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

Mithila Akter, Marzana Akter Rima and Zinia Rahman*

¹Department of Genetics & Fish Breeding, Gazipur Agricultural University, Gazipur, Bangladesh *Corresponding author: <u>zinia@gau.edu.bd</u>

ARTICLE INFO

Article History: Received: July 14, 2024 Accepted: Feb. 26, 2025 Online: April 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 socioeconomic 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 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 & Sehriban, 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 probioticenhanced 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; Avdin & Sehriban, 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 & Sehriban, 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 & Sehriban, 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 & Sehriban, 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).

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
<i>Pediococcus acidilactici</i> 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 <i>et</i> <i>al.</i> 2018
P. acidilactici	Male zebrafish	Increased	Valcarce <i>et al</i> .
		reproductive performance,	2015
		sperm and semen quality	

Table 1. Uses of probiotics in carp breeding

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.

1	16 1		
Probiotic strain	Test species	Beneficial effects	Reference
Lactobacillus sp. (isolated		Improved growth rate and the lowest FCR.	Sumaraw et al.
from the digestive tract of	Carp fry		2019
catfish)			
Saccharomyces cerevisiae	Gibel carp	Improved weight gain, specific growth rate, feed conversion ratio	He <i>et al</i> . 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.	Koi carp	Improved weight gain, specific growth rate,	Dhanaraj et al.
cerevisiae		feed conversion ratio	2010
Lactobacillus fermentum	Cirrhinus mrigala	Showed better growth and improved feed utilization	<i>al.</i> 2021
Bacillus subtilis, Lactococcus		Showed higher growth, PER, digestibility and	Mohapatra <i>et al</i> .
lactis and Saccharomyces	Rohu fingerlings	lower FCR	2012
cerevisiae Bacillus subtilis	Common carps	Enhanced growth	Al-Faragi and
Ductinus succinis	(Cyprinus carpio)		Alsaphar, 2012
Bacillus cereus (isolated from		Resulted a higher growth rate, increase in	Bhatnaga and
the gut of <i>Cirhinus mrigala</i>)	Cirhinus mrigala	digestibility and a low feed conversion ratio	Lamba, 2015
Bacillus sp. (with Artemia)	Ctenopharyngodon	Improved growth and health of fish	Jafaryan <i>et al</i> .
	idella	1 0	2011
Ecotec' containing Lactobacillus acidophilus, LA-5, Bifidobacterium, BB- 12, Streptococcus thermophiles,			Kanwal and Tayyeb, 2019
STY-31, and <i>Lactobacillus</i> <i>delbrueckii</i> spp. <i>Bulgarian</i> , LBY- 27.	Labeo rohita	Greater weight gain, lower FCR	

T 11 A	T T (· · · · ·	•		.1	C
Table 2.	Uses of	problotics	1n (carp	growth	performance

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**)

Probiotic strain	Test species	Beneficial effects	Reference
LAB (Lactic Acid	Carp (Cyprinus	Inhibited the growth of pathogenic	Al-Faragi and
Bacterra)	carpio)	bacteria Aeromonas sp. and viorio sp	Al-Saphar,
			2012
Bacillus subtilis	Indian Major Carp	Control of infection	Kumar et al. 2006
		Against A. hydrophila	
Lactobacillus lactis,		Increased survival against A. hydrophila	Mohapatra <i>et al</i> .
B. subtilis,	Labeo rohita	meetion	<i>et al.</i> 2021
B. megaterium and			
Saccharomyces cerevisiae			
Bacillus subtilis FPTB13	Catla catla	Immunomodulation and	Sangma and
		disease resistance	Kamilya, 2015
Showanalla xiamononsis	Grass com	Improved disease resistance against A	Wu at al. 2015
Snewanena xiamenensis	Glass carp	hydrophila	w u <i>ei ui</i> . 2015
Pseudomonas aeruginosa	Zebrafish	Inhibiting biofilm formation and	Vinoi <i>et al.</i> 2015
		enhancing defense mechanisms against Vibrio parahaemolyticus	
Flavobacterium	Common carp	Enhance disease resistance against A.	Chi et al. 2014
sasangense		nyarophila	
Bacillus circulans	Rui	Enhance immunity and control <i>A</i> . <i>hydrophila</i>	Bandyopadhyay and
			Mohapatra,
			2009

Table 3. Uses of probiotics in carp disease resistance

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).

