Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(2): 2601 – 2623 (2025)
www.ejabf.journals.ekb.eg

The Impact of Probiotics on Breeding Success, Growth Performance, and Disease Resistance of Carp, a Popular Fish group in Bangladesh

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ARTICLE INFO
Article History:
Received: July 14, 2024
Accepted: Feb. 26, 2025
Online: Aril 26, 2025

Keywords:
Antibiotics,
Aquaculture,
Carp,
Fish growth,
Immunity,
Probiotic,
Reproduction

ABSTRACT
Carp culture in Bangladesh faces significant challenges such as environmental degradation and disease outbreaks due to intensive farming practices. Traditional remedies like antibiotics pose risks to aquatic and human health, necessitating sustainable alternatives. Probiotics have emerged as a vital solution in carp culture of Bangladesh, offering benefits such as enhanced growth, disease resistance, and improved health parameters for fish species like rui (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*). However, challenges such as improper usage due to lack of technical knowledge and inadequate product labeling hinder optimal utilization of probiotics. *Bacillus* species, *Lactobacillus* species, *Enterococcus* species, *Carnobacterium* species, and the yeast, *Saccharomyces cerevisiae*, offer several benefits in carp culture. Future prospects include local strain development to tailor probiotics to specific needs, potentially enhancing sustainability and reducing reliance on imports. Despite promising benefits, ongoing research is needed to optimize probiotic application and deepen understanding of their mechanisms in fish health. This review highlights the pivotal role of probiotics in fostering sustainable and productive aquaculture practices in Bangladesh and beyond.

INTRODUCTION

Aquaculture plays a pivotal role in food security in Bangladesh by meeting the increasing demand for animal protein and contributing significantly to the socio-economic development of communities reliant on carp fish farming. As the aquaculture industry expands, driven by population growth and rising consumer demand, it faces numerous challenges including disease outbreaks, deteriorating water quality, environmental degradation, and declining productivity. Disease remains a primary concern, traditionally managed with drugs, antibiotics, and vaccines, which can have detrimental effects on aquatic ecosystems and human health through the development of antibiotic resistance.

Probiotic is defined as live micro-organisms, which when administered in adequate amounts confer a health benefit on the host **(FAO/WHO, 2001)**. The word “probiotics” was first used by **Parker (1974)**. According to his definition, probiotics are such types of organisms and substances that contribute to gut microbial balance **(Parker, 1974)**. The Latin preposition “pro” means “for” and the Greek word “biotic” means "bios" or "life". So probiotic means "for life" **(Galesoupe, 1999)**. Probiotic was best defined as "a live microbial feed supplement which beneficially affects the host animal by improving its intestinal microbial balance" **(Fuller, 1989)**.

In recent years, probiotics have emerged as a promising alternative to chemical treatments in carp culture. Probiotics are typically including species of *Bacillus*, *Lactobacillus*, *Enterococcus*, *Carnobacterium*, and yeast such as *Saccharomyces cerevisiae* **(Hossain *et al.*, 2013; Suguna, 2020)**. These microorganisms offer multifaceted benefits such as enhancing digestion and nutrient absorption, strengthening immune responses, improving water quality, and promoting growth and reproductive performance in fish **(Martínez *et al.*, 2012)**. Importantly, probiotics mitigate the risks associated with antibiotic use, contributing to sustainable aquaculture practices.

Carps are popular source of protein and the demand of carp species in Bangladesh are increasing due to their high market value and consumer preferences. Due to the increasing number of population, fish farmers are now focusing to produce a large number of carp fishes to fulfill the demand. The intensive carp culture practice is facing many problems like weaken carp's immune system leading to diseases, reducing carps growth resulting production loss which is major concern for carp farmers. Probiotics could be a healthy solution for many problems in carp culture. This review sets the stage for exploring the effect of probiotics specifically on breeding, growth performance, and disease resistance in carps, the most popular fish species in Bangladesh. Understanding how probiotics influence these key aspects of carp aquaculture is crucial for optimizing production efficiency, reducing dependency on antibiotics, and ensuring the long-term sustainability of fish farming operations. This review aimed to consolidate current knowledge, highlight challenges, and outline future research directions to advance the application of probiotics in carp aquaculture.

Properties of probiotic

Probiotics used in carp culture must possess diverse properties to ensure they provide a wide range of beneficial effects on fish health and ecosystem stability. Understanding these properties is crucial for sustainable aquaculture practices. Probiotics possess several desirable properties crucial for their effectiveness in aquaculture. They are non-pathogenic and non-toxic, ensuring they do not pose risks to the fish or the environment. They have the ability to colonize the fish gut effectively, where they exert beneficial effects including the activation of immune cells, enhancement of antibody production, and promotion of antioxidant activity **(Afrc, 1989; Dhanaraj *et al.*, 2010a; Michael, 2014)**. Moreover probiotics also demonstrate resilience against varying environmental conditions such as temperature fluctuations, pH changes and oxygen levels, which is essential for their stability and efficacy in aquatic systems **(Fuller, 1989; Michael, 2014)**. Probiotics exhibit high tolerance to acidic conditions and bile salts, along with antimicrobial properties that inhibit pathogenic species, contributing to improved disease resistance in fish. Probiotics adhere well to mucosal and epithelial surfaces, possess bile salt hydrolase activity, and synthesize vitamins, riboflavin, folate and enzymes essential for fish health **(Kechagia *et al*., 2013; Reid, 2015; Hamad *et al*., 2022; Fusco *et al*., 2023)**. Importantly, they resist digestive fluids and do not adversely affect the host organism, making them valuable tools in promoting sustainable aquaculture practices. These properties ensure that probiotics contribute positively to fish health, improve disease resistance, and support sustainable aquaculture practices. Research and development focused application of probiotics in carp culture.

