Probiotic Supplements in Aquaculture: Latest Developments and Future Trends

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Abstract

Aquaculture is one of the fastest growing fish farming venture in the world. With the intensification of culture practices, different methods and technologies have developed simultaneously. Usage of different chemical additives, antibiotics, prophylactics, medicines, etc. has become more widespread for reducing disease risk and to increase production for commercial benefit. Some of this methods, technologies, and substances may bring commercial benefits for producers; but, over the year, adverse health effect of these substances for consumption has become a great concern. The probiotic application instead of other chemotherapeutic drug is more safely, eco-friendly because it is nonantibiotic and alternative source of antibiotic. It fights against different infectious disease by increasing the population of beneficial bacteria. It accelerates the growth, increases immune response, improves the digestibility, and also improves the water quality. The probiotic helps fish to fights against different types of pathogens and improves the anti-bacterial, anti-viral, and anti-fungal properties. To identify probiotic supplements use in aquaculture, their current condition and future perspective different journal and scientific paper are reviewed. The probiotics use in aquaculture is recent trend. But it has not been studied extensively in the field of aquatic environment. This review study provides recent knowledge of the use of probiotic supplements in aquaculture with the latest developments and future prospects.

Keywords

Probiotic · Supplements · Aquaculture · Antibiotic · Disease outbreak

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16.1 Introduction

In recent year, aquaculture has developed worldwide rapidly for meeting the increasing demand of fish as a food. The vastly increasing population is the cause of overfishing from wild stock. It increases the pressure in wild water resources. To mitigate this problem, aquaculture plays a significant role. Aquaculture increases not only the fisheries production but also the economic condition of the country. Nowadays, disease outbreak in aquaculture is causing great loss to the farmers. Different chemical additives and medicines have been used indiscriminately worldwide to reduce risk of disease outbreak as a preventive and curative method, and Bangladesh has been no exemption. The widespread use of antibiotics and different prophylactics has created a great concern due to antibiotic resistance of some bacterial species. Use of different chemical substances may also have a harmful effect on the consumer. Aquaculture provides 56.72% of total fish production in Bangladesh (DoF 2019), which is more than half and its' contribution in total fish production can't be neglected. So the use of such harmful substances is needed to be controlled and reduced concerning consumer health. Different probiotic substances can be used as a replacement as these substances doesn't have any adverse health effect and increase fish growth and improves immune response against any pathogenic substance. Different probiotic substances are already in use in aquaculture and their effect on fish health and against any virulent pathogen needed to be tested in order to avoid any adverse effect on fish. Probiotics are screened by fish gut assessment by testing the effect of bacteria and other substances *in vivo* and *in vitro* simultaneously.

The probiotics are live microorganisms, which are competent to adapt, colonize, and produce within the gut of the host and develop a constructive stability of microorganisms to advance animals' health (Cruz et al. 2012). The numerous benefits of probiotics for growth, defense, and intestinal health of the host were revealed, and broader use of probiotics in aquaculture could prevent diseases, promote growth, and reduce the extensive use of antibiotics (Austin and Austin 2016). Probiotics retard or completely inhibit the development of pathogenic bacteria following a competitive elimination, also boost up the resistance and secretion of mucosal enzymes to stimulate host growth, and they do not cause secondary pollution difficulties (Xia et al. 2020).

To control and compete with pathogenic bacteria and to promote the growth of the cultured organisms, probiotics can be introduced as "bio-friendly agents" into the cultural environment (Farzanfar 2006). Some contemporary studies have clearly validated the beneficial effects of probiotics on immune system modulation, stress tolerance and growth rate of cultivated fishes, African catfish (Al-Dohail et al. 2009), Nile tilapia (Lara-Flores and Olvera-Novoa 2013), Japanese flounder (Taoka et al. 2006), and also increasing interest in south-east Asian aquaculture (El-Haroun et al. 2006).

16.2 Probiotics, Types, Quality, and Function

The word "probiotic" is a modified word of probiotika (Lilly and Stillwell 1965). Probiotics is a term originates from Greek word "Pro" and "Bios" (Schrezenmeir and de Vrese 2001). According to Parker (1974), "Organisms and substances that exert beneficial effects on the host by balancing its intestinal microbes." Fuller (1989) defined probiotic as "live microbial food supplement that benefits the host (human or animal) by improving the microbial balance of the body" and in extreme range of temperatures and salinity variations of probiotics would be performed effectively. It is also found that probiotics are live microorganisms, which, if consumed in acceptable amounts, confer health benefits to the host (Guarner and Schaafsma 1998). It is also defined as "microbial cells administered in a certain way, which reaches the gastrointestinal tract and remain alive with the aim of improving health" (Gatesoupe 1999). Different types of microorganisms are comprised in probiotics. Those are unicellular algae, beneficial bacteria, fungi, yeast, and bacteriophages. The probiotics would be defined for aquaculture as "a probiotic organism can be regarded as a live, dead or component of a microbial cell, which is administered via the feed or to the rearing water, benefiting the host by improving disease resistance, health status, growth performance, feed utilization, stress response, which is achieved at least in part via improving the hosts microbial balance or the microbial balance of the ambient environment" (Merrifield et al. 2010).

