

Aquaculture and Probiotics: An Emerging Opportunity Integrating Conventional Farming to Biotechnology

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Abstract

The probiotics are generally defined as beneficial organisms showing beneficial effects under certain amount. Vigorous research has demonstrated the potential of probiotics in a number of conditions, including prevention of diseases, management of proper health status among humans. In contrast, the role of probiotics in animal is not much studied in comparison to human probiotics despite their great potential of improvement of several biotechnological industries. The role of probiotics in fish growth is also evident in a number of studies. Proper knowledge of suitable probiotic strain in addition to information about probiotics for their increased yield can get astonishing results for their potential in improvement of pisciculture industry. Though natural bacteria may exert probiotics effects on fish growth, but the cataloging of probiotics need more in-depth studies for identification of proper conditions and bacterial strains for maximum utilization. This article highlights current status of probiotics in fish industry their knowledge gaps and potential opportunities.

Keywords: Probiotics, growth, fish industry, siderophores, aquaculture

INTRODUCTION

Addition of beneficial bacteria for improving health and growth of fishes and shrimps is already well established. Significant research interest arose after detection of biotechnological potential of probiotics in improving sustainability in addition to direct effects on aquaculture productivity [1]. Several diseases are known to affect the productivity of fish industry and generally it is affected by exposure to different pathogens and environmental conditions in addition to host susceptibility of different cultivated organisms. The probiotic bacteria normally growing with an animal or human confers several beneficial effects due to their ability to protect the host for their own survival [2, 3]. The natural diversity of bacteria is so huge that these beneficial bacteria are not limited to a particular environment, and we can find them associated with all sorts of animal species [4].

Infectious outbreaks are linked to significant economic loss worldwide, including a loss of nearly 750 million dollar reported in China in 1993 only, while India reported a loss of 210 million dollar during 1995–1996 due to these infectious outbreaks and these are majorly related to poor farm environment, genetic factors, nutritional abnormality and production of toxins [5]. Probiotics are able to improve overall environment by exerting multiple effects on whole aquaculture system. The high organic matter in water supports the growth of several bacteria including pathogens. In contrast, probiotics are the substances with the ability to promote the growth of probiotics. While considering huge diversity of bacteria coupled with their wide metabolic mechanisms, some beneficial environmental bacteria can grow on these organic matters and thus solve the dual purpose of reducing

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Received Date: September 27, 2021

Accepted Date: November 19, 2021

Published Date: January 10, 2022

Citation: Fozia Farooq, Basma Hussain, Tajdar Husain Khan. Aquaculture and Probiotics: An Emerging Opportunity Integrating Conventional Farming to Biotechnology. Research & Reviews: Journal of Veterinary Science and Technology. 2021; 10(3): 12–17p.

harmful organic waste and resultant pathogens [6]. Since the aquaculture system relies on quality of water including the amount of organic matters, this is a primary requirement for the growth of fishes and shrimps.

Moreover, the degradation of organic substances generates several toxic substances and reduces oxygen and probiotic bacteria can play an important role in checking this process. In addition to exerting several environmental benefits, probiotics can also directly influence fish growth in a number of ways. It is important to understand underlying mechanisms for beneficial effects of probiotics for growth of aquaculture system. We compiled here introductory information about role of probiotics in aquaculture and their knowledge gaps for providing better information about this aspect of aquaculture industry. This work was intended to provide an overview of probiotics with mechanistic aspects in improving yield from pisciculture industry through utilization of biotechnological approaches.

HOST BENEFITS OF PROBIOTICS IN AQUACULTURE

Probiotics are known to exert several direct benefits to the cultivated aquaculture species. These benefits may range from competitive inhibition of pathogens to production of certain direct substances for killing harmful organisms. During the course of evolution, bacterial have developed several mechanisms for their competitive advantage in ecosystem. They are able to produce a wide variety of chemical mediators with the ability to either kill the bacteria or inhibit their growth [7–9]. Figure 1 represents some of the key mediators involved in this process.

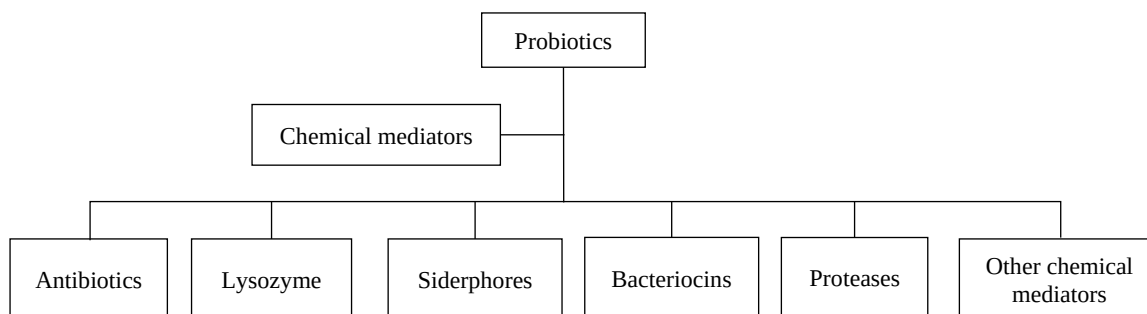


Figure 1. Some chemical mediators secreted by probiotics.