Mechanisms of action on carps

Probiotics offer a natural and environment friendly approach in carp culture that minimizes the potential negative impacts on culture and ecosystem effects. Probiotics offer multiple benefits in fish body through various mechanism of action. The mechanism of action of probiotics work synergistically to enhance carp growth and survival, increase immunity, improve digestion, reduce pathogenic load that maximize the benefits for both fish and environment.

Competition for resources

Probiotics are good bacteria that compete with pathogenic bacteria for resources such as space or adhesion/binding site, nutrients etc. that will inhibit the action of pathogenic bacteria (Fig. 1). Probiotics inhabit in the binding site in carps gut which is known as "Competitive exclusion". For this reason pathogenic bacteria can't colonize in the carp gut that reduces the chance of infection and promotes a healthy gut microbiota. Probiotics absorb essential nutrients that are required by pathogenic bacteria for their growth. Probiotics make it unavailable so that pathogen can't get enough nutrients for their survivability **(Lara-Flores, 2011; Hai, 2015; Kumar *et al*., 2016; Loh, 2017; Rajyalakshmi *et al*., 2019)**.

Enhancement of immune system

Probiotics enhance the immune system of carps. They activate both cellular and humoral immune defenses. There are some pathogenic bacteria which are responsible to cause disease in fishes. Probiotics can help to increase specific and nonspecific immune system by increasing phagocytic activity, antimicrobial activity, inducing lysozome, cytokines, lectins, antiproteases, natural antibodies (Fig. 2). Probiotic helps increase their different kinds of diseases such as viral, bacterial, fungal, parasitic disease resistance ability **(Lara-Flores, 2011; Tuan *et al*., 2013; Hai, 2015; Kumar *et al*., 2016; Loh, 2017; Rajyalakshmi *et al*., 2019)**.

Contribution to digestion and nutrient utilization

Probiotics produce digestive enzymes such as proteases, lipases that help in the digestion process (Fig. 1). Carp gut may lack these enzymes helping healthy balance of bacteria in gut that is essential for good digestion and nutrient absorption **(Lara-Flores, 2011; Tuan *et al*., 2013; Hai, 2015; Kumar *et al*., 2016; Loh, 2017; Rajyalakshmi *et al*., 2019)**.

Production of antimicrobial substances

Probiotic produces inhibitory substances like bacteriocins, organic acid and ammonia, hydrogen peroxide, siderophores, lysozomes, protease, antibiotics etc (Fig. 2). It also lowers pH. These substances directly kill or inhibit the growth of pathogens. Bacteriocines are one of the most important of these compounds. These compounds disrupt the harmful bacteria's cell walls or interfere with their metabolism **(Kumar *et al*., 2016; Loh, 2017; Rajyalakshmi *et al*., 2019)**.

Water quality improvement

Probiotics can break down organic matter in the water, reducing waste and improving oxygen levels. This creates a healthier environment for carp and helps prevent the spread of disease **(Tuan *et al*., 2013; Hai, 2015; Kumar *et al*., 2016; Loh, 2017; Rajyalakshmi *et al*., 2019)**.

Effects on carp breeding

Probiotics play a crucial role in enhancing carp breeding in aquaculture by addressing the nutritional needs essential during the breeding season. Carp require diets rich in protein, lipids, fatty acids, vitamin C, vitamin E, and carotenoids to support optimal reproductive performance **(Watanabe, 1995)**. Insufficient levels of these nutrients can negatively impact reproductive outcomes. While various commercial diets for brood stock include fresh organisms like squid, tubifex, mussel, krill, daphnia, and small crustaceans, these may not always provide adequate nutrition **(Aydin & Şehriban, 2019)**. Incorporating probiotics into the diet of broodstock offers several benefits. Probiotics can enhance reproductive efficiency by promoting gonadal development and improving the quality of gametes (eggs and sperm). They can increase fertilization rates, hatching rates, and overall fecundity (the reproductive potential of an organism). Furthermore, probiotics contribute to improving larval and egg quality, as well as enhancing the survival rates of larvae **(Abasali & Mohamad, 2010; Giorgini *et al*., 2010; Gioacchini *et al*., 2010 a, b, c; Gioacchini *et al*., 2011; Ariole, 2012; Gioacchini *et al*., 2012; Gioacchini *et al*., 2013; Miccoli *et al*., 2015; Carnevali *et al*., 2017)**. So far many probiotics have been used on the reproduction of carps. We can see some evidence of that in Table (1). Feeding broodstock diets supplemented with probiotics thus represents a promising strategy to optimize carp breeding outcomes in aquaculture. By ensuring that the nutritional requirements of the broodstock are met through probiotic-enhanced diets, aquaculturists can potentially enhance the overall success and productivity of their breeding operations.

