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REVIEW ARTICLE

NON-INFECTIOUS AND INFECTIOUS PATHOLOGICAL PATTERNS IN TILAPIA AND CATFISH: A REVIEW OF THE LITERATURE ON CAUSES AND CLINICAL MANIFESTATIONS

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Introduction:-

Tilapia and catfish are among the most cultured species in the world due to their hardiness and feeding habits with a low-demanding diet. Although they are easy to maintain and feed, very resistant, and well adapted to aquaculture, their farming is often confronted with the appearance of diseases. Indeed, the well-being of these fish can be compromised by two types of conditions: non-infectious diseases due to environmental factors and infectious and parasitic diseases due to viruses, bacteria, fungi, and parasites. These biological pathogens are hazardous for farmed and wild fish and are responsible for massive losses in fish production; therefore, they are considered a significant threat to the expansion of the aquaculture industry. Pathogens cause infectious diseases, either acting alone or in co-infections. Co-infections usually occur when two or more different pathogens cause disease in the same susceptible species, either as a simultaneous infection or a secondary infection. This potentiates their pathogenic effects and results in severe consequences for the host. Numerous studies on bacterial, parasitic, fungal, and viral co-infections have been conducted in different fish species (Assis et al., 2017, Walakira et al., 2014, Peatman et al., 2018). Co-infections have been associated with severe consequences, detrimental to susceptible fish as they increase their susceptibility to diseases by altering their course while increasing their severity through synergistic outcomes.

In the last few years, freshwater fish farming has been proliferating with the scarcity of captured fish (FAO, 2022). With the development and intensification of fish farming, the importance of disease occurrence as one of the most detrimental factors to fish farming is becoming apparent. Disease management and controlling pathogens are essential in aquaculture for successful fish farming. The etiology of fish diseases and the description of their symptomatology is an integral part of the farm health assessment process. The present review aims to provide an overview of infectious pathogens and non-infectious factors and their anatomical-clinical expressions in two groups of fishes among the most cultured in the world, in Africa and particularly in Senegal: Tilapias and catfishes, which include several genera and species such as *Oreochromis niloticus*, *Sarotherodonmelanotheron*, *Clarias gariepinus*, *Clariasanguillaris*, *Ictalurus punctatus*, etc.

Major non-infectious diseases of tilapia and catfish

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Diseases of freshwater fishes, including tilapia and catfish, can be caused by different environmental factors such as exposure to pollutants, change in physicochemical parameters of water, or nutritional disorders.

Diseases caused by dissolved oxygen depletion

Dissolved oxygen (DO) plays a vital role in the growth and maintenance of physiological functions of aquatic animals and in improving water quality. When dissolved oxygen levels in water are low, it is considered hypoxia. The minimum oxygen requirement varies among fish species but also depends on size, age, physiological condition, and health status (Bickler and Buck, 2007). Dissolved oxygen deficiency in fish is characterized clinically by signs of asphyxiation associated with acute mortality. For tilapia, the tolerated DO concentration should be greater or at least 5 ppm; catfish are more tolerant as they have an adaptation that allows them to breathe oxygen from the air. Low dissolved oxygen can occur at high water temperatures or during heavy biodegradation of organic wastes by aquatic bacterial activity that consumes dissolved oxygen through an aerobic oxidation reaction (Eissa et al., 2016). Low oxygen levels (hypoxia) can result in poor growth and impaired reproductive and physiological functions leading to stress and reduced immune responses (Bickler and Buck, 2007).

Diseases caused by carbon dioxide

Carbon dioxide (CO_2) results from the respiration of aerobic organisms, including plants, during which the consumption of 1 g of oxygen produces 1.375 g of carbon dioxide. The direct harmful effects of carbon dioxide are apathy and loss of balance and responsiveness, which can lead to unconsciousness and death if the presence of carbon dioxide is maintained. In the open environment, disorders due to direct carbon dioxide toxicity are unusual. They can affect pond fish in case of acidification of the environment caused by the night respiration of the organisms. High concentrations of carbon dioxide in the water disrupt the respiratory activity of the fish. Thus, a concentration of 25 mg/L reduces the oxygen transport capacity of the blood by half because the high content of this gas slows down the diffusion of carbon dioxide through the gill lamella in the water, and it remains in place in the fish's hemoglobin, blocking the site where oxygen should be fixed. This hypoxic situation can lead to a range of disorders from growth retardation to asphyxiation, which can lead to mortalities but also represents a risk of susceptibility to certain pathogenic organisms (Kinkelin et al., 2018).

Toxicity of non-ionized ammonia and nitrites

Non-ionized ammonia, NH_3, is highly toxic to aquatic organisms. High protein diets fed to fish in intensive culture systems result in high levels of ammonia as the primary nitrogen-containing excretory product, so that when alkaline or neutral water is reused without treatment other than oxygenation, toxic levels of ammonia can be generated. The recent development toward recirculating systems for the production of high-value species requires that ammonia be removed by biological filtration on every cycle (Robert, 2012). When non-ionized ammonia is present, the excretory capacity of aquaticsanimals decreases, and ammonia concentration in their tissues increases, leading to hyperplasia of the gill epithelium and fusion of secondary lamellae leading to reduced O_2 diffusion efficiency and functional disorders in the kidney and liver. Excessive non-ionized ammonia in the water is toxic to fish and causes methemoglobinemia which is known as brown blood disease; affected fish show brown blood, signs of asphyxiation, and anemia (Boyd Tucker, 2014). Ammonia disrupts osmoregulation, increasing urine production in freshwater (Eddy, 2005).

The presence of nitrite in the environment results from the incomplete oxidation of ammonia to nitrate (nitrification). Nitrite poisoning also leads to "brown blood disease," a name derived from signs revealed by the color of the gills and the blood. This coloration is due to the formation of methemoglobin from hemoglobin, by the oxidation of iron from the heme groups of the former, from Fe^{+2} to Fe^{+3}. This makes hemoglobin unfit for oxygen transport. Respiratory distress, hyperventilation, inappetence, lethargy, and reduced physical activity often coincide (Aggergård and Jensen, 2001).

Figure 1:- Operculum and caudal peduncle section showing brown gill and blood discoloration in a catfish affected by brown blood disease (Boyd and Tucker, 2014).

Supersaturation and gas bubble disease

The nitrogen N2, a too high oxygen concentration 02, and carbon dioxide from the air that is dissolved in the water can be potentially dangerous for fish when they are in excess or deficit (oxygen). Another gas element, ammonia (NH3), is also a concern from protein catabolism, which is an essential form of nitrogenous excretion in teleosts. These gaseous elements are responsible for the supersaturation leading to gas bubbles disease. This disease is mainly caused by gas supersaturation resulting from direct use of deep groundwater, heavy algal blooms, and a sudden change in water temperature and mixing waters of different temperatures. Gas embolisms form within blood flow vessels when air and water come into contact at a pressure above atmospheric, and the gases in the atmosphere (especially nitrogen) enter into solution in the water. Excessive nitrogen dissolved in the water passes through the gill filament epithelium and into the bloodstream until it reaches equilibrium with the surrounding environment (Donand Katz, 1987). Nitrogen bubbles then form emboli in the vasculature, obstructing blood flow. In the acute form, fish suffer severe mortalities of up to 100% loss, especially in juveniles, floating of the fish at the water surface due to excessive swim bladder swelling, exophthalmos, skin blisters due to subcutaneous emphysema. Whereas in the chronic form, there are gas-filled blisters of varying size present in the skin, gills, and various internal organs, rupture of the gas swim bladder is usually associated with secondary bacterial, fungal, and parasitic infections (Eissa et al., 2016).

