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A Review Studies on Role of Lactic Acid Bacteria in Improved Growth, Enhancing Immunity and Gut Health in Fish Farming

Sarmad J. Jalil[1], Khalidah S. Al-Niaeem[2*], Salah M. Najim[2]
[1]Department of Histology and Anatomy, College of Veterinary Medicine, Shatrah University, Iraq
[2]Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Iraq
***Corresponding Author: khalidah.khaudeyer@uobasrah.edu.iq**

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ABSTRACT

This study aims to review and analyze recent studies on the use of lactic acid bacteria (LAB) as probiotics in fish farming, focusing on the period from 2010 to 2024. The results demonstrate that LAB plays an important role in improve growth rates, enhancing immunity, and improving feed conversion efficiency, in addition to supporting gut health and aquatic environment quality. Strains such as *Pediococcus acidilactici* and *Lactobacillus plantarum* are among the most effective and commonly used. Evidence also indicates the importance of using local strains adapted to the culture environment to achieve the best results, and emphasizes the need to determine optimal dosages to avoid any side effects. Despite the promising results, the study highlights a lack of long-term applied studies in local environments, especially in Iraq, indicating the need to expand field research. The study concludes with recommendations for increased field research, the definition of precise application protocols, monitoring the effects of long-term use, and the development of new strains and their combination with other probiotics. It also highlights future trends that rely on modern microbiome technologies and artificial intelligence to enhance the sustainability and effectiveness of aquaculture systems.

INTRODUCTION

Aquacultures production exceed capture fisheries production for human consumption at 2016, and it contribute 52% of the total harvest weights of aquacultures animals for human consumption at 2018 **(FAO, 2020)**. The 2024 edition of The State of World Fisheries and Aquaculture (SOFIA) said global fisheries and aquacultures production at 2022 surged to 223.2 million tons, a 4.4 percentage increased from the year 2020 **(FAO, 2024)**. Aquacultures are current the world fast-growth food sector, with a global production of 85.3 million tons in 2019. It contributes significant to nutrition and food security, particular in the food-insecure regions, while supported the livelihood of several million people worldwide **(Sudheesh *et al*., 2012; Alhtheal *et al*., 2024; Bashar *et al*., 2025)**. Infection in fish leads to disease outbreaks are a major concern for the aquacultures sector because they can results in significantly economic damage owing to morbidity and death.

The higher fish-rearing densities currently used in aquacultures enable the spread and transfer of pathogenic microorganism and are often a primary cause of such catastrophic outbreaks **(Ringø & Song, 2018; Shakir *et al*., 2024)**. The overreliance on antimicrobials not only fails to fully address these health challenges but also contributes to increase resistance of bacterial and emergence of multidrug-resistant bacterial and causes environments strains **(Hussein & Jumma, 2024; Torres-Maravilla *et al*., 2024)**. Antibiotics are used to avoid the transmission of diseases in fish farms, pose a considerable threat toward aquacultures and effect on human health **(Nayak, 2010; Huang *et al*., 2019)**. Utilizing contemporary biotechnologically method to increase fish production has the potential to significant increased fish quantity and quality in aquacultures system, while also meeting demand **(Sudheesh *et al*., 2012; Jumma, 2024)**. The probiotics using is one from strategy, which are living bacteria, beneficial bacterial supplement to the water or fish to improved water quality, immune function, and digestion. Adopting alternative feeding additives **(**synbiotics, prebiotics, and probiotics**)** were important for aquaculture **(Bonadero *et al*., 2023; Khanjani *et al*., 2023)**. Optimal gastrointestinal **(**GI**)** function is essential for sustainable animal production. Effective function of the finfish GI tract and its gut microbiota plays and important roles in host health **(Ringø *et al*., 2003; Round & Mazmanian, 2009)**, and several complex mechanism are involved, and in the absence of gut microbiota, normal immunity development, and functions are impaired. Lactic acid bacteria **(**LAB**)** are a significantly type of bacterial that are widely utilized in the probiotic and food. They are generally regarded as safe and possess unique feature that make them ideal for these application **(Zhang *et al*., 2020; Oday *et al*., 2024)**. Important function properties of probiotic LAB including their resistance to acidic gastric juices, capacity of adhesion to the walls of the GI tract and antagonistic action against pathogenic microorganism which might endanger the human **(Hsieh *et al*., 2008; Piątek *et al*., 2012; Ammar *et al*., 2019)**. In addition, some LAB secreted substances with a bacteriostatic effect such as H2O2 and bacteriocins called lactocins **(**e.g. lactocidin, lactacin, acidophilin and nisin**)** thus prevent the development of pathogenic micro-organism **(Ringø *et al*., 2018; Adeshina *et al*., 2023a)**. Lactic acid bacteria contribute to improved gut health by modifying the gut microbiome and enhancing nutrient absorption, while also stimulating the immune response. Specifically, LAB can lower intestinal pH, creating an environment less hospitable to harmful bacteria and improving the efficiency of nutrient uptake. Furthermore, they activate immune enzymes like lysozyme and increase the production of IgM and IgT antibodies due to enhances immune function in fish **(Adeshina *et al*., 2023b; Al-Bayati *et al*., 2024)**. The fish gut microbiota play important roles at GI tract development, mucosal tolerance, digestive function, stimulation the host immunity responses, and protection against infection, also some studies indicate that the use of strains such as *Pediococcus acidilactici* and *Lactobacillus plantarum* in the Nile tilapia **(**Oreochromis niloticus**)** diets resulted in significant improvements in growth and increased survival rates after challenge with the pathogenic bacterium *Aeromonas hydrophila* **(Wang *et al*., 2018; Essa *et al*., 2020; Adeshina *et al*., 2023)**. Experiments on Atlantic salmon **(**Salmo salar**)** have also shown the roles of Lactococcus lactis in enhancing natural immune and resisting environmental stresses **(Aljoburi *et al*., 2024; Frontiers in Marine Science, 2024)** Despite these benefits, **Nayak (2010)** notes the lack of long-term field studies on the use of probiotics in fish farming, which is consistent with the reality in local environments such as Iraq. This calls for intensive research efforts to evaluate their effectiveness and establish appropriate usage protocols. Based on the above, the use of lactic acid bacteria is a strategic option for achieving sustainable fish production, enhancing food security, and reducing reliance on antibiotics, in line with recent global trends toward safer and environmentally friendly aquaculture systems.