Increased GSI and fecundity

Probiotics play a vital role in enhancing reproductive parameters such as GSI (Gonad Somatic Index), fecundity, and egg quality in carps **(Abasali & Mohamad, 2010)**. GSI measures the development of reproductive organs, with a higher GSI indicating increased reproductive capacity and enhanced fertility **(Taborsky, 1998; Al-Deghayem *et al*., 2017)**. Fecundity, which measures the number of eggs produced by a female fish during a spawning season, is critical for evaluating reproductive success in aquaculture. Research indicates that probiotic supplementation can significantly boost fecundity by promoting a healthier gut environment. Probiotics work by reducing harmful bacteria and enhancing beneficial microbial populations in the fish gut. This improved gut health facilitates better absorption of nutrients from food, supporting optimal gonad (sperm and egg) development and enhancing egg production **(Gioacchini *et al*., 2010a, b, c; Volkoff & London, 2018; Aydin & Şehriban, 2019)**. Furthermore, probiotics contribute to reducing stress levels in carp, which in turn enhances their reproductive capacity. Probiotics also play a role in influencing hormone production, such as testosterone and estrogen, which are crucial for gonad growth and maturation. By fostering a favorable microbial balance and supporting hormonal regulation, probiotics contribute positively to reproductive performance and overall breeding success in aquaculture **(Aydin & Şehriban, 2019; Sumon *et al*., 2022)**.

Gamete and larval quality

Successful carp breeding in aquaculture hinges not only on the quantity but also on the quality of gametes and larvae, which are critical for sustainable practices. Probiotics play a pivotal role in enhancing these aspects by competing with pathogenic bacteria present in gametes, thereby reducing the risk of disease transmission to offspring. This competition leads to healthier larvae, contributing to overall breeding success **(Aydin & Şehriban, 2019)**. Probiotics also have a direct impact on sperm quality by improving motility, which is crucial for successful fertilization. They enhance egg viability and larval quality by imparting resistance to diseases and increasing stress tolerance, ultimately improving the survival rates of larvae. Additionally, probiotics enhance nutrient absorption and digestion in larvae, which promotes better growth and development during the early stages of life **(Gioacchini *et al*., 2011, 2012, 2013; Carnevali *et al*., 2013; Vílchez *et al*., 2015; Ahmadnia-Motlang *et al*., 2017; Aydin & Şehriban, 2019)**. By bolstering the health and resilience of gametes and larvae, probiotics contribute significantly to the overall quality and success of fish breeding in aquaculture. Their ability to improve disease resistance, stress tolerance, and nutrient utilization underscores their importance in ensuring sustainable and productive fish farming operations.

Fertilization rate and hatching rate

Probiotics are showing great promise in boosting both fertilization rate and hatching rate in fishes **(Aydin & Şehriban, 2019)**.

Table 1. Uses of probiotics in carp breeding

Probiotic strain	Test species	Beneficial effects	Reference
Lactobacillus rhamnosus IMC 501 (Synbiotec)	*Danio rerio*	Increased oocyte maturation, fecundity, numbers of ovulated eggs, follicle development, reproduction improvement, GSI	Gioacchini *et al*. 2011
Pediococcus acidilactici along with nucleotide	Goldfish (*Carassius auratus)*	Showed positive result in semen quality (motility and density) and egg indices (egg diameter, ovum diameter, absolute fecundity, relative fecundity gonadosomatic index, and fertilization and hatching rate).	Mehdinejad *et al*. 2018
P. acidilactici	Male zebrafish	Increased reproductive performance, sperm and semen quality	Valcarce *et al*. 2015

Effects on carp growth performance

Numerous studies have demonstrated the positive impact of probiotics on the growth of carp species, contributing to improved health and reduced reliance on chemical growth promoters. Table (2) shows a list of probiotics that have been used on carp growth performance. Probiotics enhance various aspects such as digestibility, feed conversion ratio (FCR), protein efficiency ratio (PER), and body composition **(Ige, 2013)**. Probiotics play a crucial role directly or indirectly by producing digestive enzymes like amylase, protease, and lipase, which enhance the breakdown of complex carbohydrates, proteins, and lipids (Fig. 1). This process increases appetite and improves the digestibility of carp species, leading to better nutrient absorption and higher growth rates (Fig. 1) **(Irianto & Austin, 2002; Ige, 2013; Doan *et al*., 2018; Valiallahi *et al*., 2018; Arani *et al*., 2019; Subedi & Shrestha, 2020; Suguna, 2020)**. Probiotics also serve as a source of essential nutrients such as vitamins, amino acids, and fatty acids, further supporting growth (Fig. 1) **(Irianto & Austin, 2002; Doan *et al*., 2018; Wuertz *et al*., 2021)**.

