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Edwardsiella tarda- The Despised Threat to Nigerian Aquaculture and Human Health: A Review

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ABSTRACT

Impediment to the aquaculture industry and consequently, impoverishment of the Nigerian populace can be attributed to several factors ranging from managemental to infectious or noninfectious. Despite the abundantly blessed land capacity and nourishment, the industry continues to face several losses. As part of the very important infectious agents known to cause high morbidity and mortality across several fish species is *Edwardsiella tarda*. *E. tarda* is directly associated with enteric septicemia in several fish species and ages. Infections caused by this bacterium is usually presented as gastrointestinal (gastroenteritis) and extra-intestinal (myonecrosis, bacteremia and septic arthritis) infections. *E. tarda* is an economic and public health threat because of its extensive impacts on the aquaculture industry as well as its ability to cause severe human infections such as diarrhea, gastroenteritis, typhoid-like illness, peritonitis with sepsis, cellulitis and meningitis. Furthermore, they are associated with the global antimicrobial resistance (AMR) in human and animal population. The threat posed by this bacterium have necessitated this current review on the overview of the risk factors and the presence of the organism in Nigeria. An elucidation into the bacterium, its epidemiology, threat to aquaculture industry and the global population are reviewed and the probable ways to control the presence of the organism are also discussed. Novel genetic engineering of the genes of the organism as a vital tool to drug and vaccine development are germane in this current age as a useful tool and strategy to have a world safe and in health. In conclusion, this review highlighted the necessary steps and approach to mitigate the bacterium and safe the Nigerian aquaculture from the emergence of a fatal infectious disease from fishes to human, as well as improvement in global trading.

Key words: *Edwardsiella tarda*, Enteric septicemia, Zoonosis.

Background: The aquaculture in Nigeria

Nigeria is enormously blessed with land capacity averaging over 900,000 square kilometers with abundance of rain, rich groundwater resources and water surface system. Rainfall characteristically increases from the west to the east and from the north to the south with annual rainfall of 1778 mm, 4318 mm, 1270 mm and 508 mm in the Western, eastern, central and northern regions, respectively. These attributable rainfall and environmental characteristics are most suitable for a successful and flourishing aquaculture. Fish represents an important dietary element and one of the few animals' protein source available for an average Nigerian (FAO, 2017). Despite these innumerable land and water qualities, Nigeria spends an average of 97 billion Naira ($630 million) annually on the importation of about 700,000 tons of fish and fish products from USA, Europe (Ozigbo *et al.,* 2014). The increase in the importation is due to the failure of the production system to meet up the average 2.6 million tons required market demand of Nigeria as the total production in Nigeria currently approximates only about 680,000 tons per annum. These short falls in the production can be attributed to the insufficient large-scale fry production, lack of modern-day equipment supply, unreasonable farm design and settlement and most importantly, emerging and/or remerging infectious diseases. The aquaculture sector in Nigeria is presently driven by the private sector, owning to the current trend and growth in the Nigerian aquaculture sector. In spite the great potentials of the environment, lack of resources, knowledge and expertise of identification and control infectious agents and some other managemental defaults continues to flaw the aquaculture sector. Disease outbreaks are the primary limiting factor in catfish production. Cumulative losses in catfish production cycles are regularly between 15-20% of total fish stocked. Producers report infectious disease accounts for the largest percentage of losses, with approximately 65% of fry and fingerlings lost during production (USDA, 2006). Approximately 45% of inventory losses on catfish farms are attributable to infectious diseases, of which 60% are associated with single or mixed bacterial infections (Hawke and Khoo, 2004). The most important pathogens responsible for these loses are

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Edwardsiella, Aeromonas, Vibrio, Flavobacterium and Streptococcus (Xu and Zhang, 2014). *Edwardsiella tarda* has recently been identified to cause a new upsurge in the incidence and prevalence of septicemia in different fish species in the US as well as causing human infections (Park *et al.,* 2012) making the organism an economic and zoonotic important.

Edwardsiella tarda- The organism, disease and pathology

The genus Edwardsiella includes two species of bacteria that cause major diseases in fish: *Edwardsiella tarda* (Ewing *et al.,* 1965) infects fish and other animals and *Edwardsiella ictaluri (*Hawke, 1979) infects fish only. A third species, *Edwardsiella hoshinae*, infects birds and reptiles. *Edwardsiella tarda* produces the disease commonly known as fish gangrene, emphysematous putrefactive disease of catfish or red disease of eels and hereafter known in this text as Edwardsiella septicaemia (ES) and *E. ictaluri* causes 'enteric septicaemia of catfish' (ESC) (Fig 1). Because *E. tarda* and E. ictaluri produce distinctively different diseases, they are discussed separately.

Edwardsiella tarda is a Gram-negative bacterium responsible for enteric septicemia in both marine and freshwater fish species (Buján *et al.,* 2018) and culminates in severe economic losses in aquaculture worldwide (Wang *et al.,* 2005). A wide range of fish are affected by *Edwardsiella tarda*, including, Japanese eel (Anguilla japonica) (Egusa, 1979), channel catfish (*Ictalurus punctatus*) (Meyer and Bullock, 1973), Japanese flounder (*Paralichthys olivaceus*) (Nakatsugawa, 1983), tilapia (*Oreochromis* spp.), tropical ornamentals (Bullock and McCraran, 1989; Dixon and Contreras, 1992), chinook salmon (*Oncorhynchus tshawytscha*) (Amandi *et al.,* 1982), spawning Atlantic salmon (*Salmo salar*) (Martin, 1984), farmed rainbow trout (*Onchorhynchus gairdneri*) in Australia (Reddacliff *et al.,* 1996), brook trout (*Salvelinus fontinalis*) (Uhland *et al.,* 2002). Diseases due to *Edwardsiella tarda* are not limited to fish species. Infections have also been reported in reptiles, birds, swine, ruminants, marine mammals, warm blooded animals and importantly, humans.

