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Bacillus Species beyond Antibiotics: The Tiny Superheroes of Aquaculture

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INTRODUCTION

Biotics in aquaculture are now an emerging and promising technology in global feed industry. Recently global aquaculture industry surpass capture industry .which will increase the market demand of artificial feed and growing market demand will come with many new challenges like antibiotic resistance, environmental sustainability, feed efficiency. To promote good life balance probiotics, prebiotics, synbiotics, postbiotics were used as ecofriendly alternatives. Probiotics are mainly the good bacteria, prebiotics are the food for the good bacteria, synbiotics mixture of both food and good bacteria and postbiotics are mainly the byproducts derive from them respectively. For example *Lactobacillus delbrueckii* subsp. *bulgaricus* India's national microbe is a probiotic mainly consumed involved in fermentation of yogurt and cheese. Among all live microorganisms bacteria from *Bacillus* genus occur widely in the aquatic environment, used as tiny superhero in aquaculture, food industry and food product at the point of sale. These bacteria earn this status because they not only boost fish and shrimp health, growth, survival, water quality but also promote sustainable farming by replace antibiotics.

Bacillus spp. are spore forming, Gram-positive, rod shape (2.5-10μm) chemoheterotrophic bacteria that can synthesize antimicrobial compound, on toxic, nonpathogenic, has ability to sporulate and quorum quenching properties. Application and mode of action bacillus vary according to two separate type of administration i.e. as an aquatic microbe mainly use to solve the problem like nitrification, de-nitrification, water quality and pathogen and gut microbes which are helpful for disease and stress resistance, improvement of digestion and digestive enzyme, promote growth, reproduction and immune function. Probiotic can be applied in aquaculture via feed, water immersion, spraying, or injection, with feed and water methods. There are for about 500 described species of bacillus genus but ongoing genomic reclassifications have moved many in new genera leaving the core genus with around 200-300 valid species as of recent taxonomy.

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Only few species like *B. subtilis* (mainly utilize for gut health, growth promotion, vibrio control in fish and shrimp),*B. licheniformis* (improve feed digestibility, water quality, biofloc stability), *B. clausii* (used for spore stability, immunity boost), *B. velezensis* (helpful in enzyme production, disease resistance),*B. amyloliquefaciens* (have anti-algal effect and promote nutrient cycling), *B. coagulans* (known for stress tolerance and provide better larval survival) dominate aquaculture and covers 90%+ commercial product.

B. subtilis known for secreting antimicrobial peptide like (subtilin, Subtilosin)and competes via quorum quenching. Scientist recommended keeping the doses range of this species should be 10^{8}-10^{10} CFU/Kg feed or 10^{6}CFU/L water weekly, with spores viable 6-12 months in saline feed. It slashes antibiotic needs by 70-90%, cuts water exchanges, and boosts survival/growth (e.g., 20% faster in SE Asia shrimp farms). The efficacy of probiotic varies for the different aquaculture fish species and their growth stages. Particularly supplementation of *B. subtilis* in tilapia (*Oreochromis niloticus*), crucian carp (*Carassius auratus var. Pengze*), eel (*Anguilla japonica*), Giant seaperch (*Lates calcarifer*) and whiteleg shrimp (*Litopenaeus vannamei*) production system was recommended and resulted better health and growth. As a result of probiotic's metabolic activity post biotics are released *B. subtilis* exhibited significantly higher antibacterial activity against various pathogenic strains, enhance biofilm formation and enhance antioxidant activity. Immune related gene expression (IL-1β, IL-10, IFN-γ, and TNF-α) up-regulation in *labeo rohita* as postbiotics properties make it a promising application in aquaculture. Powders, feed additives, and multi-strain blends (as a water sprays boost blood health, infection resistance, cutting death by 20-30%) are available at Indian market for the fish farmer. According to different scientist its addition in RAS(system cleans the aquaculture waste effectively. Farmers are recommended to dose it weekly to remove 94% earthy tastes (geosmin) and 97% odors (2-MIB).this turns pond waste in high protein biofloc feed (35% more protein) for better digestion and gut bacteria balance. There are different strain of this species like *DDKRC1and ANSB060* are also available, already tested in *P. monodon* and *C. carpio* respectively Provide better growth, immunity decreased aflatoxin B1 residues in hepatopancreas. it is embodies resilience in health, immune, nutrition, fisheries and environment make this particular species i.e. *Bacillus subtilis* was declared Kerala's official state microbe in January 2026, making it the first Indian state to designate one.