POTENTIAL MECHANISMS FOR DIRECT HOST BENEFITS

The probiotics bacteria can influence aquaculture system through a number of mechanisms. The antimicrobial substances secreted by these beneficial bacteria can directly affect pathogens and therefore prevent several diseases in the aquaculture industry [10]. Moreover, these bacteria are known to influence microbial quorum sensing affecting their ability to communicate with the environment and thus influencing their overall pathogenesis and survival. The quorum quenching molecules produced by probiotics are able to inhibit growth of several bacteria [11].

IMMUNOMODULATORY ABILITY OF PROBIOTICS

The probiotics are also known to exert several direct benefits for growth of aquaculture animals. In addition, to their ability for prevention of infection as mentioned in earlier text, the probiotics bacteria are also known to provide immunomodulatory activity and therefore support host immune response which affects the overall growth of animals. Several studies have investigated role of probiotics on the immune status of aquaculture animals, including localized and systemic effects on both innate and adaptive component of immune system [12].

Probiotics bacteria can enhance barrier function and modulate several signaling event at localized level leading to immunomodulation in animals. In addition, these signaling events coupled with secretion of certain metabolites in systemic circulation affects overall systemic immunity [13]. These

modulations are primarily related to innate component of immunity and therefore affect aquaculture animals as they primarily rely on this branch of immunity for any potential infectious threat.

The gut microbiota of these animals also harbors a large number of microbiota organisms similar to human being and they provide a number of benefits to animal. For example, these microbiota organisms exert anti-inflammatory activity and regulate balanced production of anti and pro inflammatory cytokines. For example, addition of commercial probiotics Aquastar® Growout on tilapia fish found that it can regulate gene expression of IL-10 and TGF beta those are involved in anti-inflammatory response [14]. Therefore, these organisms can be used to regulate inflammatory response and resultant diseases in animals.

PROBIOTICS USED IN AQUACULTURE INDUSTRY

Several articles have catalogued probiotics strains used in aquaculture industry. Their first use in aquaculture industry was proposed in 1986 with the objective to test increased hydrobionts growth under the influence of these bacteria [15]. The role of probiotics as growth promoter for animals was reported with *Bacillus toyoi* in 1986 [16]. Probiotics are generally identified as an agent with the ability to reduce mortality of fish larvae [17]. Some probiotics are already known to reduce harmful bacteria in ponds. For example, *Bacillus* spp. is shown to decrease pathogenic *Vibrio* spp. in shrimp ponds [18]. Moreover, probiotics are known to exert beneficial effects through alteration of microbial metabolism, induction of host immunity, enhanced animal's appetite through production of vitamins, detoxification of the toxic metabolites, and help in digestion of complex indigestible compounds [19]. Figure 2 present few mechanisms for beneficial effects of probiotics in aquaculture animals.