Infections caused by this organism is generally presented as both gastrointestinal (gastroenteritis) and extra-intestinal infections (such as: myonecrosis, bacteremia and septic arthritis) (Leung *et al.,* 2012) in fishes while it is known to cause extra-intestinal manifestation such as biliary tract infection, bacteremia, skin and soft tissue infection, liver abscess, peritonitis, intra-abdominal abscess, tubo-ovarian abscess and mycotic aneurysm mostly in other immunocompromised animals (Ebisawa *et al.,* 2018). Infection is known to occur through the protein-protein interactions between the outer membrane proteins of *E. tarda* and proteins in the gills of fishes, followed by intracellular replication in the intestinal phagocytic cells of the fish before progressing to systemic infection where they reach a critical mass and spread deeper inside the host's body (Leung *et al.,* 2012). Signs associated with disease caused by this organism is usually in forms of petechial hemorrhage, poor pigmentation, protrusion and opacity of eyes, lesions on the skin, liquefaction and necrosis of tissues and organs such as kidney, spleen and liver (Devi *et al.*, 2016; Park *et al.,* 2012) (Fig 1).

Epidemiology of *Edwardsiella tarda*

Edwardsiella tarda is a ubiquitous organism that has been isolated from both animals and environments of most continents. It is believed so far that the intestinal contents of infected or carrier animal is the most common source of the organism which often are aquatic animals. *E. tarda* is more prevalent in environments with high temperature, poor water quality and high organic content which allow its adherence to and replication in cell lines (Park *et al.,* 2012). Occurrence of *E. tarda* in both Nile tilapia and African catfish has been reported with prevalence ranging from low to high. In Uganda; 5% and 50% in tanks (Walakira *et al.,* 2014), Egypt; 10-70% (Sedeek, 2017) in Nigeria, from *C. gariepinus*; 3.5% (Efuntoye *et al.,* 2012). The bacterium is also known to occur in other continents as reported by Kumar *et al.,* (2016) in Korea and in the Mediterranean (Katharios *et al.,* 2015). In the United States of America, it has been isolated from water samples, pond-mud samples and from the animals that dwells in the environments (Wyatt *et al.,* 1979). Introduction of infection to a new environment may be associated with the introduction of asymptomatic infected live fish, or animal faeces with bacteria, contaminated feeds, or water (Park *et al.,* 2012). Transmission of Edwardsiella bacteria between fishes in the farm is from faecal shedding from infected fish or from the carcasses of a dead fish (Park *et al.,* 2012). Vertical transmission from infected brood stock to fry has not been demonstrated (Park *et al.,* 2012). Ciliated protozoans such as Trichodina and Tetrahymena pyriformis can act as a vector for *E. tarda* transmission to farmed fish.

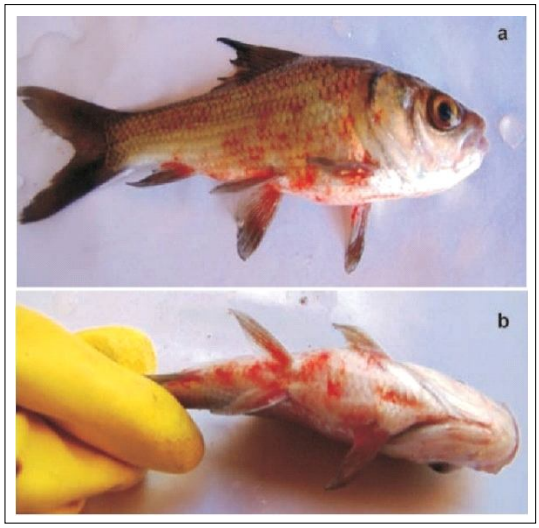

Fig 1: The pathological lesions associated with infections caused by *Edwardsiella tarda* in tilapia.
Source: Devi *et al.*, 2016.

Edwardsiella tarda is transmitted to humans through contamination with infected water and the infections normally manifests as gastrointestinal (Fig 2).

The threat to Nigerian aquaculture industry

Aquaculture represents one of the fastest growing sources of animal protein production in Nigeria which principally have been geared towards extermination of hunger and poverty. Because of the health benefits attributed to fish products over other sources such as beef, as well as the affordability of fish, majority of citizens have found solace in fish consumption. In response to this, there is an increase demand and a consequential increase in the production and expansion of aquaculture industry in Nigeria (Charles *et al.,* 2020).