Effects of climatic fluctuation and abrupt changes in temperature, pH, and turbidity

Fish have upper and lower thermal tolerance limits and optimal temperatures for growth, egg incubation, food processing, and disease resistance. These optima vary among species and may differ depending on parameters such as dissolved oxygen and water pH. Many infectious diseases are modulated by temperature, with their magnitude closely related to a specific temperature range(Elgendy et al. 2015. In many host-pathogen systems, there is a balance between host defenses and pathogen invasiveness, but this balance is easily altered by temperature change, especially if it is rapid. Water temperature also affects other properties of the aquatic environment important to fish health (Robert, 2013). In freshwater, pH can be affected by inadequate filtration systems and increased carbon dioxide from respiration. pH is important because fish must maintain a constant internal pH and acid-base balance in their blood. Bicarbonate ions are released if blood pH becomes acidic to bring the pH back to average values. In reverse, adding carbon dioxide or removing bicarbonate ions lowers the blood pH. This mechanism is controlled by carbonic anhydrase enzyme activity in the blood and gills. Most fish can cope with chronic pH changes within certain limits. Sudden drops in pH cause severe distress in some species, and the fish may attempt to escape by jumping out of the water; this stress from pH changes is fatal if continued (Robert, 2013). As cold-blooded animals, fish are influenced by the surrounding water temperature, which affects the body temperature, food consumption, food conversion, growth rate, and other bodily functions (Azevedo et al., 1998).

Freshwater fish, including tilapia and catfish, are not exempt from this requirement and are sensitive to extreme weather events, differences in water temperature variation, flow velocities, and water quality (Lebel. et al. 2009). Any water color, odor, taste, turbidity, or temperature change can produce physical pollution to fish. During floods, turbidity increases due to the significant increase in suspended solids. Expected consequences on farmed fish are hyperplasia of the gill surface and excessive mucus production on the skin and gills. Fish eggs in the wild and under farmed conditions are very vulnerable to silt deposits resulting in low hatchability. These deposits inhibit respiration through the chorionic membrane and promote microbial development (Robert, 2013).

Diseases due to pollution (organic and inorganic)

Pesticides, nitrates, heavy metals, and their derivatives can be responsible for health problems in fish. Nile tilapias exposed to pesticides show a variety of issues, especially during reproduction, with a low survival capacity of fry due to endocrine disruption (Abd El-Gawad et al., 2011). These chemicals accumulate in living organisms and cause adverse effects on aquatic flora and fauna, thus constituting a public health problem when contaminated animals are used for human food. Many diseases can affect fish due to inorganic water pollution, such as environmental gill disease, brown blood disease, and environmental hypoxia. Pollutants under certain conditions can be responsible for various skin lesions in fish. Cases of deep ulcers and barbel loss have been attributed to chronic irritation by chemical contamination of sediments in a Canadian study (Uhland et al., 2000; Mikaelian and Martineau, 1997). In affected individuals, necrosis and exposure of the dermis in ventral caudal, anal, pelvic, and pectoral fins and severe deep ulcerations of the skin in the thoracic region with exposure to underlying muscle tissue. In some individuals, ulcerations are localized on the jaw and lower lip with a loss of some barbels. Hemorrhagic borders clearly delimit the necrotic areas. Localization of these ulcerations, especially at the level of the fins and contact areas of the resting fish (Figure 1), suggests chronic irritation by chemical contamination of sediments (Mikaelian and Martineau, 1997).

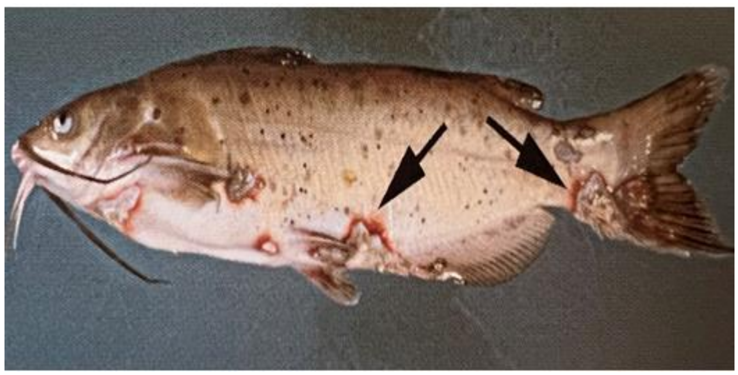

Figure 2:- Skin and fin ulceration (arrows) on catfish *Ictalurus punctatus* (Mikaelian and Martineau, 1997).

Nutritional diseases

Nutritional diseases, defined by Snieszko (1972) as "the deficiency, excess or imbalance of components present in the diet of a fish," are not easily diagnosed. Compromised nutritional diets often increase a species' susceptibility to infectious diseases, which are much more apparent, and mask the underlying predisposing cause.

Nutritional diseases occur primarily in farmed fish due to either overfeeding or deficiencies. Overfeeding farmed fish leads to accumulation, degradation, and fermentation of uneaten feed, resulting in increased ammonia levels in the water. Nutritional deficiencies include deficiencies in amino acids and essential fatty acids, which lead to nutritional disorders such as loss of appetite, poor feed utilization, and growth delay (Tacon, 1992). It has been reported that in addition to essential amino acids and fatty acids, some non-essential amino acids and fatty acids can have a toxic effect on fish when present in excessive amounts in the diet (Choo et al., 1991).

Malnourished fish are usually darker than usual and have softer skin due to tissue protein catabolism. Improperly fed larvae and fry often have enlarged heads and fragile bodies. Gills may be pale, and starved fry may have severe parasite loads. During necropsy of a malnourished fish, in addition to the absence of abdominal fat, there is often distension of the gallbladder, caused by bile retention, associated with the lack of food in the gut. In the African catfish *Clarias gariepinus*, a poor vitamin C diet with fish meal substituted by protein-rich blood, animal or poultry meal but deficient in certain amino acids necessary for balanced catfish growth is incriminated in cases of crack head disease (Figure 3) (Eniola, 2016).

Figure 3:- Catfish affected by crack head; these fish were fed with a poor vitamin C diet with fish meal substituted with an animal meal (Eniola, 2016).

Malformations

Diet or rearing methods affect, in particular, the development of the vertebral column leading to scoliosis, lordosis, or, sometimes, opercular, mandibular, or maxillary deformation. Lesions related to genetic, hormonal, or incubation temperature effects are apparent early in the hatchery. In contrast, nutritional or rearing lesions, which will be widely distributed in affected stocks, can occur at any stage of development (Robert, 2013). In addition to feed-associated skeletal abnormalities, several other abnormalities are related to genetic effects. For example, eye disorders are common in embryos, and in particular, microphthalmia and anophthalmia can frequently occur in some cases (inbreeding). Intensification of rearing conditions and artificial feed may lead to the appearance of disorders, especially malformations (Figure 3) (Hamdouniand Dhaouadi, 2014). These malformations, whose origin is most often unknown, appear randomly in fish at the end of larval development and can cause severe economic losses. Causes of these deformities may be related to rearing parameters such as nutrition, temperature, and rearing management; they affect different body parts, including the skeleton (Eissa et al., 2009). However, some malformations may have other origins, notably traumatic manipulations that can injure the larvae, which are also a source of malformations. Most often, fractures or dislocations usually heal with deformities. Some color changes, skeletal malformations (e.g., brachycephaly), and aplasia are examples of anomalies that may enjoy a genetic etiology (Uhland et al., 2000).

Figure 3:- Opercular malformations and branchiostegal ray prominence (arrows) in tilapia fry (Hamdouniand Dhaouadi, 2014).

Handling injuries

In farmed fish, the handling required for grading, treatments, sorting, harvesting, transport, and skin trauma associated with certain types of pens and cages can cause severe external injuries (Hubert, 1983, Nielsen and Johnson, 1983, Uhland et al., 2000) (Figure 4). In cages and net pens, some species may continually abrade their skin, particularly the snout, while attempting to escape. Lesions caused by these manipulations can be hemorrhagic and erode down to the skeleton. If they become secondarily infected with *Flavobacterium sp* or *Vibrio sp*. there may be heavy mortalities, and even if recovery occurs, bizarre malformations may result (Anderson and Conroy, 1969). Excessive currents associated with too rapid tank emptying or exorbitant flow rates can cause pectoral fin rupture in fish. The tissue regenerates typically but is usually enlarged and hyperplastic and may serve as a focus for infection. Biting attacks by conspecifics, when stocking density is high, are common and usually associated with attempts at territorial settlement and result in injuries between conspecifics (Robert, 2013).