Name of company	Trade name	Composition
	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%
SK + F	Safegut	Nonantibiotic eco-friendly byproduct, probiotics, vitamins and enzymes
	Biopond	Probiotics, zeolite, minerals
	Biogrow	Probiotics, prebiotic, vitamin, minerals
	Aqua 4	Prpbiotics Rhodopseudomonas spp, zeolite
	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
	1111 1 100	<i>B. licheniformis, B. anyloliaefaciens</i>
	Pond Guard	Bacillus subtills, B. licheniformis, Nitrosomonas
		spp., Nitrobacter spp. Aerobactor spp., Zeolite,
	Pond Plus	Yucca extract
		Bacillus subtills, B. licheniformis, Nitrosomonas
	Aci Fish Premix	spp., Nitrobacter spp. Rhodococcus, Zeolite
ACI	GP Fish Gel	Vitamin, minerals, probiotics, growth promotant and attractant

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

.	1
Navio Plus	Probiotics, amino acid, growth promoter,
	multiprotein, fish oil, taste enhancer, liquid glucose,
Power Lac	vitamin
	Bacillus subtills, B. licheniformis, B. megaterium,
	Lactobacillus acidophilis, L. plantarum, Yeast
	Lactobacillus lactis
Biomax	Maximum consortium of probiotics biofixed on a
	calcareous matrix
Probio-aqua	Rhodopseudomonas palustris
1	
Gastrap	Lactic acid bacillus, Bacillus subtilis,
F	Saccharomyces cereviceae. Xylanase, amylase.
	Protease cellulase hemicellulose phytase.
	betaglucanase linase aminonitrogen in a fortified
	hase
Square Aquamix	base
Square Aquanna	Vitamin minoral amino acid probiotic
nH Fixer	Vibrio maintain
Bio Grow	Probiotics, prebiotic, vitamin, minerals
GPA	Bacillus subtills, Lactobacillus spp.
	Saccharomyces cerevisiae, lipase, protease,
	Amylase
IKI-IKI	Bacillus subtills. B. licheniformis.
	Navio Plus Power Lac Biomax Probio-aqua Gastrap Square Aquamix pH Fixer Bio Grow GPA

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.

REFERENCES

- Afrc, R. F. (1989). Probiotics in man and animals. Journal of Applied Bacteriology, 66, 365 -378. <u>https://doi.org/10.1111/J.1365-2672.1989.TB05105.X</u>
- Amenyogbe, E. (2023). Application of probiotics for sustainable and environmentfriendly aquaculture management-A review. Cogent Food & Agriculture, 9(1), 2226425. <u>https://doi.org/10.1080/23311932.2023.2226425</u>
- Aydin, F. and Şehriban, Ç. Y. (2019). Effect of probiotics on reproductive performance of fish. Natural and Engineering Sciences, 4(2), 153-162.<u>http://dx.doi.org/10.28978/nesciences.567113</u>
- Abasali, H. and Mohamad, S. (2010). Effect of dietary supplementation with probiotic on reproductive performance of female live bearing ornamental fish. Research

Journal of Animal Sciences, 4(4), 103-107. http://dx.doi.org/10.3923/rjnasci.2010.103.107