Edwardsiella infections cause mortalities in infected fish leading to a serious economic loss in aquaculture (Park *et al.,* 2012, Charles *et al.,* 2020). The economic impact of *E. tarda* as mortality and morbidity in fish ranges from 5% to 70% globally. The disease course is usually characterized by mild to severe conditions, whilst clinical signs can vary between fish species. In channel catfish for example, it starts with small cutaneous lesions at the dorsolateral aspect of the fish that soon progresses to large necrotic abscesses within the flank muscle or caudal peduncle where the form convex swollen areas with loss of pigmentation. This can also be characterized with putrid smelling emphysematous diseases (Park *et al.,* 2012). In some other fish species, acute infections have been characterized with severe hyperemia, congested fins, ecchymosis or petechia haemorrhages on various body surfaces, gas-filled pockets in the skin and large necrotic lesions in the muscle and swollen and hyperemic anal regions. Internally, the infection can be characterized by extensive septicaemia and hyperaemia of the peritonium; oedematous, abscessed and mottled kidney and liver. A variety of clinical signs occur in other species of fish. For example, *E. tarda* causes exophthalmia and cataracts in tilapia and striped bass, as well as abscesses in internal organs (Baya *et al.,* 1997). Japanese flounders, naturally infected with *E. tarda*, develop ulcerative lesions and loss of skin, which expose underlying muscle, haemorrhage in fins, rectal protrusion and swelling of the spleen. Infected cage-cultured largemouth bass developed necrotic lesions on the caudal peduncle.

The impact of *E. tarda* in wild fish populations is unknown due to the absence of routine spatial and temporal *E. tarda* environmental disease monitoring and effects of *E. tarda* on fish populations. While extensive infections and economic losses are common to Edwardsiella infections, little or no information is available regarding the rate of incidence/prevalence, the attributable morbidity and mortality, chemotherapeutics and its associated cost

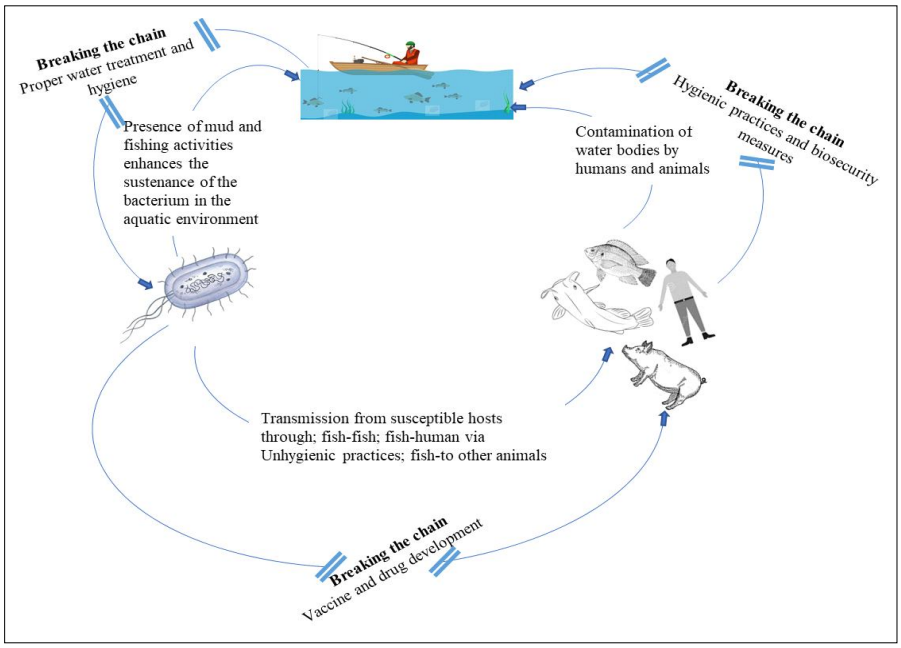

Fig 2: Schematic diagram describing the epidemiology of *Edwardisiella tarda*. In the presence of the suitable environmental conditions, such as muddy ponds, the bacterium undergoes a smooth multiplication and maintenance that supports their transmission to suitable hosts. The transmission to the suitable hosts serves as a medium for further multiplication and replication, as well as source of continuous water contamination and transmission to humans. Unhygienic practices by humans through the handling and/or processing of infection fish leads to the infection of the human hosts. In same likeliness, consumption of infected fish by other animals and humans keeps the transmission cycle continuous. The transmission chain can be broken through adequate adherence to hygienic practices, water treatment and chemotherapeutics. Vaccine development is a novel area that can be useful for the prevention of the infection in fish.

implications and the diagnostic materials and techniques in Nigeria. Furthermore, the extent of economic loss due to this infection is also unknown. The threat posed by this organism is further exacerbated by the progression of the diseases caused (Charles *et al.,* 2020). Usually, the disease caused by *Edwardsiella tarda* is a chronic problem that that would not only increase fish morbidity and mortality, but also increase production cost, reduced feed conversion rates and delayed harvesting time. Infection is usually not confined to any age or size group, thereby, losses associated to *Edwardsiella tarda* range from moderate to high resulting in reduced availability and productivity of fish to the market and public, as well as loss of revenue to the producer whose daily income depends on the fish markets.

Due to the unaesthetic appearance of fish infected with *E. tarda*, a poor perception of fishery products from areas where infection has been reported may deter their purchase and consumption by humans for fear of sickness. Tourism may also be impacted because of human perception of an unclean environment (Charles *et al.,* 2020).

The public health and food safety threats

As *Edwardsiella tarda* is a threat to fish, so is it a threat to humans. Transmission to human usually occur through the handling/or consumption of undercooked sub-clinically ill fish intended for human consumption. Contamination of equipment can occur when sub-clinically ill fish is processed and the equipment are not properly cleaned and disinfected. Human infections principally occur through digestive tract or muscle infection through puncture wounds by spines or bones of infected fish. This can be attributed we occupational and recreational exposure of human to *E tarda* infections (Ogunleye *et al.,* 2021).

