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Application of herbal dietary supplements in aquaculture – a review

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Abstract

Aquaculture is another mainly crucial food manufacturing division in the globe and it's also economical importance in many countries. Disease outbreaks are mainly affected to decrease aquatic production, prior chemotherapeutics and antibiotics treatments are supportive to manage the infections. In this method, residues cause side effects on humans and aquatic animals. Researchers find out pro-pre-synbiotics methods used to enhance the feed quality and aquatic production. Herbal dietary feed supplementation development is eco-friendly, non-toxic, cost-effective, and easily handle for the preparation of feeds for aquatic animals in aquaculture. This review provides some information regarding herbal dietary feed supplements is assist to improve aquatic animals' health and also getting better quality of aquatic feed in the aquatic sector. These review reports enlighten the way of upcoming investigations progress of novel applications in aquaculture.

Key words: medicinal plants, feed additives, immunostimulants, disease resistance, aquaculture

Aquaculture is an alternative main significant food-manufacturing division in the world, China has shaped various types of aquatic products compared to other countries since 1991, and also China has well developed in the aquatic division as well 2000 years ago

(FAO, 2020). China is the most imperative fish-manufacturing country in the globe (FAO, 2020). China's aquaculture production targeted 62.2 million tonnes (14.6 million tonnes from capture fisheries and 47.6 million tonnes from aquaculture) in 2018 (FAO, 2020). China produced more aquatic products compared to other countries like India, Vietnam, Bangladesh, Indonesia, Norway, and Egypt, with an additional 60% of fish production being produced in China (Coates et al., 2023). The aquaculture division is the main vital supply of minerals, protein, and vitamins in different developing countries (Karim et al., 2022). The aquatic sector produced diverse types of aquatic products including aquatic plants, algae, fish, molluscs, crustaceans, and dissimilar other aquatic fauna (Asche et al., 2022). Fish is the major essential, easiest, and most inexpensive dietary protein source and half of the world's population turns to dietary protein sources in fish (Ghafoor et al., 2020).

Nutrition is the key vital thing that maintained the growth and reproduction of fish, they provide full significance for fish production and nutrition, as well as functional foods are the most excellent feed for fish to support and enhance natural healthy fish production (Abdel-Tawwab et al., 2022). In addition, the fish products ratio is noticeably raising day by day hanging on consumers' demands around the globe. Some new techniques are used to enhance the fish growth ratio and fish production in farms (Hu et al., 2022; Tibbetts et al., 2023). To prevent or protect the infection outbreaks, maintain fish growth activity, and improve feed intake, diverse types of antibiotics and chemicals are incorporated into the aquatic feed supplements to manage the diseases. This method causes various complexity, drug tolerance, and ecological contamination in aquaculture (Ye et al., 2020). Several studies described that antibiotics, disinfectants, and chemotherapeutics are used to manage fish infections (Lieke et al., 2020). Natural methods like immunostimulants, probiotics, prebiotics, synbiotics, and medicinal herbs are one more approach to controlling antibiotic use in the aquatic sector (Ghafarifarsani et al., 2021a,b,c; Rufchaei et al., 2021; Ajdari et al., 2022; Elabd et al., 2022; Ahmadifar et al., 2023; Ghafarifarsani et al., 2023; Malekpourzadeh et al., 2023; Nedaei et al., 2023). Medicinal plants are essential to dietary feed supplements and chemotherapeutics in aquaculture (Chavda et al., 2022). Feed supplement is the major significant diet also evaluating the appropriate amount and standard is crucial. Accepted dietary feed supplement system is inexpensive and available for aquatic organisms, aquaculture expenses are about 40%-50% of the overall production expenditure (Hussein et al., 2022).