In aquaculture, probiotics contribute to improving FCR, a critical metric that measures the amount of feed required to produce one kilogram of fish. A lower FCR indicates more efficient feed utilization, reduced feed wastage, and improved overall efficiency, thereby lowering production costs and promoting environmental sustainability. PER indicates how efficiently protein from the feed is converted into fish body protein. Probiotics enhance protein utilization, leading to a higher PER, which signifies less protein waste and reduced environmental impact. This improvement in PER also potentially lowers feed costs, making fish farming more economical **(Bandyopadhyay & Mohapatra, 2009; Dhanaraj *et al*., 2010; Shefat, 2018)**. Furthermore, probiotics may influence the body composition of carp by increasing muscle mass and reducing fat content, which is beneficial for commercial purposes. This enhancement in body composition aligns with market preferences for leaner fish with higher protein content. Overall, incorporating probiotics into carp farming not only enhances growth performance and nutrient utilization but also promotes economic efficiency and environmental sustainability in aquaculture practices.

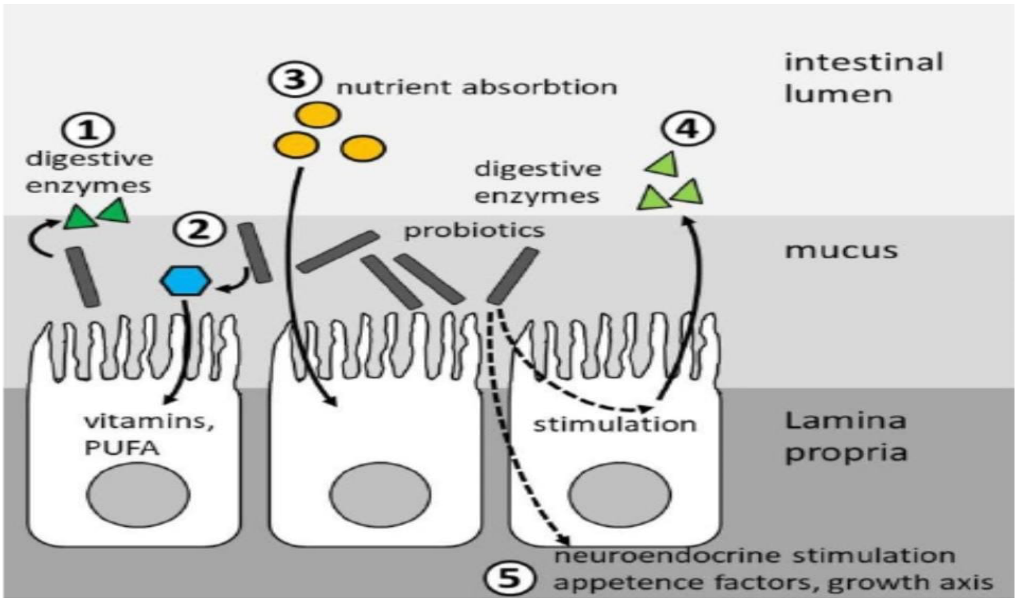

Fig. 1. Nutrition and growth-related effects (modes of action) of probiotics in the gastrointestinal tract (GIT), including direct effects such as (1) secretion of digestive enzymes; (2) absorption of (micro) nutrients such as cofactors, vitamins, and polyunsaturated fatty acids; (3) indirect effects, including elevated nutrient uptake/absorption; (4) stimulation of enzyme secretion, as well as (5) neuroendocrine stimulation of appetence and growth **(Wuertz *et al*., 2021)**

Effects on carp disease resistance

Carps are susceptible to various diseases including viral, bacterial, fungal, parasitic, and environmental stressors, posing significant challenges in carp culture. Traditionally, antibiotics have been widely employed for disease treatment due to their availability and rapid efficacy. However, their overuse has led to concerns such as antibiotic resistance and residues in the environment, affecting ecosystems, humans, and other animals **(Pérez-Sánchez *et al*., 2014; Dawood, 2021; Limbu *et al*., 2021)**. To address these issues sustainably, alternatives like probiotics are increasingly favored for disease control and prevention in carp farming.