E. tarda isolates from fish are like those of human origin, therefore, isolates from fish are potential human pathogens. Because *E. tarda* has such a wide host susceptibility and environmental adaptation it may enter the human food chain through fish processing plants and/or poor sanitation Nucci *et al.* (2002). As far as human infection is concerned, some of the earliest isolation of *E. tarda* were from human faeces (Ewing *et al.,* 1965). Human infections are often characterized as intestinal and extraintestinal infections. Intestinal infections are manifested as diarrhoea and gastroenteritis while extraintestinal infections includes may produce a typhoid-like illness, peritonitis with sepsis, cellulitis and meningitis. Occasionally, *E. tarda*-induced abscesses have been seen in liver. The disease is more prevalent among the vulnerable groups of the human population (children and adult over 50 and those with pre-existing liver disease and underlying iron overload states (cirrhosis, red cell sickling and leukemia). Because *E. tarda* is an emergent bacterium for food borne disease of humans, its potential impact on food production and safety must be significant. Based on the findings so far, there is sufficient evidence to indicate that *E. tarda* can be a public-health problem.

The ability of *E. tarda* to infect human has been demonstrated. Its ability relies on the invasion of the Hep-2 cell monolayers, production of cell- associated haemolysin and siderophores and express mannose-resistant hemagglutination against guinea-pig erythrocyte (Janda *et al.,* 1991). Principally, haemolytic activity was found as a major virulent factor in the pathogenesis of *E. tarda* in humans.

Responding to various degrees of economic losses due to infectious diseases as well as preventing zoonoses, antimicrobial agents have been devised to combat the challenges emanating from microorganisms in aquaculture practices. The inappropriate usage of these agents by farmers without adequate prescription has contributed to the current global public health concerns associated with the antimicrobial resistance (AMR). *Edwardsiella tarda,* like many other bacteria have been reported to have overtime developed resistance to several commonly used antibiotics (Efuntoye *et al.,* 2012, Nagy *et al.,* 2018, Ogunleye *et al.,* 2021, Charles *et al.,* 2020) and drug resistant infections have been predicted to likely be associated with the mortality of up to 10 million people annually if the current trends of antimicrobial resistance persist (Dadgostar, 2019). Overuse of antibiotics has been implicated as the major cause of resistance (Johnson *et al.,* 2006). Antimicrobial resistance strains have evolved to become a serious health problem worldwide (Chiu *et al.,* 2002). *E. tarda* have been found show resistance to antibiotics such as Ceftazidime, Meropenem, Cefuroxime, Tetracycline and Cotrimoxazole (Nagy *et al.,* 2018, Ishola *et al.,* 2021).

Diagnosis

Clinical signs of *E. tarda* infections vary between species of fish, therefore, they are generally of little use, except to indicate the likely presence of a bacterial infection. Edwardsiella infection in fish, like any other bacterial infection can be diagnosed by several methods including clinical signs, histopathology, haematology, bacterial isolation and biochemical characteristics (Park *et al.,* 2012; Hemraj *et al.,* 2013).

Edwardsiella septicemia in fish is characterized by the attributable lesions which include necrotic abscesses in the muscle that emit a putrid odor when incised. Skin lesions includes muscle abscess with or without petechia hemorrhages. Morbidity and mortality can be acute or chronic causing various degrees of fish losses. Commonly, the organism resides in the intestinal tract of the infected fish, thereby, adequate isolation is based on their recovery from the intestinal tract of the infected fish. Furthermore, they can also be recovered from the environmental samples such as water bodies and pond muds.

Edwardsiella tarda is identified in the laboratory as a motile, facultatively anaerobic, Gram-negative rod; categorized as a member of the family Enterobacteriaceae, first recognized by Trabulsi *et al* in 1962, followed by a description of *E. tarda* in the mid-1960s. Diagnosis involves identification of the bacterium using microbial culture techniques followed by biochemical characterization of the isolates. The bacteria can be isolated from infected tissues

using general culture media like Brain Heart Infusion agar (BHI), Trypticase Soy Agar (TSA), MacConkey agar, Blood Agar, Xylose Lysine Deoxycholate (XLD) agar or a selective medium *(E. ictaluri* medium or EIM) for the recovery of *E. ictaluri* (Charles *et al.,* 2020). *E tarda* is normally seen as small, circular, raised, clear colonies with black centers on XLD and pale on MacConkey agar. Alternative techniques to direct detection of the bacteria can also be used like serological methods which include using Enzyme immunosorbent assay (ELISA), loop-mediated isothermal amplification (LAMP), indirect fluorescent antibody (IFA) test, fluorescent in situ hybridization (FISH) and use of molecular techniques like Polymerase Chain Reaction (PCR).

Treatment strategies

The use of antimicrobials has become the most important step to controlling infections caused by *E. tarda* especially, because vaccines against the organisms are not available. The use of antimicrobial medicated-feeds alongside feed restriction which causes selective pressure on the microbial flora in aquatic environments and often promotes antibiotic resistance and multidrug-resistant (MDR) species have become the proven strategy for controlling *E. tarda* (Buján *et al.,* 2018). As antibiotic medicated feeds promote AMR and MDR, feed restriction also results in reduced growth rates and subsequently, delay in harvest. Sulfadimethoxine/ormetoprim (Romet-30™), florfenicol (Aquaflor®) and oxytetracycline (Terramycin®) have been approved by the FDA for treatment of bacterial infections in aquaculture. Resistance of *E. tarda* to these approved antimicrobials have been confirmed by the presence of plasmid-mediated AMR genes in *E. tarda* isolate obtained from infected and/or mortalities of fish (Hirai *et al.,* 2015). These therefore limits the control options available for *E. tarda.* A prompt action against increase in the frequency rate of MDR- *E. tarda* should be instituted to prevent ascent from the current 6.4% to an alarming rate.