Figure 4: Pressure necrosis secondary to capture trauma on a channel catfish *Ictalurus punctatus* (Uhland et al. 2000).

Tumor diseases

Tumors are rare in fish farming, but fish can develop them like all other animal breeds. In wild fish, most tumors observed are associated with exposure to environmental contaminants or viral infection. However, spontaneous tumors can also be observed in all fish species (Uhland et al., 2000). These tumors often develop in older fish, and their prevalence remains low (Lair and Martineau, 1997). Being externally visible in fish, skin tumors are among the most frequently reported. Tumors of epithelial tissue, whether internal or external surfaces or glandular tissue, are characterized by their ability to grow in clusters or masses of similar cells, which can suggest an epithelial origin even in the most anaplastic neoplasms. They are also characterized by their ability to stimulate the production of the local proliferation of capillaries and a supporting connective tissue stroma to provide nutrition and oxygenation to what is often a very rapidly growing neoplasm (Robert, 2013). In the catfish *Ameriurusnebulosis*, tumors with numerous hyperplastic nodules along their entire length localized to the barbels are reported by (Uhland et al., 2000). These tumors are present with multiple hyperplastic nodules along their entire length (Figure 5). In other species, multilobed and pedunculated tumors with proliferative lesions of the epidermis ranging from papilloma (benign exophytic tumor) to squamous cell carcinoma (malignant tumors) have been described by Mikaelian and Martineau(1997).

Figure 5: Hyperplastic nodules of the barbels in the brown bullhead *Ameiurus nebulosus* (Uhland et al. 2000).

Common bacterial diseases of tilapia and catfish

Edwardsiellosis

Edwardsiellosis or septicemic enteritis is caused by a highly contagious gram-negative, oxidase-negative bacterium of the Enterobacteriaceae family that affects tilapia but is more common in catfish. The species involved are opportunistic pathogens with a worldwide distribution and a broad host range. They are ubiquitous and healthy hosts can serve as reservoirs. They are mainly *Edwardsiellaictaluri*, *Edwardsiellatarda*, *Edwardsiellaanguillarum*, and rarely *Edwardsiella piscicida*. *Edwardsiellaictaluri* is responsible for catfish septicemic enteritis (ESC) or Edwardsiellosis. This infection is manifested by lethargy, apathy, an unwillingness to feed, disoriented fish, and swimming in spirals. The disease can also occur in an asymptomatic form without presenting clinical signs. In the acute nervous form, there is a darkening of the skin, raised skin patches progressing to superficial ulcers on the flanks and head, and generalized hemorrhaging (fin base, around the mouth, on the throat, on the operculum, in the abdomen and intestines), exophthalmos, distension of the abdomen and ascites (A.G.D.A.W.E, 2020). There are also pale gills and lesions on the liver and other internal organs, especially in the spleen, which is soft and pale, petechiae in the kidney, and swelling of the anal orifice with leakage of feces (A.G.D.A.W.E, 2020). In the chronic encephalic form, affected catfish exhibit swelling on the head, progressing to erosion of connective tissue and exposure of the brain "cranial hole" (Hawke et al., 1998) and granulomatous inflammation of the brain (Figure 6).

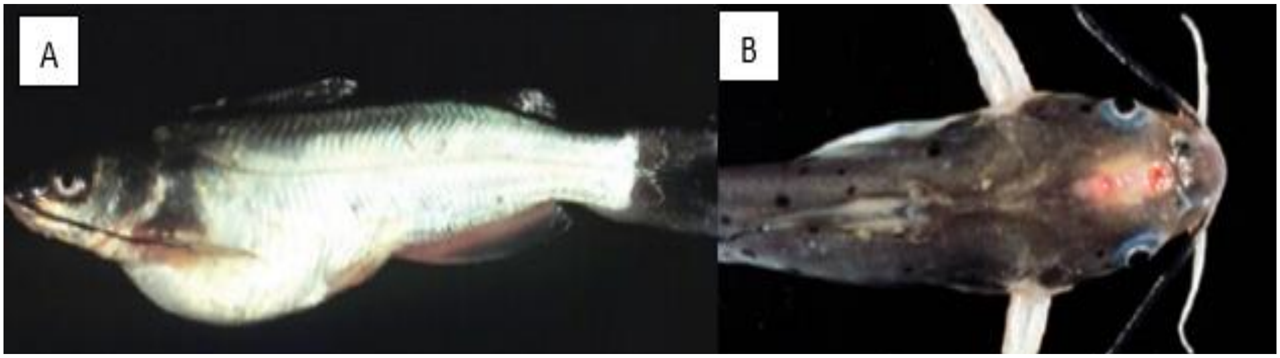

Figure 6:- Catfish fry showing signs of ESC with distended abdomen and exophthalmia (A), cranial foramen ulceration in chronic ESC (B) (Hawke et al., 1998).

In tilapia, fish infected with *Edwardsiellaictaluri* typically develop sepsis, focal suppurative or granulomatous lesions, and skin ulcerations (Buller, 2014). Clinical signs include behavioral alteration, exophthalmia, degeneration of pigmentation, lethargy, and swimming disorders (Park, 2012). External lesions vary between species, and Nile tilapia typically develop a swollen abdomen due to ascites (Bullock, 1985). Internal, necrotizing, and granulomatous lesions are observed in the spleen and anterior kidney, with high levels of bacteria in its organs (Figure 7).

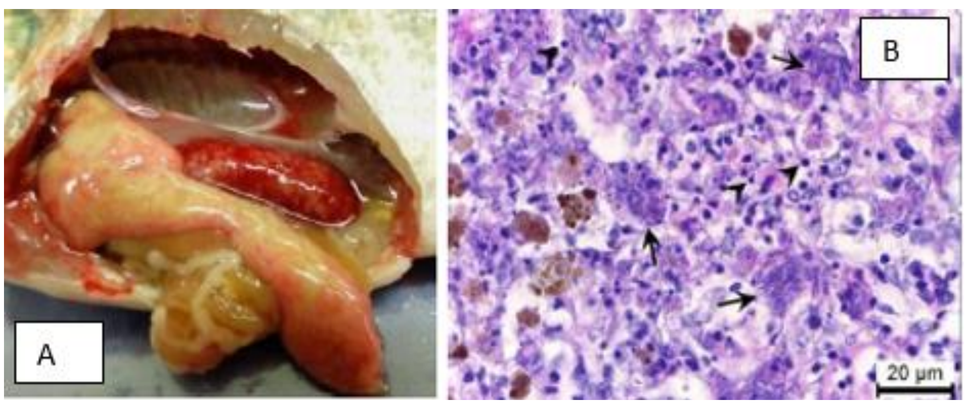

Figure 7:- Necrotizing and granulomatous lesions in the spleen (A), with a high number of bacteria count (B) (Soto et al., 2013).

Mobile Aeromonas hemorrhagic septicemia

Aeromonas spp. are Gram-negative bacteria that are ubiquitous in freshwater environments and are well-known pathogens of many species of farmed and wild fish. They are responsible for infections in several species, including carp (*Cyprinuscarpio*), catfish (*Ictalurus punctatus*, *Clarias gariepinus*), and tilapia (*Oreochromis spp*.) (Baumgartner et al. 2017). *Aeromonas spp*. are responsible for several different diseases, the most important being "skin rot" or "fin rot" and Aeromonas mobile septicemia (AMS). Several bacteria can contribute to Mobile Aeromonas Septicemia (MAS), including virulent *Aeromonas hydrophila, A. bestiarum*, *A. sobria, A. schubertii*, *A. caviae*,and*Pseudomonas spp*. Infection can lead to devastating mortalities (80-100%) in farmed tilapia (El-Sayed, 2006, Bondad et al., 2005). In tilapia farming, *Aeromonas hydrophila*, an opportunistic pathogen in fish and humans (Deen et al., 2014), is considered the most important species of the genus *A. hydrophila*. It is widely distributed in aquaculture and is probably the most common bacterial disease infecting wild and farmed tilapia (El-Sayed, 2006). Infected tilapia typically exhibits dark color, inappetence, skin ulcers and hemorrhages, fin loss, and exophthalmos. Internal signs include ascites, inflammation, congestion, and enlargement of the liver, kidneys, and spleen (Figure 8) (Wassif, 2018), a pale liver, and the presence of numerous focal hemorrhagic necrotic lesions in the liver, heart, and skeletal muscles, as well as on visceral and peritoneal muscles (Deen et al., 2004).