Table 2. Uses of probiotics in carp growth performance

Probiotic strain	Test species	Beneficial effects	Reference
Lactobacillus sp. (isolated from the digestive tract of catfish)	Carp fry	Improved growth rate and the lowest FCR.	Sumaraw *et al*. 2019
Saccharomyces cerevisiae	Gibel carp	Improved weight gain, specific growth rate, feed conversion ratio	He *et al*. 2011
B. circulans PB7 and *B. amyloliquefaciens*	Catla	Improved weight gain, feed conversion ratio, protein efficiency ratio	Bandyopadhyay and Mohapatra, 2009
L. acidophilus and *S. cerevisiae*	Koi carp	Improved weight gain, specific growth rate, feed conversion ratio	Dhanaraj *et al*. 2010
Lactobacillus fermentum	*Cirrhinus mrigala*	Showed better growth and improved feed utilization	Krishnaveni *et al*. 2021
Bacillus subtilis, Lactococcus lactis and *Saccharomyces cerevisiae*	Rohu fingerlings	Showed higher growth, PER, digestibility and lower FCR	Mohapatra *et al*. 2012
Bacillus subtilis	Common carps (*Cyprinus carpio)*	Enhanced growth	Al-Faragi and Alsaphar, 2012
Bacillus cereus (isolated from the gut of *Cirhinus mrigala*)	*Cirhinus mrigala*	Resulted a higher growth rate, increase in percent gain in body weight, high protein digestibility and a low feed conversion ratio	Bhatnaga and Lamba, 2015
Bacillus sp. (with *Artemia*)	*Ctenopharyngodon idella*	Improved growth and health of fish	Jafaryan *et al*. 2011
Ecotec' containing Lactobacillus acidophilus, LA-5*, Bifidobacterium,* BB-12, *Streptococcus thermophiles,* STY-31, and *Lactobacillus delbrueckii* spp. *Bulgarian,* LBY-27.	*Labeo rohita*	Greater weight gain, lower FCR	Kanwal and Tayyeb, 2019

Probiotics offer a natural solution without the detrimental effects associated with antibiotics, pesticides, and insecticides **(Ezhil Nilavan & Joseph, 2022)**. They stimulate both specific and nonspecific immune responses in fish, enhancing immunity against pathogenic bacteria by activating immune cells such as phagocytes and lymphocytes (Fig. 2) **(Nayak, 2010; Rosidah, 2021; Wuertz *et al*., 2021)**. Certain probiotics also promote the production of antibodies targeted against specific pathogens, further bolstering disease resistance **(Fuller, 1992)**. Moreover, probiotics contribute to improving water quality by breaking down organic matter and reducing harmful substances **(Balcazar *et al*., 2006; Suguna, 2020)**. This creates a healthier aquatic environment essential for fish health, as pathogen-free water reduces disease risks. Probiotics also directly combat pathogens by producing antibacterial substances like bacteriocins, lysozymes, hydrogen peroxide, and peptides such as defensins and chemokines **(Verschuere *et al*., 2000; Servin, 2004; Rosidah, 2021; Wuertz *et al*., 2021)**. These substances inhibit pathogen growth and prevent their attachment to the Gastrointestinal Tract (GIT), thereby reducing infection rates (Fig. 2). Additionally, probiotics compete with pathogens for essential nutrients and adhesion sites within the GIT, further lowering pathogen levels (Fig. 2) **(Lalloo *et al.*, 2010; Suguna, 2020; Rosidah, 2021; Wuertz *et al.*, 2021)**. This competitive exclusion mechanism helps maintain a balanced microbial community in the fish gut, contributing to overall health and disease prevention in carp aquaculture. So far there has been a lot of work on probiotics on disease resistance in carps (Table 3).

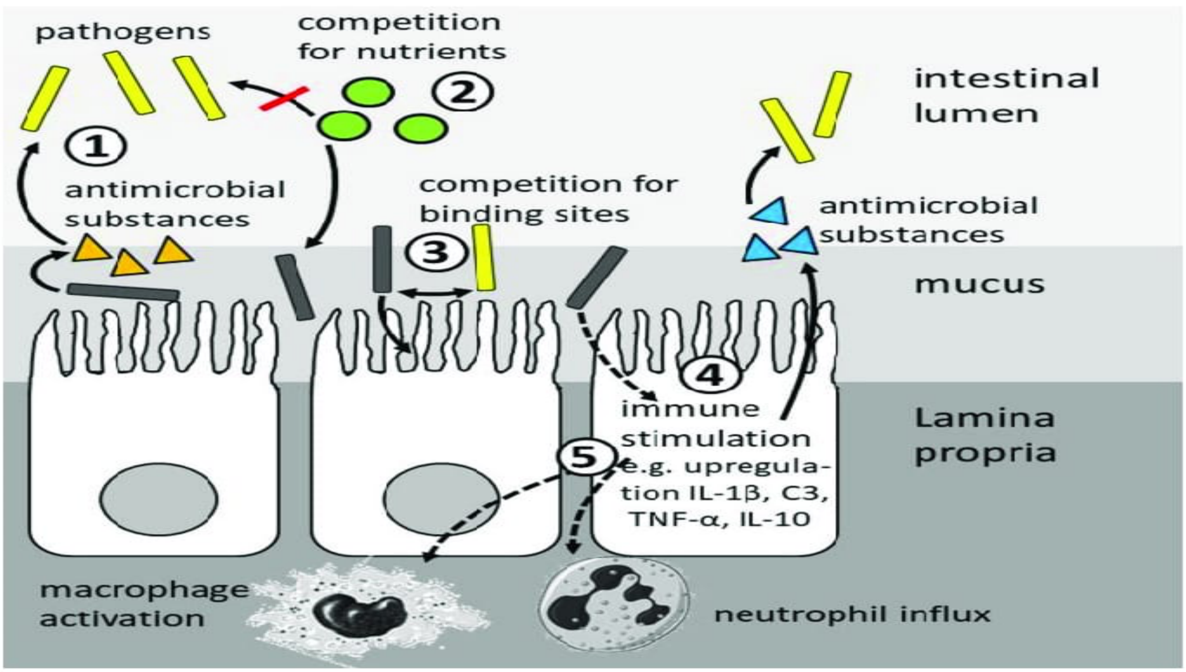

Fig. 2. Health and disease-resistance-related effects (modes of action) of probiotics in the gastrointestinal tract (GIT), including direct effects such as (1) secretion of antimicrobial substances, (2) competition for nutrients, and (3) binding sites, as well as (4) indirect effects such as stimulation of immune parameters and (5) activation of macrophages and the influx of neutrophils **(Wuertz *et al.*, 2021)**