- Ariole, C.N. and Okpokwasili, G.C. (2012). The effect of indigenous probiotics on egg hatchability and larval viability of *Clarias gariepinus*. Revista Ambiente & Água
 An Interdisciplinary Journal of Applied Science, 7(1), 81-88. <u>http://dx.doi.org/10.4136/ambi-agua.712</u>
- Al-Deghayem, W. A.; Al-Balawi, H. F.; Kandeal, S. A. and Suliman, E. A. M. (2017). Gonadosomatic index and some hematological parameters in African catfish *Clarias gariepinus* (Burchell, 1822) as affected by feed type and temperature level. *Brazilian archives of biology and technology*, 60(00), e17160157. <u>http://dx.doi.org/10.1590/1678-4324-2017160157</u>
- Ahmadnia-Motlagh, H.; Hajimoradlo, A.; Ghorbani, R.; Agh, N.; Safari, O. and LashkarizadehBami, M. (2017). Reproductive performance and intestinal bacterial changes of *Carassius auratus* fed supplemented lactoferrin and *Lactobacillus rhamnosus* PTCC 1637 diet. Iranian Journal of Ichthyology, 4(2), 150-161. doi: 10.7508/iji.2017
- Arani, M.M.; Salati, A.P.; Safari, O. and Keyvanshokooh, S. (2019). Dietary supplementation effects of *Pediococcus acidilactici* as probiotic on growth performance, digestive enzyme activities, and immunity response in zebrafish (Danio rerio). Aquac Nutr 2019; 25(4):854-861. <u>http://dx.doi.org/10.1111/anu.12904</u>
- Al-faragi, J. and Al-saphar, S. (2012). Impact of Lactic acid bacteria (LAB) as probiotic against bacterial pathogen from *Cyprinus carpio* L. Al-Anbar Journal of Veterinary Sciences, 5(1).
- Banerjee, G. and Ray, A. K. (2017). The advancement of probiotics research and its application in fish farming industries. Research in veterinary science, 115, 66-77. <u>https://doi.org/10.1016/j.rvsc.2017.01.016</u>
- Balcazar, JL.; Blas, ID.; Ruiz-Zarzuela, I.; Cunningham, D.; Vendrell, D. and Muzquiz JL. Review: The role of probiotics in aquaculture. Vet Microbiol 2006;114:173-86. <u>https://doi.org/10.1016/j.vetmic.2006.01.009</u>
- Bhatnagar, A. and Lamba, R. (2015). Antimicrobial Ability and Growth Promoting Effects of Feed Supplemented with Probiotic Bacterium Isolated from Gut Microflora of *Cirrhinus mrigala*. Journal of Integrative Agriculture. 14(3): 583-592. <u>http://dx.doi.org/10.1016/S2095-3119(14)60836-4</u>
- Bandyopadhyay, P. and Mohapatra, P. K. D. (2009). Effect of a probiotic bacterium *Bacillus circulans* PB7 in the formulated diets: on growth, nutritional quality and immunity of *Catla catla* (Ham.). Fish physiology and biochemistry, 35(3): 467-478. <u>http://dx.doi.org/10.1007/s10695-008-9272-8</u>
- Carnevali, O.; Avella, M.A. and Gioacchini, G. (2013). Effect of probiotic administration on zebrafish development and reproduction. General and Comparative Endocrinology, 188, 297– 302.https://doi.org/10.1016/j.ygcen.2013.02.022