Herbals are another main essential dietary feed supplement in the aquaculture sector and they provide an affirmative reaction in fish like growth maintenance and health development effects. Herbals extract of diverse plants like Lamb's ears (*Stachys lavandulifolia*), Lemon balm (*Melissa officinalis*), and Small water pepper (*Polygonum minus*) were provides better growth specification in different fish species like Rainbow trout (*Oncorhynchus mykiss*), pirarucu (*Arapaima gigas*) (Adel et al., 2020; Bilen et al., 2020; Dias et al., 2023). Herbals are exhibits a potentially curative approach in fish, this approach is inexpensive, better accuracy without toxicity (Techaoei, 2022). In addition, medicinal herbs incorporated into the feed are a novel way to maintain growth and health development and

protect or prevent diseases in aquatic organisms (He et al., 2022; Wangkahart et al., 2022). Herbal dietary feed additive is an optional way to the chemical treatment used to control diseases. The herbal dietary management progression has helpful possessions on functional feed factors in the aquatic sector (e.g. Gupta et al., 2021; Van Doan et al., 2021; Alemán-Ramirez et al., 2022; Vijayaram et al., 2023). Dietary management (oral or injection) of herbal complement is considerably better for growth response, immune system, and infection confrontation in opposition to bacterial, viral, and parasitic infections. An elevated quantity of herbal dietary feed supplements may provoke immunosuppression without negative impacts but assist to decrease the depletion effect of aquatic animal diseases (Sharma et al., 2021). Dissimilar plants and their by-products have different types of bioactive combinations like alkaloids, phenols, polyphenols, quinone, terpenoids, lectine, and polypeptides, these components are efficient alternatives for chemicals, vaccines, antibiotics, and other artificial combinations in the aquatic sector (Harikrishnan et al., 2020; Rufchaei rt al., 2022). Herbs contain different kinds of successful dietary feed additives including alkaloids, flavonoids, tannins, organic acids, polysaccharides, volatile oils, and nutrients (vitamins, minerals, carbohydrates, and amino acids) (Zhu, 2020). The previous study pointed out that dietary supplementation of Chinese herbs significantly promotes growth, enhancing immunity, better meat condition and flavour of fish, and maintaining gut microflora formation in Hybrid grouper (*Epinephelus lanceolatus*♂ × *Epinephelus fuscoguttatus*♀) (Sun et al., 2022).

Abarike et al. (2022) investigated that dietary inclusion of feed supplements in different herbs such as Guava (*Psidium guajava*), Bitter melon (*Momordica charantia*), and Neem (*Azadirachta indica*) is supportive of improved growth and body formations (i.e., elevated crude protein, and lesser moisture and crude lipids) in Nile tilapia (*Oreochromis niloticus*) differentiated to the test group. In the past two decades, medicinal herbs dietary feed additives had considerably eradicated the use of chemicals, drugs, and antibiotics in aquaculture and they provide several biological mechanisms with various optimistic reaction (optimal level) such as modulating the immune system, attractive growth, antioxidant, appetite stimulation, digestive function, antidepressant and hepatoprotective response in aquaculture (Yilmaz 2019b; Araby & Abbass, 2022; Mahboub et al., 2022; Sönmez et al. 2022; Tadese et al. 2022; Wang et al., 2022; Yilmaz et al., 2022; Quintino-Rivera et al., 2023). Many types of medicinal herbs and dietary feed supplements are examined to provide some positive responses challenging a broad spectrum of pathogens' action and turn-on reactions on immunopoietic cells (Effendi et al., 2022). Different types of medicinal herbs feed additives as a dietary supplements showed that antimicrobial activity, supported growth, and development of Rohu (*Labeo rohita*) (Harikrishnan et al., 2020). Herbs dietary feed additives as possible immunostimulants in aquatic organisms, several studies investigated the response at the molecular mechanism level on Indian lotus (*Nelumbo nucifera*) and Astragalus (*Astragalus membranaceus*) (An et al., 2022; Zhao et al., 2023). Medicinal herb feed additive used as a dietary supplement had considerably increased the function of bactericidal activities, natural killer cells, phagocytic cells, complement, lysozyme activity, and antibody reactions in Walking catfish (*Clarias batrachus*) fry (Sharma et al., 2021). The small bowel plays a vital responsibility in nutrient absorption for fish growth (Dawood et al.,

2020a). Nutritional oregano essential oil used as a dietary administration process showed to altered gut microbiota composition, and negative effects on intestinal pro-inflammatory genes (TNF-a and TGF-b) in Common carp (*Cyprinus carpio*) (Abdel- Latif et al., 2020). The role of immunostimulants is to trigger the immune system of the host against harmful microbes. This process is quite different depending upon the classification of immune reaction, quantity, and way of management, instance, and stage of exposure (Ang et al., 2020). This review provides some information on herbal dietary feed supplement types, dosages, and administration methods utilized to enhance aquatic animals' health and get better quality aquatic feed supplements in the aquaculture sector.

