A review on the Role of probiotics in aquaculture production and their future in tropical environments

ABSTRACT

This review explores the potential of probiotics in enhancing fish production in tropical environments, characterized by high temperatures, humidity, and year-round precipitation, which covers about 36% of the world's land, where fish production activities as a global enterprise are fully based. Aquaculture is commonly referred to as fish farming because fish farming is the principal form of aquaculture which implies some sort of intervention in the rearing process to enhance production processes such as regular stocking, feeding, and protection from diseases and predators. The value or contribution of aquaculture to the globe cannot be over-emphasized in terms of the provision of animal protein, propagation of the desired species of fish, Aquaculture, the method of fish farming, plays a crucial role in providing animal protein, essential fatty acids (omega-3 and omega-6), and other health benefits while supporting global food security. This review revealed that one of the most significant technologies that evolved in response to successful aquaculture production and disease control problems is the use of beneficial bacteria (probiotics) which have been considered a valid alternative to prophylactic use of antibiotics with fast growth promotion of the aquatic animals. Effects of probiotics on the environmental temperature, immune modulations of aquatic animals, production, and reproductive performances such as good hatchability and survivability in fish production including Catfish (*Heterobranchus dorsals*), Tilapia (*Oreochromis niloticus*), Carp (*Cyprinus carpio*) production and Stress tolerance responses to environmental factors have been reviewed. This work highlighted the extent of success and contribution of probiotics in the tropical environment.

Keywords: Probiotics, Fish Production, Success, Tropical environment

INTRODUCTION

Aquaculture has become an important activity in many countries of the world (Balcazar, *et al.* 2000), which is described as the farming of aquatic organisms including fish, mollusks, crustaceans, aquatic plants, and animals (FAO, 2016) by the intervention of the rearing techniques to enhance production in a controlled environment for commercial, recreational or public purposes with private ownership of the livestock being cultivated. Aquaculture is commonly referred to as fish farming (Souza, 2018) because fish farming is the principal form of aquaculture (FAO, 2006) which implies some sort of intervention in the rearing process to enhance production processes such as regular stocking, feeding, and protection from diseases and predators. It could also be regarded as a form of agriculture that involved the cultivation, propagation, and marketing of these aquatic organisms (Kolndadacha, 2010). The breeding, rearing, and harvesting of the aquatic plants and animals take place in all types of water environments such as ponds, rivers, lakes, the ocean, and man-made closed systems on the land, which could include freshwater, brackish water, and salt water, either in the natural or manipulated body of water as receptacles.

The contribution of aquaculture to global development is immense. It provides animal protein, facilitates the propagation of desirable fish species, and supplies essential omega-3 and omega-6 fatty acids, which are crucial for human health. These fatty acids support immunity and help prevent conditions like cancer and heart diseases (FAO, 2017) to mention, but few. It is important also to note that aquaculture provides a good source of employment because FAO (2006) reported that in sub-Saharan Africa alone aquaculture offers employment directly or indirectly to over 6.9 million people. These facts are attributed to the high demand of fisheries and aquaculture in both developed and developing countries which continued to grow making it a significant sector in the world.

However, aquatic organisms like any other terrestrial animals can experience problems related to disease conditions either due to deterioration of the environment or from ill handling that results in a serious economic loss [54]. With the increased interest and participation in the practice of aquaculture, the incidence of disease outbreaks is being increasingly recognized as a serious constraint to aquaculture growth and trade affecting economic development (Verschuere, *et al.* 2000) in the tropics. Even though dramatic disease outbreaks in aquaculture in the tropics have not yet been recorded, there are several reports of losses in many fish farms, but because of unawareness of disease impact on aquatic animals and lack of proper diagnosis, the cases are limited to individual farms and passed unnoticed to the public, instead the cause of losses are attached to water or natural reasons.

One of most significant technology that evolved in response to disease control problem is the use of beneficial bacterial (probiotics) which have been considered a valid alternative to prophylactic use of antibiotics for control of bacterial pathogens in aquaculture. There is growing advocacy to shift from the use of the troublesome antimicrobial agent to use a safer technology that is free from public health hazard. The application of beneficial (probiotics) bacteria which control pathogens through variety of mechanisms of action is globally viewed to be alternative to antibiotic treatment. These probiotics have been used in both animals and humans for ages without any known pathology. The United State Food and Drug Administration (FDA) designated probiotics Generally Recognized as Safe (GRAS) (Doron and Snydman, 2015).