On the basis of the mode of application, probiotics are classified as feed and pond probiotics. The feed probiotic is used through the feed supplements. By this method, the probiotic directly finds their way to gut or gastointestine and helps in beneficial microbiota growth to fight against the pathogen. It can be mixed with the feed supplements in two ways: (1) preparing the artificial feed by using probiotics such as pellets, granules, crumbles, flakes, and microencapsulated diets and (2) the natural live organisms, which reared in probiotics used as feed. Live organisms reared in probiotics enrich media as a result it encapsulated by probiotics. This procedure is called bioencapsulation (Nayak 2010b). The pond probiotic is used in water to improve the water environment for unusual stress condition of fish and other aquatic biota. The deteriorate condition is created by low dissolved oxygen, accumulation of dissolved ammonia, nitrite, and also the hydrogen sulfide in the pond sediments. In this case, probiotics create the antagonistic properties and eliminate the pathogenic organisms from waterbody by bio-control process. The probiotics also increase the beneficial bacteria into the waterbody, which are responsible for the breakdown of complex organic matter into simpler form. It helps in bioremediation by controlling or reducing the biochemical or chemical oxygen demands. The oxidizing capacity reduces the toxic elements like ammonia and nitrite and make them harmless (Nayak 2010b). Probiotics work in different ways in aquaculture systems as presented in the Fig. 16.1.

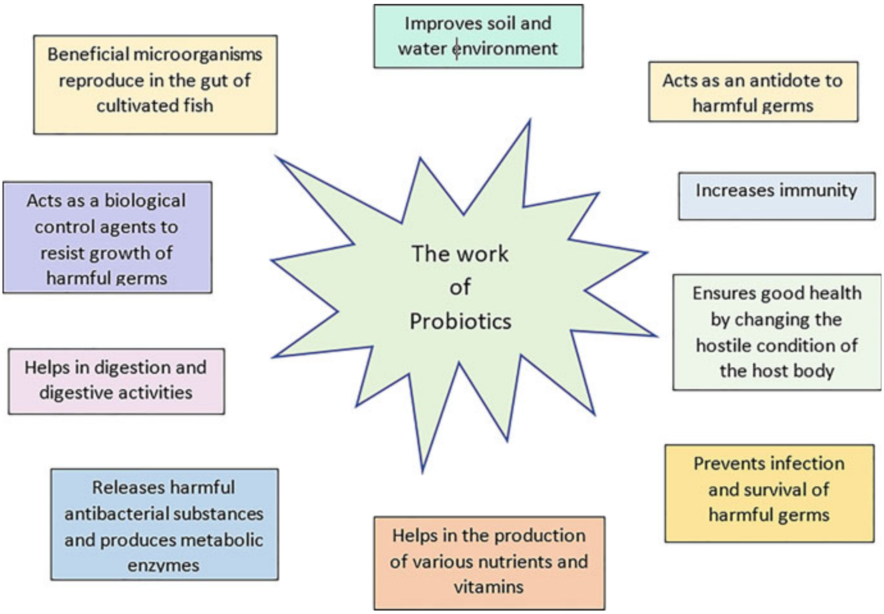


Fig. 16.1 Function of probiotics in different ways in aquaculture systems

16.2.1 Significance of Probiotics

Probiotic amplify the growth of desirable benignant microbiota in the intestinal tract of fishes. The digestible compounds are breakdown by different process during food consumption. It produces vitamins and detoxification of the diet, which helps animate the dearth and improving nutrient, and all those are cause by the help of probiotics (Irianto and Austin 2002). It makes the favorable condition by increasing the production and immune response in fishes, thereby reducing risk of disease (Fig. 16.1). It also helps in maintaining water quality by reducing organic pollutants. According to Mamun et al. (2018), probiotics helps the host by:

- Increasing length of the villus
- Natural killer cells
- Antibodies
- Protease enzyme
- Antioxidant enzyme
- Cytokines
- Complements

The *Bacillus* species reduces metabolic waste in water. Among them, some helps to control the bacterial pathogen, some improves growth, some provides nutrients, some bacteria shows antiviral activity, and some helps to improve fecundity. The combination of different bacteria together can be more beneficial than single species. It was found that reduction in the outbreak of white spot syndrome virus (WSSV) can possibly by combination of *Pediococcus, Staphylococcus*, and *Haemolyticus pentosaceus* (Leyva-Madrigal et al. 2011). *Bacillus subtilis* and *Lactobacillus acidophilus* combination could increase the hematocrit values and also serum bactericidal activity in *Oreochromis niloticus* (Aly et al. 2008). The live probiotics provide more advantage than inactivated ones.

16.2.2 Selection Criteria and Selection Process for Probiotics

The probiotic selection is a fecund issue. It must identify by maintaining certain qualities (Merrifield et al. 2010; Pandya 2016), which are as follows:

1. Probiotics must help the fish to fight against different pathogenic bacteria. It also should have the fruitful effect on growth, developmental ability, and protectoral criteria.
2. The selection criteria of the probiotic are less harmful for host organisms.
3. It should not show the resistance power and maintain the hereditary traits.
4. It should be efficient for feed, exhibits acid bile tolerance and resistance to gastric juice, and also have the adherence ability to the digestive tract.
5. Probiotic should show the decent sensorial things, have fermented accomplishment, have tolerance to freeze drying, and have great viability during storage and packaging period.

Selection of microorganisms for probiotics is very important and useful because it is important to identify the efficient probiotic organism by isolating the organism, characterization, testing, and lastly certification of the organisms for its probiotic efficiency (Fig. 16.2).