Applications of herbal dietary feed supplements role in aquatic animals

Dietary additives of different medicinal plants such as Turmeric (*C. longa*), Lemongrass (*Cymbopogon citratus*), Drumstick tree (*Moringa oleifera*), Rosemary (*S. rosmarinus*), Rucola (*Eruca sativa*), Thyme (*Thymus vulgaries*) contain numerous valuable property like growth enrichment, immunostimulator, bactericidal activity, anti-stress and antioxidant in diverse fish species such as *C. carpio*, *O. mykiss*, and Caspian roach (*Rutilus caspicus*) fry (Abd El-Naby et al., 2020; Ghafarifarsani et al., 2022a,b,c,d; Yousefi et al., 2022). Dietary inclusion of feed additive Gokshur (*Tribulus terrestris*) extract at 400 mg/kg for 88 days trial periods in *O. niloticus* showed that to enhance growth performance, nutrient utilization, and some immunological and biochemical traits (El-Kady et al., 2022). Dietary incorporation of feed supplements in *S. rosmarinus* leaf powder (RLP) (10 g/kg) for 60 days trial period showed that growth development, improved feed utilization, antioxidant, infection resistance, and immune system activity in *O. niloticus* diets (Naiel et al., 2020). Dietary incorporation of feed additives in *T. terrestris* extract 500-750 mg/kg showed improved health condition, growth performance, testicular function, semen quality, and reproductive efficiency without adverse impacts on water quality in 45 days trial periods in male *O. niloticus* (Hassona et al., 2020). Dietary feed supplementation of Coriander seed extract (*Coriandrum sativum*) 2% is notably improved growth response, immune system activity, and infection confrontation challenge *Yersinia ruckeri* in *O. mykiss* for 8 weeks trial period (Farsani et al., 2019). In addition, dietary feed additives of *P. minus (Polygonaceae)* extract 15 mg/kg in *O. mykiss* showed significantly enhanced growth performance, immune system response, and infection tolerance against *Y. ruckeri* in 8 weeks trial period (Adel et al., 2020). Dietary feed supplementation of medicinal plant Common mallow (*Malvae sylvestris*) flower extract 3% and 5% of *O. mykiss* diet notably better growth activity, immune system, and infection tolerance against *Y. ruckeri* for 8 weeks trial period (Rashidian et al., 2020b). Dietary feed additive administration of medicinal plant Oak acorn (*Quercus brantii*) extracts (OAE) 600 mg/kg had significantly improved innate and mucosal immune system reaction and bactericidal activity of *Y. ruckeri* and *Streptococcus iniae* of *O. mykiss* fingerlings for 8 weeks trial period (Ghafarifarsani et al., 2021 b).

Dietary feed administration of twelve Chinese medicinal plants 8–12 g/kg in European eel (*Anguilla Anguilla*) in a 4-weeks feeding trial demonstrated better growth activity, immune response, and digestive enzymes in fish (Huang et al., 2020). Dietary