Table 3. Uses of probiotics in carp disease resistance

Probiotic strain	Test species	Beneficial effects	Reference
LAB (Lactic Acid Bacteria)	Carp (*Cyprinus* carpio)	Inhibited the growth of pathogenic bacteria *Aeromonas* sp. and *Vibrio* sp	Al-Faragi and Al-Saphar, 2012
Bacillus subtilis	Indian Major Carp	Control of infection Against *A. hydrophila*	Kumar *et al*. 2006
Lactobacillus lactis, B. subtilis, B. megaterium and *Saccharomyces cerevisiae*	*Labeo rohita*	Increased survival against *A. hydrophila* infection	Mohapatra *et al*. 2014; Saravanan *et al*. 2021
Bacillus subtilis FPTB13	*Catla catla*	Immunomodulation and disease resistance	Sangma and Kamilya, 2015
Shewanella xiamenensis	Grass carp	Improved disease resistance against *A. hydrophila*	Wu *et al*. 2015
Pseudomonas aeruginosa	Zebrafish	Inhibiting biofilm formation and enhancing defense mechanisms against *Vibrio parahaemolyticus*	Vinoj *et al*. 2015
Flavobacterium sasangense	Common carp	Enhance disease resistance against *A. hydrophila*	Chi *et al*. 2014
Bacillus circulans	Rui	Enhance immunity and control *A. hydrophila*	Bandyopadhyay and Mohapatra, 2009

Challenges and problems of using probiotics

Undoubtedly, probiotics offer promising benefits for fish farming, ranging from enhanced disease resistance to improved nutrient absorption and growth. However, their application in aquaculture comes with several challenges that need careful consideration. Firstly, selecting the most effective and appropriate probiotic strain is crucial. Using the wrong strain may not confer any benefits or could potentially be harmful to the fish **(Gatesoupe, 1999; Tuan *et al*., 2013; Jamal *et al*., 2019; Amenyogbe, 2023)**. Secondly, developing effective routes or methods of probiotic administration is essential to ensure optimal uptake and efficacy within the fish. Advanced technology is often required for the preparation and formulation of probiotics to maintain their viability and effectiveness **(Gatesoupe, 1999; Shefat, 2018; Jamal *et al*., 2019)**. Farmers must be educated about the molecular mechanisms and effects of probiotics to make informed decisions about their application and benefits **(Hosain & Liangyi, 2020)**. Proper dosage of probiotics is critical; improper application or overuse can lead to the development of antibiotic resistance in fish, compromising their effectiveness **(Gatesoupe, 1999; Hosain & Liangyi, 2020; Amenyogbe, 2023)**. The ratio of probiotics in feed formulations must be carefully balanced to avoid detrimental effects on the culture farm. While probiotics have shown benefits in improving the fish gut microbiota, their effects on other organs and systems remain less understood. Improper management or misuse of probiotics can potentially introduce pathogens, contaminating the final fish products and posing risks to human health. Lastly, probiotics generally work more slowly than antibiotics, requiring longer periods for noticeable effects on fish health and disease prevention **(Hosain & Liangyi, 2020)**. Advanced technology required to prepare probiotics which are the main challenge **(Wang *et al*., 2008)**. Addressing these challenges through research, education, and careful application protocols is essential to maximize the benefits of probiotics in sustainable fish farming practices.

Uses of probiotic in Bangladesh

Bangladesh holds a prominent position in global inland fish production, ranking third after India and China. It is also the fifth-largest aquaculture producer worldwide, ensuring self-sufficiency by providing approximately 63g of fish per person daily, exceeding the daily requirement of around 60g **(Banerjee & Ray, 2017)**. However, the aquaculture sector in Bangladesh faces significant challenges such as environmental degradation and the proliferation of pathogenic microorganisms due to intensive farming practices. To combat bacterial diseases, which are a primary constraint on fish production, a variety of chemicals including antibiotics and drugs have traditionally been employed. While these substances can initially boost production, their continuous and excessive use poses risks to aquatic animal health, the environment, and human health **(Pérez-Sánchez *et al*., 2014; Dawood, 2021; Limbu *et al*., 2021)**.

Therefore, there is a pressing need for alternative, eco-friendly disease management approaches to ensure the sustainable development of the aquaculture sector and safe food production. Probiotics have emerged as a vital tool in Bangladeshi fish farming, offering benefits such as enhanced fish growth, disease resistance, improved digestibility, immunological responses, blood chemistry, gut health, and overall fish health **(Suguna, 2020; Rosidah, 2021)**. In reproduction, probiotics have been shown to increase egg production, fecundity rates, fertilization, and hatching rates. Popular among carp farmers in Bangladesh—such as for rui (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus cirrhosis*)—probiotics play a crucial role in controlling various bacterial, viral, fungal, and parasitic diseases outbreaks **(Al-Faragi & Al-Saphar, 2012)**.