Some studies on lactic acid bacteria in fish farming published during 2010 to 2024

Studies published between 2010 and 2024 (Table 1) have showed that the addition of lactic acid bacteria to aquaculture fish or feeding significant improve growth rate, feed conversion efficiency, and immunity function, as well as improve gut health and water quality.

The strains of *Pediococcus acidilactici* and *Lactobacillus plantarum* have shown a significantly increase in finally fish weight and a decrease of feeding conversion rates **(Abumourad *et al*., 2013; Adeshina *et al*., 2023)**. Lactic acid bacteria use has also been association with increase of markers humoral and cellular immunity, such as antibody levels and lysozyme activity **(Jahangiri & Esteban, 2018; Naiel *et al*., 2021)**. Some studies have showed the ability of LAB to inhibition the growth of bacterial pathogens such as Streptococcus agalactiae and Aeromonas sobria, causes improve survival rate and reduced mortality rate **(Abou-El-Atta *et al*., 2019; Darbandi *et al*., 2022)**. The studies of Basrah University have confirmed the importance of used local LAB strains adaption to the environmental. These strains show improve growth rate ranging from 105-178%, and a significantly improved in the feeding conversion rates **(**from 2.94 to 1.83**)**, indication the effectiveness of these strains in local aquacultures condition **(Basrah University, 2023)**. Some studies of region indication that LAB administrations has contributed to improve intestinal structures, such as increase villus length, which enhances nutrient absorption and feeding utilization efficiency **(Jalloob *et al*., 2022; Hoseini *et al*., 2023; MDPI Microorganisms, 2023)**. The studies of global on sea bream and salmon indication to role of LAB in strength immunity and reduce environment stress **(Ringø & Song, 2018; Frontiers in Marine Science, 2024)**. Most studies agreement with the numerous benefits that LAB provides at improves fish growth and health and also found clear differences in the numerous of these benefits depending on the type of fish, dose, and the aquaculture system **(Merrifield *et al*., 2010; Nayak, 2010)**. While some studies recorded modest or limited effects of using the LAB, especially with low doses **(Veisi *et***

***al*., 2023)**. Some studies recorded the higher doses of LAB cause digestive disturbances or decrease appetite, this causes are importance for determine the optimal doses according to the fish type and the aquaculture environment **(Ringø & Song, 2018; Soltani *et al*., 2019; Adeshina *et al*., 2023)**. The feed quality, stocking density, and water temperature, these factors affected the effectiveness of LAB, the most studies have not adequately addressed these factors **(Martínez Cruz *et al*., 2012; Jasim *et al*., 2021)**. The lack of long-term field studies, particularly in Iraq, also limits the generalizability of the results. Another aspect that requires attention is assessing the potential side effects of the continued use of LAB, such as alterations in the natural microbial balance in the gut or the potential development of undesirable bacterial resistance **(Nayak, 2010)**. Furthermore, most studies focus on a limited number of common strains without further exploration of other strains that may offer additional or complementary benefits **(Frontiers in Marine Science, 2024; Saleh, 2024)**.

