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Phytotherapy and combined nanoformulations as a promising disease management in aquaculture: a review

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Abstract

Aquaculture-based foods have enriched nutritional and medicinal value to meet the needs of the global population. Recently, improper maintenance of aquatic organisms in aquaculture sector led to the outbreak of infectious diseases by pathogens. Treatment of disease by conventional methods (chemical) causes adverse effects to culturing organisms, the environment, and even to consumers. As an alternative to conventional methods, a variety of medicinal plant compounds like curcumin, quercetin, silymarin, Ajoene, and caffeic acid were used for disease control since they enhance the non-specific immunity. Phytotherapy-based techniques/compounds were preferred by aqua industry to develop resistance against a variety of aquatic pathogens in culture organisms since they are inexpensive and eco-friendly. Recent advances in nanotechnology pave the way to incorporate various medicinal plant-based nanoformulations to control aquatic microbial pathogens. Therefore, this review expresses in detail the versatile uses of phytotherapies and their based nanoformulation as a promising tool for disease management in aquaculture.

Highlights

• Aquaculture and their food was highly nutritive, market value. During culture practices easily affected by pathogens leads to loss of social—economic value.
• Using of chemicals causes adverse effects in culturing organisms, consumer producer and environment.
• In this review explains about using of herbs and their consequences in aquaculture industry and their beneficial effects such as increase production rate, stress relief agent, Aphrodisiac activity, Anti- pathogenic activity and also act as immunostimulants.
• Using of herbal based medicine in aquaculture industry safe to environment, farmer, consumer level. Hence to farming "ORGANIC AQUACULTURE"

Keywords Aquaculture · Pathogens · Plants · Nanoformulation · Disease management · Immunostimulant

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Introduction

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans, and aquatic plants in water ecosystems both marine and freshwater (FAO 2016). It provides high-quality nutritive foods and job opportunities and also increases the economy of the country (Martinez-Porchas and Martinez-Cordova 2012). When aquaculture production becomes intensive, it will increase the outbreak of diseases in aquatic organisms due to several factors such as environment, host, pathogen, and pollution (Snieszko 1974; El Hajam et al. 2020). During culture practices, aquatic organisms contract illness due to various infectious diseases caused by bacteria, viruses, fungi, protozoa, and helminthic parasite (Bondad-Reantaso et al. 2005). Controlling infectious diseases in the aquaculture industry helps to raise the economic and socioeconomic levels of all countries in the world (Subasinghe 2009). Aquaculture management focuses on preventing and treating diseases using prophylactic approaches including chemotherapeutants, antibiotics, and vaccines. The continuous use of these prophylactic measures in the aquaculture sector leads to the development of resistant pathogens. Furthermore, their residue persists in the environment and enters all aquatic organisms (Romero et al. 2012). At this point in time, aquaculture focuses on a high level of production, promising food safety and preventing diseases in aquatic organisms. Moreover, the application of plants and their consequent were applied in aquaculture to overcome the development of microbial resistance in aquaculture industry as they are rich in assortment of nutrients (Hasan 2000). They can be administered as an entire plant or parts by the use of amalgamation of extract compounds, or erstwhile immunostimulants. Being environmental cheaper, plants shows minimum side effects and hence used as option to antibiotics in fishery industry. The relevance of plants as natural and undamaging composite has probable in aquaculture as a substitute for antibiotics (Van Hai 2015). Natural plant products present a practicable supplement in the aquatic organisms that have the characteristics as growth promoting capability, strength, operate as appetite stimulators, boost to perk up the immune system, persuade maturation and amplify feed burning up, and protect the organisms from pathogen such as bacteria, virus, fungi, and parasite that will be enormously used in the culture of aquatic organisms (Dawood et al. 2021; Hodar et al. 2021) and decrease the side effects of artificial compounds, outlay, and green approaches. There is an urgent need of a new innovative method, and in this aspect, the progress of a variety of nanoformulation (especially nanoparticles) combined with animal-based components (Iswarya et al. 2018; Rubeena et al. 2020) and phyto components (Vaseeharan et al. 2012; Manju et al. 2016; Luis et al. 2020) could act as a disease control agent and applications of nanotechnology combined with phyto components in aquaculture industries have reliable properties such as enhancing the delivery system, bioavailability, and sustained discharge of bioactive compounds. In literature, plant-based extracts and their use in pathogenic microbes and disease control measures were vastly reported, whereas plants and their based bioactive compounds and combined nanoformulation mechanistic pathways in a variety of aquatic organisms in aquaculture disease management are very scanty. Besides, each part of the plant's system has its own mode of action on each aquatic organism, which has different mechanisms for the metabolism and immunization (Sinha et al. 2021a, b; Rashidian et al. 2021a; Hossein Hoseinifar et al. 2020a, b). Hence, more scientific research is needed to understand the mechanism of action of plant compounds and their nanoformulations role in the control of diseases in aquatic organisms. This review is focused towards plant compounds and their combined nanoformulation as biomedicine and their versatile roles in disease management in the aquaculture industries.

