IRSTI 34.34.15

F.G. Sagymbek[1*], A.D. Serikbaeva[2], T.B. Abdigaliyeva[1], R. Yelnazarkyzy [3]

[1]Almaty Technological University, Almaty, Kazakhstan
[2] Kazakh National Agrarian Research University, Almaty, Kazakhstan
[3] S. Seifullin Kazakh Agro Technical University, Astana, Kazakhstan
**Corresponding author: sagymbek.fatima@gmail.com*

Probiotics and their application in aquaculture for improving the growth and immunity of fish

Abstract. *To increase the digestibility and digestibility of feed, stimulate the growth and development of animals, and increase nonspecific immunity, enzyme, probiotic, prebiotic and combined enzyme-probiotic preparations, as well as complex probiotic preparations enriched with phytocomponents are used.*

Probiotics for artificially grown fish are beneficial bacteria and live microbiological additives that are traditionally added to agricultural aquaculture systems to maintain health, productivity and growth. Therefore, a promising direction in aquaculture is the use of feed with probiotic cultures. The use of probiotics is associated with solving various health problems, in particular, with increasing the efficiency of digestion and stimulating growth and development. Probiotics, having a positive effect on the host's body, contribute to the restoration of digestion, biological status, and immune response and increase the effectiveness of vaccination. The use of probiotics significantly reduces the cost of treating diseases in animals, increases productivity and improves product quality. In recent years, many studies have been conducted on the use of various probiotics in fishing. This review is aimed at generalizing the topic of the possible use of gram-positive bacteria as probiotics in a comprehensive study of the existing literature. With the expansion of ideas about the biological effectiveness of probiotics and the proof that the structural elements of cells and their metabolites are at least effective in some cases. As a result, various types of bacteria, including bacilli, lactic acid bacteria, and microbes, were used to improve the growth and immunity of various fish. However, this study conducted a review of the scientific literature showing that probiotics in aquaculture have a positive effect on the overall productivity of fish.

Keywords: *probiotics, aquaculture, fish, bacterial strain, review, lactic acid bacteria, feed.*

DOI: 10.32523/2616-7034-2023-144-3-16-25

Introduction

Fishing is one of the main sources of food for humanity. Aquaculture has undergone significant changes in the last decades under the influence of scientific and technological advances. This sector is growing at an unprecedented rate and supplies more than half of the world's fish for human consumption [1].

Recently, the role of probiotics in fish farming is growing. This is primarily due to diseases, which represent a major challenge for fish farming and a huge problem for further growth and expansion. Probiotics for artificially farmed fish are beneficial bacteria that are traditionally added to aquaculture farming systems to support their health, productivity and growth [2]. The widespread use of antibiotics for the prevention and control of bacterial diseases in fish farms has led to problems such as drug resistance, accumulation of antibiotics

in tissue and immunosuppression. Thus, probiotics as a prophylactic agent are progressively used in aquaculture [3]. In this regard, currently, various probiotics are widely used as means of maintaining and restoring the normal physiological state of animals, and the interest of scientists and practitioners in the use of microorganisms in agricultural production is increasing significantly. [4].

It is crucial to raise fish using environmentally friendly feed and competitive in price and taste. Fish require natural living conditions more than any other agricultural animals because they are sensitive even to significant fluctuations in the parameters of the aquatic environment (availability of oxygen, pH, nutrient and microflora). Therefore, the biological role of nutrient-balanced diets is now being supplemented by the functional importance of friendly microflora, whose deficiency must be compensated artificially [5].

In recent years, scholars have conducted a series of studies on the use of probiotics in fish farming. Thus, it is important to analyze these papers to provide useful information on scientific progress. This review will thus focus on summarizing published articles until 2020 that report gram-positive microorganisms applied as probiotics and their effect on productive performance in different fish.

The role of probiotics in aquaculture

Recently, more importance is given to industrial methods of fish breeding with the use of various types of feed. However, natural food contains a wider range of biologically active components that are regulators of many metabolic processes. Consequently, in addition to the balance of essential nutrients in the food for the rearing of physiologically full-fledged young fish, biologically active substances are important, which include feed probiotics [6].

The term "probiotics" is used to describe a broad class of microorganisms with antagonistic activity against pathogenic microflora. Probiotics are usually referred to as preparations based on live microbial cultures used for the correction of microbial cenosis during the treatment and prevention of a wide range of diseases associated with dysbiotic conditions [7]. Probiotics also help in the post-stress adaptation by increasing the resistance of the microorganism to pathogens; they improve the digestive system through the additional production of enzymes in the digestive tract. Also, probiotics reduce the accumulation of organic contaminants and effectively maintain water quality [8]. Modern probiotics can easily satisfy the desire for sustainable aquaculture as they can enhance two key factors: growth efficiency and disease resistance. Benefits of such supplements include improved feed value, enzymatic contribution to digestion, inhibition of pathogens, antimutagenic and anticarcinogenic activity, and enhanced immune response [9].