Table 1. Some studies on lactic acid bacteria in fish farming (2010–2024)

Fish species	**LAB strain/ application method**	**Dose/ concentration**	**Key findings**	**Reference**
Oreochromis niloticus	L. plantarum	10^6 CFU/g	Growth, immunity (IL-6, TNF-α), ↓ infection by Pseudomonas fluorescens	**Abumourad *et al*. (2013)**
Cyprinus carpio	Lactic acid (as metabolite)	Diet supplementation	Antioxidant enzymes; digestive activity; gut microbiome modulation	**Hoseini *et al*. (2023)**
Oreochromis niloticus	L. plantarum, P. acidilactici	10^6–10^9 CFU/g	Final weight 95.4 ± 3.2 g; FCR ≈ 1.28; lysozyme ≈ 34.2 U/ml	**Adeshina *et al*. (2023)**
Cyprinus carpio	L. rhamnosus	Not specified	Survival $88.7 \pm 4.5\%$; FCR 1.35; IgM 22.1 ± 1.8 mg/dl	**Frontiers in Marine Science, 2024**
Sparus aurata	L. plantarum	Not specified	Villus length (412 ± 25 µm); FCR 1.22 ± 0.03	**MDPI Microorganisms, 2023**
Salmo salar	*Lactococcus lactis*	Not specified	Phagocytic activity ($76.5 \pm 3.9\%$); survival ($91.2 \pm 2.8\%$)	**Ringø and Song, (2018)**
Oreochromis niloticus	P.acidilactici, P.pentosaceus	Not specified	Antagonistic vs E. coli, K. pneumoniae; storage safety	**Darbandi *et al*. (2022)**
Oreochromis niloticus	L.plantarum + Whey protein	10^6 CFU/g	Resistance to *Aeromonas sobria*; growth and immunity	**Abou-El-Atta *et al*. (2019)**
Oreochromis niloticus	L. casei	Not specified	Immunity vs cadmium toxicity; antioxidant activity	**Veisi *et al*. (2023)**
Oncorhynchus mykiss	L. plantarum (with	10^7 CFU/g	Cellular immunity; survival vs Yersinia	**Soltani *et al*. (2019)**

	vaccine)		ruckeri	
Acipenser baerii	L. plantarum	10^7 CFU/g	Final weight; immunity; flesh quality	**Pourgholam *et al*. (2016)**
Oreochromis niloticus	LAB + Biofloc	Not specified	Water quality; immunity; survival	**Mohammadi, (2021)**
Oreochromis niloticus	Lactobacillus spp.	Not specified	Humoral & cellular immunity; growth	**Naiel *et al*. (2021)**
Salmo salar	LAB via rearing water	Not specified	Absorption; immunity; feed efficiency	**Jahangiri and Esteban, (2018)**
Oreochromis niloticus	LAB in rearing water	Not specified	Fish health; mortality	**Jahangiri and Esteban, (2018)**
Cyprinus carpio	Mixed LAB	Not specified	Water quality; microbial balance; pathogenic bacteria	**Martínez Cruz *et al*. (2012)**
Oncorhynchus mykiss	LAB (review on salmonids)	Not specified	Overview of LAB as immune boosters in salmonids	**Merrifield *et al*. (2010)**
Multiple species	LAB (review: probiotics & fish immunity)	Not specified	Innate & adaptive immune responses	**Nayak (2010)**
Multiple species	LAB as probiotics	Not specified	Fundamentals of LAB use; pathogens	**Verschuere *et al*. (2000)**

Review of studies on effect the lactic acid bacteria in fish farming in Iraq

The Iraq used of the LAB in fish farming because the prominent role in improve growth rate, enhancing immunity, and beneficent digestive health in fish. The local studies have focused on isolation and characterization these bacteria from the aquatic environments and fish intestinal, in addition to evaluation their effective as a probiotic alternative to antibiotic (Table 2).