The aim of this review was to assess the extent of success and contribution of probiotic applications to the tropical aquaculture and environment.

Effects of probiotics in tropical environment

Unlike terrestrial environment, aquatic system is a delicate make up due to the chemistry of the water. The environment is prone to pollution coupled with the fact that the cultured animals have direct contact with environment and the microorganisms therein. Contamination from nitrogenous compounds can be a serious issue in aquaculture. Probiotics especially Gram-positive bacteria have been observed to be environmentally friendly bacteria (Mathew and Jerome, 2012), because of their role in improving water quality. So many beneficial bacteria have the ability to handle the harmful effect of deteriorating nature of aquaculture environment to favor the cultured animals. These actions of probiotics could be through elimination of toxic organic compounds by converting them to less harmful compounds. Although Fukami, *et al.* (1997) did not specify bacterial species, but that certain bacteria possess significant algicidal effect on several species of microalgae. Cruz, *et al.* (2012) added that some probiotics directly uptake or decompose organic matter or toxic materials to reduce disease incidence, enhancing zooplankton number, reducing odor and ultimately enhancing aquaculture production. Development of water quality, enhancement of survival and growth and better health condition has been attributed to *Bacillus species* (Ngau and Phu, 2011). Photosynthetic and heterotrophic bacteria are also reported to aid in decomposition of remnant of food materials, extra plankton and convert them to inorganic salts like phosphate and nitrate which enhances the water quality (Ibrahim, 2015). Nitrifying bacteria could also be added to the pond or tanks when there is an incidental increase of ammonia or nitrate level is observed according to Edun and Akinrotimi, (2011).

One important benefit obtained from the use of probiotic bacteria in culture environment is in the fast organic breakdown, free amino acid and glucose are released providing food for the microorganism (Raja, *et al.*, 2015) which cause the microorganism to multiply faster for their target action. In an experiment by Cruz, *et al.* (2012) when *Bacillus licheniformis* and *B. subtilis* were added in feed of cultured tilapia (*O. niliticus*), they observed that the water quality parameters showed acceptable range for the fish cultivation. Cruz, *et al.* (2012) therefore suggested that by maintaining high level of probiotic in fish productions, farmer can minimize the accumulation of dissolved and particulate organic carbon during growing season (Edun and Akinrotimi, 2011).

Effects of probiotics on environmental temperature

It is necessary to maintain the environmental factors within an acceptable range for the cultured animals to thrive well and yield maximum production. Fluctuation of temperature beyond acceptable range increases the vulnerability of fish to pathogenic microorganisms in aquaculture system. Heat stress is one of the most serious climatic problems of tropical and subtropical region of the world. High fish mortalities have been noticed to occur during high water temperature (Raja *et al.*, 2015). Hassan, *et al.* (2015) also reported that excess heat suppress body weight gain in broiler due to less feed intake, less metabolic activity and intestinal dysbiosis, this cannot be different from aquatic animals.

Probiotic bacteria play a great role in regulating temperature in both aquatic and terrestrial environments. In the experiment of Hassan, *et al.* (2015) supplementing probiotic (protaxin®) in broiler feed during high environmental temperature, there was a significant increase in body weight gain and suppress the stressful condition. Mohapatra, *et al.* (2014) reported that 3 species including *Bacillus subtilis, Lactobcillus lactis and Saccharrmyces* *cervisiae* have been used to overcome temperature associated stress. There is also evidence that feeding fish with probiotics showed lower blood glucose level, which was due to the probiotic ability to reduce the effect of stressor according to Mahapatra, *et al.* (2014). Banerjee, *et al.* (2010) reported a success in having a higher quality of temperature, pH, NH_3 and H_2S when probiotics were added, thus maintaining a positively healthy environment for shrimp and prawn larvae. So probiotics helps to maintain the temperature, stimulate more feed intake, more nutrient absorption, more metabolic activity which result to body weight gain (Hassan, *et al*. 2015).

Effect of probiotics bacteria on immune-modulations of aquatic animals.