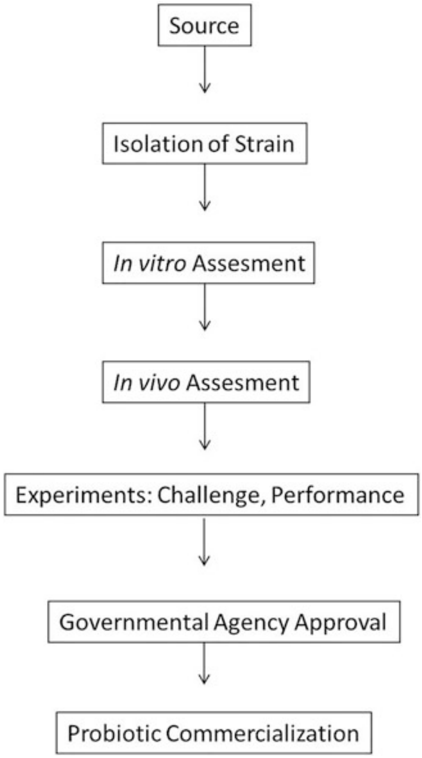
16.2.3 Application of Probiotics

The probiotics can be used in three ways, but mixing with feed additives has been the most common method used in aquaculture (Hai et al. 2009). In aquaculture system, there are different ways by which probiotic application is conducted. It can be applied via dietary supplements or direct application to the water as a form of live feed supplements such as *Artemia*, *Rotifer*, pellet feed, etc. (Fig. 16.3):

1. Can be directly used as feed additives
2. Can be administered through oral
3. By mixing with water

Considering on broad aspect, probiotics are distributed into two categories: (a) gut probiotics, which managed by oral to the fish along with food to increase

Fig. 16.2 Flowchart of probiotic selection (de Azevedo and Brag 2012)



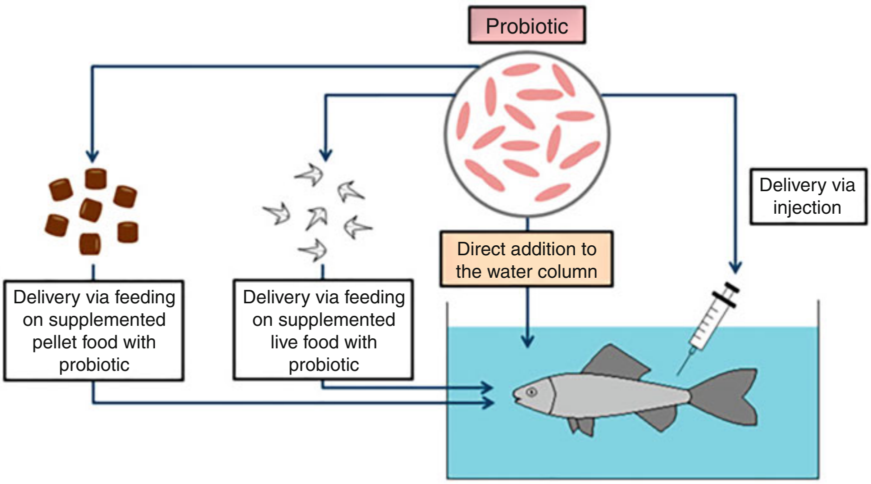


Fig. 16.3 Probiotic application methods in aquaculture (Moriarty 1998; Skjermo and Vadstein 1999)

Table 16.1 Gut probiotics and their beneficiary effects on aquatic organisms (Hasan and Banerjee 2020)

Probiotics name	Beneficial effects	Reference(s)
Lactobacillus rhamnosus	Enhance immunity and reduce disease susceptibility	Nikoskelainen et al. (2003)
Lactobacillus plantarum	Enhance stress tolerance	Taoka et al. (2008)
Lactobacillus rhamnosus	Improve blood quality	Panigrahi et al. (2010)
Streptococcus sp.	Improve feeding efficiency and growth rate	Lara-Flores and Olvera-Novoa (2013)
Bacillus subtilis	Enhance cellular immunity	Sanchez Ortiz et al. (2015)
Bacillus subtilis + Lactococcus lactis + Saccharomyces cerevisiae	Enhance survival rate, foster metabolism, enhance weight	Abareethan and Amsath (2015)
Bacillus amyloliquefaciens	Enhance antibody concentration, reduce stress	Nandi et al. (2018)
Bacillus subtilis + Lactobacillus rhamnosus	Enhance the food digestibility	Munirasu et al. (2017)
Lactobacillus sp.	Reduce pathogen load, provide protection against *Aeromonas hydrophila*	He et al. (2017)
Bacillus cereus	Protect from *Aeromonas hydrophila* infection	Dey et al. (2018)
Bacillus, Arthrobacter, Paracoccus, Acidovorax, etc.	Reduce pathogen load and provide nutrients	Nandi et al. (2018)
Alcaligenes sp.	Enhance volatile short chain fatty acids	Asaduzzaman et al. (2018)

the gut associated beneficial microbial flora (Table 16.1), and (b) water probiotics, the probiotics provided into the water, which helps to excluding of the harmful pathogenic bacteria from the waterbody by using essential nutrients and make the pathogenic bacteria to die in starving condition (Table 16.2).

