., 2014).

| Taxonomic Classification | Pathogen | Caused disease |
|---|---|---|
| **Virus** | Tilapia lake virus (*TiLV*) | Viral disease of Nile Tilapia |
| | Infectious pancreatic necrosis virus (*IPNV*) | Pancreatic necrosis |
| | Viral nervous necrosis (V*NN*) | Nerve necrosis |
| | Tilapia larvae encephalitis virus (*TLEV*) | Tilapia larval encephalitis |
| | Infectious spleen and kidney necrosis virus (*ISKNV*) | Infectious necrosis of spleen and kidney |
| | Iridovirus Bohle (*BIV*) | Bohle disease |
| | Lymphocystis disease virus (LCDV) | Tilapia syncytial hepatitis virus |
| **Gram-negative bacteria** | *Aeromona hydrophila* | Septicaemia by Aeromonas |
| | *Aeromona veronii* | Forunculosis by Aeromonas |
| | *Aeromona jandaei* | Septicaemia by pseudomonas |
| | *Aeromona spp.* | Francisellosis |
| | *Pseudomonas spp.* | Columnariosis |
| | *Francisesella noaturensis* | Edwardsiellosis |
| | *Francisella orientalis* | Vibriosis |
| | *Flavobacterium columnare* | Yersinioses |
| | *Edwardsiella tarda* | Bacteremia by *S. putrefaciens* |
| | *Vibrio anguillarum* | Gastroenteritis by *Plesiomonas* |
| | *Vibrio sp.* | |
| | *Yersinia sp.* | |
| | *Shewanella putrefaciens* | |
| | *Plesiomonas shigelloides* | |
| **Gram-positive bacteria** | *Streptococcus agalactiae* | Estreptococcosis |
| | *Streptococcus iniae* | Estaphylococosis |
| | *Streptococcus sp.* | Lactococose |
| | *Staphylococcus spp* | |
| | *Lactococcus garviae* (potentially zoonotic pathogen) | |
| **Fungi** | *Saprolegniaparasitic* | Fungi Mycotic disease of Nile tilapia Saprolegniosis |
| | *Aspergillus japonicus* | Aspergillomycosis |
| **Ciliated protozoan parasites** | *Ichthyophthirius multifilis* | Ichtiofiriasis white spot disease (ich) |
| | *Trichodina sp. Trichodina* | Tricodinasis |
| | *Chilodonella sp.* | Chilodonelosis |
| **Flagellate protozoan parasites** | *Ichtiobodo necator* | Ichthiobodose ou Cóstia |
| | *Hexamita sp.* | Hexamitosis |
| | *Eimeria sp.* | Coccidiosis |
| | *Tripanossoma sp.* | Tripanossomiasis |
| **Monogenetic trematode parasites** | *Dactilogyrus sp.* | Datilogirosis Gyrodatilosis Cyclidogirosis |
| | *Girodactylus sp.* | |
| | *Cichlidogirus sp.* | |
| **Digenetic trematode parasites** | *Clinostomum spp. Diplostomum spathicum* | Clinostomiasis Diplostomiasis |
| **Cestode parasite** | *Diphillobotrium* | Diphilobotriasis |
| **Parasite Acanthocephala** | *Acanthogyrus sp. Acanthosentis tilapiae* | Acanthocephaliasis |
| **Parasites Arthropoda Argulus** | *Argulus* (Branchiura) | Argulosis or fish lice |
| | *Ergasilus* (Copépoda) | Ergasiloses |
| | *Lernea* (Copépoda) | Lernaeoese |
| **Nematode parasite** | *Genus Amplicaecum* | Heartworm disease |
| **Isopod parasite** | *Nerocila orbignyi* | Nerocila disease |

## THERAPIES AND PREVENTION

Once the disease is established it can be controlled to reduce or eliminate the source of infection by severing the connection between the infectious source and the fish, reducing the susceptibility of the fish to infection by applying accurate diagnostic techniques and determining the spreading disease methods and interrupting them. In response to the occurrence of disease and death in tilapia culture, the most common immediate action is to stop feeding the fish, collect and remove dead carcasses, increase water flow or change the water if the water salinity is low. Few producers resort to the veterinary services to help solve the problem the most practiced is the self-administration of some chemicals or disinfectants without prescription from antibiotics, biotherapeutics, probiotics, bio remediators, prebiotics phytotherapy and some homemade recipes (Ali et al., 2020; Journal of environmental science and technology, 2020). Although the global trend is to avoid the use of antibiotics in aquaculture production including tilapiculture aiming to avoid drug residues in the fish fillet and that may cause harm to consumers as well as to reduce the high rate of antibiotic resistance currently faced (Desbois et al., 2021) The most commonly applied chemical compounds are presented in Table 8.