Immunomodulation refers to any process in which an immune response is altered to a desired level, while immuno-modulator is a chemical agent that modifies the immune response or the functioning of the immune system (Bidhan, *et al.*, 2014). The immune response involves recognizing pathogen or foreign material and the mounting of a reaction to eliminate it (Raphael and Luis, 2012). Immunomodulation can be beneficial or detrimental to the host (Snydman, 2008). Probiotics can modify the immune response of the host by interacting with epithelial cells and by modulating the secretion of anti-inflammatory cytokines which could result in a reduction of inflammation (Stefan, *et al.* 2009). Variety of bacteria, viruses and parasites have been reported to modulate the immune system by altering the way antigens are exposed on their surfaces (Shira and Snydman, 2015)

The immune systems of lower and higher vertebrate are similar with 2 integral components, such as innate, natural or non-specific defense immunity and adaptive, acquired or specific immune responses (Verschuere, et al., 2000). Immune modulation of blood leukocyte in humans by lactic acid bacteria had been observed **(**Bidhan, *et al.,* 2014**).** *Lactobacillus casei* in particular was found to be active in the stimulation of phagocytic activity when administered to mice (Rocha-Romirez, *et al.*, 2017). *Lactobacillus acidophilus* and *Bifidobacterium bifidum* have been shown to influence some immune functions, which involve one or several components of an immune response including humoral, cellular or non-specific immunity (Drisko, *et al.*, 2003) as reported in the study of Mikulic, *et al.* (2017) that *Lactobacillus casei* and *L. acidophilus* in yogurt enhanced numbers of IgA-producing plasma cells.

For bacteria to be effective in the process of immune-modulation, it is necessary for them to migrate from the gut to the blood circulatory systems (Oyetayo and Oyetayo, 2005). Mixture of bacterial strains comprises of *Bacillus* and *Vibrio spp* was administered to juvenile of white shrimps presented a protective effect against pathogen *Vibrio haveyi* and white spot syndrome during the work of Balcazar, *et al.* (2006) and the protection was attributed to the stimulation of the immune system by increasing phagocytosis and anti-bacterial effects. Stefan, *et al.* (2009) listed various probiotic bacteria that are effective in immunomodulation as seen in the table below.

Table 1: Probiotic bacteria that are effective in immune-modulatory activities

Identity of the probiotics	**Species/method of application**	**Effects on the host**	**Reference (s)**
Bacillus subtilis and *B. licheniformis*	Rainbow trout /Feed (*Onchorhynchus mykiss*)	Increased resistance to *Yersinia ruckeri*	Raida, *et al.* (2003)
B. subtilis and *Lactobacillus delbriieckii*	Gilthead seabream / feed	Stimulate cellular innate immune response	Salinas, *et al.* (2005)
B. subtilis (ATCC 6633) *L. acidophilus*	Nile tilapia (*Oreochromis niloticus*)	Stimulated the gut immune system: enhance the immune and health status	Mesalhy, *et al.* (2008)
Carnobacterium maltaromaticum B26, *C. divergens*	Rainbow trout (*O. mykiss*)/ Feed	Enhance the cellular and humoral immune response	Kim and Austin, (2006)
L. rhamnosus	Rainbow trout (*O. mykiss*)/ Feed	Increase resistance to *Aeromonas salmonicida*, reduced mortality from furunculosis	Nikoskelainen, *et al.* (2001)
L. rhamnosus ATCC53103	Rainbow trout (*O. mykiss*)/ Feed	Enhanced immune parameters; stimulated immune response	Nikoskelainen, *et al.* (2003)
L. rhamnosus	Rainbow trout (*O. mykiss*)/	stimulated immune	Panigrah, *et al.* (2005)

	Feed	response	
L. delbrueckii subsp *bulgaricus*	Rainbow trout (O. mykiss)/ Feed	Enhanced humoral immune response	Tukmechi, *et al.* (2007)
L. rhamnosus ATCC53103, *B. subtilis*, *Enterococcus faecium*	Rainbow trout (*O. mykiss*)/ Feed	Modulated cytokine production; stimulated immune response	Panigrah, *et al.* (2007)
Lactococcus lactis subsp lactis Lactobacillus sake, *Leuconostoc mesentroides*	Rainbow trout (O. mykiss)/ Feed	Stimulated phagocytosis; Enhanced non-specific immunity	Balcazar, *et al*., (2006)
Micrococcus luteus	Nile tilapia (*O. niloticus*)/Feed	Enhanced non-specific immune parameters, improved resistance against *Edwardsiella tarda* infection	Taoka, *et al.* (2006)

Source: Stefan, et al. (2009)

The Effects of Probiotics on Production and Reproductive Performance of Aquatic Organisms.