16.2.4 Probiotic Use as Supplements in Aquaculture

In aquaculture sector, the probiotics are currently most usable agents to increase the growth of the fish with less negative impact (Nicolas et al. 2007; Wang et al. 2008). In fish farming, the probiotics are used to emphasize on fish species, fish size, and condition of the feed adaptation. Nowadays, the commonest probiotics are the yeast, *Saccharomyces cerevisiae*, *Enterococcus* sp., *Lactobacillus* sp., and *Bacillus* sp.; all lactic acid bacteria are used in aquaculture industry (Rahiman et al. 2010). The modification of the gut microflora and replacing the destructive microorganisms from the gut by the use of sufficient quantities of beneficial microbes in feed of the host might fulfill the result. Intestinal balance is enlightening in the animal during

Table 16.2 Water probiotics and their role in maintaining water quality (Hasan and Banerjee 2020)

Probiotics name	Beneficial effects	Reference (s)
Bacillus sp.	Reduces the load of ammonia and nitrite	Porubcan (1991)
Enterococcus faecium ZJ4	Improves water quality and enhances immunity	Wang and Wang (2008)
Lactobacillus acidophilus	Improves water quality	Al-Dohail et al. (2009)
Bacillus NL110, Vibrio NE1	Reduces ammonia and nitrite concentration	Rahiman et al. (2010)
Nitrosomonas sp., *Nitrobacter* sp.	Reduces the concentration of ammonia, phosphates and nitrite in culture pond	Padmavathi et al. (2012)
Rhodopseudomonas palustris, Lactobacillus plantarum, Lactobacillus casei, Saccharomyces cerevisiae	Reduces nitrate load, maintains water pH, and enhances dissolve oxygen concentration	Melgar Valdes et al. (2013)
Paenibacillus polymyxa	Enhances immunity and reduces pathogenic stress	Giri et al. (2013)
Lactobacillus rhamnosus	Reduces pathogen load in culture tank	Talpur et al. (2013)
Pseudomonas sp.	Enhances transcription rate of anti-microbial peptide	Ruangsri et al. (2014)
Bacillus sp.	Promotes the growth of beneficial algae and reduces the growth of harmful algae	Lukwambe et al. (2015)
Nitrosomonas sp., *Nitrobacter* sp.	Reduces pathogen load in culture pond and increases dissolved oxygen content	Sunitha and Krishna (2016)

bacterial colonization in gut, and furthermore extraordinary bacterial strains by utilizing live microbial feed added substance, emphatically affecting the creature, which help battle against the dangerous microorganisms and affecting the organic entities' exhibition (Martínez Cruz et al. 2012). Understanding the development, the increase of the respectable probiotic microbial strains multiplies the stomach-related compounds such as activities of lipases, proteases, and amylases in the gut (Boonthai et al. 2011; Roberfroid 2007). However, the actions of probiotics are as following aspects:

1. Probiotic produce different types of antibacterial compounds; those are bacteriocin, antibiotics, lysozymes, siderophores, proteases, organic acids, and also hydrogen peroxide, which cause sudden shock to pathogenic bacteria (Fuller 1989).

2. Probiotic shows the competitively excluding characters. It competes with the pathogenic bacteria by introducing inhibitory compound and also compete for the space, oxygen, and for nutrients (Fuller 1989).
3. The probiotics make the colony into the fish gut and those colonization followed to the gut wall of fish, which highly show the preventive and inhibitory characters for the pathogenic bacteria to adhere to the gastrointestinal tract.
4. The probiotics produce the potential nutrients, which increase the nutrient in the culture animals.
5. Probiotics compete for the oxygen so that they reduce the availability of the oxygen to the pathogenic bacteria.
6. The probiotics animated the humoral or cellular immune response (Fuller 1989).
7. Probiotics help in increasing or decreasing of the relevant enzyme that's why the microbial metabolism is altered (Fuller 1989).
8. It boosts the lactose utilization, which helps in cancer inhibition. The lactic acid forming bacteria helps to control serum cholesterol.
9. Probiotics detoxify the metabolites, which is produced by the pathogenic bacteria in the intestine.

16.3 Latest Development of Probiotics in Aquaculture

Advancement of probiotics for business use in aquaculture is a multidisciplinary interaction requiring both observational and key examination, full-scale preliminary, and a monetary appraisal of its employments. Probiotics application in aquaculture is of incredible advantage to the host fish, fish farmer, or fish consumer severally. Significantly, probiotics settle the microbial populace of the fish's GI plot through the end of pathogenic microorganisms and expanded edibility and bioavailability of supplements needed for ideal development and great well-being. Farmers should be urged to include probiotics for feed to appreciate the relating benefits it presents. There are several benefits of probiotic in aquaculture, which are described below:

16.3.1 Probiotics as Potential Candidates

Application of probiotics in aquaculture sector is becoming popular for their better and nonpathogenic performance. There are different types of bacteria selected for probiotics, but among them the lactic acid forming bacteria (LAB), Bifidobacterium and streptococcus, are mostly popular (Giri et al. 2013). At present, there are different types of bacteria such as *Aeromonas media*, *Bacillus subtilis*, *Lactobacillus helveticus*, *Enterococcus faecium*, and *Carnobacterium inhibens* are vastly used as probiotics. Those bacteria are meaningfully effective against pathogenic bacteria. On the other hand, it is found that there are some gram-negative facultative symbiotic anaerobic bacteria that also play a significant role, such as *Vibrio*, *Pseudomonas*, *Plesiomonas*, and *Aeromonas*. Those bacteria are found in the gastrointestinal tract (GIT) of fish and shellfish. Apart from these discussed laboratory-based probiotics, various experimentally approved commercial probiotics are also available in the market, which is also effective in aquaculture (Verschuere et al. 2000) (Table 16.3).