inclusion of feed additive in Chinese medicinal herbs combination (CHMM; *Medicago falcata, Allium sativum* and included of Asafoetida (*Ferula sinkiangensis*) aqueous extract 20 g/kg notably improved growth activity, innate immunity, gut digestion of Japanese sea bass (*Lateolabrax japonicus*) for 28 days experiment (Xu et al., 2020). Dietary inclusion of feed additives in fermented Chinese medicinal herbs (FCMH) 1% had notably improved growth activity, immune system, liver antioxidant, and expression of the gut inflammatory gene in juvenile Largemouth bass (*Micropterus salmoides*) for 8 weeks experimental period (Zhou et al., 2022). Dietary incorporation of feed supplement in fermented Ginkgo (*Ginkgo biloba*) leaves 0.125%~0.25% of *O. niloticus* for 60 a day trial period showed noticeably improved antioxidant activity, immune system response, lipid metabolism, and infection resistance against harmful microbes in fish (Abdel-Latif et al., 2021). Dietary inclusion of feed additive in Lemon verbena (*Aloysia citrodora*) extracts 10-20 mg/kg showed significantly improved feed utilization, growth performance, and immune system defense challenge *Aeromonas hydrophila* disease in Siberian sturgeon (*Acipenser baerii*) for 8 weeks of experimental analysis (Adel et al., 2021). Dietary feed supplement investigation of Chinese herbal medicine mixture (CHMM) 9 g/kg showed enhanced growth activity, body protein components, enteric trypsin response, non-specific immune system activity, and antioxidant capability of *A. Anguilla* for 42 days trial period (Huang et al.,2020). Dietary administration of feed additive in medicinal plants Bhumi amla (*Phyllanthus amarus*) and *P. guajava* L (0.08% and 0.5%) for 6 weeks trial study shows improved growth performance, immune gene expression, and infection tolerance of Striped catfish (*Plotosus lineatus*) (Nhu et al., 2020). Dietary feed supplementation of Aswagandha (*Withania somnifera*) root extract at 0.05% shows a noticeable improvement in growth percentage, feed intake, survival level, and digestive function of white leg shrimp (*Litopenaeus vannamei*) (Rao et al., 2020). Dietary feed incorporation of medicinal herbs Chamber bitter (*Phyllanthus urinaria*) and Indian almond (*Terminalia catappa*) extract at 1% shows beneficial effects in *L. vannamei* like improving growth performance, immunity disease resistance against *White spot syndrome virus* (WSSV) for 4 weeks trial period respectively (Isnani et al., 2021). Dietary feed supplementation of combined allicin 0.5% Astragalus polysaccharides (APS) 0.1%, and Chlorogenic acid (CGA) 0.1% pointed out that to enhance immunity, antioxidant, and protection against *Vibrio harveyi* disease in *L. vannamei* without biomolecule damage in 21 days trial period (Pu & Wu, 2022).

Table 1. Herbal feed supplements role in aquatic animal's health

Figure 1. Applications of herbal supplements in aquaculture

Applications herbal dietary feed supplements role in the growth response of aquatic animals

Padala et al. (2021) pointed out that dietary inclusion of feed supplements in Peppermint (*Mentha piperita*) at various concentrations (2g/kg) significantly improved growth activity, feed consumption, survival, weight gain, leucocytes, erythrocytes,

hematocrit, hemoglobin, lysozyme, respiratory burst, phagocytic activity, anti-protease, and bactericidal activities and also a depletion in serum glucose, triglycerides, cholesterol, and lipids level in treated *L. rohita* for 4 weeks trial period respectively. Dietary feed supplementation of Coneflowers (*Echinacea purpurea*) 1000 mg/kg and Garlic (*A. sativum*) 1000 mg/kg showed significantly improved body weight gain, survival rate, cold stress resistance during the winter season, and protection in opposition to *Aeromonas hydrophila* disease in Beluga sturgeon (*Huso huso*) for 2 months experimental period (Bazari Moghaddam et al., 2022). Dietary incorporation of feed supplements in Sugar apple (Annona squamosa) 20 g/kg diet in fish fed for 60 days period, the study revealed that to improved weight gain, survival rate, specific growth percentage, feed efficiency, proximate composition and hematological parameters of *O. niloticus* fingerlings (Almarri et al., 2023). Dietary feed additives of *Astragalus caudiculosus* 2.5-5% for 90 days study report showed that to enhanced growth performance, antioxidant and survival in *O. mykiss* (Sönmez et al., 2022). Dietary feed supplementation of Roselle (*Hibiscus sabdariffa*) 0.5% for 60 days experimental analysis shows that to improved growth performance, survival, blood erythrocyte, catalase (CAT) hematocrit (Hct), hemoglobin (Hb), plasma and hepatic superoxide dismutase (SOD), and also lower plasma cortisol, glucose, hepatic malondialdehyde (MDA) content, and hemolysis rate for *O. mykiss* (Hoseini et al., 2021).