The primary aspect to consider in the prevention of disease in tilapicultura is the elimination of predisposing factors since the absolute majority of pathogens are opportunistic and cause epizootic outbreaks associated with predisposing stress factors such as: abrupt drop or rise in water temperature, stock handling , degradation of water quality parameters, introduction of unquarantined fish stock, uncontrolled water source, high stocking density, poor hygiene, high amounts of organic material in the ponds, inadequate aeration, food quality and availability, incorrect location of the farm with poor access roads and electrical supply (Cortés-Sánchez et al., 2021; Prabu et al., 2019; Zamri-Saad et al., 2014). Therefore, some preventive practices have been applied by producers either totally or partially according to each context to avoid, limit the disease-promoting effects of predisposing factors are proposed in the different international codes, agreements and voluntary or mandatory guides that implemented provide a certain level of protection against pathogens and the occurrence of outbreaks as are the OIE aquatic animal health code, the code of practice and procedure manual for consideration of introductions and transfer of marine and freshwater organisms, and the FAO code of conduct for responsible fishing. There are also country-specific regional regulations according to the specific legislation and problems of each country. Among the various strategic measures for sustainable production and biosecurity the actions taken involve (Journal of environmental science and technology, 2020):

- Prevent exposure to pathogens both physical, chemical and biological;
- Controlling the environmental conditions;
- Selecting the diet, amount of food and feeding frequency;
- Application of vaccination programmes and the development of vaccines against local diseases;
- Application and sanitary programmes;
- Eggs disinfection to prevent pathogen transmission vertically and horizontally.

A measure recommended by Zamri-Saad et al. (2014), is seasonal cultivation which consists of stopping cultivation during the hottest season that corresponds to the most critical period for favouring the disappointment of infectious diseases and maintaining cultivation only in the months with temperate environmental conditions, the latter being considered a drastic measure.

Vaccination is a preventive method that has been developed for some diseases in tilapia culture. Currently for example there are vaccines available against vibrioses, furunculosis, enteric red mouth disease and streptococcosis (Bondad-Reantaso et al., 2005; Journal of environmental science and technology, 2020; Su & Su, 2018).

**Table 8.** Chemical compounds used to treat diseases in tilapiculture, their classification and application (Albuquerque et al., 2015; Ali et al., 2020; Cortés-Sánchez et al., 2021; De Castro & Xavier, 2020; Desbois et al., 2021; Emam et al., 2024; Journal of environmental science and technology, 2020; Prabu et al., 2019; Schalch et al., 2009).

| Pharmacological classification | Chemical compound | Application in tilapicultura |
|---|---|---|
| **Disinfectants** | Saline solution (NaCl) | Baths |
| | Formalin (H2CO) | Baths |
| | Chlorine ($Cl_2$) | Baths |
| | Agricultural lime (CaMg (CO3)2) | Baths |
| | Potassium permanganate (KMnO4) | Baths |
| | Copper sulphate ($CuSO_4$) | Baths |
| **Antibiotics** | Erythromycin Terramycin Sulfamethazine | In feeding |
| **Biotherapeutics** | Microorganisms (bacteria, microalgae or yeast) | In feeding or in rearing water |
| **Probiotics** | | |
| **Prebiotics** | | |
| **Bio remediators** | | |
| **Phyto therapeutics** | Leaves and seeds of Moringa oleifera and others in nutrition | In feeding |

Diagnosis, information and technology are others strategies presented because the rapid identification of pathogens in asymptomatic fish or in the beginning of infectious process is a preventive measure of disease occurrence fundamental in helping producers in developing biosecurity programs (Abdelsalam et al., 2023).

Thus, the application of good management practices, training farmers in observing general signs of diseases in fish and the existence of a linkage with official organs for assistance is the key factor in disease prevention in tilapiculture.

## MAIN DIFFICULTIES IN DISEASE MANAGEMENT IN TILAPIA PRODUCTION UNITS

There are several difficulties faced by the tilapia production units in the management of diseases and this includes the increase and globalization of trade and markets; the intensification of productive practices by the movement of reproducers, post larvae, larvae, juveniles and other intermediated commodity movements that cause and maintain local, regional and transboundary diseases; the interaction between farmed and wild populations; poor or non-existent biosecurity parameters; poor awareness of emerging diseases; lack of knowledge of endemic pathogens in global and local tilapia farming; difficulties diagnostics at all diagnostic levels; little confirmation diagnosis; lack of technical and institutional assistance; indiscriminate use (self-treatment) of conventional and natural therapeutic substances applied in the treatment of diseases in tilapia farming due to inexperience of producers and climate changes (Bondad-Reantaso et al., 2005; Zamri-Saad et al., 2014).

## CONCLUSIONS

Tilapiculture is currently the most expanded fish production worldwide, with the largest global production in territorial terms and with a projection perspective for the next 10 years that guarantees that tilapiculture is the bet for supplying the existing need for good quality animal protein, optimising the exploitation of fishing resources that have been overexploited and destroyed by climate change in recent years, and is an ally in the fight against hunger, poverty, unemployment and underdevelopment of rural populations and localities such as in Africa, Sul and Latin America, and many Asiatic countries. The industry has been affected with outbreaks of viral, bacterial, parasitic and fungal diseases all over the world with mortalities and productive losses that threaten the sustainability and the security of the industry in the future, making necessary the improvement and the incentive to the application of measures, practices and strategies of productive growth and intensified biosecurity guaranteeing its sustainable development.

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