Probiotics also contribute to regulating water parameters critical for aquaculture, including pH levels, dissolved oxygen, alkalinity, chemical oxygen demand, biological oxygen demand, total dissolved solids, temperature, ammonia levels, phosphate levels, water hardness, transparency, and heavy metal content. By controlling natural feed in water, probiotics help maintain water transparency and optimal temperature conditions. Most probiotics used in Bangladeshi aquaculture are imported and available in either powder or liquid form. These commercial probiotics vary in biochemical composition, concentration, dosage, and specific functions. Key ingredients commonly found in these probiotics include *Bacillus*, *Lactobacillus*, and *Nitrosomonas*, each serving specific roles in enhancing fish health and productivity (Table 4).

Table 4. List of some of commercial probiotics used in Bangladesh for aquaculture **(Hossain *et al*., 2023)**

Name of company	Trade name	Composition
SK + F	Pondcare	*Bacillus subtills, B. licheniformis, B. polymyxa, B. pumillus, B. megaterium, Bacillus subtills, B. licheniformis B. coagulans, B. amyloliqefaciens, Aspergillus niger, A. oryzae*
	Gasonil	*Bacillus subtills, B. licheniformis, B. polymyxa,B. pumillus, B. megaterium, B. coagulans,* Yucca 30%
	Safegut	Nonantibiotic eco-friendly byproduct, probiotics, vitamins and enzymes
	Biopond	Probiotics, zeolite, minerals
	Biogrow	Probiotics, prebiotic, vitamin, minerals
	Aqua 4	Prpbiotics *Rhodopseudomonas spp, zeolite*
ACI	Yucca Plus	Yucca extract (saponin, glycocomponent)
		Rhodopseudomonas spp., B. subtilis
	Aqua Photo	*Rhodopseudomonas sp., B. subtilis*
	Ariake	*B. amyloliqefaciens, B. licheniformis, B. pumillus* Starch, Calcium carbonate
	MI Plus	*Bacillus subtills, B. licheniformis, Bacillus subtills, B. licheniformis, B. amyloliqefaciens*
	Pond Guard	*Bacillus subtills, B. licheniformis, Nitrosomonas* spp., *Nitrobacter* spp. *Aerobactor* spp., Zeolite,
	Pond Plus	Yucca extract
	Aci Fish Premix	*Bacillus subtills, B. licheniformis, Nitrosomonas* spp., *Nitrobacter* spp. *Rhodococcus, Zeolite*
	GP Fish Gel	Vitamin, minerals, probiotics, growth promotant and attractant

	Navio Plus Power Lac	Probiotics, amino acid, growth promoter, multiprotein, fish oil, taste enhancer, liquid glucose, vitamin *Bacillus subtills, B. licheniformis, B. megaterium, Lactobacillus acidophilis, L. plantarum,* Yeast *Lactobacillus lactis*
Square	Biomax Probio-aqua Gastrap Square Aquamix	Maximum consortium of probiotics biofixed on a calcareous matrix *Rhodopseudomonas palustris* *Lactic acid bacillus, Bacillus subtilis, Saccharomyces cereviceae,* Xylanase, amylase, Protease, cellulase, hemicellulose, phytase, betaglucanase, lipase aminonitrogen in a fortified base Vitamin, mineral, amino acid, prebiotic
CP	pH Fixer	*Vibrio maintain*
SK + D	Bio Grow	Probiotics, prebiotic, vitamin, minerals
Opsonin	GPA IKI-IKI	*Bacillus subtills, Lactobacillus* spp. *Saccharomyces cerevisiae,* lipase, protease, Amylase *Bacillus subtills, B. licheniformis, B. amyloliqefaciens*

Among the above listed commercial probiotics, Pondcare, Safegut, GPA, IKI-IKI, Aqua 4 and Probio-aqua are most commonly used by the farmers of Bangladesh (Fig. 3). Many farmers in Bangladesh lack technical knowledge regarding the proper dosage and application of probiotics. As a result, they sometimes overuse probiotics in hopes of achieving better results, inadvertently causing adverse effects due to microbial imbalances in their culture systems. The concept of probiotics remains unclear to many farmers, prompting them to seek advice from experts or various companies when encountering issues. Additionally, some farmers have reported that probiotics do not perform effectively, attributing this to potential adulteration in the probiotic products which can lead to negative side effects.

A significant challenge is the inadequate labeling of commercially available probiotics, which often fails to specify the correct dosage, target species, age, or size. This lack of clarity complicates proper usage and can undermine the efficacy of probiotics in aquaculture practices. Therefore, there is a crucial need to raise awareness among Bangladeshi farmers about both the benefits of probiotics and the potential harms of overuse **(Hossain *et al.*, 2023)**. Moreover, there is a strong case for developing probiotics locally using indigenous strains. This approach could not only address the specific needs of Bangladeshi aquaculture but also ensure better control over probiotic quality and effectiveness. By promoting local probiotic development, Bangladesh can potentially enhance the sustainability and productivity of its aquaculture sector while minimizing dependence on imported products.