Kate et al. (2023) examined that dietary inclusion of feed supplement in 1% of Katuk ethanolic extract (*Sauropus androgynous*) stimulated appetite, improved growth performance, and increased food utilization (inferior feed conversion percentage) in Orange spotted grouper (*Ephinephelus coioides*) for 70 days experimental period respectively. Sutthi et al. (2020) examined the dietary feed supplementation of *P. minus* leaf extract 70ml/kg for 60 days in fingerling Climbing perch (*Anabas testudineus*), study results demonstrated that feed efficiency (FE), weight gain (WG), specific growth rate (SGR), average daily growth ratio (ADG), and protein efficiency ratio(PER) values, Hct, red blood cells (RBC) and total white blood cell count (WBC) concentrations are considerably higher and lowest feed conversion value differentiated to the test group. Dietary feed additives of herbal medicine mixture of 5-12.5 g/kg notably improved the growth activity of Eels (*Anguilla japonica*) (Abarike et al., 2019; Shadrack et al., 2021).

Munglue et al. (2019) reported that dietary feed supplementation of herb Rice paddy (*Limnophila aromatica*) extract (LAE) 1% significantly improved growth activity, feed efficiency, and gut morphology of Catfish (Siluriformes) for 8 weeks trial period. A dietary feed supplement combination of *Aloe vera* polysaccharides (0.66% and 0.8%) and *A. sativum* shows significantly improved growth activity, feed intake, survivance, and hematological index of African catfish (*Clarias gariepinus*) juveniles (Gabriel et al., 2021). Dietary incorporation of feed supplement in *C. sativum* seed extract 2% considerably enhanced immunological parameters, growth performance, and infection confrontation in opposition to *Y. ruckeri* disease of *O. mykiss* for 8 weeks trial period (Farsani et al., 2019). Dietary incorporation of feed additive in Clove (*Eugenia caryophyllata*), buds extract (ECBE) 15 g ECBE/kg appreciably improved growth

action, feed intake, intestinal villi/absorption, and disease confrontation in opposition to *A. hydrophila* of *C. gariepinus* for 12 weeks trial period (Dawood et al., 2020 a). Dietary incorporation of feed supplements in Velvet bean (*Mucuna pruriens*) and Pumpkin (*Cucurbita mixta*) extracts 4 g/kg and 6 g/kg diet noticeable development in growth activity, survival percentage, feed conversion ratio (FCR), WG, PER, SGR, and FE, innate immunity, phagocytic activity, respiratory burst activity, complement activity, and lysozyme activity and also infection confrontation against *A. hydrophila* disease in Tilapia (*Oreochromis mossambicus*) for 4 weeks experimental analysis (Abd El-Gawad et al., 2020; Kurian et al., 2020).

Dietary incorporation of feed supplements in oregano essential oil 20 g/kg diet for 2 months shows significantly enhanced growth performance (feed intake, weight gain, weight gain percentage, specific growth rate, and final body weight,) and intestinal histo morphology (villus width, villus height, and crypt depth) with no inflammatory action, and with the possible hepato-protective consequence of *C. carpio* fingerlings (Abdel-Latif et al., 2020). Dietary incorporation of feed supplement in Chestnut (*Castanea sativa*) and olive mill wastewater extracted polyphenol 0.2% for 8 weeks shows significantly better growth activity, immune parameters, and antioxidant defence of *C. carpio* and diminished feed conversion ratio in fish (Jahazi et al., 2020). Dietary feed supplementation of Almond oilcake (*T. catappa)* (FTC), Water fern (*Salvania molesta*) (FSM), and Duckweed (*Lemna minor*) (FLM) 300 g/kg significantly better final body weight, digestive enzyme action, specific growth rate, and decreased feed conversion ratio of Rohu (*L. rohita*) fed diets (Goswami et al., 2020). Dietary incorporation of feed supplements in the Chameleon plant (*Houttuynia cordata*) leaf extract 10 g/kg for 60 days trial period exhibited that weight gain %, specific growth rate, expression of higher insulin-like growth factor-I (IGF-I), muscle alanine aminotransferase and aspartate aminotransferase, protease activities, no changes in amylase and lipase activity and decreased feed conversion rate were examined in *L. rohita* (Rosmin et al., 2023).