16.3.2 Probiotics for Sustainable Aquaculture

Maintenance of the sustainable aquaculture is very important, but the disease outbreak increases the risk of this sector, which makes the burning concern develop research to mitigate this problem. People use antibiotics, but this creates more problems in this sector. The application of probiotics is safer than antibiotics. According to FAO recommendation, probiotic application is beneficial. It helps to improvement in the aquatic environment and reduces the mortality (Subasinghe 2005). It also increases the resistant against pathogenic bacteria (Irianto and Austin 2002). The favorable effect of the probiotics depends on the application time (Verschuere et al. 2000).

16.3.3 Maintenance of Water Quality

Probiotics have significant capabilities to convert the organic nutrient in the field of the aquaculture, which helps to improve the water environment for fish culture (Wang et al. 2007; Wang and Wang 2008). The nitrogenous compound such as ammonium and ammonia (NH_3) are toxic and main concern for fish culture. Paradigm of this concern the cat fish rearing into the pond (Sahu et al. 2008). The maintenance of water environment probiotics is used in the recent period of time. It is use to mitigate hazardous condition of the water environment and balancing the water quality ($NH_3/NO_2/NO_3$). But the candidates for probiotics is limited (Wang et al. 2007) (Fig. 16.4).

Different photosynthetic bacteria such as *Bacillus*, nitrifiers, and denitrifiers are combined together because of their strong tendency of combination. There are different species of fish culture in diverse condition treated with the probiotics, which sometimes labeled as multifunctional activities (Wang and Wang 2008). Probiotics play a significant role to transforming the organic CO_2, which helps in the maintaining higher production reducing the load of organic carbon and increase the better health of the fish (Fig. 16.4).

16.3.4 Enhancement of Growth and Survival

To improve the growth of different cultivated fish species in the aquaculture sector, probiotics play a great role. For example, *Puntius gonionotus* showed the significant weight gain when *Enterococcus faecalis* causes supplemented with feed at the amount of 10^7 and 10^9 cfu per gram (Allameh et al. 2016). Probiotics combined and colonized into the gastrointestinal gut wall of the fish for long-time application duration. It colonizes because of higher multiplication capacities into the gut wall.

Table 16.3 Commercial probiotics for aquaculture available in the market (Hasan and Banerjee 2020; Rahman et al. 2017)

Product name	Company name	Composition
Prosol	Prosol Chemicals	*Bifidobacterium longum, Lactobacillus acidophilus, Lactobacillus rhamnosus, Lactobacillus salivarius, Lactobacillus plantarum*
Progut	Lincoln Pharmaceuticals	*Yeast cell wall, Mannoproteins, Betaglucans, nucleotides, and peptides*
Lact-Act	Geomarine Biotechnologies	*Lactobacillus sporogenes*
Engest	Microtack	*Bacillus subtilis, Bacillus megaterium, Bacillus licheniformis*
Grobact	Tropical Biomarine Systems	*Lactobacillus rhamnosus, Lactobacillus acidophilus, Saccharomyces boulardii, Bacillus coagulans, Streptococcus thermophilus, Bifidobacterium longum, Bifidobacterium bifidum*
Prolacto	Drug International	*Lactobacillus acidophilus, Bifidobacterium bifidum, Lactobacillus bulgaricus, and fructooligosaccharides*
Probio Diet	Prowin Bio-Tech	*Saccharomyces* sp., *Lactobacillus* sp. *and Bacillus* sp.
Hydroyeast Aquaculture	Agranco Corp	*Streptococcus faecium, Lactobacillus acidophilus, Yeast, Bifidobacterium* sp.
Biotix Plus	Matrix Biosciences	*Lactobacillus* sp.
Aqua Star	Biomin	*Pediococcus* sp., *Lactobacillus* sp., *Enterococcus* sp., *Bacillus* sp.
Natu Rose	Artemia International	*Haematococcus pluvialis*
Enterotrophotic	National Centre for Aquatic Animal Health, India	*Bacillus cereus, Arthrobacter nicotianae*
Pond Plus	Novozymes	*Different kind of heterotrophic bacteria*
Eco-Pro	Biostadt India Limited	*Rhodopseudomonas palustris*
Eco marine	Organic Pharmaceuticals Ltd.	*Bacillus subtilis*, *B. pumilus, B. amyloliquefaciens, B. megaterium*
Profs	Eon Pharmaceuticals Ltd.	*Bacillus* sp. and *Pediococcus* sp.
Aqua gold	Organic Pharmaceuticals Ltd.	*Rhodopseudomonas* sp.
Aqua photo	ACI Animal Health	*Bacillus subtilis* and *Rhodopseudomonas*
pH fixer	CP Aquaculture	*Bacillus* sp.
Super Biotic	CP Aquaculture	*Bacillus* sp.
Super PS	CP Aquaculture	*Rhodobacter* sp., *Rhodococcus* sp.
Procon-PS	Rals Agro Ltd.	*Bacillus* sp. *Rhodococcus*, and *Rhodobacter*
Pond care	SK + F Bangladesh Ltd.	*S. faecalis* and other bacteria