Plants as immunostimulants in aquaculture

The majority of medicinal plant, extracts, and their bioactive compounds were used in aquaculture management for control a wide variety of diseases, enhancing immunity against microbial pathogens and increasing growth parameters (Vaseeharan and Thaya 2014; Elumalai et al. 2020; Nath et al. 2019) (Fig. 1). During a disease outbreak in aquatic organisms, they develop immunity, by means of a non-specific immune system that helps to reduce the chance of infection (Barman et al. 2013; Chakraborty and Hancz 2011). Various reports mention the use of plants and their parts as a better immunostimulant against aquatic pathogens. Leaf powder of *Origanum vulgare* has enhanced the cellular and humoral immune response and antioxidant properties in *Sparus aurata* by dietary supplement (Beltrán et al. 2020). Moreover, allicin incorporated into the diet formulation increases antioxidant, biochemical, and immunological parameters in *Oreochromis niloticus* reported by Hamed et al. (2020). Similarly, a dietary supplement of *Gracilaria gracilis* powder showed to be a potent immunostimulant in *Danio rerio* (Hoseinifar et al. 2018) and algal extracts of *Gracilaria gracilis* proved to be a potent antimicrobial agent against aquatic pathogens as reported by Capillo et al. (2018). Likewise, plant-based flavonoids such as quercetin and silymarin mixed with dietary supplement enhance the immunity, growth, and antioxidant profile in aquatic organisms (Pês et al. 2018; Wang et al. 2019; Xu et al. 2019; Wei et al. 2020). Kurian et al. (2021) reported that 0.6–0.9 g/kg dietary supplement of *Leucas aspera*, oxy-cyclodextrin, and sodium bentonite in *Oreochromis niloticus* can enhance the innate immunity via higher expression of an immune-related gene such as interleukin-1 beta (IL-1β), immunoglobulin M (IgM), transforming growth factor-beta (TGF-β), and interferon gamma

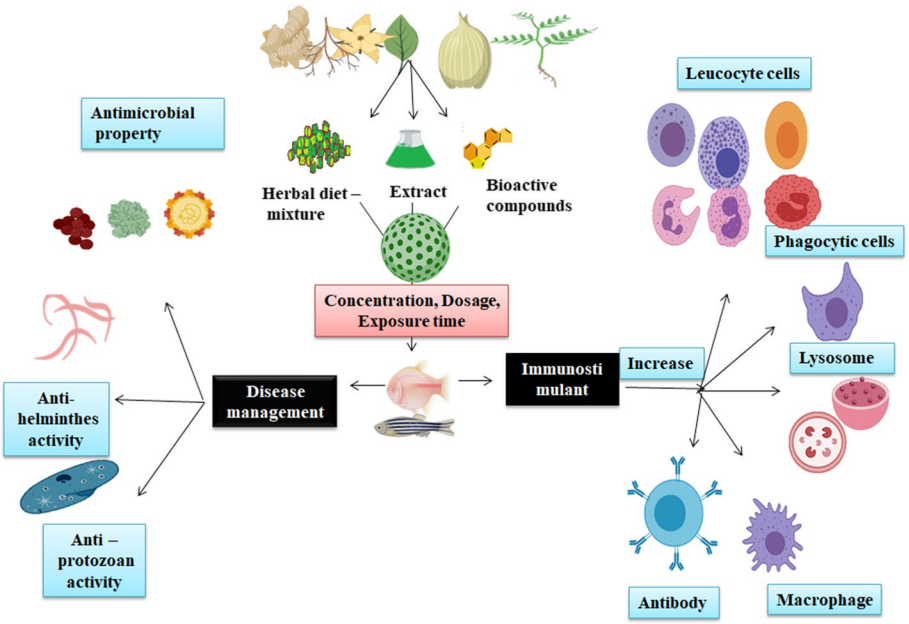

Fig. 1 Phytotherapy and its nanoformulation as disease management in the aquaculture sector