Lactic acid bacteria have been observed to enhance the production of inhibitory substances against pathogenic organisms reducing the chances of pathogenic bacteria to establish diseases that will result to mortality. When probiotic bacteria are established in the gut they enhance brood-stock and larval nutrition by synthesizing essential nutrients (proteins and fatty acids) and enzymes such as amylase, protease and lipase (Irianto and Austin, 2002). Other roles of probiotic bacteria in the intestine is the enhancement of host enzyme secretion through maturation of fish intestinal secretory cells, which increases the efficacy of the complex proteins and lipids included in the diet (Ghosh, *et al.*, 2008), thus increasing the rate at which they can be assimilated by the host animal. Similar finding was reported by De Schrijver and Ollevier, (2000) in shrimp juvenile (*Scophthalmus maximus*) who investigated protein digestion and resulted in an increased digestion and absorption of protein, particularly in the distal portion of the gastrointestinal tract when *Vibrio proteolyticus* as probiotic was supplemented in feed. So, probiotic bacteria that support synthesis of essential nutrients bring about better reproductive performance which also supplied energy to sustain the spawning activities of the fish.

Mohammad, *et al.* (2017) assessed probiotic-enrich dietary effect on the reproductive performance and larval growth produced from the brood-stock fish for 60 days, reported that the average fecundity of the fish increased proportionally to the concentration of probiotic supplementation in the feed using 2 probiotics (PRO$_1$ and PRO$_2$) comprises of *Bacillus subtilis* at different concentrations. The result of their study demonstrated that incorporation of probiotic in the feed favorably influenced the reproductive performance of the fish in terms of high fecundity, high fry survival, high average weight gain and length reducing fry mortality and deformity and general good health. So their observation was that probiotics can be used as brood stock, feed additive that can have a greater economic values. Bacteria such as *Bacteroides and Clostridium sp.* have supplied nutrients like fatty acids and vitamins to the host in fish aquaculture according to Mohammad *et al.* (2017). Some microorganisms such as *Agrobacterium sp.*, *Pseudomonas sp.*, *Microbacterium sp*. and *Staphylococcus sp*. may contribute to nutritional processes like *Bacillus subtilis* and *Lactobacillus rhamnosus* (Renuka, *et al.*, 2013, Balcazar, *et al*., 2006 Wand and Xu, 2005) that will influence the reproductive performance of aquatic species positively.

The early attempt to study the effect of probiotic on reproductive performance of fish was carried by Ghosh, *et al*. (2007) who isolated a strain of *B. subtilis* from the intestine of carp (*Cirrhinus mrigala)* incorporated in feed at different concentrations for four different species of ornamental fishes and reported that using the probiotic bacteria (*B. subtilis*) produced an increase in the gonad somatic index in terms of fecundity, viability, and high production of fry from the female of all the four species of ornamental fishes. Probiotics and reproductive performances in aquaculture are of high economic value if managed properly, because, reproduction process is a pillar for any production yield of animal, thus the financial outcome from aquaculture business (Abasali and Mohammad, 2010).

Proteins and fatty acids are very important constituents of the yolk, and their presence in diet consequently supports good oocyte development, maturation and higher rate of egg yolk production. Besides the regulation of reproductive physiology, essential fatty acids also supply energy to sustain the spawning activities, they also produce vitamins (B-complex) and certain stimulants which play a key role in the elevation of reproductive performance of the probiotic feed-fed fish and reduce mortality or deformity among the fish (Abasali and Mohaammed, 2010). The opinion of Ghosh, *et al.* (2007) and Cruz, *et al.* (2012) on the ability of probiotics (*B. subtilis*) to synthesize vitamin B complex especially thiamine (B_1) and B_{12} contribute to reduce mortality and deformity in fish production is substantial. A commercial probiotic containing *L. acidophilus, L. casei, Enteroccus faecium* and *Bifidobacterium thermophiles* have also been reported to increase reproductive performance of aquatic organisms because of their influence on nutritional contributions (Abasali and Mohammad 2010). Probiotic (Vibact®) comprising *streptococcus faecalis, Clostridium butyricum, Bacillus mesentericus,* lactic acid bacteria, have been employed by Chitra and Krishnaveni, (2013) to propagate ornamental fish (*Poecillia shenops*) that favorably influenced the reproductive performance in terms of fecundity, high gonado-somatic index, high fry survival, less fry mortality and deformity, high average body weight and length of fries.