The efficiency of aquaculture is largely determined by the quality and quantity of used feed. Reducing feed costs is one of the main economic factors that increase the profitability of fish farming [10]. Probiotics that are added to the feed have a significant impact on feed consumption per unit of fish growth because they contribute to their fuller assimilation, neutralization of mycotoxins coming with feed, displace pathogenic microflora, strengthen the general resistance of the fish organism [4].

In previous studies, the beneficial effects of the use of probiotics in fish feed have been reported. According to published papers, the majority of commercial probiotics contain mostly *Lactobacillus* and *Bacillus* sp. [11,12].

General mechanism of probiotic action

An effective probiotic for fish farming, able to populate the intestines, and has a dual beneficial effect. Probiotics realize their positive effect on the macroorganism through a whole arsenal of mechanisms, not all of which have yet been fully deciphered. Among the well-studied ones are antagonistic activity against pathogenic and conditionally pathogenic microorganisms [13]. Secondly, probiotics have an adhesive activity to intestinal epithelial cells and can successfully compete with pathogenic and conditionally pathogenic microbes for adhesion sites on the intestinal wall and, as a consequence, for limiting nutrients, which eventually also leads to

inhibition of undesirable microflora growth [14]. The effects of probiotics on nutrient utilization, digestion and growth have been studied extensively [2].

The gram-positive microorganisms applied as probiotics affect the growth performance and immunity of fish.

Bacillus species. The search for microorganisms that can be used as probiotics represents the basis for the development of probiotic preparations. The microbial organisms used as probiotics or tested as potential probiotics are given in Table 1. As a result of years of targeted screening, strains like *Bacillus subtilis* and *B. licheniformis*, B. *coagulans*, *B. firmicutes* (*Paenibacillus polymyxa*), *B. pumilus* have been selected for the development of corrective probiotics [12,15]. Some experimental strains of these bacteria can possess distinctly expressed antagonistic activity to a wide range of pathogenic and conditionally pathogenic microorganisms [16]. Bacilli are saprophytes and are major participants in the decomposition of protein substrates. Owing to their high activity, they are often antagonistic to other microorganisms. One of the important advantages of these bacteria is their spore-forming ability, which allows them to remain viable under unfavourable environmental conditions (including the moisture-heat treatment of raw materials and feed in the process of pelleting and extrusion) [17]. Spore resistance can be explained by various factors, such as the presence of thick protein layers of spores, reduced permeability of the spore core, or reduced water content in the spore core (Mingmongkolchai and Panbangred 2018).

Bacillus spp. are well known for their ability to produce extracellular enzymes. When used in aquaculture feed, these enzymes can improve digestibility and reduce the feed conversion ratio. Ultimately, improving the feed conversion ratio in aquaculture feeds is economically beneficial because the feed can be a major cost to the producer and, also helps improve water quality by reducing waste [19]. Studies show that they secrete biologically active substances in the intestine and produce various digestive enzymes. As a result, digestion improves, feed assimilation increases, average daily weight gain increases, and the growth of fish are stimulated. For instance, Bacillus spp. isolated from the pond of common carp stimulated productive performance [20].

Bacillus subtilis bacteria, which are present and proliferate in the intestinal lumen, produce metabolites that inhibit the growth of pathogenic and opportunistic microflora, such as *staphylococci, protozoa, shigella, escherichia, pseudomonads, Candida* fungi and other organisms [21]. *Bacillus subtilis* bacteria are not capable of forming colonies in the intestines of fish - once the preparation is discontinued, they are gradually eliminated from the organism, but maintenance of their high concentration in the digestive tract increases the survival rate and productivity of fish [22].

Numerous publications have shown that probiotics with *Bacillus subtilis* improve growth and stimulate the immune system [12,15,23]. For instance, Opiyo et al. (2009) revealed that *B. subtilis* led to significantly higher protein at 5 g kg−1 ($P < 0.05$).

In addition, it has been reported that *B. coagulans*, *B. licheniformis* and *B. firmicutes* (*Paenibacillus polymyxa*) ($P < 0.05$) enhanced the resistance of fish fry against bacterial challenge [24].

Lactic acid bacteria (LAB). LAB in probiotic supplements normalize the intestinal microflora not only by suppressing pathogens, but also by increasing immunity; their activity products - immunoglobulins and lactoglobulins have antimicrobial, antiviral, and anticancer effects [25].

Lactobacilli produce large amounts of acetic, formic, lactic acids and hydrogen peroxide, which have high antiseptic, bactericidal and antioxidant properties (Teame et al. 2020). One mechanism for preventing colonization by pathogens in the intestine is competition for adhesion sites on the surface of the intestinal epithelium. Bacteria that grow slowly but attach to the intestinal wall can colonize the intestine, while non-adherent species are compensated by increasing their growth rate. Attachment provides the microorganism with resistance to the leaching of intestinal contents. It follows that if a probiotic strain can occupy adhesion sites on the intestinal wall, it takes root in the digestive tract, and vice versa [27].