(IFN-γ) and improve regulation of tumor necrosis factor-alpha (TNF-α) as well as improve health status.

Anti-protozoan activity

In the current scenario, parasitic infections in intensive culture are the most common problem in culturing systems. Thus, the aquaculture sector is in urgent need of a treatment for parasitic infection using plants and their derivatives instead of chemicals. Soares et al. (2016) experimentally proved that essential oil from *Lippia alba* has a 40–50% efficiency to treat the protozoan parasite *Ichthyophthirius multifiliis* in *Colossoma macropomum*. Similarly, an ethanolic extract combination of *Cynanchum atratum* and *Sophora flavescens* (6 mg/L) has effectively treated an *Ichthyophthirius multifiliis* infection in Grass carp *Ctenopharyngodon idella* within 10 days (Fu et al. 2021). European sea bass's egg sac infected by crustacean parasite *Lernanthropus kroyeri could be treated by* dipping the egg in extracts of garlic and onion (Yavuzcan Yildiz et al. 2019**).** Correspondingly, Ajoene ((E, Z)-4, 5, 9-trithiadodeca-1,6,11-triene 9-oxide) compound isolated from *Allium sativum* treats protozoan parasite *Spironucleus vortens* (Williams et al. 2016). Alcoholic extract *Terminalia catappa* (850 mg/L) effectively destroys (100%) theront stage of *Ichthyophthirius multifiliis* within 2 h (Fu et al. 2021). Optimized extracts from *Rhus verniciflua* Stokes (gallic acid, fustin, and fisetin) incorporated with diet (100 mg/kg body weight/day) have anti-parasite effects *Miamiensis avidus* in cultured olive flounder within 1–2 weeks (Shin et al. 2021). The use of plant-based formulation in the aquaculture industry against protozoan disease management is illustrated in Table 1. Accordingly, plants and their phyto-consequents were used to treat protozoan parasitic infection during outbreak conditions in the fishery industries.

Anti-helminthes activity

The chemical anti-helminthic drug "levamisole" applied in the fishery industries creates persisted chemical residues in the environment, which leads to contamination and toxicity in aquaculture-based products. Phytoconstituents effectively eradicate inhabiting helminths parasites and reduce associated infections in cultured organisms. Plant-derived bioactive compounds such as sanguinarine, cryptopine, β-allocryptopine, protopine and 6-methoxyl-dihydro-chelerythrine from *Macleaya microcarpa* (Wang et al. 2010b), dioscin and polyphyllin D from the rhizome of *Paris polyphylla* (Wang et al. 2010a), and osthol and isopimpinellin from the fruit of *Fructus cnidii* (Wang et al. 2008) have a significant potency in eradicating *Dactylogyrus intermedius*. In vivo treatment of carp *Cyprinus carpio* with garlic and onion extracts reduced *Gyrodactylus elegans* found on the skin (Yavuzcan Yildiz and Bekcan 2020). Soares et al. (2016) reported that fry of *Colossoma macropomum* fish were infected with helminths parasite (*Anacanthorus spathulatus*, *Notozothecium janauachensis*, and *Mymarothecium boegeri*), and when they were treated with essential oil of *Lippia alba* (100 mg/L & 150 mg/L) by bath treatment within 30 min, it reduced the abundance of helminthes parasites infection. Hence, plants and their phyto-consequences are proved to be a potent tool to control the helminthes parasite infection effectively. In recent years, many researchers focused on working with different medical plants and their derivatives in the aquaculture sector efficiently to control the anti-helminthes action