- Carnevali, O.; Maradonna, F. and Gioacchini, G. (2017). Integrated control of fish metabolism, wellbeing and reproduction: the role of probiotic. Aquaculture, 472, 144–155. <u>https://doi.org/10.1016/j.aquaculture.2016.03.037</u>
- Chi, C.; Jiang, B.; Yu, X.-B.; Liu, T.-Q.; Xia, L. and Wang, G.-X. (2014). Effects of three strains of intestinal autochthonous bacteria and their extracellular products on the immune response and disease resistance of common carp, *Cyprinus carpio*. Fish & Shellfish Immunology, 36, 918. <u>https://doi.org/10.1016/j.fsi.2013.10.003</u>
- Dias, D. D. C.; Furlaneto, F. D. P. B.; Sussel, F. R.; Tachibana, L.; Gonçalves, G. S.; Ishikawa, C. M. and Ranzani-Paiva, M. J. T. (2020). Economic feasibility of probiotic use in the diet of Nile tilapia, *Oreochromis niloticus*, during the reproductive period. Acta Scientiarum. Animal Sciences, 42.http://dx.doi.org/10.4025/actascianimsci.v42i1.47960
- Doan, H.; Hoseinifar, SH.; Khanongnuch, C.; Kanpiengjai, A.; Unban, K.; Kim, V. and Srichaiyo, S. (2018). Host-associated probiotics boosted mucosal and serum immunity, disease resistance and growth performance of Nile tilapia (*Oreochromis niloticus*). Aquaculture. 491. https://doi.org/10.1016/j.aquaculture.2018.03.019
- Dhanaraj, M.; Haniffa, M. A.; Singh, S. A.; Arockiaraj, A. J.; Ramakrishanan, C. M.; Seetharaman, S., and Arthimanju, R. (2010). Effect of probiotics on growth performance of koi carp (*Cyprinus carpio*). Journal of Applied Aquaculture, 22(3): 202-209. <u>https://doi.org/10.1080/10454438.2010.497739</u>
- **Dawood MAO.** Nutritional immunity of fish intestines: important insights for sustainable aquaculture. Rev. Aquac 2021;13:642-663. <u>https://doi.org/10.1111/raq.12492</u>
- Ezhil Nilavan, S. and Joseph, T. C. (2022). Probiotics in aquaculture. ICAR-CIFT.FAO/WHO, 2001. Report on Joint FAO/WHO Expert Consultation on Evaluation of Health and Nutritional Properties of Probiotics in Food Including Powder Milk with Live Lactic Acid Bacteria. ¹ 1–4 October, Cordoba, Argentina Fuller R(1989) A review: probiotics in man and animals. Journal of Applied Bacteriology 66: 365–378. <u>http://dx.doi.org/10.1111/j.1365-2672.1989.tb05105.x</u>
- **Fuller R.** Probiotics: History and Development of Probiotics. New York: Chapman and Hall; 1992.
- Fusco, A.; Savio, V.; Cimini, D.; D'Ambrosio, S.; Chiaromonte, A; and Schiraldi, C.(2023). In vitro evaluation of the most active probiotic strains able to improve the intestinal barrier functions and to prevent inflammatory diseases of the gastrointestinal system. Biomedicine 11:865. <u>https://doi.org/10.3390/biomedicines11030865</u>
- Galesoupe, F.J. (1999). The use of probiotic in aquaculture 180: 147-165. <u>https://doi.org/10.1016/S0044-8486(99)00187-8</u>
- Giorgini, E.; Conti, C.; Ferraris, P.; Sabbatini, S.; Tosi, G.; Rubini, C.; Vaccari, L.; Gioacchini, G. and Carnevali, O. (2010). Effects of *Lactobacillus rhamnosus* on zebrafish oocyte maturation: an FTIR imaging and biochemical analysis.

Analytical and Bioanalytical Chemistry, 398(7- 8), 3063–3072. <u>http://dx.doi.org/10.1007/s00216-010-4234-2</u>