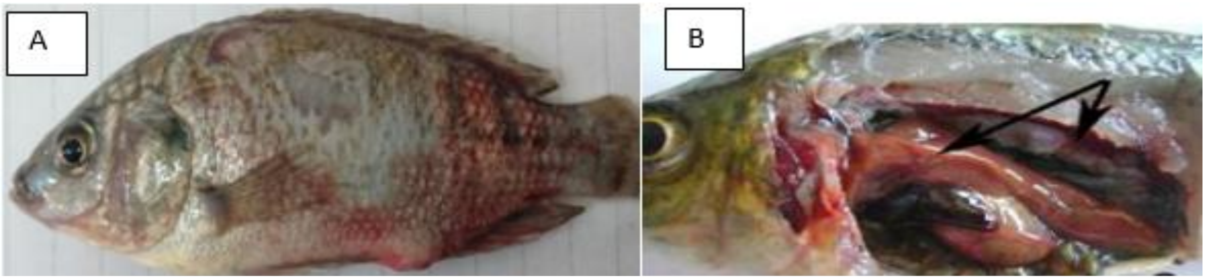

Figure 8:- Tilapia showing hemorrhages and skin ulcers (A), internal bleeding (B) from virulent *Aeromonas hydrophila* infection (Wassif, 2018).

In catfish, virulent *Aeromonas hydrophila* is responsible for different disease outbreaks on farms. A study by Angka et al. in 1995 concluded that a disease in African catfish *Calrias gariepinus*, reared in Java in 1980 that caused severe skin and muscle lesions and high mortalities was due to a virulent strain of mobile *Aeromonas hydrophila*. Infections due to mobile Aeromonas are reported by other authors such as Tiamiyu et al., who showed in 2020 in Nigeria that *Aeromonas bestiarum* infections lead to severe hemorrhagic dermatitis with ascites and abdominal and fin hyperemia, petechiae, skin depigmentation, and ulceration. In motile *Aeromonas spp*. conditions marked edema in the submucosa and muscularis of the stomach, sepsis, and splenomegaly are frequently noted. On microscopy, the spleen shows ellipsoid necrosis with macrophage infiltration and foci of infarction filled with bacteria (Baumgartner et al., 2017). A study conducted by Reda et al. (2012) on African catfish *Clarias gariepinus* infected with *Aeromonas hydrophila* demonstrated the destruction of fin rays, hemorrhagic lesions, and superficial skin ulcers evolving into deep ulcers (Figure 9).

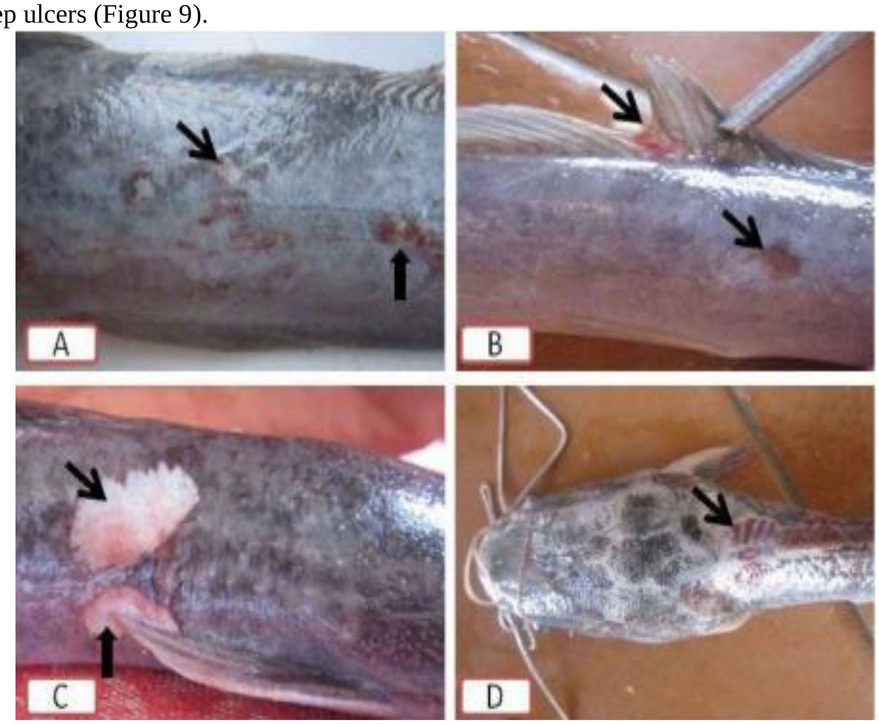

Figure 9:- Clinical signs in African catfish (*Clarias gariepinus*) infected with *Aeromonas hydrophila*showing the destruction of fin rays (A&B), hemorrhagic lesions, and early skin ulcers (C) that progress to deep skin ulcers (D) (Reda et al., 2012).

Columnaris disease due to *Flavobacteriumcolumnare*

Columnariasis is a bacterial infection that can be external or internal due to a Gram-negative bacterium of the Cytophagaceae family, in the form of a long stem of the genus and species *Flavobacteriumcolumnare*. This bacterium is ubiquitous in the aquatic environment, especially in freshwater. Columnariasis, also known as saddle disease, is manifested in the African catfish *Clarias gariepinus* by developing deep ulcers and necrotic lesions on the gills (Peatman et al., 2018). When touched, the skin is rough; the infection on the dorsal fin and surrounding epidermal tissue gives the impression of a saddle on the fish's back (Declercq et al., 2013).

Figure 10:- *Clarias gariepinus* naturally infected with *F. columnare*, showing typical signs of a saddle-shaped ulcer on the dorsal part of the body and caudal peduncle (Peatman et al., 2018).

Infected tilapia often shows external lesions such as skin and gill erosion and necrosis. In acute cases, these lesions can spread rapidly and result in high mortalities within hours or secondary infections with *Saprolegnia spp*. This infection is a significant problem in catfish farming. In 2001, columnaris disease occurred in Nile tilapia (*Oreochromis niloticus*) and catfish (*Clariaslazera*) farming in Egypt (Salah, 2013). This disease has also been identified in red tilapia. Clinical signs were external and internal, including gill, skin, and fin necrosis with skin lesions, often yellowish (Figure 10) due to the pigmentation of *F. columnare* (Dong et al., 2015).

Figure 10:- Red tilapia infected by *Flavobacteriumcolumnare* showing gill necrosis with the yellowish coloration of lesions (A), loss of scales with localized skin lesions on the peduncle (B) Dong et al., 2015).

Streptococcosis

It is a common disease caused by Gram-positive bacteria that is ovoid in shape and affects almost all fish species. The bacteria responsible for Streptococcosis in aquaculture are *Streptococcus agalactiae*, *Streptococcus iniae*, *Streptococcus dysagalactiae*, and *Lactococcusgarviae* (Tavares et al.,2018). Mortalities are variable but sometimes very high, up to 90%. The main risk factors are poor water quality and high temperatures (31-33°C). *Streptococcus iniae* is responsible for the primary infections in tilapia. It is manifested by clinical signs that begin with erratic swimming, exophthalmos, body darkening, and loss of appetite (Figure 11) (Dong et al., 2015). The liver histological examination of a Nile tilapia infected with *S. agalactiae*shows hyperactivation of melanomacrophages centers with overloaded melanophores in the pancreas, severe hepatocyte degeneration, and melanophores accumulation.