Another commonly available species named b. licheniformis has been commonly studied in some crustaceans i.e. Macrobrachium, white leg shrimp (*Litopenaeus vannamei),penaeus japonicas* and sea cucumbers. its mainly reduce skin ulcerative syndrome in sea cucumber, it slashes mortality by 40%. Recent 2025 studies highlight it's target use in high value species like sea cucumbers, Blue swimming crab (*Portunus pelagicus*), Chinese mitten crab (*Eriocheir sinensis*),Mud crab and Gilthead seabream (*Sparus aurata*). its mainly reduce skin ulcerative syndrome in sea cucumber, it slashes mortality by 40%. Reduce Vibrio counts (e.g., *V. parahaemolyticus, V. vulnificus*) by 50-70% in shrimp like *Penaeus vannamei* ponds, Protect Chinese mitten crab against *Citrobacter freundii* (cutting mortality by 30-50%) and water dosing enhances blood health (PCV, RBCs) and resistance to bacterial pathogens. Integration of both *B.subtilis* and *B.licheniformis* help full for increased resistance to *Yersinia ruckeri* in the species *O. mykiss* A strain of this particular species P40 from teleost fish *leporinus sp*. was reported to produce broad spectrum antibacterial peptide against pathogenic and spoilage organism. *B. licheniformis* dosages for aquaculture vary according to the species, systems and application. Normally 10^{6}-10^{9} CFU/Kg in feed or0.2-3g/kg feed was recommended by the scientist but need to adjust for water volume and frequency. Shrimp like *Penaeus vannamei* were given 2-3g/kg feed for moulting. Crabs needed 6ml/kg little higher than the other species recommended by some scientist. Sometimes depend on the water condition like ammonia drops (1g/kg) also recommended by aquaculture specialist.

Other Bacillus species named *B. clausii* surpass antibiotic by commendable spore stability that endures harsh pond condition even above heat greater than 80^{0}C and extreme pH.it is also helpful lysozyme/phagocyte enhancement and gut barrier fortification, while reducing vibrio loads. In case of *P. vennamei* its elevate antioxidant enzyme, haemocytes and cytokines cutting stress mortality by 20-40% during EMS (Early Mortality Syndrome) outbreak. A strain of *B. amyloliquwfanciens* HN helpful for remove

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nitrite-N efficiently up to 20mg/L at proper pH-8 and 300c and often combined with clay for algal bloom control. Some scientist recommended dose 10^8 CFU/g feed for shrimp of *B.coagulans* to resist AHPND (Acute Hepatopancreatic necrosis disease) in shrimp by elevating antioxidant (SOD/CAT)and immunity over antibiotics. There is also recommendation of *B.aerius* and *B.circulans* for the fish species like *Pangasius bocourti* and *Labeo rohita* to improve growth performance, feed conversion ratio, and blood profiles. Scientist also confirm *B. velezensis* BV1704-Y holds promise as an effective probiotic for protecting zebrafish against *A. hydrophila* infection, offering potential benefits for the aquaculture.

Now there is many available probiotic are in the market but farmer also suggested must exercise caution while using probiotic because now researcher found presence of antimicrobial resistance gene in bacillus probiotic which indicates a potential risks to one health. *B.clausii* and *B.coagulan* generally safe but if poorly sourced it may carry genes like (beta-lactams, tetracycline) to human gut pathogens which are antibiotic resistance. Some bacillus species also known that may harbor virulence genes producing cytotoxin or enterotoxin. Always verify strain-specific safety via genomic screening, hemolytic/antibiotic tests, and reputable suppliers to avoid gene transfer compromising One Health. Farmer must take recommendation from aquaculture specialist before using any probiotic. To get the most out of the probiotic, the researcher must prioritize a specific dose and time based on the circadian rhythm of the culture species. Aquaculture is revolutionized by Bacillus probiotics, which are powerful antibiotic substitutes that provide unparalleled immunity, growth, and improvements in water quality—but only after thorough strain screening to avoid AMR and toxin hazards. For risk-free, sustainable farming that surpasses chemical crutches, give priority to certified, tested products at precise dosages.