Prevention strategies- Virulence, vaccination and vaccine development

The *E. tarda* is known to exhibit a two-component system (TCS) with which they survive stress impacted by the intracellular environment of the invaded hosts during infections. Several of these systems (TCS) have been found to play vital roles in the pathogenesis of the bacterium. The TCS is known to be comprised of a transmembrane histidine kinase sensor that interacts with the outward signals, internal signals and a cytoplasmic response regulator which facilitate proper change in the bacterial cell physiology (Derzelle *et al.,* 2004). In response to external stimuli, the histidine kinase sensor autophosphorylates at a conserved histidine residue and then transfers the phosphoryl group to the regulator component, promoting its binding to DNA to regulate transcription of virulence genes (Capra and Laub, 2012). Importantly, these TCS are suitable targets for the development of vaccine to control the bacterial infections.

Efforts have been put in place severally to develop alternative methods to the control of infections caused by *E. pscicida*. This is more imminent due to the few available and/or approved AMs used in aquaculture as well as the recent spate of AMR/MDR globally. Several vaccines ranging from mutant attenuated live vaccines as demonstrated by several researchers such as asdA (Banikalyan and Roy, 2018), EsrA-EsrB (Yin *et al.,* 2019), *luxS* /AI-2 (Sun *et al.,* 2020), uhpA (Liu *et al.,* 2020), *etc.*, as well as *E. ictaluri* vaccines have been proven effective against the bacterium by several researchers through the administration at fingerling stage (Griffin *et al.,* 2020).

rstA mutant gene

rstA mutant gene has been found to be involved in the downregulation of bacteria adherence to HeLa cells thereby downregulating the pathogenicity of *E. coli*. RstA mutant genes have been recorded to affect sporulation and toxin gene expression, as demonstrated by Liu *et al.,* 2019. Till date, little or nothing have been done to establish facts about the identification and the virulence properties of the rstA genes and its mutant in *E. tarda*. This therefore serves as an integral justification for this study to ascertain the effects of this gene in the pathogenicity of *E. tarda.*

Quorum sensing regulation (QSR) system

Quorum Sensing Regulation (QSR) is known to cause autoinduction in bacteria cells through two conserved regulatory gene products: LuxItype acyl-HSL synthase and LuxR-type transcriptional activator whose activity requires a particular acyl-HSL made by the cognate LuxI enzyme (James, 2002). These genes are known to facilitate virulence, biofilm development and many other processes in *P. aeruginosa* (James, 2002).

Two-component *crp*/Δ*crp* system

Peng *et al.,* 2019 found *crp* gene to be associated with the capacity of the bacterium to utilize maltose and impaired motility due to the lack of flagella synthesis. This evidencing that the deletion of this gene impairs the ability of the bacterium to evade host immune clearance, thereby, conferring immunity on the fish and the infections caused by *E. pscicida.*

Two-component asdA system

Banikalyan and Roy, 2018 demonstrated the recombinant attenuated *Edwardsiella* vaccine (RAEV) useful for the providing immunity against the infections caused by the bacterium. This group found asd genes to be associated with obligate requirement for diaminopimelic acid (DAP) or a plasmid vector with the wild-type asdA gene to grow, thereby enabling the synthesis of recombinant antigens that induces protective immunity against the bacterium.

Two-component EsrA/EsrB system

EsrA-EsrB have been found to play vital roles in the pathogenicity of the bacterium by controlling the expression of the T3/T6SS machineries of the bacterium as well as some

effector cells (Liu *et al.,* 2017, Yin *et al.,* 2019). The systematic review and studies of the operations and activities of the regulatory networks of the EsrA-EsrB operations will therefore be important for the understanding of *E. piscicida* pathogenicity (Yin *et al.,* 2019). Based on this, The Mutation of *esrA-esrB* has therefore been found to be a fruitful strategy for development of live attenuated vaccines against edwardsiellosis in fish (Yin *et al.,* 2019).

Two-component LuxS/AI-2 system

LuxS/AI-2 is known to be an important quorum sensing system which affects the growth, biofilm formation, virulence and metabolism of the bacterium (Sun *et al.,* 2020). The *luxS* /AI-2 gene mutant strains were found to decrease *E. piscicida* growth (Sun *et al.,* 2020).

UhpA/UhpB-UhpC mutant

UhpA/UhpB-UhpC is known to enable cell to acquire phosphorylated sugars from its environment that can be used as carbon or energy sources (Liu *et al.,* 2020). The deletion of the uhpA gene deletion decreased the metabolic level *E. piscicida*, increases flagellar-related gene expression in *E. pscicida* and increased the T3SS- and T6SS-related gene expression in *E. piscicida* Liu *et al.,* 2020).

Use of *E. ictaluri* vaccine

It has also been reported that the use of *E. ictaluri* vaccine provides a cross protection against *E. pscicida*. This was demonstrated by Griffin *et al.,* (2020), who administered the *E. ictaluri* live attenuated vaccine orally through feed mix and then by immersion bath. It was found to provide suitable protection immunity against infections caused by the bacterium. One very important achievement of this vaccination is the use of both the oral and immersion bath methods ensuring that all the fishes are vaccinated, as fishes that could not be vaccinated orally will most certainly be vaccinated through the bath immersion. Presently, these vaccines have not been commercialized on large scale and made available for use by the farmers.