The isolation of Pediococcus pentosaceus from carp pond water in Basrah and tested its properties as a probiotic. The results demonstration the bacteria ability to resistance bacterial pathogens, suggesting its potential use as a probiotic to improved fish health and water quality **(Raghad *et al*., 2019)**. Also, isolation LAB bacteria from the common carp **(**Cyprinus carpio**)** intestinal and addition as supplement probiotic in fish feed, the results of LAB were significantly improvement in growth rate and feeding conversion efficiency, enhancing the health of the intestinal microflora and reduce the feeding conversion index **(Al-Noor *et al*., 2023; Al-Juhaishi *et al*., 2025)**. **Erdeni *et al*. (2023)** study was significantly in the used of LAB to accelerate the process of decomposition dead fish in a healthy way. This method helps reducing decomposition time and increase process efficiency, suggesting the potential for this technology to be employed in aquatic waste management and sustainable fish farming. **Mohammed (2025)** used the protein hydrolysates from fish waste as a nutrient source for the growth of *Lactobacillus* and *Bifidobacterium*, this study not directly applied to fish feeding but this result open the way for the development of bio-based additives as local source.

Table 2. Some local studies on lactic acid bacteria in Iraqi aquaculture

Title	**Type of Bacteria**	**Main Findings**	**Year**
Study the Probiotic Properties of *Pediococcus pentosaceus Isolated from* Fish Ponds in Basrah City	*Pediococcus pentosaceus*	Probiotic properties, pathogen resistance, improved water quality	2018
Isolation and characterization of LAB from the fish intestine for application as probiotics in young common carp	LAB isolated from common carp intestine	Improved growth **(**178%**)**, better feed conversion ratio **(**from 2.94 to 1.83**)**, enhanced gut health	2023
Enhancing the composting process by using lactic acid bacilli for the hygienic disposal of dead fish	Various LAB strains	Accelerated decomposition of dead fish, improved sanitary and environmental conditions	2023
Impact of fish waste protein enzymatic hydrolysate on growth of some *Lactobacillus* sp. and *Bifidobacterium* sp.	*Lactobacillus* and *Bifidobacterium*	Supported growth of beneficial bacteria using fish waste hydrolysate	2025

The effect of lactic acid bacteria on fish growth and health

Table (3) shows a comparison of the results of studies examining the effect of LAB on various fish within various culture systems. The comparison focused on growth rates, feed conversion ratio (FCR), immune response, and potential side effects, considering the type of fish, dosage, and duration of application.

The results of the comparison show that the use of LAB in most cases achieves a clear improvement in growth performance and feeding utilization efficiency, while enhancing immunity responses against pathogens.

However, these benefits are not consistent across all studies, with some studies recording limited or variable effects. This is due to several factors:

1. Strain Effect: The importance of selecting the appropriate strain such as *Pediococcus acidilactici* and *Lactobacillus plantarum* showed superior results comparative with other strains **(Ringø & Song, 2018; Adeshina *et al*., 2023)**.
2. Dosage Variation: The higher doses cause gastrointestinal disturbances or decrease appetite, and low doses were non-significantly results **(Soltani *et al*., 2019; Veisi *et al*., 2023)**.
3. Fish Species: The Nile Tilapia and Common Carp increased significantly to response comparative with other species **(Naiel *et al*., 2021)**.
4. Nutritional and Environmental Conditions: Feed quality, water quality, and Storage density were main factors that determine the level of effectiveness **(Martínez Cruz *et al*., 2012)**.

5. Duration of application: The experiments long-term were stable effects comparative with experiments short-term, especially with increase immunity **(Merrifield *et al*., 2010)**. The application of LAB in fish farming requires careful management as type of strain, dosage concentration, and rearing conditions, to get effective and sustainable results **(Ringø *et al*., 2018)**.