Gioacchini, *et al.* (2011), assessed the effect of probiotic (*Lactobacillus rhamnosus* IMC 501) on the reproductive performance of zebrafish and found out that probiotic administration significantly has great effect on the oocyte maturation and ovulation. The probiotic also induce a significant increase in both estradiol receptor and vtg gene which attributed to the effective performance of reproduction of the fish (Ibrahim, 2015). After administration for 10 days their result showed a significant increase of gonadosomatic index and total number of eggs ovulated.

Table 2: Different applications of probiotics in aquaculture.

Application	Identity of the probiotics	Aquatic species applied on	Refernce

Growth promoters	*Bacillus sp. S11* *Bacillus sp* *Carnobacterium divergens* Alteromonas CA2 *Lactobacillus helveticus* *Lactobacillus lactis AR21* *Streptococcus thermophiles* *Streptomyces* *L. casei* *Bacillus* NL 110, Vibrio NE 17 *Bacillus coagulans*	*Penaeus monodon* Catfish *Gadus morhua* *Crassostrea gigas* *Scophthalmus maximus* *Brachionus plicatilis* *Scophthalmus maximus* *Xiphophorus helleri* *Poeciliopsis gracilis* *Macrobrachium rosenbergii* *Cyprinus carpio koi*	Rengpipat, *et al.*,1998 Queiroz and Boyd, 1998 Gildberg, *et al.*, 1997 Douillet and Langdon, 1994 Gatesoupe, 1999 Harzeveli, *et al.*, 1998 Gatesoupe, 1999 Dharmaraj and Dhevendaran, 2010 Hernandez, *et al*. 2010 Rahiman, *et al.*, 2010 Lin, *et al.*, 2012
Pathogen inhibition	*Bacillus sp.* *Enterococcus faecium SF 68* *L. rhamnosus ATCC53103* *Micrococcus luteus A1-6* *Pseudomonas fluorescens* *P. fluorescens AH2* *Pseudomonas sp.* *Roseobacter sp. BS. 107* *Saccharomyces cerevisiae, S. exiguous, Phaffia rhodozyma* *Vibrio alginolyticus* *V. fluvialis* *Tetraselmis suecica* *Carnobacterium sp. Hg4-03* *Lactobacillus acidophilus* *Bacillus spp., Enterococcus sp.*	Penaeids *Anguilla anguilla* *Oncorhynchus mykiss* *Oncorhynchus mykiss* *Oncorhynchus mykiss* *Oncorhynchus mykiss* *Oncorhynchus mykiss* Scallop larvae *Litopenaeus vannamei* *Salmonids* *Oncorhynchus mykiss* *Salmo salar* *Hepialus gonggaensis larvae* *Clarias gariepinus* *Farfantepenaeus brasiliensis* *Epinephelus coioides*	Moriarty, 1998 Chang and Liu, 2002 Nikoskelainen, *et al.*, 2001 Irianto and B Austin, 2002 Gram, *et al.*, 1999 Gram, *et al.*, 2001 Spanggaard, *et al.*, 2001 Ruiz-Ponte, *et al.*, 1999 Scholz, *et al.*, 1999 Austin, *et al.*, 1995 Irianto and Austin, 2002 Austin, *et al.*, 1992 Youping, *et al.*, 2011 Abdullah, *et al.* 2011 Moreira, *et al.*, 2011] Zhang, *et al.*, 2012