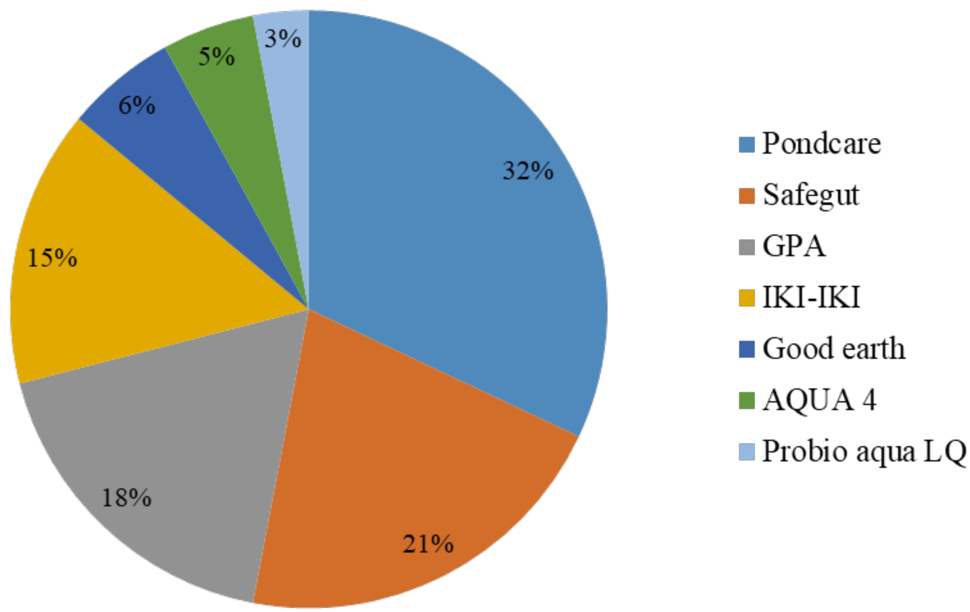

Fig. 3. Most commonly used probiotics on the basis of farmer's perception in Bangladesh **(Hossain *et al*., 2023)**

Future perspective

The future outlook for probiotics in carp species is highly promising, poised to revolutionize the aquaculture industry towards greater sustainability and productivity. Probiotics offer numerous advantages for carps, including enhanced growth and nutrient absorption, environmental sustainability, effective disease control, and reduced reliance on antibiotics. Despite these promising prospects, several challenges hinder the path to successful probiotic application in aquaculture. Many critical questions regarding probiotic use remain unanswered, necessitating further research and development. In Bangladesh, only a few commercial probiotics have been licensed, but their use is expected to expand rapidly in the near future. Realizing the full benefits of probiotics depends on factors such as dosage, feeding duration, administration methods, and environmental conditions. Therefore, it is crucial for farmers to acquire proper technical knowledge on probiotic usage to maximize their benefits. Efforts are underway to discover more efficient probiotic strains tailored to the needs of carp aquaculture. Presently, probiotics are being integrated into modern aquaculture production systems like recirculating aquaculture systems and biofloc systems, reflecting ongoing research and innovation in the field. Future research on probiotics should prioritize molecular biotechnology tools to deepen our understanding of their mechanisms of action, which remain incompletely understood in fish. With continued research, innovation, and responsible implementation, probiotics have the potential to play a pivotal role in fostering a sustainable, healthy, and productive aquaculture industry worldwide.

CONCLUSION

The use of probiotics in the aquaculture industry has expanded significantly. Probiotics, live microorganisms with health benefits, are increasingly integrated into carp culture to enhance its health and sustainability. They serve as a natural and effective alternative for sustainable carp farming, addressing issues associated with intensive practices. Probiotics contribute to favorable conditions for carp development by providing essential nutrients, enzymes that aid digestion, improving feed efficiency, and boosting growth performance. Moreover, probiotics enhance disease resistance and bolster immunity through various mechanisms. In carp culture, feeding costs can constitute a substantial portion (60-80%) of operational expenses in intensive farming. Probiotics help manage these costs effectively. They also mitigate environmental stress by reducing organic matter in water bodies. However, challenges such as strain ineffectiveness and incorrect dosing exist. To optimize probiotic effectiveness, appropriate strains should be selected, administered at optimal doses and durations, and integrated into proper carp farming practices. In Bangladesh, probiotics are widely used, highlighting the need for increased awareness among farmers about their benefits and proper application techniques. Developing probiotics from local strains can reduce dependency on imports and associated costs. Integrating probiotics with Good Aquaculture Practices in carp farming can increase production and ensure the production of safe, organic products meeting future protein demands. Continued studies are essential to address challenges associated with probiotic use in carp culture and to fully understand their applications across different aquaculture systems. This ongoing research will contribute to enhancing the sustainability and productivity of carp farming practices globally.

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