The beneficial effects of Lactobacilli of normal gut microflora have led to their widespread

use in probiotics. The following Lactobacillus species are most commonly used as probiotics in aquaculture: *L. acidophilus* [28], *L. helvetica* [11], *L. rhamnosu* [29,30], *L. plantarum* [31 - 33], *L. delbrueckii subsp. Lactis* [34, 35], *L. delbrueckii subsp. Bulgaricus* [36].

Ahire et al. (2019) reported that *Lactobacillus helveticus* showed antimicrobial activity against fish Aeromonas spp. In addition, it increased antioxidant levels and enhanced the selective absorption of essential trace elements in goldfish [11].

Furthermore, Soltani et al. (2019) evaluated the effects of probiotic supplementation on immune and growth performance in fish. The authors demonstrated that supplementation with *Lactobacillus plantarum* 426951 could improve the growth and some immune status of Rainbow trout vaccinated against yersiniosis [33]. Similar results have been investigated in other studies [31,32].

Enterococci faecium are part of the normal microflora of the gastrointestinal tract of humans and many vertebrates and play a crucial role in providing mucosal colonization resistance. Wang et al. (2008) isolated an *E. faecium* ZJ4 from the intestinal tract of a healthy piglet and investigated its significant effect on the body weight of tilapias [37].

Micrococcus. Micrococcus is a genus of gram-positive bacteria. The role of *Micrococcus luteus* in human and animal disease is minimal, subsequently, it can be used as a probiotic. In a study with tilapia, *M. luteus* enhanced fish growth and health in vivo [38].

Further perspectives. Modern fish farming is based on intensive technologies, including closed water supply plants, which feature high planting density in limited areas, which greatly increases the risk of infection of fish with pathogens of dangerous infections. Feeding probiotic preparations are widely used in animal breeding practice, which allows for improving the existing systems of breeding and feeding of farm animals, and becomes an important component of the modern rational feeding of animals.

The review of available literature revealed the promising effects of probiotics on the growth performance of various fish. This helps to reduce feed costs and improve the economic efficiency of horseshoe fish farming. The analysis of potential probiotics has shown that their further study and implantation into aquaculture can contribute to the increase of fish yield. However, research on the potential effect of probiotics lacks in fish; therefore, it still needs further exploration in various fish species.

Table 1

Different species of microorganisms and their beneficial effects on growth performance and immunity of fish

№	**Probiotic candidates** Gram-Positive Bacteria	**Aquatic species**	**Effects**	**References**
1	*Lactobacillus helveticus*	*Carassius auratus*	antimicrobial activity, improved health, reduced mortalities	[11]
2	*Lactobacillus plantarum 426951*	*Oncorhynchus mykiss*	improved growth performance and immune status	[33]
3	*Lactobacillus plantarum CCFM639*	*Tilapia*	**Enhances growth performance,** feed utilization, and antioxidant ability	[31]
4	*Lactobacillus plantarum* (PTCC no. 1058)	Siberian sturgeon *Acipenser baerii*	improve growth performance and feed utilization, immunological parameters	[32]

5	*Bacillus coagulans* (MTCC 9872) *Bacillus licheniformis* (MTCC 6824) *Paenibacillus* **polymyxa** (MTCC 122)	*Cyprinus carpio* fry	improve growth, feed utilization, non-specific immune responses and disease resistance	[24]
6	*Enteroccus faecium* ZJ4	Tilapia *Oreochromis niloticus*	Improved growth performances and the immune responses	[37]
7	**Micrococcus luteus**	***Nile tilapia***	enhanced the fish growth and health	[38]
8	*Bacillus* sp.	*Cyprinus carpio*	increased the growth performances and digestive enzyme activities	[20]
9	*B. coagulans* B16	Tilapia *Oreochromis niloticus*	enhance immune and health status, growth performance	[39]
10	*Bacillus subtilis*	*O. niloticus*	significant improvement in growth parameters	[12]
11	*B. pumilus*	Tilapia *Oreochromis niloticus*	enhanced growth	[40]
12	*Lactobacillus rhamnosus IMC 501*	clownfish larvae	the higher body weight, earlier metamorphosis, and lower deformity incidence	[29]
13	*Lactobacillus acidophilus*	*Cyprinus carpio*	Improved growth performance and total heterotrophic microbial load	[41]
14	*Lactobacillus* **spp.**	**gilthead sea bream** *Sparus aurata***, L.**	increase growth parameters and digestive enzyme activities	[42]
15	*B. subtilis*	**Nile tilapia (***Oreochromis niloticus***)**	**Improved growth, survival and body composition**	[23]
16	*L. rhamnosus*	red sea bream	improvements in growth performance, feed utilization, immune response and oxidative status	[30]
17	*L. lactis* ssp. *lactic* ST G45	Siberian sturgeon (Acipenser baerii)	promote growth performance and boost some immune response	[43]