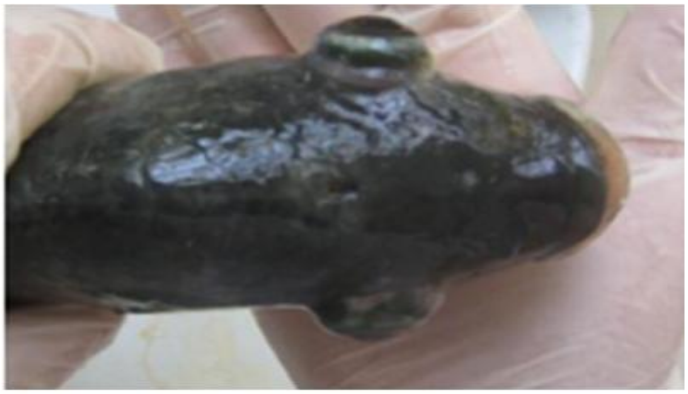

Figure 11:- Skin darkening and severe exophthalmia in tilapia infected with *Streptococcus iniae* (Dong et al.,2015).

Spontaneous pathological changes are noted in channel catfish, *Ictalurus punctatus* infected with *Streptococcus iniae*. Macroscopic signs are usually hemorrhages, petechiae on the skin, and congestion of internal organs, especially the liver, spleen, and kidneys. Other clinical manifestations may appear, including discoloration at the fin ray margins, enteritis, and ascites. Histological examination shows edema, degeneration, and necrotic changes in many organs. In addition, hepatitis, splenitis, and interstitial nephritis with numerous monocyte and neutrophil infiltrates were noted. The infection causes acute sepsis in catfish with *S. iniae* in monocytes and macrophages (Chen et al., 2011).

Yersiniosis

*Yersinia rucker*i is a Gram-negative rod of the Enterobacteriaceae family. It is the causative agent of Red Mouth Enteric (RME), which causes significant economic losses in salmonid farming, causing hemorrhagic septicemia. In recent years, the disease has spread rapidly to European countries, Australia, Africa (South Africa, Egypt), and South America (Austin et al., 2007). In Egypt, *Y. ruckeri* was first isolated from apparently healthy, moribund Nile tilapia from the Nile River in Giza province. Affected fish showed typical signs of Yersiniosis (Eliza et al., 2010, Figure 11), including extensive hemorrhages of the lips, mouth, fins, and skin, and hemorrhagic gastroenteritis, accompanied by congestion of the internal organs.

Figure 11:- *Oreochromis niloticus* infected with Yersiniosis showing congested spleen, liver, and intestine with subcutaneous and renal hemorrhages (Eliza et al., 2010).

In channel catfish *Ictalurus punctatus*, unusual disease outbreaks occurred in farms in Arkansas, USA, during the 1995 and 1996 winters. The affected fish had unique hemorrhagic rings around the eyes and raised hemorrhagic areas covering the frontal foramina. Other signs included abnormal swimming, lethargy, loss of balance, and exophthalmia. Bacterial isolates from the moribund fish have been identified as *Yersinia ruckeri* (Danley et al., 1999).

Vibriosis

Vibrio spp. are Gram-negative motile rods that cause hemorrhagic septicemia in fish. *Vibrio* infections commonly occur in marine and estuarine fish and are occasionally recorded in freshwater fish, causing significant mortalities in aquaculture. These infections are caused mainly by the genus *Vibrio anguillarum* and *V. vulnificus*. Vibriosis is favored by intensive recirculation systems where morbidity can reach 100% (Dalsgaard et al., 1999). *Vibrio vulnificus* serotype 2 is cosmopolitan and the only one with the genetic information to infect fish and humans. *V. anguillarum* was isolated from 62% of clinically affected Nile tilapia in Egypt. The isolation percentages from skin lesions, muscle, spleen, liver, and kidney, were 35, 22, 43, 48, and 60% (Shahat, 2000). In channel catfish *Ictalurus punctatus*, an epizootic outbreak caused by *Vibrio anguillarum* has been reported by Lewis (1985). Lesions in infected fish included ulcerations and petechiae on the body and caudal peduncle. Internally, hemorrhages were present in the liver and kidneys, filling the intestinal tract with a clear, viscous fluid. Vibriosis has also been encountered in catfish farms in China. Six bacterial strains were isolated from the different catfish species affected between 2011 and 2013 in Zhengchuan Province. The clinical and pathological characteristics were similar to those previously described for vibriosis-infected fish (Geng et al., 2014).

Major viral diseases common to Tilapia and catfish

Herpesvirus infections

Herpesviruses are large, complex DNA viruses with a distinct virion morphology consisting of four distinct structures: nucleus, capsid, integument, and envelope (Davison et al., 2005). Catfish are susceptible to herpesviruses, and two herpes viruses cause infections in these species. These are the channel catfish herpes virus known as *Ictalurid herpesvirus*-1 (IcHV 1) and the black catfish herpes virus or *Ictalurid herpesvirus*- 2. *Ictalurid herpesvirus*-1 is widespread in North America and is present in nearly all commercial populations of the channel catfish, *Ictalurus punctatus* (Goodwin, 2012). Affected individuals exhibit symptomatology that varies considerably during primary and recurrent infections and is likely controlled by the virus's dose and the fish's immune status. During primary infection, viruses often undergo productive replication in various cell types of the natural host. This can result in either viremia and acute disease with high morbidity and mortality or mild illness and spread of the virus throughout a population, creating a mass of surviving carriers. The most common manifestation of the alloherpesvirus-associated disease is dermal or epidermal cell proliferation, skin and gill lesions, hemorrhages, sometimes ascites, and kidney and liver necrosis (El-Hady and Khatib, 2009). Lucky first reported that pathological changes are similar to carp pox in catfish (*Silurusglanis*) (Abowei, 2011).

Viral encephalitis of tilapia larvae is a novel herpes-like virus responsible for juvenile mortality in tilapia. Shlapobersky et al. (2010) reported an outbreak due to a virus whose morphological, molecular, and biophysical characteristics of the pathogen suggest a herpes-like virus. This new disease is marked by a swirling syndrome and severe mortalities in laboratory-reared tilapia larvae. They have designated the disease Viral encephalitis of tilapia larvae.

Iridoviruses

Iridoviridae are single-segmented double-stranded DNA viruses. Their virions, with a diameter above 180 nm, are characterized by an icosahedral capsid, two envelopes, one internal enveloping the nucleocapsid and the other external. Iridoviruses are responsible for diseases in catfish. These infections are manifested by fry showing anorexia, apathy, and ataxia and congregating around the water source or heater. Generally, moribund fish move slowly but sometimes exhibit sudden rapid spiral movements. Macroscopic signs of infection are hemorrhages and petechiae on the skin and sometimes on the eyes and barbels. A post-mortem examination shows an often an enlarged liver and spleen and an absence of food in the digestive tract (Saleh, 2021).

Iridoviruses are responsible for infections in several other fish species. However, there have been few reports of Iridovirus infections in tilapia. Still, in 1985 in Taiwan, Tung et al. isolated from tilapia a DNA virus of the Iridovirudae family, similar to infectious pancreatic necrosis virus (IPNV), which is known to be present in eels and catfish, a DNA virus of the Iridovirudae family. Dong et al. (2015) also isolated and characterized several pathogens, including Iridoviruses involved in co-infections during natural outbreaks of Nile Tilapia (*O. niloticus*); their pathogenicity was confirmed in an experiment with red tilapia.

Tilapia viral diseases

Infection due to Orthomyxoviruses

Orthomyxovirids are viruses composed of 8 single-stranded RNA segments of negative polarity, with a total length of approximately 14,000 nucleotides, each segment enclosed in a helically symmetric nucleocapsid (Kinkelin et al. 2018). An envelop surrounds the entire assembly with glycoprotein projections to form a spherical virion with a diameter of 80-120 nm, often pleomorphic (Kawaoka et al., 2005).