	Lactococcus lactis		
Nutrient digestibility	*L. helveticus* *Bacillus* NL 110, Vibrio NE 17 *Carnobacterium sp. Hg4-03* *Lactobacillus acidophilus* *Shewanella putrefaciens* Pdp11	*Scophthalmus maximus* *Macrobrachium rosenbergii* *Hepialus gonggaensis larvae* *Clarias gariepinus* *Solea senegalensis*	Gatesoupe, 1999 Rahiman, *et al.*, 2010] Youping, *et al.* 2011 Dohail, *et al.*, 2009 Tapia, *et al.*, 2012
Water quality	*Bacillus sp. 48* *Bacillus* NL 110, Vibrio sp. NE 17 *Lactobacillus acidophilus* *B. coagulans* SC8168 *Bacillus sp., Saccharomyces sp.*	*Penaeus monodon* *Macrobrachium rosenbergii* *Clarias gariepinus* *Pennaeus vannamei* *Penaeus monodon*	Wang, *et al.*, 2008 Rahiman, *et al.*,2010 Dohail, *et al.* 2010 Zhou, *et al.*, 2009 Shishehchian, *et al.*, 2009
Stress tolerance	*Lactobacillus delbrueckii* *Alteromonas sp.* *B. subtilis, L. acidophilus, S. cerevisiae* *L. casei* *Pediococcus acidilactici* *Shewanella putrefaciens* Pdp11	*Dicentrarchus labrax* *Sparus auratus* *Paralichthys olivaceus* *Poecilopsis gracilis* *Litopenaeus stylirostris* *Makimaki*	Carnevali, *et al.*, 2006] Varela, 2010 Taoka, *et al.*, 2006 Hernandez, *et al.*, 2010] Castex, *et al.*, 2009 Tapia, *et al.*, 2012
Reproduction improvement	*Bacillus subtilis* *L. rhamnosus* *L. acidophilus, L. casei, Enterococcus faecium, Bifidobacterium thermophilum*	*Poecilia reticulata, Xiphophorus maculatus* *Danio rerio* *Xiphophorus helleri*	Ghosh, *et al.*, 2007 [Gioacchini, *et al.*, 2010] Abasali and Mohamad, 2010

Source: Cruiz, et al., (2012)

Effect of probiotic on hatchability and survivability in fish production

i. Catfish (*Clarias gariepinus*) production

African catfish is the popular species for aquaculture business in Nigeria. The fish species has the advantage of being resistance to diseases and handling stress in addition to having high growth rate, thus its commercial importance worldwide. Survivability of fish during production is dependent on water quality and management technique of the farmer. Lactic acid bacteria such *as lactobacillus, Lactococcus, Enterococcus,* and *Streptococcus,* have been reported to convert hexose sugars to lactic acid thus producing, an acidic environment that inhibit the growth of several species of harmful bacteria. It can be said that the lactic acid might have enhance the production of inhibitory substances against the pathogenic organism. There was a highest growth performance, survival and feed utilization of African catfish when probiotics was applied at 5 day interval and the success was attributed to the effect of probiotics that help to maintain the density of bacteria at suitable form. Putra (2017), Hatch rate was influenced by probiotic PRO_2 (*B. subtilis*) showing higher performance due to the increase in beneficial bacterial load in their digestive tracts which protected them from pathogenic attack by secreting some beneficial enzyme, producing B group of vitamins which could have accounted for reduced number of dead fry in all the four ornamental fish species (Ghosh, et al., 2007). The probiotic bacteria in the fish intestine enhance host enzyme secretion by the superior maturation of the fish. When probiotic is established in gut, it enhances brood-stock and larval nutrition by synthesizing essential enzymes such as amylase, protease, lipase (Irianto and Austin, 2002). An experiment using mixture of indigenous bacteria composed of *Bacillus, Pseudomonas, Acinetobacter* and *Flavobacterium* isolated from the aquatic environment had beneficial impact on the survival rate of eggs and larvae of *Clarias gariepinus* and the hatching rate and larval survival increased with the increasing bacterial load, even up to the highest dose of 10^8 cells/ml employed in the study of Ariole and Okpokawasili (2012)