- Gioacchini, G.; Maradonna, F.; Lombardo, F.; Bizzaro, D.; Olivotto, I. and Carnevali, C., (2010a). Increase of fecundity by probiotic administration in zebrafish (Danio rerio). Reproduction, 140(6), 953– 959. https://doi.org/10.1530/REP-10-0145.
- Gioacchini, G.; Bizzaro, D.; Giorgini, E.; Ferraris, P.; Sabbatini, S. and Carnevali,
 O. (2010b). Oocytes maturation induction by *Lactobacillus rhamnosus* in *Danio rerio*: in vivo and in vitro studies. Human Reproduction. 25, i205–i206.
- Gioacchini, G.; Giorgini, E.; Ferraris, P.; Tosi, G.; Bizzarro, D.; Silvi, S. and Carnevali, O. (2010c). Could probiotics improve fecundity? *Danio rerio* as case of study. Journal of Biotechnology, 150, 59– 60.https://doi.org/10.1016/j.jbiotec.2010.08.156
- Gioacchini, G.; Lombardo, F.; Merrifield, D.L.; Silvi, S.; Cresci, A.; Avella, M.A. and Carnevali, O. 2011.Effects of probiotic on zebrafish reproduction. Journal of Aquaculture Research and Development, S1.002. <u>http://dx.doi.org/10.4172/2155-9546.S1-002</u>
- Gioacchini, G.; Giorgini, E.; Merrifield, D.L.; Hardiman, G.; Borini, A.; Vaccari, L. and Carnevali, O. (2012). Probiotics can induce follicle maturational competence: the *Danio rerio* case. Biology of Reproduction, 86(3), 65-75. <u>https://doi.org/10.1095/biolreprod.111.094243</u>
- Gioacchini, G.; Dalla Valle, L.; Benato, F.; Fimia, G.M.; Nardacci, R.; Ciccosanti, F.; Piacentini, M.; Borini, A. and Carnevali, O. (2013). Interplay between autophagy and apoptosis in the development of *Danio rerio* follicles and the effects of a probiotic. Reproduction, Fertility and Development, 25(8), 1115-1125. <u>https://doi.org/10.1071/RD12187</u>
- Hossain, M. I.; Kamal, MM.; Mannan, MA. and Bhuyain, MAB. (2013). Effects of Probiotics on Growth and Survival of Shrimp (*Penaeus monodon*) in Coastal Pond at Khulna, Bangladesh. J. Sci. Res., 5(2): 363– 370.² <u>https://doi.org/10.3329/jsr.v5i2.11815</u>
- Hamad, G. M.; Amer, A.; el-Nogoumy, B.; Ibrahim, M.; Hassan, S. and Siddiqui, S.
 A. (2022). Evaluation of the effectiveness of charcoal, *Lactobacillus rhamnosus*, and *Saccharomyces cerevisiae* as aflatoxin adsorbents in chocolate. Toxins 15:21. <u>https://www.mdpi.com/2072-6651/15/1/21#</u>
- Hai, N. V. (2015) "The use of probiotics in aquaculture." Journal of applied microbiology 119, no. 4: 917-935. <u>https://doi.org/10.1111/jam.12886</u>
- He, S.; Wan, Q.; Ren, P.; Yang, Y.; Yao, F. and Zhou, Z. (2011). The effect of dietary saccharoculture on growth performance, non-specific immunity and autochthonous gut microbiota of gibel carp *Carassius auratus*. Journal of Aquaculture Research and Development, 2(Special issue). <u>https://doi.org/10.4172/2155-9546.S1-010</u>

- Hosain, M. A. and Liangyi, X. (2020). Impacts of probiotics on feeding technology and its application in aquaculture (2020) Journal of Aquaculture. Fisheries & Fish Science, 3(1), 174-185. <u>http://dx.doi.org/10.25177/JAFFS.3.1.RA.622</u>
- Hossain, M. K.; Shahjahan, M.; Kari, Z. A. and Téllez-Isaías, G. (2023). Trends in the Use of Probiotics in Aquaculture of Bangladesh—Present State, Problems, and Prospects. Aquaculture Research, 2023. https://doi.org/10.1155/2023/5566980
- **Ige, B. A.** (2013). Probiotics use in intensive fish farming. Afr. J. Microbiol. Res, 7(22), 2701-2711. <u>http://www.academicjournals.org/AJMR</u>
- Irianto, A. and Austin, B. (2002). Use of probiotics to control furunculosis in rainbow trout, Oncorhynchus mykiss(Walbaum). J Fish Dis; 25:333-42. <u>http://dx.doi.org/10.1046/j.1365-2761.2002.00375.x</u>
- Jamal, M. T.; Abdulrahman, I. A.; Al Harbi, M. and Chithambaran, S. (2019). Probiotics as alternative control measures in shrimp aquaculture: A review. Journal of Applied Biology and Biotechnology, 7(3), 69-77. <u>http://www.jabonline.in</u> DOI: 10.7324/JABB.2019.70313
- Jafaryan, H.; Soltani, M.; Noferesti, H. and Ebrahimi, P. (2011). Effect of adding probiotics into the rearing tanks of grass carp (*Ctenopharyngodon idella*) for the exploitation of *Artemia urmiana*, *Artemia fransiscana* and *Artemia parthenogenetica*Nauplii. Int. J. Vet. Res, 5(3), 157-161
- Kechagia, M.; Basoulis, D.; Konstantopoulou, S.; Dimitriadi, D.; Gyftopoulou, K.; Skarmoutsou, N. and Fakiri, E. M. (2013). Health benefits of probiotics: a review. International Scholarly Research Notices, 2013(1), 481651. <u>https://doi.org/10.5402%2F2013%2F481651</u>
- Kumar, R.; Mukherjee, S. C.; Prasad, K. P. and Pal, A. K. (2006). Evaluation of *Bacillus subtilis* as a probiotic to Indian major carp *Labeo rohita* (Ham.). Aquaculture Research, 37, 12151221. <u>http://dx.doi.org/10.1111/j.1365-2109.2006.01551.x</u>
- Kumar, V.; Roy, S.; Meena, D. K. and Sarkar, U. K. (2016). Application of probiotics in shrimp aquaculture: importance, mechanisms of action, and methods of administration. Reviews in Fisheries Science & Aquaculture, 24(4), 342-368. <u>https://doi.org/10.1080/23308249.2016.1193841</u>
- Krishnaveni, G.; Vignesh, S.; Vidhyalakshmi, N.; Vijay, V. and Ramesh, U. (2021). Effects of dietary supplementation of *Lactobacillus fermentum* URLP18 on growth, innate immunity and survival against *Aeromonas hydrophila* ATCC 7966 challenge in freshwater fish *Cyprinus carpio* (common carp). Aquaculture Research, 52(3), 1160-1176. <u>https://doi.org/10.1111/are.14974</u>
- Kanwal Z and Tayyeb, A. (2019). Role of dietary probiotic Ecotec in growth enhancement, thyroid tuning, hematomorphology and resistance to pathogenic challenge in *Labeo rohita* juveniles. Journal of Applied Animal Research;47(1):394-402. <u>https://doi.org/10.1080/09712119.2019.1650050</u>