Edwardsiella tarda- what we know so far in Nigeria

So far, little or nothing is known about the incidence/ prevalence of *E. tarda* both in fish and in humans, the spatio-temporal distribution, the economic impacts and losses. The earliest report of *E. tarda* was by Gugnani *et al.,* 1986 who isolated the organism from wall gecko. In the recent time, Ogunleye *et al.,* 2021 reported a 62.5% prevalence of the bacterial from a study in Ibadan, Oyo State Nigeria and Ogbonne *et al.,* 2018 described the antibiotic resistance pattern and plasmid profiling of the organism. These three reports being the only available reports indicates a dearth of knowledge and information on *E. tarda* and an indication of fish infections due to *E. tarda* as well as human exposure to the infections. According to our previous report on the detection and antibiogram of *Edwardsiella tarda* from *O. niloticus* sold in Ibadan, Oyo State, we have been able to establish based on bacteriological and morphological evidence that *E. tarda* is present and culturable from tilapia and could serve as a source of infection for fish consumers and handlers suggesting human and public health risks associated with the bacterium.

CONCLUSION- THE WAY FORWARD

In this short briefing, we have provided insights into the threat and one of the possible causes of the current impediments to a successful aquaculture in Nigeria, the contribution of *E. tarda* to the industry as well as the threat to human population. *E. tarda* infection is one of the most significant bacterial diseases that is responsible for different range of morbidity and mortality in fish and several disease conditions across different age groups of human population. The socioeconomic losses as well as the public health and food safety threats posed by this bacterium and the current trend of increasing demands and consequential increase in production of fish and fish products in Nigeria. We also discussed how its significance in terms of international trades necessitates urgent and aggressive efforts towards the identification and elimination of this bacterium in Nigeria.

Efforts should be geared towards the surveillance, epidemiology and the development of *SMART* diagnostic models for the rapid identification of the organism in Nigeria. For the benefit of the sector and the profitability of investors in this company, there is urgent need to intensify work towards identifying this organism in the aquaculture value chain in Nigeria. This would be beneficial not only towards the health of humans but also for promotion of international trades.

Conflict of interest: None.

REFERENCES

Abdel-Latif, H.M.R., Sedeek, E.K. (2017). Diversity of *Enterobacteriaceae* retrieved from diseased cultured *Oreochromis niloticus*. International Journal of Fisheries and Aquatic Studies. 5(1): 29-34.

Amandi, A., Hiu, S.F., Rohovec, J.S., Fryer, J.L. (1982). Isolation and characterization of *Edwardsiella tarda* from Fall Chinook Salmon (*Oncorhynchus tshawytscha*). Applied Environmental Microbiology. 43: 1380-1384.

Banikalyan, S. and Roy, C. (2018). Construction of Recombinant Attenuated Edwardsiella piscicida vaccine (RAEV) with Regulated Delayed Attenuation: Encoding I-antigen of *Ichthyophthirius multifiliis*. International Association for Aquatic Animal Medicine.

Baya, A.M., Romalde, J.L., Green, D.E., Navarro, R.B., Evans, J., May, E.B., Toranzo, A.E. (1997). Edwardsiellosis in wild striped bass from the Chesapeake Bay. Journal of Wildlife Diseases. 33(3): 517-525.

Buján, N., Balboa, S.L., Romalde, J.E, Toranzo, A., Magariños, B. (2018a). Population genetic and evolution analysis of controversial genus Edwardsiella by multilocus sequence typing. Molecular Phylogenetic Evolution. 127: 513-521.

Buján, N., Toranzo, A.E., Magarinos, B. (2018b). *Edwardsiella piscicida*: A significant bacterial pathogen of cultured fish. Journal of Disease of Aquatic Organ. 131: 59-71.

Bullock, G.L. and McCraren, J.P. (1989). Edwardsiella infections of fishes. Fish Health Bulletin, no. 1. Washington, DC: United States Fish and Wildlife Service.

Capra, E.J. and Laub M.T. (2012). The evolution of two-component signal transduction systems. Annual Review of Microbiology. 66: 325-347.

Chiu, C.H., Wu, T.L., Su, L.H. (2002). The emergence of Fluoroquinolone resistance in *Salmonella enterica* serotype choleraesuis in Taiwan. New England Journal of Medicine. 346: 413-419.

Dadgostar, P. (2019). Antimicrobial Resistance: Implications and costs. Journal of Infection and Drug Resistance. 12: 3903-10.

Derzelle, S., Turlin, E., Duchaud, E., Pages, S., Kunst, F., Givaudan, A., Danchin, A. (2004). The phoP-phoQ two-component regulatory system of photorhabdus iuminescens is essential for virulence in insects. American Society of Microbiology Journal of Bacteriology. 186(5): 1270-1279.

Devi, T.B., Abraham, T.J., Kamilya, D. (2016). Susceptibility and pathological consequences of catla, Catla catla (Hamilton) experimentally infected with *Edwardsiella tarda*. Archives of Polish Fisheries. 24: 209-217.

Dixon, B.A. and Contreras, B. (1992). Isolation of *Edwardsiella tarda* from the freshwater tropical petfish, *Metynnis schreitmuelleri* (Ah1) and *Trichogaster trichopterus* (Pallas). Journal of Aquariculture and Aquatic Sciences. 6(2): 31-32.