Table1 Anti-protozoan activity

S. No	Experimental Animal	Plant	Preparation of plant materials	Protozoa- pathogen	Administration	Experiment duration	Reference
1	Tilapia fingerling	Garlic	Crushed clove extract	Trichodina sp. and *Gyrodactylus* sp.	Bath	24 h	El-Galil and Aboelhadid (2012)
2	*Ictalurus punctatus*	*Galla chinensis*	Pentagalloylglucose	*Ichthyophthirius multifiliis*	Bath	-	Zhang et al. (2013)
3	*Piaractus mesoptamicus*	*Toddalia asiatica*	Chelerythrine, chloroxylonine	*Ichthyophthirius multifiliis*	Bath	72 h	Shan et al. (2014)
4	Freshwater angelfish *Pterophyllum scalare*	*Allium sativum*	Ajoene ((E,Z)-4,5,9-trithiadodeca-1,6,11-triene 9-oxide)	*Spironucleus vortens*	Oral	-	Williams et al. (2016)
5	*Piaractus mesopotamicus*	*Melaleuca alternifolia*	Essential oil	*Ichthyophthirius multifiliis*	Bath	2 h day^{-1} for 5 day	Valladão et al. (2016)
6	*Carassius auratus*	*Allium sativum*	Ethanolic extract of bulb	*Trichodina* sp.	Bath	4 days	Saha and Bandyopadhyay (2017)
7	Grass carp *Ctenopharyngodon Idella*	*Curcuma longa*	Curcumin	*Ichthyophthirius multifiliis*	Bath	4 h	Liu et al. (2017)
8	Fingerlings of *Colossoma macropomum*	*Varronia curassavica*	Essential oil – α-pinene, sabinene, and -caryophyllene	*Ichthyophthirius multifiliis*	Bath	1 h	de Castro Nizio et al. (2018)
9	European sea bass	*Allium cepa* and *Allium sativa*	Juice	*Lernantropus kroyeri*	Oral/ Bath	5, 10, 15, and 20 min	Yavuzcan Yildiz et al. (2019)
10	*Clarias gariepinus*	*Moringa oleifera*	Aqueous leaf extract	*Ichthyophthirius multifiliis*	Bath	1 h	Chika et al. (2020)

(Yavuzcan Yildiz and Bekcan 2020; Tu et al. 2021). Eugenol is 100% effective in eradicating *Neoechinorhynchus buttnerae* the parasite infection in *Colossoma macropomum* after exposure of 15 min (dos SANTOS et al., 2021).

Anti-microbial activity

Numerous medicinal plants and their bioactive compounds exhibit anti-microbial properties against several pathogens (bacteria, fungi, and viruses) naturally (Hodar et al. 2021). For example, flower extract of *Malvae sylvestris* and olive waste cake mixed with the basal diet in rainbow trout (*Oncorhynchus mykiss*) enhance innate immune responses as well as growth parameters and resistance against fish pathogens *Yersinia ruckeri* (Rashidian et al. 2020a). Vazirzadeh et al. (2020) reported that dietary inclusion of sea weeds (*Gracilariopsis persica*, *Hypnea flagelliformis*, and *Sargassum boveanum*) increases the immune parameters and their effects depend on the dosage and duration in rainbow trout. Hoseinifar et al. (2020a, b) revealed fingerlings of rainbow trout (*Oncorhynchus mykiss*) fed with basal diet of olive waste cake improve growth and immune parameters. Dietary administration of corncob derived xylooligosaccharides significantly improved survival rate and mucosal and serum immune response in fingerlings of *Oreochromis niloticus* against *Streptococcus agalactiae* (Van Doan et al. 2018). Fruit extracts of *Quercus brantii* increase the growth performance and serum enzyme level in *Oncorhynchus mykiss* (Rashidian et al. 2020b). This property helps to increase the use of phytotherapy in the aquaculture farms. Moreover, plants help to enhance immunity in aquatic organisms and also speed up their immune memory cells to prevent secondary pathogenic infection and severity in intensive culture practices**.**