18	Lactobacillus plantarum Lactobacillus brevis Lactobacillus acidophilus Bacillus subtilis	olive flounder *Paralichthys olivaceus*	enhanced the growth, blood biochemical constituents, and nonspecific immunity	[44]
19	*Lactobacillus delbrukei subsp. Bulgaricus* *L. acidophilus*	**rainbow trout** *Oncorhynchus mykiss*	growth performance by improving digestive enzyme activity, gut microflora and growth gene expression	[36]
20	*Lactobacillus acidophilus*	**Snakehead (***Channa striata***)**	Improved growth and the expression of immune regulatory genes	[28]
21	*L. lactis* *B. subtilis*	**Rohu** *L. rohita*	Better growth, protein efficiency ratio, nutrient retention and digestibility	[45]
22	*L. lactic* L19 *E. faecalis* W24	**snakehead fish (***Channa argus***)**	promoted growth performance, humoral immunity, regulated immune-related genes expression and disease resistance	[34]
23	Bacillus *subtilis* Bacillus licheniformis	**starry flounder,** *Platichthys stellatus*	growth performance, non-specific immune responses and disease resistance	[15]
24	*Lc. lactis* WFLU12	**olive flounder, *Paralichthys olivaceus***		[35]

Conclusion

Antimicrobial activities of probiotic applications reduce the mortality rate by improving their health by supporting the immune responses and oxidative status of fish. However, it increases the growth of fish by improving the feed conversion ratio. In conclusion, it is thought that probiotics and their derivatives in aquaculture can be used reliably instead of antibiotics in healthy fish rearing and organic fishers, and this situation can be supported by future studies.

References

1. Longo S.B., Clark B., York R., Jorgenson A.K. Aquaculture and the displacement of fisheries captures. Conservation Biology – 2019. – Vol. 33 (4). – P. 832-841. DOI: https://doi.org/10.1111/cobi.13295.

2. Ringo E., Van Doan H., Lee S.H., Soltani M., Hoseinifar S.H., Harikrishnan R., et al. Probiotics, lactic acid bacteria and bacilli: interesting supplementation for aquaculture. Journal of Applied Microbiology. – 2020. – Vol. 129(1). – P. 116-136. DOI: https://doi.org/10.1111/jam.14628.

3. Ang C.Y., Sano M., Dan S., Leelakriangsak M., Lal T.M. Postbiotics Applications as Infectious Disease Control Agent in Aquaculture. – 2020. – Vol. 25(1). – P. 1-7. DOI: https://doi.org/10.4265/BIO.25.1.

4. Wanka K.M., Damerau T., Costas B., Krueger A., Schulz C., Wuertz S. Isolation and characterization of native probiotics for fish farming // BMC Microbiology. – 2018. – Vol. 18(1). – P. 19. DOI: https://doi.org/10.1186/s12866-018-1260-2.

5. López Nadal A., Ikeda-Ohtsubo W., Sipkema D., Peggs D., McGurk C., Forlenza M., et al. Feed, Microbiota, and Gut Immunity: Using the Zebrafish Model to Understand Fish Health. Frontiers in Immunology. – 2020. – Vol. 11. – P. 114. DOI: https://doi.org/10.3389/fimmu.2020.00114.

6. Chuphal N., Singha K.P., Sardar P., Sahu N.P., Shamna N., Kumar V. Scope of Archaea in Fish Feed: a New Chapter in Aquafeed Probiotics? Probiotics and Antimicrobial Proteins. – 2021. – Vol. 13. – P. 1668-1695. DOI: https://doi.org/10.1007/s12602-021-09778-4.

7. Hai N.V. The use of probiotics in aquaculture // Journal of Applied Microbiology. – 2015. – Vol. 119 (4). – P. 917-935. DOI: https://doi.org/10.1111/jam.12886.

8. Banerjee G., Ray A.K. The advancement of probiotics research and its application in fish farming industries // Research in Veterinary Science. – 2017. – Vol. 115. – P. 66-77. DOI: https://doi.org/10.1016/j.rvsc.2017.01.016.

9. Oliva-Teles A. Nutrition and health of aquaculture fish // Journal of Fish Diseases. – 2012. – Vol. 35(2). – P. 83-108. DOI: https://doi.org/10.1111/j.1365 - 2761.2011.01333.x.

10. Shokryazdan P., Faseleh Jahromi M., Liang J.B., Ho Y.W. Probiotics: From Isolation to Application // Journal of the American College of Nutrition. – 2017. – Vol. 36(8). – P. 666-676. DOI: https://doi.org/10.1080/07315724.2017.1337529.

11. Ahire J.J., Mokashe N.U., Chaudhari B.L. Effect of Dietary Probiotic Lactobacillus helveticus on Growth Performance, Antioxidant Levels, and Absorption of Essential Trace Elements in Goldfish (Carassius auratus). Probiotics and Antimicrobial Proteins. – 2019. – Vol. 11(2). – P. 559-568. DOI: https://doi.org/10.1007/s12602-018-9428-5.