- Lara-Flores, M. (2011). The use of probiotic in aquaculture: an overview. International Research Journal of Microbiology, 2(12): 471-478.
- Loh, J. Y. (2017). The role of probiotics and their mechanisms of action: an aquaculture perspective. *World Aquac*, 48, 19-23.
- Limbu, SM.; Chen LQ.; Zhang, ML. and Du ZY. (2021). A global analysis on the systemic effects of antibiotics in cultured fish and their potential human health risk: a review. Rev. Aquac;13:1015-1059. <u>http://dx.doi.org/10.1111/raq.12511</u>
- Lalloo, R.; Moonsamy, G.; Ramchuran, S.; Gorgens, J. and Gardiner. N. (2010). Competitive exclusion as a mode of action of a novel *Bacillus cereus* aquaculture biological agent. Lett. ¹ Appl.Microbiol., 50: 563–570 (2010). <u>https://doi.org/10.1111/j.1472-765x.2010.02829.x</u>
- Martínez Cruz, P.; Ibáñez, A. L.; Monroy Hermosillo, O. A. and Ramírez Saad, H. C. (2012). Use of probiotics in aquaculture. International scholarly research notices, 2012. ² <u>https://doi.org/10.5402%2F2012%2F916845</u>
- Michael, ET.; Amos SO. and Hussaini, LT. (2014). A Review on Probiotics Application in Aquaculture. Fish Aquac J 5: 111 <u>http://dx.doi.org/10.4172/2150-3508.1000111</u>
- Miccoli, A.; Gioacchini, G.; Maradonna, F.; Benato, F.; Skobo, T. and Carnevali,
 O. (2015). Beneficial bacteria affect *Danio rerio*development by the modulation of maternal factors involved in autophagic, apoptotic and dorsalizing processes. Cellular Physiolology Biochemistry, 35(5), 1706-18. <u>http://doi.org/10.1159/000373983</u>
- Mehdinejad, N.; Imanpour, M.R. and Jafari, V. (2018). Combined or individual effects of dietary probiotic, *Pediococcus acidilactici* and nucleotide on reproductive performance in goldfish (*Carassius auratus*). Probiotics and Antimicrobial Proteins, 1-8, <u>https://doi.org/10.1007/s12602-017-9377-4</u>
- Mohapatra. S.; Chakraborty, T.; Prusty, AK.; Das, P. and Paniprasad, K.(2012). Use of different microbial probiotics in the diet of Rohu, *Labeo rohita* fingerling: Effects on growth, nutrient digestibility and retention, digestive enzyme activities and intestinal microflora. Aquaculture Nutrition 18: 1-11. <u>http://dx.doi.org/10.1111/j.1365-2095.2011.00866.x</u>
- Mohapatra, S.; Chakraborty, T.; Prusty, A. K.; Prasad, K. P. and Mohanta, K. N. (2014). Dietary multispecies probiotic supplementation enhances the immunohematological responses and reduces mortality by *Aeromonas hydrophila* in *Labeo rohita* fingerlings. Journal of the World Aquaculture Society, 45(5), 532-544. <u>http://dx.doi.org/10.1111/jwas.12144</u>
- Nayak, SK. (2010). Probiotic and immunity: A Fish Perspective Fish Shellfish. Immunologi;29:2-14. <u>https://doi.org/10.1016/j.fsi.2010.02.017</u>
- **Parker, R.B.** (1974). Probiotics the other half of the antibiotics story. Anim Nutr Health, 29: 4-8.