Ebisawa, K.F., Nishimura, S., Yamamoto, S. (2018). Mycotic aneurysm caused by *Edwardsiella tarda* successfully treated with stenting and suppressive antibiotic therapy: A case report and systematic review. Annual Clinical Microbiology and Antimicrobial. 17(1): 21.

Efuntoye, M.O., Olurin, K.B., Jegede, G.C. (2012). Bacterial flora from healthy Clarias gariepinus and their antimicrobial resistance pattern. Advanced Journal of Food Science and Technology. 4: 121-125.

Egusa, S. (1979). Notes on the culture of the European eel (*Anguilla anguilla* L.) in Japanese eel-farming ponds. Rapports et Proces-Verbaux des Reunions, Conseil Internationale pour l'Exploration de la Mer. 174: 51-58.

Ewing, W.H., Mcwhorter, A.C., Escobar., M.R., Lubin, A.H. (1965). Edwardsiella, a new genus of Enterobacteriaceae based on a new species, *E. tarda*. International Journal of System and Evolutionary Microbiology. 15(1): 33-38.

FAO. (2017). Part I Statistics and main indicators. Fishery and Aquaculture Country Profiles. ftp://ftp.fao.org/FI/Document/fcp/en/FI-CP-NG.pdf.

Griffin, M.J., Greenway, T.E., Byars, T.S. (2020). Cross-protective potential of a live-attenuated *Edwardsiella ictaluri* vaccine against *Edwardsiella piscicida* in channel (*Ictalurus punctatus*) and channel × blue (*Ictalurus furcatus*) hybrid catfish. Journal of World Aquaculture Society. 51: 740-749.

Gugnani, H.C., Oguike, J.U., Sakazaki, R. (1986). Salmonellae and other enteropathogenic bacteria in the intestines of wall geckos in Nigeria. Antonie van Leeuwenhoek. 52: 117-120.

Hawke, J.P. (1979). A bacterium associated with disease of pond cultured channel catfish, *Ictalurus punctatus*. Journal of Fisheries Board of Canada. 36: 1508-1512.

Hawke, J.P. and Khoo, L.H. (2004). Biology and Culture of Channel Catfish. Elsevier, Amsterdam. 387-443.

Hemraj, V., Diksha, S., Avneet, G. (2013). A review on commonly used biochemical test for bacteria. Innovare Journal of Life Science. 1(1): 1-7.

Hirai, Y., Asahata-Tago, S., Ainoda, Y., Fujita, T. and Kikuchi, K. (2015). *Edwardsiella tarda* bacteremia. A rare but fatal water- and foodborne infection: Review of the literature and clinical cases from a single centre. The Canadian Journal of Infectious Diseases and Medical Microbiology. 26(6): 313-318. https://doi.org/10.1155/2015/702615.

Ishola, O.O., Ogunleye, S.C., Olayemi A.O., O.A., Adedeji, O.B. (2021). Presence of *Salmonella spp* from *Oreochromis niloticus* (Tilapia) Sold in Ibadan, Nigeria. International Journal of Research and Innovation in Applied Science. 6(4): 76-81. doi.org/10.51584/IJRIAS.2021.6403.

James, P.P. (2002). Early activation of quorum sensing. Journal of Bacteriology. p. 2569-2571.

Janda, J.M., Abbott, S.L., Oshiro, L.S. (1991). Penetration and replication of *Edwardsiella spp*. In HEp-2 cells. Infection and Immunity. 59: 154-161.

Johnson, J., Kuskowski, M., Menard, M. (2006). Similarity between human and chicken *Escherichia coli* isolates in relation to ciprofloxacin resistance status. Journal of Infection Disease. 194: 71-8.

Katharios, P., Kokkari, C., Dourala, N. (2015). First Report of Edwardsiellosis in Cage-Cultured Sharpsnout Sea Bream, Diplodus Puntazzo from the Mediterranean. BMC Veterinary Research. 11: 155-161.

Kumar, G., Engle, C.R., Tucker, C.S. (2016). Costs and risk of catfish split-pond systems. Journal of the World Aquaculture Society. 47: 327-340.

Leung, K.Y., Siame, B.A., Tenkink, B.J., Noort, R.J., Mok, Y.K. (2012). *Edwardsiella tarda* virulence mechanisms of an emerging gastroenteritis pathogen. Microbes Infection. 14: 26-34.

Liu, J., Sun, Y., Huang, J., Ding, L., Ye, T., Wang, X. (2020). UhpA in Edwardsiella piscicida decreases the pathogenicity and the capability of inducing cytokine response in zebrafish. Aquaculture Reports. 17: 100-293.

Liu, Y., Li, S., Li, W., Wang, P., Ding, P., Li, L., Wang, J., Yang, P., Wang, Q., Xu, T., Xiong, Y., Yang, B. (2019) RstA, a two-component response regulator, plays important roles in multiple virulence-associated processes in enterohemorrhagic *Escherichia coli* O157: H7. Gut Pathology. 1: 11:53. doi: 10.1186/s13099-019-0335-4.

Liu, Y., Zhao, L., Yang, M., Yin, K., Zhou, X., Leung, K.Y., Liu, Q., Zhang, Y., Wang, Q. (2017). Transcriptomic dissection of the horizontally acquired response regulator EsrB reveals its global regulatory roles in the physiological adaptation and activation of T3SS and the cognate effector repertoire in *Edwardsiella piscicida* during infection toward turbot. Virulence. 8(7): 1355-1377. doi: 10.1080/21505594.2017.1323157.