Table 3. Comparison of the effect of some strains of lactic acid bacteria in fish farming

Fish species	Probiotic strain(s)	Dose (CFU/g feed or mL water)	Duration (weeks)	Key outcomes	Study
Nile tilapia (*Oreochromis niloticus*)	*Lactobacillus plantarum*	10^8 CFU/g	8	Improved growth and immunity	**Abumourad *et al*. (2013)**
Nile tilapia	*Lactobacillus plantarum, Pediococcus acidilactici*	10^9 CFU/g	6	Enhanced growth, immune response	**Adeshina *et al*. (2023)**
Common carp (Cyprinus carpio)	Mixed lactic acid bacteria	10^7 CFU/g	10	Increased antioxidant status	**Hoseini *et al*. (2023)**
Common carp	Mixed LAB	10^8 CFU/mL (water)	5	Improved water quality and immunity	**Martínez Cruz *et al*. (2012)**
Various fish species	Multiple LAB strains	Variable	Variable	Immunomodulation	**Nayak (2010)**
Nile tilapia	Lactobacillus casei	10^8 CFU/g	8	Protective effects vs. toxicity	**Veisi *et al*. (2023)**

Factors affecting the effectiveness of lactic acid bacteria in improving fish health and growth

Fig. (1) presents a comprehensive overview of the most important factors that determines the effective of using LAB in improve fish growth and health. These factors including the strain, dose, environment, fish species, feed, and duration of application act together in a complex manner and any change in one factor effect on effective of the probiotic.

1- Bacterial strain selection for probiotic

Bacterial strains are the primary determinant of LAB effective, as ability to adhesion with intestinal wall, resist acidity and digestive enzymes, and produce antimicrobial substances. **Al-Noor *et al*. (2023)**, who reported in Iraq demonstrated that local isolates of bacterial strains from the intestines of common carp were significant more effective in improve growth and digestive parameters than imported commercial strains. **Ghori *et al*. (2022)**, who demonstrated that strain variation leads to significant variation in fish response to probiotics.

2- Dose and administration method

The dosage determines is important for addition to feeding of fish, as low or higher concentrations because was non-significantly effect and cause physiologically stress or microbial imbalance **(Sabah *et al*., 2024)**. **Raghad *et al*. (2019)** reported that Pediococcus pentosaceus doses of 10^8 CFU/g in common carp feeding contributed to improve immunity without side effects. **Ringø *et al*. (2020)** founding the selection administrations of methods that ensure live bacteria reach the intestine, such as feed addition or bio-encapsulation.

3- Fish species and environment conditions

The fish responses to LAB depend on species. The freshwater species as common carp, have showed greater benefits from microflora modifications **(Al-Noor *et al*., 2023)**, while marine species are affected by water salinity and temperature. **Nayak (2010)** study also indicates that environment conditions, such as temperature and dissolved oxygen are factors determinant of LAB survival and metabolic activity.

4- Feed quality and duration of application

The feed quality is important in the success of LAB, as the presence of prebiotics such as inulin enhances its stability in the intestine. **Mohammed (2025)** demonstrated that the addition of fish waste proteolysis help supports the growth of Lactobacillus and Bifidobacterium, suggestion the potential for designing low-cost, locally source feeds that support probiotics. **Hoseinifar *et al*. (2018)** who reported the long-term use is essential to achievement sustained stabilization of beneficial microflora.

5- Effects of lactic acid bacteria on gut microbiota and digestive enzymes

When LAB settles in the intestine, it modified the microflora composition and enhances the production of digestive enzymes such as amylase and protease. A study by **Al-Noor *et al*. (2023)** recorded the added of local LAB to common carp feed was significantly increase in protein efficiency and feed digestibility.

6- Immune response

LAB contributes to enhancing the immune system efficiency by activating non-specific immunity **(**such as increased lysozyme and macrophage activity**)** and specific immunity (such as increased IgM). **Raghad *et al*. (2019)** shown that *Pediococcus pentosaceus* enhanced fish resistance to bacterial pathogens in Basrah ponds, and agreement with study by **Newaj-Fyzul and Austin (2015)**, who reported on the ability of probiotics to reduce mortality rates in fish farms.

7- The final result: Growth performance and disease resistance

All factors increased growth rates, improve feed conversion efficiency, and enhanced disease resistance. The local studies in Iraq confirm these results are importance of careful management of LAB use within sustainable aquaculture systems **(Al-Noor *et al*., 2023; Mohammed, 2025)**.

The effective of LAB is not the results of a single factor, but rather the results of the interaction of several interconnected factors, including strain, dosage, environment, fish species, feed, and duration of application. Therefore, any program for using LAB in aquaculture requires carefully design that takes all these factors to accounts to achievement maximum benefits **(Ringø *et al*., 2020; Singh *et al*., 2024)**.