- Pérez-Sánchez, T.; Ruiz-Zarzuela, I.; de Blas, I. and Balcázar, J. L. (2014). Probiotics in aquaculture: a current assessment. *Reviews in Aquaculture*, 6(3), 133-146. <u>http://dx.doi.org/10.1111/raq.12033</u>
- Reid, G. (2015). The growth potential for dairy probiotics. Int. Dairy J. 49, 16–22. <u>http://dx.doi.org/10.1016/j.idairyj.2015.04.004</u>
- Rajyalakshmi, K.; Suman Joshi, D. S. D.; Kishore Babu, M.; Oudah, M. A. and Krishna Satya, A. (2019). Role of probiotics and their mode of action in aquaculture: a review. *International Network for Nature Science*, 14, 573-586. <u>http://dx.doi.org/10.12692/ijb/14.2.573-586</u>
- Rosidah (2021). A mini-review: Effect of probiotics on the growth and health of fish. Int J Fish Aquat Stud 9 (4):49-53. <u>https://doi.org/10.22271/fish.2021.v9.i4a.2522</u>
- Suguna, T. (2020). Role of probiotics in aquaculture. International Journal of Current Microbiology and Applied Sciences, 9(10), 143-149. <u>https://doi.org/10.20546/ijcmas.2020.910.019</u>
- Subedi, B. and Shrestha, A. (2020). A review: Application of probiotics in aquaculture. International Journal of Forest, Animal and Fisheries Research, 4(5). <u>https://dx.doi.org/10.22161/ijfaf.4.5.1</u>
- Shefat, S. H. T. (2018). Probiotic strains used in aquaculture. International Research Journal of Microbiology, 7(2), 43-55. <u>http://www.interesjournals.org/IRJM</u>
- Sumaraw, JT.; Manoppo, H.; Tumbol, RA.; Rumengan, IFM.; Dien, HA and Sumilat, DA. (2019). Evaluation of the effect of probiotic bacteria on growth performance and survival rate of carp, *Cyprinus carpio* Jurnal Ilmiah Platax; 7:1. <u>http://dx.doi.org/10.35800/jip.7.1.2019.23216</u>
- Servin, A. (2004). Antagonistic activities of Lactobacilli and Bifidobacteria against microbial pathogens. Microbiol Rev 2004; 28: 405-40 <u>https://doi.org/10.1016/j.femsre.2004.01.003</u>
- Saravanan, K.; Sivaramakrishnan, T.; Praveenraj, J.; Kiruba-Sankar, R.; Haridas, H.; Kumar, S. and Varghese, B. (2021). Effects of single and multi-strain probiotics on the growth, hemato-immunological, enzymatic activity, gut morphology and disease resistance in Rohu, *Labeo rohita*. Aquaculture, 540, 736749. <u>https://doi.org/10.1016/j.aquaculture.2021.736749</u>
- Sangma, T. and Kamilya, D. (2015). Dietary *Bacillus subtilis*FPTB13 and chitin, single or combined, modulate systemic and cutaneous mucosal immunity and resistance of catla, *Catla catla* (Hamilton) against edwardsiellosis. Comparative Immunology, Microbiology and Infectious Diseases, 43, 8-15. <u>https://doi.org/10.1016/j.cimid.2015.09.003</u>
- Sumon, M. A. A.; Molla, M. H. R.; Hakeem, I. J.; Ahammad, F.; Amran, R. H.; Jamal, M. T. and Hasan, M. T. (2022). Epigenetics and probiotics application toward the modulation of fish reproductive performance. *Fishes*, 7(4), 189. <u>https://doi.org/10.3390/fishes7040189</u>