Anti-bacterial activity

In the aquaculture farms, bacterial diseases cause potential mortality to cultured organisms and lead to severe economic loss to the farmers. Recently, plant-based medicine acts on the aquatic pathogen and develops resistance in aquatic organisms. Fingerlings of Asian sea bass (*Lates calcarifer*) were fed with dietary supplement of powdered ginger, garlic (Talpur and Ikhwanuddin 2012; Talpur et al. 2013), and neem leaf alone (Talpur and Ikhwanuddin 2013) that can enhance immunity and resistance against *Vibrio harveyi*. Likewise, in rainbow trout (*Oncorhynchus mykiss*), a diet mixed with rhizome of ginger (Nya and Austin 2009a) and garlic (Nya and Austin 2009b) can increase immune cells and develop resistance against *A. hydrophila* bacteria. Similarly, extract of green tea can enhance immunity and survival rate in *Oreochromis niloticus* against infection of *A. hydrophila* (Abdel Tawwab et al. 2010). Le Anh Dao et al. (2020) evaluates that the antibacterial properties of ethanolic extracts of *Phyllanthus amarus* and *Euphorbia hirta* in in vitro condition show that they have efficient antibacterial properties against *Aeromonas hydrophila* and *Edwardsiella ictaluri*. Van Doan et al. (2019) observed that fingerlings of Nile tilapia, *Oreochromis niloticus*, infected with pathogenic bacteria of *Streptococcus agalactiae* fed with powdered *Boesenbergia rotunda* have boosted the immune system via enhanced lysozyme and peroxidase, alternative complement system, and increased phagocytosis index. Hence, a plant-based diet for intensive culture practices provides better anti-bacterial agents, enhances

immunity during outbreak conditions, and prevents various bacterial pathogenic infections (Arunachalam et al. 2021).

Anti-viral activity

Virus disease causes a significant problem in aquaculture practices (Seibert and Pinto 2012). Antiviral plants and their compounds may cease replication of viruses in the host cells and may enhance non-specific immunity and immune-related genes (Citarasu 2010; Sun et al. 2021; Jiang et al. 2021). Extract of *Cynodon dactylon* administered via in vivo (intramuscular injection – 2 mg/animal and orally with feed -2%) has enhancing properties on immune responses (Balasubramanian et al. 2008) and a diet including mixed extract of *Cynodon dactylon*, *Aegle marmelos*, *Tinospora cordifolia*, *Picrorhiza kurroa*, and *Eclipta alba* and has efficient immunostimulant properties (Citarasu et al. 2006) in shrimp *Penaeus monodon* against WSSV (white spot syndrome virus). The aqueous extracts of the mangrove plant, *Ceriops tagal*, have more efficiency in controlling the WSSV shrimp disease (Sudheer et al. 2011). Aqueous flower extract of *Lonicera japonica* (LAE) and its bioactive compounds such as isochlorogenic acid A (IAA), isochlorogenic acid B (IAB), isochlorogenic acid C (IAC), caffeic acid (CA), luteolin (LT), and inositol (IS) have a potent inhibitory effect against the infection of spleen cells of grouper (GS) with *iridovirus Guangxi* (SGIV-Gx) as reported by Liu et al. (2020a). Quercetin compounds isolated from *Illicium verum* have effectively controlled *grouper iridovirus* (GIV) infection as described by Liu et al. (2020b). Hence, the use of phytotherapy in aquatic industries effectively controls the virus via cease replication and blocks the protein synthesis. There are very few reports on plant-based drugs to control viral pathogens in the aquaculture sector. It is likely that further investigation may be carried out on the topic of phytotherapy control of viral pathogens.

Antifungal activity

Different plant extracts and their bioactive compounds act on fungal species via rupture or altering the cell wall permeability and affect fungal metabolism including RNA and protein synthesis (Citarasu 2010). Various fungal and oomycetes diseases occur during culture practices, namely Fusariosis, Branchiomycosis, Ichthyophoniasis, Hyphomycetes, Saprolegniasis, and Aphanomyces sp. (Yanong 2003). Najafi and Zamini (2013) observed essential oil of *Eucalyptus* sp. added in *Rutilus frisii* eggs present in water can prevent eggs from oomycete infection. binti Abang (2017) reported that 24 and 48 h' exposure to various plant extracts of *Piper betle* (betel, leaves), *Curcuma longa* (turmeric, rhizome), and *Etlingera coccinea* (tuhau, stem) more efficiently inhibits the growth of marine fungus *Fusarium moniliforme*. Rainbow trout infected with fungal pathogen *Saprolegnia parasitica* treated by 8 weeks of dietary supplement on *Aloe barbadensis* showed an increased innate immunity, upregulation of TNF-α (tumor necrosis factor-α), IL-1b, IL-6, and IL-8 (IL-interleukin) gene expression, and increase growth (Mehrabi et al. 2019). Ethanolic extracts of *Allium sativum* and *Artemisia sieberi* increase the survival rate of eggs and larvae of rainbow trout (*Oncorhynchus mykiss*) and also prevent oomycete infection during exposure of these extracts as shown by Amani Denji et al. (2020). These plant extracts act on fungal species and alter the normal metabolism of the cell wall of fungus which leads to