Martin, J.D. (1984). Atlantic Salmon and Alewife Passage Through a Pool and Weir Fishway of the Magaguadavic River, New Brunswick, Canada during 1983. Abstract. Canadian Manuscript Report of Fisheries Aquatic Sciences.

Meyer, F. and Bullock, G. (1973). *Edwardsiella tarda,* a new pathogen of channel catfish (*Ictalurus punctatus*). Applied Microbiology. 25(1): 155-156.

Nagy, E., Fadel A., Al-Moghny, F.A., Ibrahim, M.S. (2018). Isolation, identification and pathogenicity characterization of *Edwardsiella tarda* isolated from *Oreochromis niloticus* fish farms in Kafr-Elshiekh, egypt. Alexandria Journal of Veterinary Sciences. 57(1): 171-179.

Nakatsugawa, T. (1983). *Edwardsiella tarda* isolated from cultured young flounder. Fish Pathology. 18: 99-101.

Nucci. C., Silveira, W.D., Corrêa Sda, S., Nakazato, G., Bando, S.Y., Ribeiro, M.A., Castro, A.F.P. (2002). Microbiological comparative study of isolates of *Edwardsiella tarda* isolated in different countries from fish and humans. Veterinary Microbiology. 89(1): 29-39.

Ogbonne, F., Ukazu, E., Egbe, F. (2018). Antibiotics resistance pattern and plasmid profiling of *Edwardsiella tarda* isolated from *Heterobranchus longifilis*. Journal of Biosciences and Medicines. 6: 95-105.

Ogunleye S., Ishola O., Olatoye I., Adedeji O. (2021). Detection and antibiogram of *Edwardsiella tarda* from *Oreochromis niloticus* (Tilapia) obtained from selected farms in Ibadan, Nigeria. Journal of Food Safe and Hygiene. 6(1): 38-46.

Ogunleye S.C., Ishola O.O., Faroyin O.M., Adedeji O.B. (2021). Total aerobic and Coliform counts from *Oreochromis niloticus* obtained from selected farms in Ibadan. Sokoto Journal of Veterinary Sciences. 19(1): doi.org/10.4314/sokjvs.v19i1.8.

Ogunleye, S.C., Ishola, O.O., Okunlade, OA., Adedeji, O.B., Okocha, R. (2021). Detection and antibiogram of *Escherichia coli* 0157 from feral and cultured tilapia (*Oreochromis niloticus*) in ibadan, Nigeria. International Journal of Research and Innovation in Applied Science. 6(3): 70-75. doi.org/10.51584/IJRIAS.2021.6301.

Ozigbo, E., Anyadike, C., Adegbite, O., Kolawole, P. (2014). Review of aquaculture production and management in Nigeria. American Journal of Experimental Agriculture. 4(10): 1137-1151.

Park, S.B., Aoki, T., Jung, T.S. (2012). Pathogenesis of and strategies for preventing *Edwardsiella tarda* infection in fish. Veterinary Research. 43: 67-78.

Reddacliff, G.L., Hornitzky, M., Whittington, R.J., (1996). *Edwardsiella tarda* septicaemia in rainbow trout (*Oncorhynchus mykiss*). Australian Veterinary Journal. 73(1): 30.

Sun, Y., Chen, J., Liu, J., Huang, J., Ye, T., Wang, X. (2020). The role of uhpA in *Edwardsiella piscicida* and the inflammatory cytokine response in tilapia. Fish Shellfish Immunology. 101:192-197. doi: 10.1016/j.fsi.2020.03.028.

Trabulsi, L.R. (1962). Sodium acetate medium for the differentiation of Shigella and *Escherichia cultures*. Public Health Lab. 20: 137-140.

Uhland, F.C., Hélie, P., Higgins, R. (2002). Infections of *Edwardsiella tarda* among brook trout in quebec. Journal of Aquatic Animal Health. 12(1): 74-77.

United States Department of Agriculture. (2020). Mississippi Rises to the Top of U.S. Aquaculture. National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture. (USDA).

United States Department of Agriculture. (2006). Census of Aquaculture. (2005). National Agri-Cultural Statistics Service, United States Department of Agriculture, Washington, D.C.

Walakira, J., Akoli, P., Engole, M., Sserwadda, M., Nkambo, M., Namulawa, V., Kityo, G., Musambi, R., Abaho, I., Kasigwa, H., Mbazazi, D., Kahwa, H., Naigaga, I., Birungi, D. (2014). Common fish diseases and parasites affecting wild and farmed Tilapia and catfish in Central and Western Uganda. Uganda Journal of Agricultural Sciences. 15 (2): 113-125.

Wang, I.K., Kuo, H.L., Chen, Y.M. (2005). Extraintestinal manifestations of *Edwardsiella tarda* infection. International Journal of Clinical Practice. 59(8): 917-921.

Wyatt. L.E., Nickelson, R., Vanderzant, C. (1979). *Edwardsiella tarda* in freshwater catfish and their environment. Journal of Applied Environmental Microbiology. 38: 710-4.

Xu, T. and Zhang, X.H. (2014). *Edwardsiella tarda*: An intriguing problem in aquaculture. Aquaculture. 431: 129-135.

Yin, K., Peng, Y., Ahmed, M.A.H., Ma, J., Xu, R., Zhang, Y., Ma, Y., Wang, Q. (2019). PepA binds to and negatively regulates esrB to control virulence in the fish pathogen *Edwardsiella piscicida*. Microbiological Research. 232: 2020, 126349.