- Tuan, T. N., Duc, P. M. and Hatai, K. (2013). Overview of the use of probiotics in aquaculture. International Journal of Research in Fisheries and Aquaculture, 3(3), 89-97.
- Taborsky, M. (1998). Sperm competition in fish:bourgeois' males and parasitic spawning. *Trends in Ecology & Evolution*, 13(6), 222-227. <u>https://doi.org/10.1016/s0169-5347(97)01318-9</u>
- Volkoff, H. and London, S. (2018). Nutrition and reproduction in fish. Encycl. Reprod. 2018, 9, 743–748. <u>http://dx.doi.org/10.1016/B978-0-12-809633-8.20624-9</u>
- Vílchez, M.C.; Santangeli, S.; Maradonna, F.; Gioacchini, G.; Verdenelli, C.; Gallego, V.; Peñaranda, D.S.; Tveiten, H., Pérez, L.; Carnevali, O. and Asturiano, J.F. (2015). Effect of the probiotic *Lactobacillus rhamnosus* on the expression of genes involved in European eel spermatogenesis. Theriogenology, 84(8), 1321–1331. <u>http://hdl.handle.net/10251/68473</u>
- Valcarce, D.G.; Pardo, M.Á.; Riesco, M.F.; Cruz, Z. and Robles, V. (2015). Effect of diet supplementation with a commercial probiotic containing *Pediococcus acidilactici* (Lindner, 1887) on the expression of five quality markers in zebrafish (*Danio rerio* (Hamilton, 1822)) testis. Journal of Applied Icthyology, 31(1), 18-21. <u>https://doi.org/10.1111/jai.12731</u>
- Valiallahi, J.; Pouranasali, M.; Janalizadeh, E. and Bucio, A. (2018). Use of *Lactobacillus* for improves growth and enhanced biochemical, hematological, and digestive enzyme activity in common carp at Mazandaran, Iran. North Am J Aquac;80(2):206-215. <u>http://dx.doi.org/10.1002/naaq.10027</u>
- Verschuere, L.; Rombaut, G.; Sorgeloos, P. and Verstraete, W. (2000). Probiotic bacteria as biological control agents in aquaculture. Microbiol Mol Biol Rev;64:655-71.<u>https://doi.org/10.1128%2Fmmbr.64.4.655-671.2000</u>
- Vinoj, G.; Jayakumar, R.; Chen, J.-C.; Withyachumnarnkul, B.; Shanthi, S. and Vaseeharan, B. (2015). N hexanoyl-L-homoserine lactonedegrading *Pseudomonas aeruginosa*PsDAHP1 protects zebrafish against *Vibrioparahaemolyticus* infection. Fish & Shellfish Immunology, 42, 204212. https://doi.org/10.1016/j.fsi.2014.10.033
- Wuertz, S.; Schroeder, A. and Wanka, K. M. (2021). Probiotics in fish nutrition long-standing household remedy or native nutraceuticals? Water, 13(10), 1348.<u>https://doi.org/10.3390/w13101348</u>
- Watanabe, T. and Kiron, V. (1995). Broodstock management and nutritional approaches for quality offsprings in the Red Sea Bream.¹ In: Bromage, N.R., Roberts, R.J. Eds., Broodstock Management and Egg and Larval Quality. (pp. 154-195). Cambridge Univ. Press, Cambridge, First Publication.
- Wu, Z.Q.; Jiang, C.; Ling, F. and Wang, G.-X. (2015). Effects of dietary supplementation of intestinal autochthonous bacteria on the innate immunity and disease resistance of grass carp (*Ctenopharyngodon idellus*). Aquaculture (Amsterdam, Netherlands), 438, 105114. https://doi.org/10.1016/j.aquaculture.2014.12.041

Wang Y. B.; Li J. R. and Lin J. (2008). Probiotics in aquaculture: challenges and outlook," Aquaculture, 281, (1), 1-4. V.