ii. Effect on Catfish (*Heterobranchus bidorsalis*) production

Probiotics have been proven to be positive promoters of aquatic animal growth, survival and health according to Hai, (2015). Probiotic bacteria improve the health by controlling pathogens and improving water quality through modifying the microbial community composition of the water (Moriaty, 2005). The common probiotics employed in culture of different aquatic organisms have been reported by Gomez-Gill *et al.* (2000). The in-vitro experiment of Kolndadacha, *et al.* (2013) with potential probiotic bacteria (*Bacillus spp, B. firmus, Pseudomona. aeruginosa, Pseudomonas sp., E. coli,* and *K. aerogenes*) isolated from the skin and gastrointestinal tract of cultured *Clarias anguillaris* and *P. aeruginosa, Streptococcus spp, E. coli, Bacillus spp, Aeromonas sp, K. aerogenes, Staphylococcus aureus* and *Streptococcus faecalis* from *Heterobranchus bidorsalis* inhibited some potential pathogens isolated from the same fish species with varying degrees of zone of inhibition. They therefore reported that these strains of probiotic microorganisms might confer benefits to the health of the fish, thus the use of these potential probiotics has potential benefits for conditions such as gastrointestinal infections, growth promotion, improvement of water quality all of which affect a considerable proportion of the global concern.

iii. Effect of Probiotics on Tilapia (*Oreochromis niloticus*) production

Application of probiotics to manipulate the composition and size of pathogenic bacteria community on the skin, gills, gut and water environment of tilapia like any other aquatic animals have been used in preventing or reducing the severity of diseases, thus improving general survivability (Addo, 2013). Unlike catfish, tilapia species are fragile, but with good water quality management, survivability can be high which increases the prolificacy of the fish. The effect of probiotic bacteria has been reported to improve survivability and growth performance, optimizing immune system of tilapia and increasing host resistance to diseases or preventing pathogenic organisms from causing disease with inhibitory substances (Ekundayo, *et al.*, 2014) and consequently lower mortality in tilapia production. Some Gram-positive bacteria such as *Bacillus species* are associated with development of water quality which results in reduction of pathogenic population in the culture environment that encourages survival and growth rate with better health condition of host (Dauda, *et al.*, 2013). Apart from being water probiotics, some effects of *Bacillus species* like *B. subtilis*, improving digestibility of the host through enzymatic activity, growth performance, immune response, and disease resistance (Christian-Teoder, *et al.* 2014) are other attributes of probiotics. A number of commercial probiotics are currently available including Aqualact®, Probe-La®, Lacto-sacc®, Epicin®, Biogreen®, Environ®, Wunopuo-15® and Epizyme® containing various bacterial species in production of aquaculture organisms including *Nile tilapia* (Dauda, *et al.*, 2013). These bacteria prevent building up of organic materials that will destabilize optimum water quality parameter and to great extent result to purifying the water of culture system. Several studies have shown that bacteria of the genus *Bacillus sp* secrete exoenzymes (protease, lipases and carbohydrates) that help improve digestion and nutrient absorption resulting in better use of food, animal survival and growth performances (Rafael and Luis, 2012). Going by the general role of probiotics in aquaculture provided by Swapna and Rosamma (2008) which include: improvement of feed conversion efficacy, enhancement of immunity and disease resistance, improvement of nutrient absorption, change of bacterial composition in the gut by excluding undesirable ones, reduced mortality, enhance production and increase harvesting yield, it is therefore reasonable to say that the potential of probiotics role in successful production of shrimp and fish is paramount in aquatic animal production.

iv. Effect of probiotics on Carp (*Cyprinus carpio*) production

In carp production, the uncontrolled development of the microbial community in hatcheries has been one of the major reasons for the unpredictable and often variable results. Suantika *et al.* (2013) evaluated probiotics (*Bacillus firmus* and *B. coagulans*) against *Aeromonas hydrophila* in carp larviculture reported that the egg hatching and survival rates of 98.33% and 100% respectively from 2 ponds. When Al-Faragi and Al-Saphar (2013) assessed the effect of local probiotic on common carp (*Cyprinus carpio*) on growth performance and survival rate, they observed that lactic acid bacteria, *B. subtilis* and *Saccharomyces cerevisiae* both inhibited some intestinal bacteria and increase the non-specific immunity of the treated common carp and also prevented disease occurrence with its negative impact on the fish growth and survival rate better in all treatment which recorded up to 95% survival rate compared to 70% with control group. Similarly *Lactobacillus* bacteria showed a positive effect on growth performance and digestive enzymes activity on a common carp (*Cyprinus carpio*) after supplemented in experimental diet with high growth and feed utilization (Renuka, *et al.*, 2013).