12. Moustafa M.M., Mohamed M. The influence of some probiotics on the growth performance and intestinal microbial flora of O. niloticus. 8th International Symposium on Tilapia in Aquaculture. – 2008.

13. Williams N.T. Probiotics // American Journal of Health-System Pharmacy. – 2010. – Vol. 67(6). – P. 449-458. DOI: https://doi.org/10.2146/ajhp090168.

14. Sarao L.K., Arora M. Probiotics, prebiotics, and microencapsulation: A review // Critical Reviews in Food Science and Nutrition. – 2017. – Vol. 57(2). – P. 44-371. DOI: https://doi.org/10.1080/10408398.2014.887055.

15. Park Y., Moniruzzaman M., Lee S., Hong J., Won S., Lee J.M., et al. Comparison of the effects of dietary single and multi-probiotics on growth, non-specific immune responses and disease resistance in starry flounder, Platichthys stellatus. Fish and Shellfish Immunology. – 2016. – Vol. 59. – P. 351-357. https://doi.org/10.1016/j.fsi.2016.11.006.

16. Elshaghabee F.M., Rokana N., Gulhane R.D., Sharma C., Panwar H. Bacillus as potential probiotics: Status, concerns, and future perspectives // Frontiers in Microbiology. – 2017. – Vol. 10. – P. 1490. DOI: https://doi.org/10.3389/fmicb.2017.01490.

17. Elisashvili V., Kachlishvili E., Chikindas M.L. Recent Advances in the Physiology of Spore Formation for Bacillus Probiotic Production // Probiotics and Antimicrobial Proteins. – 2019. – Vol. 11(3). – P. 731-747. DOI: https://doi.org/10.1007/s12602-018-9492-x.

18. Mingmongkolchai S., Panbangred W. Bacillus probiotics: an alternative to antibiotics for livestock production // Journal of Applied Microbiology. – 2018. – Vol. 124(6). – P. 1334-1346. DOI: https://doi.org/10.1111/jam.13690.

19. Kuebutornye F.A., Abarike E.D., Lu Y., Hlordzi V., Sakyi M.E., Afriyie G., et al. Mechanisms and the role of probiotic Bacillus in mitigating fish pathogens in aquaculture // Fish Physiology and Biochemistry. – 2020. – Vol. 46(3). – P. 819-841. DOI: https://doi.org/10.1007/s10695-019-00754-y.

20. Yanbo W., Zirong X. Effect of probiotics for common carp (Cyprinus carpio) based on growth performance and digestive enzyme activities // Animal Feed Science and Technology. – 2006. – Vol. 127(3-4). – P. 283-292. DOI: https://doi.org/10.1016/j.anifeedsci.2005.09.003.

21. Liu C.H., Chiu C.H., Wang S.W., Cheng W. Dietary administration of the probiotic, Bacillus subtilis E20, enhances the growth, innate immune responses, and disease resistance of the grouper, Epinephelus coioides // Fish and Shellfish Immunology. – 2012. – Vol. 33(4). – P. 699-706. DOI: https://doi.org/10.1016/j.fsi.2012.06.012.

22. Zhou C., Wang H., Li X., Luo Y., Xie M., Wu Z., et al. Regulatory effect of Bacillus subtilis on cytokines of dendritic cells in grass carp (Ctenopharyngodon idella) // International Journal of Molecular Sciences. – 2019. – Vol. 20(2). – P. 389. DOI:https://doi.org/10.3390/ijms20020389.

23. Opiyo M.A., Jumbe J., Ngugi C.C., Charo-Karisa H. Different levels of probiotics affect growth, survival and body composition of Nile tilapia (Oreochromis niloticus) cultured in low input ponds // Scientific African. – 2019. –Vol. 4. – P. e00103. DOI: https://doi.org/10.1016/j.sciaf.2019.e00103.

24. Gupta A., Gupta P., Dhawan A. Dietary supplementation of probiotics affects growth, immune response and disease resistance of Cyprinus carpio fry // Fish and Shellfish Immunology. – 2014. – Vol. 41(2). – P. 13-9. DOI: https://doi.org/10.1016/j.fsi.2014.08.023.

25. Hatti-Kaul R., Chen L., Dishisha T., Enshasy H.l. Lactic acid bacteria: From starter cultures to producers of chemicals // FEMS Microbiology Letters. – 2018. – Vol. 365(20). – P. 1-20. DOI: https://doi.org/10.1093/femsle/fny213.

26. Teame T., Wang A., Xie M., Zhang Z., Yang Y., Ding Q. et al. Paraprobiotics and Postbiotics of Probiotic Lactobacilli, Their Positive Effects on the Host and Action Mechanisms // A Review. Frontiers in Nutrition. – 2020. – Vol. 7. – P. 570344. DOI: https://doi.org/10.3389/fnut.2020.570344.