Tilapia Lake Virus (TiLV)

Tilapia lake virus (TiLV) is a recently discovered RNA virus implicated in mass mortalities of tilapia in several countries, including Israel, Ecuador, Uganda, and Egypt (Del-Pozo et al., 2016, Walakira et al., 2014). This virus poses one of the greatest threats to tilapia farming, as various countries have reported infections. Mortalities attributed to TiLV have been observed in wild tilapia *Sarotherodongalilaeus*, Nile tilapia *Oreochromis niloticus*, and the commercial tilapia hybrid (from the *Oreochromis niloticus* X *Oreochromis aureus* cross) (Del-Pozo et al., 2016; Ferguson et al., 2014). The most affected organs are the eyes and brain (Eyngor et al., 2014). Macroscopic lesions (Figure 12) include changes in vision, notably crystalline lens opacity and, in most advanced cases, rupture of the lens capsule. Other lesions include skin erosions, leptomeningeal hemorrhages, and spleen congestion (Eyngor et al., 2014).

Figure 12:- A tilapia infected by TiLV showing lens rupture and loss of the eye (a), hemorrhages, and skin erosion (b) (Eyngor et al., 2014).

Tilapia syncytial hepatitis virus

A new suspected cause of tilapia mortality with a viral etiology is syncytial hepatitis of tilapia, described in Ecuador (Bacharach et al., 2016). This disease presents grossly with ascites and histologically with accumulation of hepatocellular lipoproteins, necrosis, and formation of cytoplasmic masses with multiple nuclei (syncytium) and necrosis of the gastrointestinal mucosa (Figure 13) (Ferguson, 2014). The virus associated with tilapia syncytial hepatitis is an Orthomyxovirus related to TiLV (Del Pozo et al. (2016).

Figure 12:- Ascites (1) and hepatocellular lipoprotein accumulation (2) in a tilapia affected by orthomyxovirus (Ferguson et al., 2014).

Infection due to betanoviruses

Fish nodaviridae belonging to the genus Betanodavirus are responsible for nervous system infections in fish. Nodaviridae are small viruses composed of two strands of positive, single-stranded, bisegmented RNA, with a total length of 4,500 nucleotides, whose virions are icosahedral in shape and 25 nm in diameter and lack an envelope (Schneemann et al., 2005). In tilapia, betanodavirus is responsible of viral nerve necrosis. This disease has been recorded in many farmed marine species worldwide before being recently identified in freshwater species, causing high mortalities, especially in the larval and juvenile stages of tilapia of the genus *Oreochromis spp* (Munday et al., 2002; Prihartini et al., 2015). The Word Animal Health, founded as OIE, has listed tilapia as one of the species that may be infected and may be the carrier or reservoir of this virus to which some snakes are thought to be highly susceptible (Taghreed, 2020).

Catfish viral diseases

Infection caused by Rhabdoviruses

Rhabdoviridae are single-stranded, single-segmented, helically symmetrical, enveloped RNA viruses. Their virions have a cylindrical shape with a hemispherical tip reminiscent of a shell and have earned them the name "bullet-shaped virus" (Kinkelin et al. 2018). Fish pathogenic Rhabdoviruses belong to the genus *Novirhabdovirus*, *Perhabdovirus*, and *Sprivivirus* (Dietzgen et al., 2011). Fijan et al. (1981) reported the first cases of catfish fry mortality associated with Rhabdoviruses. Diseased fish were dark and had mild to the moderate hydropic syndrome. Mild hemorrhages in the fins, gills, and edematous changes throughout the body were reported but more pronounced on the head. At necropsy of the moribund fish, a large amount of clear serous blood-tinged ascitic fluid was found in the abdominal cavities. Spleens were enlarged and lined with hemorrhages, livers were pale, and sometimes catarrhal enteritis was noted.

Infections caused by Papillomaviruses

Papillomaviruses are considered part of healthy skin microbiota (Jernigan and Farr, 2000) and are small (55 nm in diameter), icosahedral, non-enveloped viruses with circular, double-stranded DNA. Their genome ranges from 5.7 to 8.6 kilobases (kb) (Van Doorslaer et al. 2018). The majority are non-pathogenic and cause subclinical infections in infected individuals or benign, often demarcated papillomatous lesions, proliferative epithelial enlargement with an exophytic focus. Epidermal papillomas are commonly seen in many fish (Mahmoud et al., 2014). Skin diseases manifesting as papillomas have also long been known among catfish populations. A novel papillomavirus was described in Hungary in catfish with multiple epidermal hyperplasias, similar to papillomas on the skin (WHO., 1989).

Co-infections in tilapia and catfish

Infectious diseases caused by multiple pathogens and causing losses at the farm production site are probably more critical than those caused by single infections. Co-infections between bacteria, viruses, and parasites can result in varied clinical manifestations and treatment complications (Kotob, 2016).

Main co-infections in tilapia farming

Several co-infections have been reported in tilapia, including one associating *Vibrio parahaemolyticus* and *Aeromonas hydrophila*, which are major public health problems and among the leading causes of bacterial disease in Nile tilapia (*Oreochromis niloticus*). Individuals suffering from co-infections present a post-mortem clinical picture with a congested liver, cutaneous and splenic hemorrhages, and a distended gallbladder. The kidney is also congested and enlarged in the case of *V. parahaemolyticus*. In contrast, the clinical signs of fish naturally infected with *Aeromonas* were hemorrhagic septicemia in the presence of bilateral exophthalmia with hemorrhage of the gill openings, opacification of the eyes, hemorrhage, surface ulcers, abdominal distension, and massive mortalities.

A co-infection of bacteria and Iridovirus in tilapia was also found by Dong et al. in 2015. The most predominant bacteria were *Flavobacteriumcolumnare* and *Aeromonas veronii*, with the others being *Streptococcus agalactiae*, *Plesiomonasshigeloides*, and *Vibrio cholerae*. The study concluded that *A. veronii*and *F. columnare* were the two primary pathogens co-responsible for the loss of fish in tilapia farms. At the same time, the other bacteria could operate as opportunistic pathogens in outbreaks (Dong et al., 2015). *Flavobacteriumcolumnare* has also been associated with infection by *Saprolegniadiclina* on Nile tilapia reared in Egypt (Aly et al. 2000). Under certain rearing conditions, especially in cases of chronic hypoxia associated with a drop in temperature, co-infections of *Streptococcus agalactiae* and *Francisellanoatunensis subsp*. *Orientalis*have been reported in a study conducted by (Assis et al., 2017).

Co-infections of Tilapia Lake virus, *Aeromonas hydrophila* with *Streptococcus agalactiae* that resulted in a high mortality rate in red hybrid tilapia were also observed on a farm in Malaysia in January 2020. Affected fish appeared lethargic, with loss of appetite, red and hemorrhagic skin, exophthalmia, and gallbladder distension (Figure 14; Basri et al., 2020). Histopathologic evaluation revealed renal tubular deformity and severe congestion with inflammatory cells infiltrates in the brain and kidneys. Syncytial cells and intracytoplasmic inclusion bodies were enjoyed in the liver and brain sections.

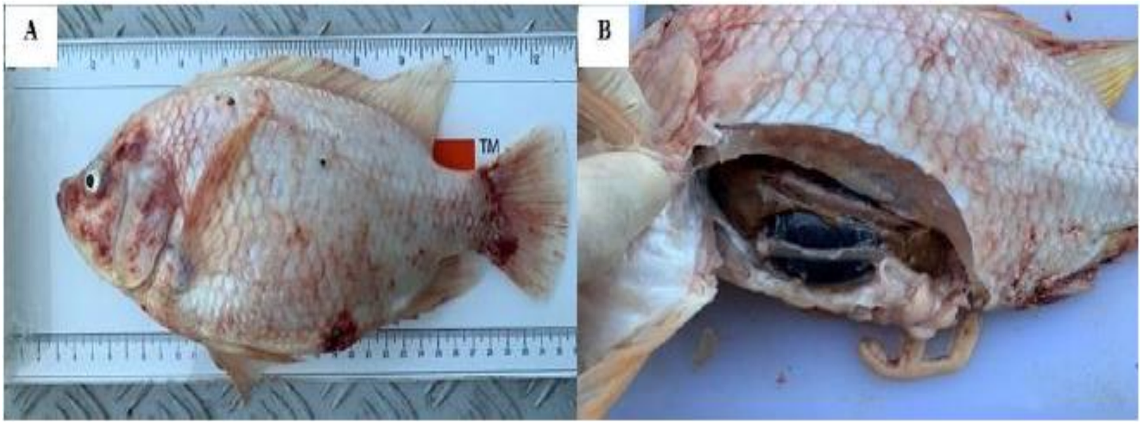

Figure 14:- Clinical signs and macroscopic lesions in red hybrid tilapia naturally co-infected with Tilapia Lake virus, *Aeromonas hydrophila*, and *Streptococcus agalactiae*. (A) Red skin with hemorrhages at the operculum and base of the caudal fin. (B) Full and enlarged gallbladder (arrow) and darkened liver. (Basri et al., 2020).