Lactobacillus sp have been reported to have the ability to produce secondary metabolites that have been incriminated to be used industrially for production of antibiotics, bio-insecticides and enzymes which hydrolyze carbohydrate, lipids and protein into sugar, fatty acids, peptides and amino acids which contribute immensely to the growth and survivability of the fish (Renuka, *et al.*, 2013). Balcazar, *et al.* (2006) had since reported other effect of *Lactobacillus sp* to improve the intestinal microflora balance which in turn cause better nutrient digestibility, higher absorption quality and increase enzyme activity, which is similar with the report of Wand and Xu

(2005) who isolated photosynthetic bacteria and *Bacillus sp* from the pond of common carp and supplemented in common carp diet for 60 days feeding experiment resulted in better growth and feed utilization than control groups. So, probiotics have successfully been used for many benefits on carp for maintaining good health and propagation like any other aquatic animals. Abareethan and Amsath (2005) mention probiotic bacteria that have been commonly used in carp production which include; *Lactobacillus spp, Bacillus sp, Saccharomyces cerevisiae* and *Lactococcus spp*.

Stress tolerance responses to environmental factors.

Stress is a condition that causes physical and mental discomfort that results in the release of stress related hormones or results in specific physiological responses like; rise in blood pressure, increase heart rate, increase blood sugar, release of cortisol (Cruz, et al.,2012). In addition, Vianello, et al. (2002) reported that stress induces a general depression on synthesis of muscle protein. The use of *L. delbrueckii* in the diet of European sea bass (*Dicentrachus lbrax*) showed a reduced level of tissue cortisol (stress marker) significantly lower than the control group (Shishehchian, et al. 2001). Hormone cortisone in fish is used as stress marker because it is directly involved in animal to stress (Cruz, *et al.*, 2012). Fish that response to heat stress will show by the increase in the circulation of this hormone in the blood. Stress test was also carried out using heat shock to determine the mean lethal time (LT50) by adding diet containing *B. substilis, L. acidophilus, Clostridium butyricum* and *Saccharmyces cerevisiae* showed greater stress tolerance in treated than control group with LT50 for 40 and 25 minutes respectively (Cruz*, et al.* 2012).

Lactase and plasma glucose are also considered appropriate indication of stress as they increase as a secondary response during stress to cover the high energy requirement induced by the situation. Raj, *et al.* (2008) evaluated the performance of probiotic on fish fry during packing, transportation stress and post-transportation condition in which a group of the fish fries were treated with probiotics prior to, during and after the transportation with same probiotic agent survived and grew better after transportation and 5 days post-transportation compared to the group treated with probiotic prior to, during transportation but not treated with probiotics after the journey, or the group that was not treated with probiotics either prior to, or during, but treated with probiotics for 5 days post-transportation nor the control group where no treatment was given throughout, their results showed that probiotic application prior to, during transportation and 5 days after transportation increased fry survival compared to the rest of the treatment and control group recorded higher mortality.

The activity of probiotics in amelioration of oxidative stress in aquatic environment has been reported from the review of Mohapatra, *et al.* (2012) that the effect could either be through improvement of diet utilization and/or play a role in antioxidant activity. *Lactobacillus fermentatum* is one of the probiotics that has antioxidant properties, while *L. fructivorans* and *L. plantarum* were found to have significantly high cortisone level with higher heat shock protein gene expression which resulted in lowering cumulative mortality in experimental shrimp during feed supplementation.

CONCLUSION

Aquaculture is being an important activity in many countries of the world (Balcazar, *et al.* 2000). This activity has been ranked the fastest growing food-producing sector in the world that has accounted for over 50% of annual world's fisheries production (Ngwu, *et al.* 2011) and produces almost half (½) of the sea foods consumed by humans globally (FAO, 2017). However, one major impediment restricting great expansion of aquaculture development, domestication and expansion are diseases which occur in all stages of production and species of fish (Welker, et al., 2005) that results in some serious economic losses. The development and spread of resistance factor among bacteria has attracted awareness that antibiotics should be used with great care which has resulted in reduced confidence in antimicrobial agents. The application of beneficial (probiotics) bacteria which control pathogens through variety of mechanisms of action has been globally viewed to be alternative to antibiotic treatment and to improve growth performance. So, probiotics in recent years have been are used as alternative measures to control the aquatic diseases since, because of its availability, efficacy and safety to both environment and public health hazard.

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