death and also boosts the immunity of aquatic organisms. Moreover, applications of phytomedicine in aquaculture industries and combined nanotechnology are more efficient to treat various aquaculture pathogens.

Plant-based nanoparticles used in aquaculture

In aquaculture, nanotechnology has a wide range of applications such as disease management, water purification, and delivery of nutrients and drugs (Shah and Mraz 2020). In addition, nanotechnology-based formulation in aquaculture industries can effectively develop the antimicrobial surface on the aquatic pathogens due to its porous nanostructures and penetration efficacy can easily prevent and control the aquatic pathogens. Many researchers pay attention to incorporating nanotechnology and phytomedicine together to obtain better aquatic industrial applications. Nanotechnology-based phyto-formulation (nanoparticles) has some effective properties, such as improving the shell life of phytochemical constituents, stability, and bioavailability, and also has adjuvant properties (antigen efficacy) (Muruganandam et al. 2019; Nasr-Eldahan et al. 2021).

The application (dietary supplements and water) of plant-based nanoparticles in the aquaculture sector increases immunity, antimicrobial activity, cures tissue damage, etc. (Rashidian et al. 2021b). For example, *Lycopersicon esculentum* leaf extract-based zinc-oxide nanoparticles have efficient inhibition of fish pathogen *Proteus vulgaris* and *Enterococcus faecalis* (Vijayakumar et al. 2019). Methanolic extracts of *Azolla microphylla*-based gold nanoparticles show effectual activity against liver damage caused by acetaminophen in common carp *Cyprinus carpio* (Kunjiappan et al. 2015). Sharif Rohani et al. (2017) reported *Aloe vera* nanoparticles to increase the growth and survival rate in *Acipenser baerii.* Likewise, ginger-based nanoparticles used in the dietary supplement of *Cyprinus carpio* fingerlings enhance the survival rate and also develop immunity against *Aeromonas septicaemia* (Korni and Khalil 2017). Kurian and Elumalai (2021) revealed that green synthesized *Leucas aspera* and oxy-cyclodextrin complex-based zinc nanocomposite at 400 mg/kg dietary supplement has enhanced antioxidant enzyme levels as well as improving immunity in *Oreochromis niloticus.* Babu et al. (2020) reported that marine red alga *Acanthophora spicifera*-based gold nanoparticles have antibacterial activity against aquaculture pathogens *Vibrio harveyi* and *Staphylococcus aureus*. Chitosan-ZnO composite acts as an effective antibacterial agent against aquatic pathogens such as *Vibrio parahaemolyticus* and *Bacillus licheniformis*, as reported by Vaseeharan et al. (2015). Green synthesized nanoparticles have better disinfectants or antimicrobial agents in aquaculture disease management (Table 2).

Recently, efficient drug delivery of plant materials into aquatic organisms, they were encapsulated with nanomaterials. Awad et al. (2020) reported galangal extract of *Alpinia officinarum* coated with mesoporous silica nanoparticles mixed with a dietary supplement of *Oncorhynchus mykiss* can enhance immunity and also develop resistance against *Yersinia ruckeri*. Normal dietary supplements of nano-encapsulated nerolidol feed with *Oreochromis niloticus* enhance the antioxidant, growth, and tissue mass, and also increase tissue meat content, as reported by Baldissera et al. (2020). Luis et al. (2020) reported that essential oil from eugenol and garlic encapsulated with zein nanoparticles have antimicrobial properties against the aquatic pathogens (*Aeromonas hydrophila*, *Edwardsiella tarda*, and *Streptococcus iniae*). Likewise nanoencapsulation of essential oil from *Melaleuca alternifolia* have effective bactericide action against *Pseudomonas aeruginosa in* Juvenile silver