Co-infections with parasites (ectoparasites) and bacteria are common in fish farms and are associated with high mortality. In March 2020, a Nile tilapia farm in Sharkia governorate, Egypt, experienced high fish mortality. Clinically ill fish were characterized by lethargy, abnormal swimming behavior, loss of appetite, skin hemorrhages, exophthalmos, and abdominal distension. Parasitological and bacteriological laboratory examinations of the diseased fish revealed simultaneous infections with *Ichthyophthiriusmultifiliis*, *Trichodinacentrostrigeata*, and *Aeromonas hydrophila*. Pathological findings revealed severe gill and skin infections with *I. multifiliis* and *T. centrostrigeata*, associated with necrosis, hemorrhages, depletion of hematopoietic organs, and cardiac inflammation (Nemeen et al., 2021).

Subcutaneous mycoses in freshwater fish are sometimes problems in fish farming. Cutuli et al. (2015) reported the presence of *Fusariumoxysporum* in subcutaneous lesions of Nile tilapia (*Oreochromis niloticus*). Some of the affected fish died due to systemic co-infection with *Aeromonas hydrophila*.

Main co-infections observed in catfish farming.

Co-infections in fish are multiple and cause more problems than single infections because of the difficulty of making a rapid diagnosis (Wise et al., 2021). Cases of multi-infections with *Streptococcus iniae*, *S. dysgalactiae*, and *S. agalactiae* serotype II in farmed Amazonian catfish were reported by Tavares et al. (2018). Infected fish showed clinical signs of melanosis, anorexia, fin erosions, and ulcerative skin lesions. In some cases, fish showed corneal opacity, oral paralysis, skin necrosis, and fin erosions. Other subjects showed anorexia, lethargy, and subcutaneous and cranial abscesses.

Gram-negative bacteria of the genus *Flavobacteriumcolumnare,Pseudomonas sp*., *Aeromonas sp, Klebseilla sp*., *Escherisia coli* and *Proteus sp*. have been isolated and implicated in pathologies in catfish and tilapia reared in Uganda. Gram-positive bacteria have also been isolated from affected fish, including *Streptococcus sp*., *Staphylococcus sp*., and *Vibrio sp* (Walakira et al, 2014). In channel *Ictalurus punctatus*, co-infections involving *Aeromonas hydrophila*, *Acinetobacter spp*., *Plesiomonas spp*., and *Pseudomonas spp*. were reported by Grizzle and Kiryu (1993). Other types of multiple infections are also noted in the same species, involving *Aeromonas veronii*, *Shewanellapurefaciens*, and *Shewanellaparauberis* (Mohammed and Peatman, 2018, Peatman et al., 2018). Nofal and Abdel-Latif (2017) reported cases of multiple infections involving *Vibrio spp*., *Aeromonas hydrophila*, and *Edwardsiellatarda* in the African catfish *Clarias gariepinus*. Other types of co-infections are often observed at the farm level. These multiple infections may concern catfish, but sometimes, in mixed farms with tilapia, the same diseases are present. Indeed, mortalities attributed to poor water quality accompanied by bacterial infections in catfish and Nile tilapia revealed co-infections of *Aeromonas spp*, *Enterococcus faecalis*, and *Vibrio alginolyticus* isolated from farmed Nile tilapia and African catfish in Egypt (Abdelsalam et al., 2021;) During experimental co-infections with motile *Aeromonas* (*A. hydrophila*, *A. caviae* and *A. sobria*) in African catfish, skin discoloration with hyperemic spots, ulcerative and hemorrhagic skin lesions, barbital and fin atrophy were noted (Figure 15) (Anyanwu et al. 2015).

Figure 15:- Skin discoloration and hyperemic spots (arrows A), hemorrhagic ulcerative skin lesions (arrows B), and fin rot in African catfish experimentally infected with motile Aeromonas(Anyanwu et al., 2015).

Common mycotic diseases of tilapia and catfish
Saprolegniasis
Saprolegniasis is a fungal disease of fish and fish eggs caused by *Saprolegnia spp*. and is commonly referred to as "aquatic molds" (Singh, 1991). It occurs in both freshwater and brackish water fish farms. *Saprolegnia* requires temperatures between 15 and 30°C (Hulvey et al., 2007, Dick, 2001). The fungi attack any existing wound or breach in the skin barrier and can spread into healthy tissue. Stress of any kind to which the fish is subjected predisposes it to disease. Typically, saprolegniasis is noticed when a cotton-like material (Figure 16, Ali et al. 2019), white to gray or brown, is present on the skin, fins, gills, eyes, or fish eggs. As the infection progresses, the fish typically become lethargic and less responsive to external stimuli (Singh 1991). However, the fungi can spread rapidly and cover most of the body. Mass mortalities have occurred due to dermal mycosis due to *Saprolegnia* in tilapia reared in ponds during periods of low temperature in non-tropical African countries, in Israel, and tilapia introduced into the United States. Eggs are severely damaged by *Saprolegnia* when infected during artificial incubation. Invasion is aided by existing necrotic substances such as unfertilized and damaged eggs (Eli et al, 2011). Zahran et al. (2017) isolated highly pathogenic *Saprolegniaparasitica* from Nile tilapia that caused 95.6% mortalities in an Egyptian fish farm.

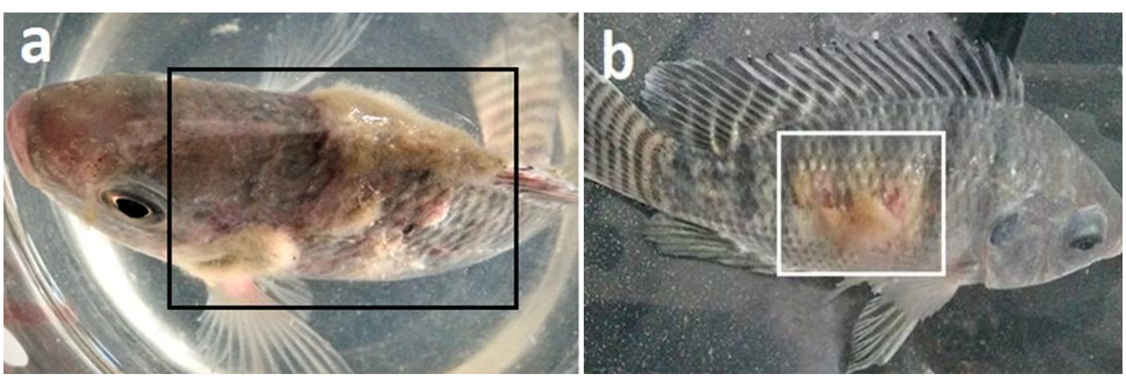

Figure 16:- Nile tilapia *Oreochromis niloticus* infected with *Saprolegniaparasitica* showing severe (a) and moderate (b) signs of infection (Ali et al., 2019).

Saprolegniasis is a common infection in tilapia and catfish. Kusdarwati (2017) showed that catfish *Clarias gariepinus* reared in Moro Krembangan Surabaya, East Java, were infected by *Aeromonas hydrophila* and *Saprolegnia sp*. due to unfavorable environmental conditions. The percentage of catfish (*Clarias gariepinus*) by *Saprolegnia sp*. was 90% of the population. The occurrence of *Saprolegnia*in channel catfish *Ictalurus punctatus* was reported by Bly, et al. (1993) in pond farms in the southeastern United States. A combination of two related factors consistently caused the disease: a rapid drop in water temperature that induces immunosuppression in catfish and the maintenance of low water temperatures (∼10°C), which promote the proliferation of a ubiquitous fungus of the genus Saprolegnia to produce high levels of fungal zoospores (≥5 spores ml^{-1}). The clinical picture of Saprolegniasis in catfish is identical to that in observed tilapia.