27. Giraffa G., Chanishvili N., Widyastuti Y. Importance of lactobacilli in food and feed biotechnology // Research in Microbiology. – 2010. – Vol. 161(6). – P. 480. DOI: https://doi.org/10.1016/j.resmic.2010.03.001.

28. Munir M.B., Hashim R., Chai Y.H., Marsh T.L., Nor S.M. Dietary prebiotics and probiotics influence growth performance, nutrient digestibility and the expression of immune regulatory genes in snakehead (Channa striata) fingerlings // Aquaculture. – 2016. – Vol. 460. – P. 59-68. DOI: https://doi.org/10.1016/j.aquaculture.2016.03.041.

29. Avella M.A., Olivotto I., Silvi S., Place A.R., Carnevali O. Effect of dietary probiotics on clownfish: A molecular approach to define how lactic acid bacteria modulate development in a marine fish // American Journal of Physiology - Regulatory Integrative and Comparative Physiology. – 2010. – Vol. 298(2). – P. 359-371. DOI: https://doi.org/10.1152/ajpregu.00300.2009.

30. Dawood M.O., Koshio S., Ishikawa M., El-Sabagh M., Esteban M.A., Zaineldin A.I. Probiotics as an environment-friendly approach to enhance red sea bream, Pagrus major growth, immune response and oxidative status // Fish and Shellfish Immunology. – 2016. – Vol. 57. – P. 170-178. DOI: https://doi.org/10.1016/j.fsi.2016.08.038.

31. Yu L., Zhai Q., Zhu J., Zhang C., Li T., Liu X. et al. Dietary Lactobacillus plantarum supplementation enhances growth performance and alleviates aluminum toxicity in tilapia // Ecotoxicology and Environmental Safety. – 2017. – Vol. 143. – P. 307-314. DOI: https://doi.org/10.1016/j.ecoenv.2017.05.023.

32. Pourgholam M.A., Khara H., Safari R., Sadati M.Y., Aramli M.S. Dietary Administration of Lactobacillus plantarum Enhanced Growth Performance and Innate Immune Response of Siberian Sturgeon, Acipenser baerii // Probiotics and Antimicrobial Proteins. – 2016. – Vol. 8(1). – P. 1-7. DOI: https://doi.org/10.1007/s12602-015-9205-7.

33. Soltani M., Pakzad K., Taheri-Mirghaed A., Mirzargar S., Shekarabi P.H., Yosefi P., et al. Dietary Application of the Probiotic Lactobacillus plantarum 426951 Enhances Immune Status and Growth of Rainbow Trout (Oncorhynchus mykiss) Vaccinated Against Yersinia ruckeri // Probiotics and Antimicrobial Proteins. – 2019. – Vol. 11(1). – P. 207-219. DOI: https://doi.org/10.1007/s12602-017-9376-5.

34. Kong Y., Gao C., Du X., Zhao J., Li M., Shan X., et al. Effects of single or conjoint administration of lactic acid bacteria as potential probiotics on growth, immune response and disease resistance of snakehead fish (Channa argus) // Fish and Shellfish Immunology. – 2020. – Vol. 102. – P. 412-421. DOI: https://doi.org/10.1016/j.fsi.2020.05.003.

35. Nguyen T.L., Park C.I., Kim D.H. Improved growth rate and disease resistance in olive flounder, Paralichthys olivaceus, by probiotic Lactococcus lactis WFLU12 isolated from wild marine fish // Aquaculture. – 2017. – Vol. 471. – P. 113-120. DOI: https://doi.org/10.1016/j.aquaculture.2017.01.008.

36. Mohammadian T., Nasirpour M., Tabandeh M.R., Heidary A.A., Ghanei-Motlagh R., Hosseini S.S. Administrations of autochthonous probiotics altered juvenile rainbow trout Oncorhynchus mykiss health status, growth performance and resistance to Lactococcus garvieae, an experimental infection // Fish and Shellfish Immunology. – 2019. – Vol. 86. – P. 269-279. DOI: https://doi.org/10.1016/j.fsi.2018.11.052.

37. Wang Y.B., Tian Z.Q., Yao J.T., Li W. Effect of probiotics, Enteroccus faecium, on tilapia (Oreochromis niloticus) growth performance and immune response // Aquaculture. – 2008. – Vol. 277(3-4). – P. 203-207. DOI: https://doi.org/10.1016/j.aquaculture.2008.03.007.

38. Abd El-Rhman A.M., Khattab Y.E., Shalaby A.E. Micrococcus luteus and Pseudomonas species as probiotics for promoting the growth performance and health of Nile tilapia, Oreochromis niloticus // Fish and Shellfish Immunology. – 2009. – Vol. 27. – P. 175-180. DOI: https://doi.org/10.1016/j.fsi.2009.03.020.