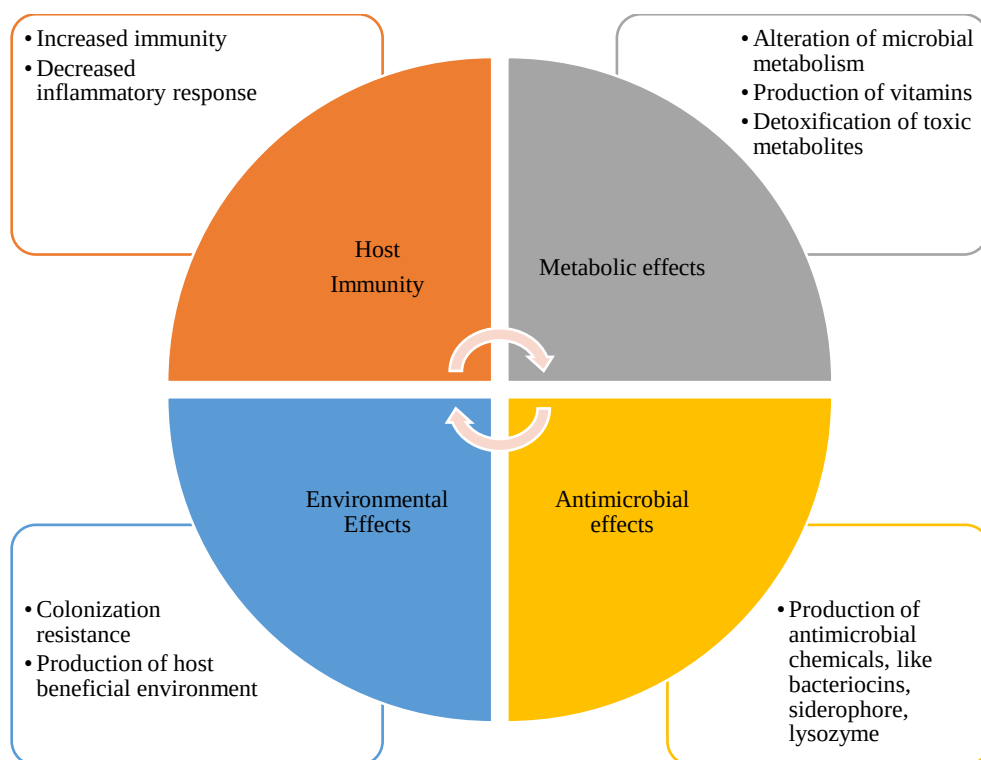


Figure 2. Schematic representation of beneficial mechanisms of probiotics in aquaculture.

The rationale for selection of probiotics strains for aquaculture involves in-vivo and in-vitro pilot level screening followed by pathogenicity testing against target organisms and selection of strains showing beneficial effects at all steps involved [20]. Probiotics are generally belonged to genera *Bifidobacterium*, *Lactobacillus*, and *Streptococcus* and different species are used to exert beneficial effects [21]. Table 1 summarizes few probiotics used in aquaculture for various applications.

Table 1. Some representative probiotics used in aquaculture industry with their related applications.

Probiotic bacteria	Animal host	Application
Bacillus sp	Penaeid aquaculture ponds	Control of harmful <i>Vibrio</i> [18]
<i>Enterococcus faecium</i> SF68 and <i>Bacillus toyoi</i>	European eel, <i>Anguilla anguilla</i> L	Reducing edwardsiellosis [22]
<i>Lactobacillus rhamnosus</i>	<i>Oncorhynchus mykiss</i>	Protection from furunculosis [23]
Supplementation of diets with different yeast	juvenile <i>Penaeus vannamei</i>	Enhancement of vibriosis resistance [24]
<i>Lactobacillus acidophilus</i>	African catfish <i>Clarias gariepinus</i> juveniles	Biocontrol agent against common pathogenic bacteria and the effects on the haematology parameters and histopathology [25]
<i>Bacillus</i> NL110 and <i>Vibrio</i> NE17	<i>Macrobrachium rosenbergii</i>	Probiotic effect on the survival, growth performance and immune response [26]
<i>Lactobacillus acidophilus</i>	African Catfish (<i>Clarias gariepinus</i>)	Effects of the probiotic on the growth performance, haematology parameters and immunoglobulin concentration [27]
B. coagulans SC8168	larvae shrimp (<i>Penaeus vannamei</i>)	Effect of probiotic on water quality, survival rate and digestive enzyme activities [28]
Lactic Acid Bacteria (LAB) strain <i>Lactobacillus delbrueckii delbrueckii</i>	European sea bass juveniles (<i>Dicentrarchus labrax</i> , L.),	Growth improvement by probiotic with particular attention to IGF-1, myostatin and cortisol gene expression [29].

SAFETY CONSIDERATIONS AND CONCLUDING REMARKS

Generally, probiotics are considered safe [30] but it was suggested be involved in certain adverse events only in susceptible individuals, including infections, abnormal metabolic activities and immune enhancements and gene transfer, though enough scientific evidences are not available to support this claim. These few adverse events are observed in patients with weak or abnormal immune response [31]. Some reports of probiotic mediated adverse events are also reported in aquaculture industry. For example, frequent use of *Bacillus subtilis* was found to be associated with bacterial white spot syndrome (BWSS) in *Penaeus monodon*, these spots were similar to viral white spot syndrome which very deadly and infectious [15]. The use of raw or half cooked aquaculture products also raises concern for infection caused due to residual probiotics present in certain animals and need detailed investigations [32]. These concerns present challenges in front of scientific community to evaluate safety aspects of probiotics in aquaculture. In addition, the development of probiotics from animal feed for growth of probiotics can provide significant ways to increase productivity of aquaculture industry.

CONCLUSION

Though, the role of probiotics is widely known for several health benefits, its understanding for application in pisciculture industry is still not much known. Though, recent studies are emerging with identification of several beneficial aspects of probiotics for aquaculture industry, still more work is required to utilize their benefits at maximum scale. Certainly, future research will open new avenues for this task and this work will provide necessary information in achieving this goal.

Conflict of Interest

FF and BH are co-founders of Innovatek Biosolutions LLP and THK is founder of Aspire Biosolutions. Both organizations are involved in development of biotechnology/healthcare products and services.

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