(continued)

Table 16.3 (continued)

Product name	Company name	Composition
AQUA LIFE-S	NAPHAVET Co. Ltd	*Bacillus subtilis, B. licheniformis, B. mesentericus, Lactobacillus acidophilus, Nitrobacter* sp., *Nitrosomonas* sp., *Saccharomyces cerevisiae, etc.*
Everfresh Pro	Blueweight, India	• *Bacillus subtilis, Bacillus licheniformis* • *Bacillus megaterium, Bacillus pumilus* • *Enzymes protease, Amylase, Cellulase* • *Xylanase,* etc.

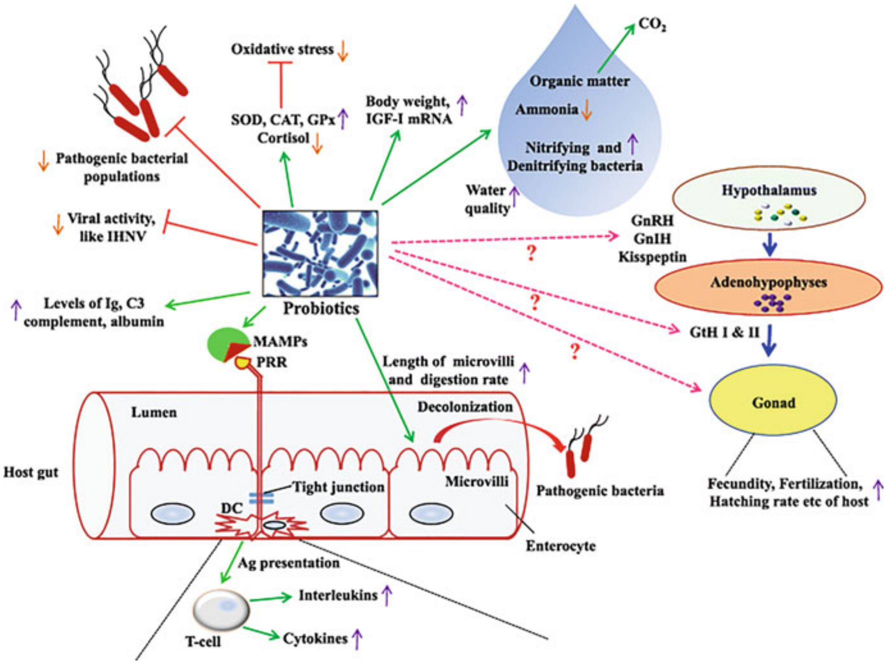


Fig. 16.4 Probiotic performance information in host body (Adopted from Hasan and Banerjee 2020)

Continuous application of probiotics into the aquaculture sector enhances the immunological factors, which helps in reduction of pathogen load into the fish gut mucus layer by increasing the microbial load into the gut (Banerjee and Ray 2017). Probiotics enhance the nutrient of the host body (Hamdan et al. 2016). Probiotics increase the crude lipid and protein and also increase the body weight of Nile tilapia (*Oreochromis niloticus*) treated with *Lactobacillus* sp. into the supplemented feed (Hamdan et al. 2016). Alongside the probiotic-treated feed supplement, different components act a critical part in development improvement of fish, for example, water quality hydrobionts species, protein level, and furthermore the hereditary opposition (Tan et al. 2016).

The species such as *Xiphophorus helleri, Xiphophorus maculates*, and *Poecilia reticulata* showed the increased growth and survival rate when it treated with *Bacillus subtilis* and *Streptomyces* sp. with the feed supplement. The growth performance and the hematological parameters showed the best result of the aquarium reared *O. niloticus* treated with higher amount of probiotics 0.2% dietary supplements into the basal feed of this fish (Hasan et al. 2021). A previous study on the *O. niloticus* showed the highest weight gain at 0.2% probiotic supplemented feed, which was differed from the control group (Chowdhury et al. 2020). The 0.2% inclusion of probiotics dietary supplement increases the growth and increases the production rate and survival rate of *Pangasianodon hypophthalmus* in floodplain cage culture (Chowdhury and Roy 2020).

16.3.5 Upliftment of Nutrient Utilization

The probiotic microorganism influences the gastrointestinal tract of the aquatic animal, which helps in the processing of dietary supplements and produces the energy. The most common probiotics used for gastrointestinal influence are lactic acid forming bacteria (Ringø et al. 2018). The nutrient digestibility increases because of higher amount of digestive enzyme (protease, amylase, cellulose, phytase, etc.). Those enzymes are produced by the influence of probiotics, which alter the gut associated microorganism community of the host (Banerjee et al. 2017; Ghosh et al. 2017). The probiotics *Lactobacillus brevis* and the *Bacillus subtilis* produce digestive enzyme phytase. Some microorganism of the probiotics contributes to produce the fatty acids, minerals, vitamins, and essential amino acids (Nayak 2010a; Newaj-Fyzul et al. 2014).