Branchiomycosis

Branchiomycosis is a fungal disease of fish that causes an acute infection of the gills and can cause high mortalities and respiratory distress in many species of freshwater fish. *Branchiomycessauguins* and *Branchiomycesdemigrans* are the fungal organisms associated with this disease and have different host specificities. Infected fish show respiratory symptoms and loss of balance. The gills are necrotic, eroded, and pale. Mortalities can occur in less than 48 hours and reach 50% of the population. Gross evaluation of the gills reveals an irregular mottled appearance due to hemorrhaging and necrosis (gill rot). It occurs in ponds with a high organic load and when the water temperature is above 20ºC (warm seasons). The infection can spread to all fish in the pond, resulting in increased mortalities (Eli, 2011). During the summer of 2014 in Egypt, (Khalil et al., 2015) found evidence of *Branchiomycesdemigrans* and *Branchiomyces spp*. in Nile tilapia (*O. niloticus*) fingerlings from private farms in Damietta, Port Said, El-Behera and Kafr-El Sheikh provinces. The disease caused several mortalities in different ponds. Ammonia, nitrite, and organic matter were above the permissible levels in the examined localities where the disease occurred.

Outbreaks of gill fungus caused by *Branchiomyces spp*. were identified in catfish fry during the summer of 1996 (Khoo et al., 1998). Mortalities ranged from a few hundred to several thousand fish per tank. The most prominent gross and histopathological clinical signs were limited to the gills. All fry examined had fungal mycelia that were mainly, but not entirely, confined to the base of the primary lamellae and the gill arches. These fungal hyphae were intravascular and occluded vessels in the gill tissue.

Ichthyophoniasis

Ichthyophoniasis is caused by *Ichtyophonushoferi*, which is characterized by granulomatous lesions on the skin of infected fish. Transmission occurs through contact with the feces of the infected host or consumption of infected carcasses. Internally, the kidneys, liver, spleen, spinal cord, heart, and brain may be swollen, with white or gray necrotic foci. A dorsoventral or lateral curvature of the spine (lordosis or scoliosis) may occur due to brain and spinal cord involvement (Eli et al., 2011). In Egypt, *Ichthyophonushoferi* has been isolated from winter-grown *O. niloticus* farms with an infection rate of 68.1% (Abbass, 2003). It was also isolated from cultured and wild Nile tilapia collected in Alexandria, El-Behera, and Kafr El-Sheikh, Egypt, between June 2006 and May 2008. Infected fish suffered from spine, mouth, and caudal peduncle deformities. The infection rate was 27.2% in farmed fish and 20% in wild fish (Shawer et al., 2011).

In Egypt, *Ichtyophonushofferi* was first identified in the wild catfish *Clariaslazera* in Alexandra (Faisal et al., 1985) and concurrently in tilapia and catfish. Clinical examination in affected individuals revealed dark gray to blackish skin discoloration with skull deformation and eye opacity. The main sites of predilection of *Ichtyophonushofferi* were the liver, followed by the spleen, heart, kidneys, intestines, ovaries, and eyes. Postmortem examination of infected fish revealed white to gray nodules of varying size in the liver, kidney, heart, spleen, and intestine (Badran et al., 2008).

Aspergillomycosis

Aspergillus spp. is responsible for systemic mycosis in tilapia. The pathogenic species most involved in tilapia diseases are *A. flavus*, *A. niger*, *A. ochraceous*, and *A. terrus*, respectively (Aly, 2013). The germ passes through the improperly stored feed under conditions of heat (over 27°C) and humidity (over 62%) that favor the growth of mycotoxin-producing fungi. Aflatoxins (mycotoxins) produced by *Aspergillus flavus* and *A. parasiticus* are the most toxic and common contaminants in fish feed. Aflatoxins destroy vitamins A, C, and B1 (Royesand Yanong, 2002). Systemic infection with *Aspergillus flavus* is associated with other diseases, especially ocular diseases in farmed fish. When Nile tilapia are fed on a diet contaminated with *Aspergillus flavus*, they present a clinical picture of inactivity, darkening of the color, edema, and exophthalmia with corneal changes.

In *Clarias gariepinus*, systemic fungal infections have become important causes of morbidity and mortality. These infections manifest as skin lesions with white absorbent cotton on the dorsal fin and throughout the body with skin wounds and eroded skin (Figure 17). A recent study by Mahboub et al. (2022) that investigated the occurrence of certain systemic pathogenic fungi inducing severe lesions in the liver and kidney of African catfish confirmed the presence of Aspergillomycosis in *Clarias gariepinus*. The study allowed the isolation of *Aspergillus ochraceous* and *Aspergillus flavus* and pigmented molds (*Cladosporiumherbarum*). The isolated fungi caused characteristic post-mortem lesions on the catfish.

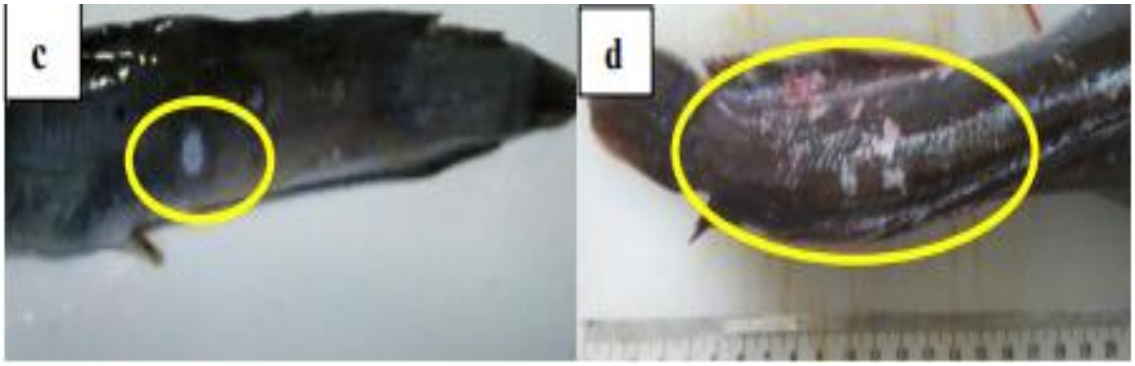

Figure 17:- African catfish *Clarias gariepinus* infected with *Aspergillussp*, represented by yellow circles: skin lesion with white cotton-like growth on the dorsal fin and all over the body (c) with skin wounds and eroded skin (d) (Sarjito et al., 2019).

Conclusion:-

The causes and symptomatology of diseases in warm water fish are varied, and some clinical signs are simultaneously presented across pathogens. The present review has highlighted the primary diseases of tilapia and catfish. The diseases described are the most common, but there are others. Some conditions, especially those caused by biological pathogens (bacteria, viruses, fungi, parasites), occur individually or in co-infections. Under appropriate environmental circumstances with water quality that matches the requirements of freshwater species and a diet that includes a variety of foods, diseases rarely affect fish. Usually, fish will only get sick when the farming conditions deteriorate and come in contact with pathogens. Healthy fish typically have a robust immune system, but when stress and deteriorating water quality affect the fish, they become more susceptible to different forms of diseases. This review provides a brief overview of the etiologies and clinical and lesion aspects of the significant diseases encountered in tilapia and catfish. These two fish species are paramount to aquaculture on a global scale. Most of these diseases are caused by opportunistic pathogens whose infectious power is only expressed when the fish's physical condition and natural (immune) defenses are weakened due to environmental disturbances or poor husbandry practices. Intensive fish farms represent the most favorable conditions for developing fish pathologies. Both fish and their aquatic environments are sources of disease propagation; pathogens can survive and sometimes multiply there. Understanding clinical pathologies and developing efficacious therapeutants for this warmwater aquaculture sector will ensure food security as the global population rapidly expands.

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