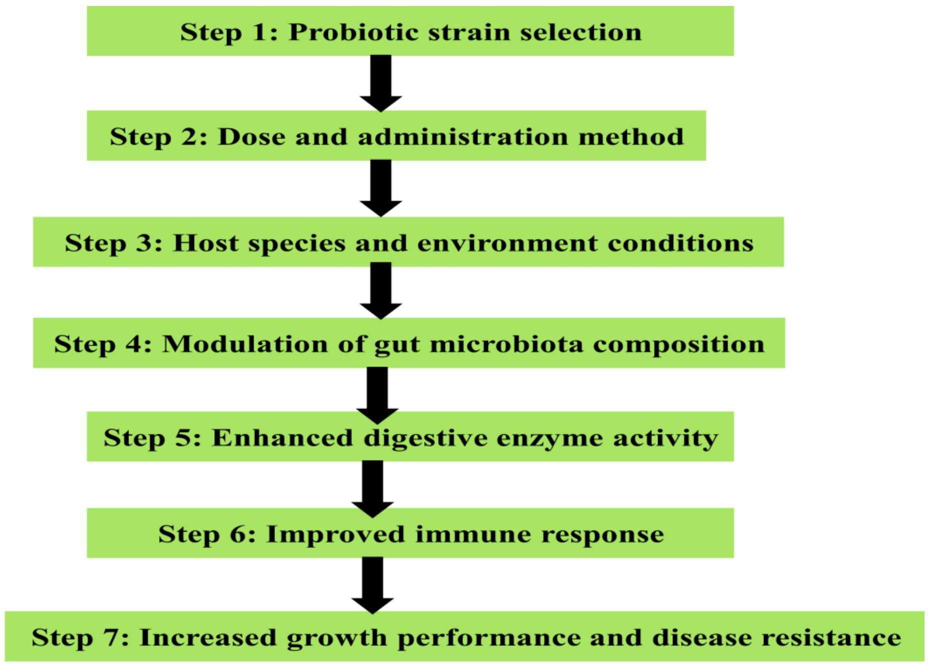

Fig. 1. Factors affecting the effectiveness of lactic acid bacteria in improving fish health and growth

CONCLUSIONS and RECOMMENDATIONS

The probiotics use in aquaculture has increase significant interest as a potential microbial agent for improved the overall health and welfare of various aquatic species raised in aquaculture environment. However, the integration of probiotics to aquaculture practices presents special challenges and considerations that require careful attention and strategic planning. The effectiveness of probiotics depended large on the selection of appropriate strains compatible with the target species and attention environment conditions. Research and experiments are also necessary to identify the best probiotic candidates for specific applications. The use of LAB in feed of fish farming is represents an effective and sustainable option for enhancing fish growth, improving their immune health, and enhancing the quality of the digestive system and the rearing environments. Most studies have demonstrated the ability of LAB to improve growth rates, increase survival rates, reduce feed conversion ratios (FCR), and enhance both humeral and cellular immune responses, and reduce the incidence of infectious diseases in fish. The use of local strains adapted to the regional environment, especially in Iraq, enhances the effectiveness of these probiotics and ensures the sustainability of their results under various farming conditions.

Despite the numerous benefits, further long-term field application studies are needed to consider differences in fish species, aquatic environments, and feed quality, as well as to precisely determine optimal dosages to avoid any potential side effects. Microbiological and environmental changes resulting from the continued use of LAB should also be evaluated to ensure stable ecological balance within aquaculture systems.

Therefore, the following are recommended:

• Intensify field research in local environments using local and appropriate LAB strains to ensure optimal results.

• Determine the optimal dosages for each fish species, considering nutritional factors and diverse rearing conditions.

• Continuously monitor environmental and microbiological impacts and evaluate long-term biosafety.

• Expand the use of LAB to include diverse and new strains, possibly combining them with probiotics or other nutritional supplements to achieve synergistic effects.

• Strengthen awareness and training programs for farmers and producers on the benefits and mechanisms of LAB use, to encourage optimal adoption and proper application of this technology.

Following these recommendations will support the sustainability of the local aquaculture sector, achieve environmentally safe and healthy production development, meet growing market needs, and reduce reliance on antibiotics and harmful chemicals.

Based on the above, it is recommended to design long-term local field studies using local LAB strains, considering environmental and nutritional factors. Precisely determine the optimal dosages and evaluate the effects of multiple dosages on fish health and growth performance. Study long-term microbiological changes to avoid any internal environmental imbalance. Expand the scope of research to include new and diverse strains of LAB, and possibly combine them with other probiotics to achieve optimal results. This will contribute to building a solid scientific foundation that facilitates the effective and sustainable application of these probiotics in Iraqi aquaculture.

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