39. Zhou X., Tian Z., Wang Y., Li W. Effect of treatment with probiotics as water additives on tilapia (Oreochromis niloticus) growth performance and immune response // Fish Physiology and Biochemistry. – 2010. – Vol. 36(3). – P. 501-509. DOI: https://doi.org/10.1007/s10695-009-9320-z.

40. Aly S.M., Mohamed M.F., John G. Effect of probiotics on the survival, growth and challenge infection in Tilapia nilotica (Oreochromis niloticus) // Aquaculture Research. – 2008. – Vol. 9(6). – P. 647-656. DOI: https://doi.org/10.1111/j.1365-2109.2008.01932.x.

41. Ramakrishnan C.M., Haniffa M.A., Manohar M., Dhanaraj M., Arockiaraj A.J., Seetharaman S. et al. Effects of probiotics and spirulina on survival and growth of juvenile common carp (Cyprinus carpio) // Israeli Journal of Aquaculture - Bamidgeh. – 2008. – Vol. 60(2). – P. 128-133.

42. Suzer C., Çoban D., Kamaci H.O., Saka Ş., Firat K., Otgucuoğlu Ö., et al. Lactobacillus spp. bacteria as probiotics in gilthead sea bream (Sparus aurata, L.) larvae: Effects on growth performance and digestive enzyme activities // Aquaculture. – 2008. – Vol. 280(1-4). – P. 140-145. https://doi.org/10.1016/j.aquaculture.2008.04.020.

43. Geraylou Z., Souffreau C., Rurangwa E., De Meester L., Courtin C.M., Delcour J.A., et al. Effects of dietary arabinoxylan-oligosaccharides (AXOS) and endogenous probiotics on the growth performance, non-specific immunity and gut microbiota of juvenile Siberian sturgeon (Acipenser baerii) // Fish and Shellfish Immunology. – 2013. – Vol. 35(3). – P. 766-775. DOI: https://doi.org/10.1016/j.fsi.2013.06.014.

44. Harikrishnan R., Kim M.C., Kim J.S., Balasundaram C., Heo MS. Probiotics and herbal mixtures enhance the growth, blood constituents, and nonspecific immune response in Paralichthys olivaceus against Streptococcus parauberis // Fish and Shellfish Immunology. – 2011. – Vol. 31(2). – P. 310. DOI: https://doi.org/10.1016/j.fsi.2011.05.020.

45 . Mohapatra S., Chakraborty T., Prusty A.K., Das P., Paniprasad K., Mohanta K.N. Use of different microbial probiotics in the diet of rohu, Labeo rohita fingerlings: Effects on growth, nutrient digestibility and retention, digestive enzyme activities and intestinal microflora // Aquaculture Nutrition. – 2012. – Vol. 18(1). – P. 1-11. https://doi.org/10.1111/j.1365-2095.2011.00866.x.

Ф.Ғ. Сағымбек[1], А.Д. Серикбаева[2], Т.Б. Абдигалиева[1], Р. Елназарқызы[3]
[1]Алматы технологиялық университеті, Алматы, Қазақстан
[2]Қазақ ұлттық аграрлық зерттеу университеті, Алматы, Қазақстан
[3]С. Сейфуллин атындағы Қазақ агротехникалық университеті, Астана, Қазақстан

Пробиотиктер және оларды балықтардың өсуі мен иммунитетін жақсарту үшін аквакультурада қолдану

Аңдатпа. Азықтың қорытылуы мен сіңімділігін арттыру, жануарлардың өсуі мен дамуын ынталандыру, спецификалық емес иммунитетті арттыру үшін ферменттік, пробиотикалық, пребиотикалық және аралас ферменттік-пробиотикалық препараттар, сондай-ақ фитокомпоненттермен байытылған кешенді пробиотикалық препараттар қолданылады.

Жасанды өсірілген балыққа арналған пробиотиктер-бұл денсаулықты, өнімділікті және өсуді сақтау үшін дәстүрлі түрде аквакультура ауылшаруашылық жүйелеріне қосылатын пайдалы бактериялар және тірі микробиалды қоспалар. Сондықтан аквакультурадағы перспективалы бағыт пробиотикалық дақылдармен жемді пайдалану болып табылады. Пробиотиктерді қолдану денсаулықтың әртүрлі мәселелерін шешумен, нақтырақ айтатын болсақ ас қорыту тиімділігін арттырумен, өсу мен дамуды ынталандырумен байланысты. Пробиотиктер иесінің ағзасына оң әсер ете отырып, ас қорытуды, биологиялық мәртебені, иммундық реакцияны қалпына келтіруге ықпал етеді және вакцинацияның тиімділігін арттырады. Пробиотиктерді қолдану жануарлардағы ауруларды емдеуге кететін шығындарды едәуір азайтады, өнімділікті арттырады және өнім сапасын жақсартады. Соңғы жылдары балық шаруашылығында әртүрлі пробиотиктерді қолдану бойынша бірқатар зерттеулер жүргізілді. Бұл шолу қолданыстағы әдебиеттерді жан-жақты зерттей отырып, пробиотиктер ретінде грам-позитивті бактерияларды ықтимал қолдану тақырыбын жалпылауға бағытталған. Пробиотиктердің биологиялық тиімділігі туралы түсініктердің кеңеюімен және жасушалардың құрылымдық элементтері мен олардың метаболиттері кейбір жағдайларда кем дегенде тиімді екенін дәлелдеу болып табылады.Нәтижесінде әр түрлі балықтардың өсуі мен иммунитетін жақсарту үшін бактериялардың әртүрлі түрлері, соның ішінде бациллалар, сүт қышқылы бактериялары, микрококтар қолданылды. Алайда, бұл зерттеу аквакультурадағы пробиотиктердің жалпы балық өнімділігіне оң әсер ететінін көрсететін ғылыми әдебиеттерге шолу жасалды.