16.3.6 Role of Probiotics on Bacteriostatic Effects

The bacterial population of probiotics secretes different substances, which have the bactericidal or bacteriostatic impact on both the gram-positive and gram-negative microorganisms. The probiotics produce inhibitory substances, for example, proteinceous substance (lysozyme and various sorts of proteases), and compound substances, for example, (hydrogen peroxide) and iron chelating siderophores (Giri et al. 2013). The LAB-based compound bacteriocins alter between populace relationship impacting by the competition for energy and substance (Kesarcodi-Watson et al. 2008; Ringø et al. 2018).

16.3.7 Prolongation in the Immune System

The probiotics help the aquatic animal by stimulating the immune system. It protects the animal by reducing the disease and pathogen entrance (Dawood and Koshio 2016; Hai 2015). Probiotics increase the immune response, which makes the species disease resistance and also reduces the malfunction of the carp species (Wu et al. 2015). The probiotic supplement feed containing 10 cfu/g diet and continued for 2 weeks increases the immune impact by combining the microbial related molecular pattern to the pathogen arrangement recognition receptors to immunogenic cells and trigger intracellular action against viral and inflammatory pathogens (Balcázar et al. 2006) (Fig. 16.3). Probiotics also boost up the secretion of the mucosal enzymes and the immune response, which helps in the host growth and prevention from the secondary pollution problems (Xia et al. 2020).

16.3.8 Influence of Probiotics in a Viral Pathogen

The probiotics life forms like *Pseudomonas* sp. and *Vibrios* sp. showed the critical impact on the irresistible hematopoietic putrefaction infection (Sahu et al. 2008). The lymphocytes disease virus also assistant by using probiotics like sporolact (*Lactobacillus* sp.) with the feed supplement of the Paralichthys olivaceus (Harikrishnan et al. 2010).

16.3.9 Probiotics Effects on Reproduction

Probiotics perform a significant character in the field of disease resistant, which is well documented, but the role of probiotic into the reproduction is not well established (Fig. 16.3). There are few research studies on this purpose to demonstrate the role of probiotics in the reproduction of the aquatic animal (Abasali and Mohammad 2011; Ghosh et al. 2008). They used different strains of *Lactobacillus acidophilus*, *B. subtilis*, and *Lactobacillus casei* to demonstrate the probiotics performance on the reproduction. The probiotics play a significant role in the reproduction of the aquatic animal. It influences the reproduction by fertilization, fecundity, gonadosomatic index, and production of the spawn in the female (Abasali and Mohammad 2011). The present studies documented that the probiotics help to increase the daily egg ovulation number compared to control. It increases the hatching rate and faster the embryonic development of the zebrafish (Gioacchini et al. 2013).

16.3.10 Additional Activities of Probiotics

Presently, it is tracked down that the probiotics assist with lessening the pressure chemical focus like cortisol and furthermore actuate the counter oxidative proteins (superoxide dismutase, catalase, and glutathione peroxidase) articulation, which assists with expanding the pressure resilience of the host (Zolotukhin et al. 2018), which are likewise fundamental for the better multiplication execution (Hasan and Banerjee 2020; Hasan et al. 2014) (Fig. 16.4).

16.3.11 Relation Between Probiotics and Food in Aquaculture

The aquaculture supplemented feed is balanced by the probiotics. This is the common practice in the commercial aquaculture. The feed provides the farmers and the consumers to improve the growth performance, production rate, flesh quality, fish immune response, and protein quantity, carcass quality, intestinal health, and also reduce the malformation of the fish (Hai 2015). But large numbers of farmers belong to low income; they are not able to provide this commercial feed. So they face in great loss. They rely on the natural feed so that the growth performance, production rate, and flesh quality is reduced and increased the mortality rate. There are many research proved that the aquaculture sector can increase the profit by using probiotic supplemented diet in the early stage of the fish. It protects the larvae from disease. But probiotic application in this early stage is difficult. There are many researchers that are found to work on this field (Table 16.4).

16.4 Future Perspectives

Nowadays, the probiotic application is becoming popular in the field of aquaculture. In the aquaculture, the probiotics are used to confer different advantages. The application of probiotics is conducted for increasing the growth, stimulates the immune system for better performance, and increases the feed efficiency and also

Table 16.4 Interaction between probiotics and different types of food in fish farming

Fish species larvae	Probiotic feed	Beneficiary effects	References
Scophthalmus maximus	Lactic acid bacteria enriched *Brachionus plicatilis*	Resistant against wide range of *Vibrio* sp.	Gatesoupe (1997)
Sparus aurata	*Lactobacillus fructivorans* and *Lactobacillus plantarum* enriched dry feed or live feed (*Brachionus plicatilis* and *Artemia salina*)	Enhanced colonization on the gut epithelial surface and significantly reduced the mortality rate during larval rearing and fry culture	Carnevali et al. (2004)
Gadus morhua	Life feed enriched probiotic bacteria *Phaeobacter gallaeciensis*	Reduced the pathogenic load during larvae culture	D'Alvise et al. (2012)
Seriola lalandi	Live feed (*B. rotundiformis* and *B. plicatilis*) and *Artemia* sp.) enriched with *Pseudoalteromonas* sp.	Enhanced survival rate of the larvae	Sayes et al. (2018)
Scophthalmus maximus	*Bacillus amyloliquefaciens* enriched *Brachionus plicatilis* and *Artemia sinica*	It improves the microbial community in live feed and ultimately confers the beneficial effects to larvae	Jiang et al. (2018)
Centropomus undecimalis	*Bacillus licheniformis* and *Bacillus amyloliquefaciens* enriched feed	Improved water quality, fish health and rearing tank environment	Tarnecki et al. (2019)

the water quality improvement. There is necessary for the farther studies to understand the proper application and mechanisms of the probiotics in the aquaculture sector. It is important to understand the suitable stage of the probiotic application in early or adult stage by further study. The study of environmental condition and amount of probiotic application in the feed supplement is also very important. The larval stage is more exposed to the environment. So it is important to identify the effect of probiotics on that condition, which amount makes it more appropriate because they grow in different microbial flora in the intestine of the larvae.