Table 2 Antimicrobial properties of green synthesis of nanoparticles in aquaculture sector

S. No	Green synthesis of nanoparticles			Aquaculture Pathogens	Reference
	Plants	Source/parts	Metal precursor of nanoparticles		
1	*Calotropis gigantea*	Leaves	Silver	*Vibrio alginolyticus*	Vaseeharan et al. (2012)
2	Mango, banana, papaya, and eucalyptus	Leaves	Silver	*Aeromonas hydrophila*	Mahanty et al. (2013)
3	*Boerhaavia diffusa*	Whole plant	Silver	*Aeromonas hydrophila*, *Pseudomonas fluorescens*, and *Flavobacterium branchiophilu*m	Kumar et al. (2014)
4	*Nigella sativa*	Essential oil	Silver and gold	*Vibrio harveyi*, *Vibrio parahaemolyticus*, and *Staphylococcus aureus*	Manju et al. (2014); Manju et al. (2016)
5	*Chromolaena Odorata* (Kirinyuh)	Leaves	Silver	*Vibrio* sp.	Yanuar et al. (2020)

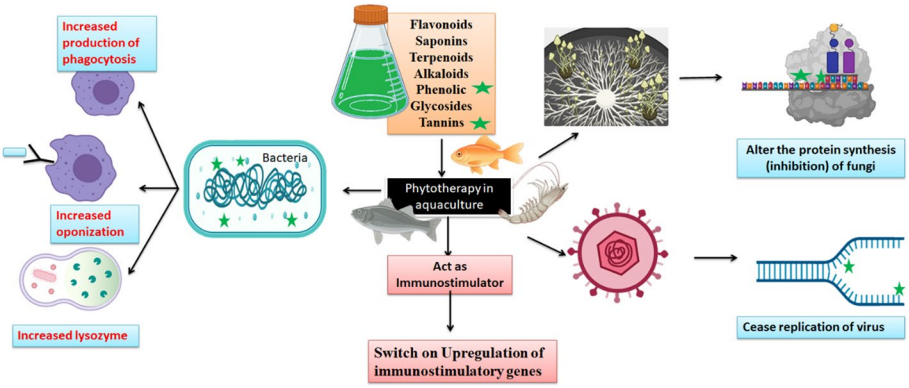

Fig. 2 Mechanism involved in phytotherapy as immunostimulant

catfish Souza et al. (2017). Hence, phytochemical-based nanotechnology more efficiently prevents microbial infection during disease outbreak conditions in the fishery industries' farms and also enhances growth, acting as an immunostimulant and a promising antibiotic in the aquaculture sector due to its delivery efficacy (Fig. 2).

Conclusion and future perspectives

In aquaculture sectors, the medicinal plant-based products such as extracts, bioactive compounds, essential oils, and nanoformulations act as good anti-pathogenic agents against bacteria, virus, fungi, protozoa, and helminthic parasite infection by enhancing immunity and performing as an efficient immunostimulant. Using phytotherapy combined with nanoformulation in culture practice will be very effective to eradicate infectious diseases. Furthermore, they specifically act on pathogens of aquatic organisms and are also non-toxic to the culture, animals, and consumers, as well as the environment. An understanding mechanism whereby plant based medicines manipulates aquatic animal's growth concert and health aspects. Systematic literature associated with this subject suggests that the immunostimulatory effects of several plant-based medicine help the route of management and organization with immunostimulants. In future, in the field of aquaculture, various research works should be carried out to determine the efficacy phases of plants and it based nanoparticle products to the environment and organisms. The immunostimulatory potential of specified materials should be unambiguously reputable, by swot up on its effectiveness and value in the framework of immunostimulants in plant-based aquaculture research. Furthermore, immunostimulant pathways and their mechanisms using plants' bioactive compounds in aquatic organisms need to be evaluated. In addition, the manufacture of plant-based nanoformulation along with dietary supplements helps aqua farmers to maintain the intensive culture organisms and improve their production, as well as to enhance the growth of aquatic organisms.

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Declarations

Ethical approval and consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

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