Түйін сөздер: пробиотиктер, аквакультура, балық, бактериялардың штамы, шолу, сүт қышқылды бактериялар, азық.

Ф.Ғ. Сағымбек[1], А.Д. Серикбаева[2], Т.Б. Абдигалиева[1], Р. Елназарқызы[3]
[1]Алматинский технологический университет, Алматы, Казахстан
[2]Казахский национальный аграрный исследовательский университет, Алматы, Казахстан
[3]Казахский агротехнический университет им. С. Сейфуллина, Астана, Казахстан

Пробиотики и их применение в аквакультуре для улучшения роста и иммунитета рыб

Аннотация. *Для* повышения усвояемости кормов, стимулирования роста и развития животных, повышения неспецифического иммунитета используются ферментные, пробиотические, пребиотические и комбинированные ферментно-пробиотические препараты, а также комплексные пробиотические препараты, обогащенные фитокомпонентами.

Пробиотики *для* искусственно выращенной рыбы - это полезные бактерии и живые микробиологические добавки, которые традиционно добавляются в сельскохозяйственные системы аквакультуры *для* поддержания здоровья, продуктивности и роста. Поэтому перспективным направлением в аквакультуре является использование кормов с пробиотическими культурами. Использование пробиотиков связано с решением различных проблем со здоровьем, в частности, с повышением эффективности пищеварения, стимуляцией роста и развития. Пробиотики, положительно воздействуя на организм хозяина, способствуют восстановлению пищеварения, биологического статуса, иммунного ответа и повышают эффективность вакцинации. Использование пробиотиков значительно снижает затраты на *лечение* заболеваний у животных, повышает продуктивность и улучшает качество продукции. В последние годы был проведен ряд исследований по использованию различных пробиотиков в рыболовстве. Этот обзор направлен на обобщение темы возможного использования грамположительных бактерий в качестве пробиотиков при всестороннем изучении существующей *литературы*. С расширением представлений о биологической эффективности пробиотиков и доказательством того, что структурные элементы клеток и их метаболиты в некоторых случаях по крайней мере эффективны. В результате различные виды бактерий, в том числе бациллы, молочнокислые бактерии, микрокки, использовались *для* улучшения роста и иммунитета различных рыб. Однако в этом исследовании был проведен обзор научной *литературы*, показывающий, что пробиотики в аквакультуре положительно влияют на общую продуктивность рыб.

Ключевые слова: пробиотики, аквакультура, рыба, штамм бактерий, обзор, молочнокислые бактерии, корм.

Information about authors:

Sagymbek F.G. – Master of Engineering and Technology, Almaty Technological University, doctoral student of Department of Food Biotechnology, 100 Tole bi street, Almaty, Kazakhstan.

Serikbayeva A.D. – Doctor of Biological Sciences, Kazakh National Agrarian Research University, Professor of the Department of Food Technologies and Safety, 28 Abay avenue, Almaty, Kazakhstan.

Abdigaliyeva T.B. – PhD, Acc. Professor, Almaty Technological University, 100 Tole bi street, Almaty, Kazakhstan.

Yelnazarkyzy R. – PhD, S. Seifullin Kazakh Agro Technical University, Astana, Kazakhstan.

Сағымбек Ф.Ғ. – техника және технология магистрі, «Тағам биотехнологиясы» кафедрасының докторанты, Алматы Технологиялық Университеті, Төле би көшесі 100, Алматы, Қазақстан.

Серикбаева А.Д. – биология ғылымдарының докторы, тамақ технологиялары және қауіпсіздік кафедрасының профессоры, Қазақ ұлттық аграрлық зерттеу университеті, Абай даңғылы 28, Алматы, Қазақстан.

Абдигалиева Т.Б. – PhD, қаум. профессор, Алматы технологиялық университеті, Төле би көшесі 100, Алматы, Қазақстан.

Елназарқызы Р. – PhD, С. Сейфуллин атындағы Қазақ агротехникалық университеті, Астана, Қазақстан.