Reducing the production cost of probiotics is vital. So that it will be affordable for both poor and middle scale farmer. This is the main concern for future technological developments of probiotics in Bangladesh. Bangladesh is lacking in assessment of screening potential probiotics from gut of different fish species that can help in developing probiotic technologies for certain commercial fish species. Development in this site can be one of the main focuses for future studies of probiotics in Bangladesh. Negative effect of different probiotic substances used in aquaculture in Bangladesh needed to be identified. This is important to identify the solution for making the probiotic viable and stable in to the new food environment that's why it is important to have future studies on new technologies and innovations (Mattila-Sandholm et al. 2002).

The study of the recent development of probiotic extraction technology, formulation, and encapsulation is also very important. By this study, we can identify the better extraction method and identify the biological carrier and barrier, material, and ingredients for making better performance of probiotics. Recent research must be carried out to identify the ingredients by treating there tradition, physical, and enzymatic way to overcome the challenges in probiotics preparation and increasing the potentiality of the probiotic-treated feed supplements. It is important to identify the specific technology for identification of the food ingredients, which is appropriately incorporating with the probiotics.

The probiotic application into the water body must be investigated specifically. It is important to identify the relationship among the quality and quantity of the probiotics used for controlling the complex compound ammonia and nitrogen from the environment of the water body (Skjermo et al. 2015). The yeast plays a significant role as probiotic, but there is lack of information regarding their use in finfish aquaculture. The probiotics play a significant role in the biofloc technology, and it showed the great result in the field of shrimp culture (Hostins et al. 2017; Widanarni et al. 2010). There are different biotechnological tools used for the determination of the immune response of the fish. But there is limited study on the technological tools used for the probiotics impact on the immune system fish (Gupta et al. 2016; Murray et al. 2010; Reyes-López et al. 2015). It is necessary to focus on the study of the probiotic administration through water and obtain the result of the efficiency of probiotics.

The probiotics used in the field of aquaculture mostly collected from the gastrointestinal tract, and after that, it applied to the host body. In the present time, the probiotics are commercially produced by different commercial company for better production of the aquaculture sector. To making the appropriate and beneficial probiotics for the field of the aquaculture, it is very important to identify the appropriate bacterial strains. Otherwise, the probiotic strains may have mutation problem or they are expensive. Sometimes act as pathogen towards the host and creates stress. There are various studies of the probiotic effectiveness that was studied by different researchers. The result showed efficiency of probiotics in the fields of the aquaculture. More study is needed to specify the effectiveness in aquaculture field. It is very much important to study the quality control of the probiotics, applications, validations, and evaluation methods. It will help to increase the better performance, quality, and functional properties of the probiotics.

16.5 Limitations in the Use of Probiotics

- The treated host or animal may not found the proper dosages of the probiotics due to leaching. So it is important to maintain the proper required dosages in the supplemented feed.
- The probiotic strains, which contain different types of bacteria, may not able to survive in the supplemented feed, because there is extreme temperature and pressure during the preparation of the feed in the extruder.
- Sometimes, there are high organic loads found in the sediments that's why the probiotic loss its efficiency in this condition.
- The exact quantity of the dosage must be calculated according to the water sediment status and for each condition (Nayak 2010b).

16.6 Conclusions

Aquaculture has undergone rapid advancement in the last few years. The main reasons for the increased interest and development of fish farming are due to the recent advances of fish culture techniques. Recently, the use of probiotics for promoting fish well-being, survival, and growth performance increased feed efficacy and enhanced immunity, and disease prevention has gained considerable attention for environment friendly aquaculture (Munir et al. 2016). It is also considered valid option to the prophylactic use of chemicals in aquaculture practices (Merrifield et al. 2010).

The use of different chemicals and antibiotics for controlling disease and increasing production has always been a matter of concern for their residual effect, drug resistance, and immune suppressants and for the adverse effect of residues in the environment. Accumulation of antibiotics and chemical residues in soil and waterbodies is degrading the environment and causing risk for wild populations. Use of a more environment friendly method can avoid these problems and benefit both the consumer and producers. Probiotics are always considered as a natural supplement of fish food that reducing production cost, while avoiding any adverse effect and ensuring consumer health. The European Union has controlled the utilization of anti-infection agents in organic entities for human utilization. As of now, customers request normal items, which staying liberated from anti-microbial and counterfeit added substances. Accordingly, the utilization of probiotics is a practical option for the hindrance of microorganisms and infectious prevention just as development speed increase in in aquaculture species. The present study will be the educational arrangement of the attractive attributes of probiotics, their method of activity, and valuable impacts on fishes, which can help to culture this fish species more commercially to focus on benefit of aquaculture production and farmers livelihood.

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