Dietary inclusion of feed supplements in medicinal plants and their by-products shows significantly enhanced growth and stimulate appetite, acted as an immunostimulant, and had antimicrobial and anti-parasitic (virus, monogeneans, and protozoans,) effects in fish and shellfish aquaculture (Chang et al., 2023). Dietary inclusion of medicinal plant feed additives in *P. urinaria* crude extract (10000 ppm) appreciably enhanced growth percentage and feed utilization but no improvement to increased survival ratio of *L. vannamei* Boone (Charoendat & Koedprang, 2019). Dietary incorporation of feed supplements in (Apiaceae) Bei Chai Hu (*Bupleurum chinense*) and *A. membranaceus* (0.25% and 0.5%) for an 8-week trial period had shown beneficial effects on growth improvement, feed conversion ratio, immune-associated enzymes including lysozyme in serum, alkaline phosphatase (AKP), superoxide dismutase (SOD), and hepatopancreas in of *L. vannamei* (Angela et al., 2020). Dietary feed additives of Green tea (*Camellia sinensis*) 0.5% for 12 weeks trial period shows that to improved growth response, feed utilization, survival, and infection tolerance against *A. hydrophila* infection in *O. niloticus* (Adeniyi et al., 2021). Dietary inclusion of feed supplements in Blackberry syrup 15 g/kg for 90 days improves fish

growth performance, immune specification, antioxidant status, and increased survival ratio against *Plesimonas shigelloides* of *O. niloticus* diets (Yilmaz, 2019). Dietary incorporation of feed supplements in *A. vera* powder at various concentrations (0.5% 1%, 2%, and 4%/kg feed) for 8 weeks showed that 0.5%, 1%, and 2% *A. vera* incorporated diet considerably better absolute growth rate, weight gain, and specific growth ratio. Feed utilization is notably improved in fish fed with an *A. vera* diet at 1% and 2%/kg feed. The feed competence percentage, feed conversion rate, and somatic indicator were considerably improved in 4% *A. vera*-supplemented fish over unsupplemented ones. and also infection tolerance against *S. iniae* disease in *O. niloticus* as well as improving antioxidant, hepatoprotective enzyme activities, plasma lipid formation level, reduced serum aspartate and alanine aminotransferase (AST and ALT) activities before and after the challenge (Kannan et al., 2022; Xu et al.,2022).

Dietary incorporation of feed supplements in Milk thistle (*Silybum marianum*) seeds 7.5 and 10 g/kg for 10 weeks shows that to improved growth response (specific growth rate (SGR), weight gain (WG), protein efficiency ratio (PER), and apparent protein utilization (APU)) increase the immune system activity, antioxidant activity (SOD and CAT) and gene expression and also lowest level of aspartate and alanine aminotransferase in *O. niloticus* fingerlings (Hassaan et al., 2019). Dietary feed supplementation of Caraway seed meal (*Carum carvi* L.; CSM) 12.5 g/kg for 12 weeks study shows that to significantly improved growth action, feed consumption, and no changes in survival condition in *O. niloticus* (Hamed et al., 2022). Dietary feed additives of 1% cinnamon showed significantly improved feed conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER), apparent protein utilization (APU), specific growth rate (SGR), and energy utilization (EU) and infection tolerance against *A. hydrophila* disease in *O. niloticus* (Abdulrahman & Sadeeq, 2023). Dietary feed incorporation of *A. citrodora* 2% shows that significantly enhanced immune-associated genes (TNF- α IL-1β, and IL-8), improved the quantity of skin mucus, lysozyme, and total immunoglobulin in serum, and also increases the antioxidant enzymes level (GPx, GST, and SOD), but not affect growth performance in *O. mykiss* (Hoseinifar et al., 2020b).

Liu et al. (2022) reported that dietary feed inclusion of 1,8-cineole (cineole) (30 μg/L) and ginger extract (*Zingiber officinale* Rosc) (20 μg/L) are considerably enhanced the survival ratio, growth activity, and increased serum CAT and SOD performance in *M. salmoides* L.. Dietary feed inclusion of *H. sabdariffa* extract (100, 200, and 400 μg/mL) notably improved levels of glutamate oxalate transaminase (GOT), glutamate pyruvate transaminase (GPT), lactate dehydrogenase (LDH), and malondialdehyde (MDA) and also considerably decreased the levels of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) of Red Tilapia (*Oreochromis* spp.) (Diab et al., 2023). Dietary feed incorporation of Palm fruit (*Phoenix dactylifera* L. *Arecaceae*) 200 ml/kg DPE for 8 weeks study showed increased growth activity, antioxidant level, and immune system response in *C. carpio* fingerlings (Kari et al., 2022). Dietary feed additives of herbal supplements in Wormwood (*Artemisia annua*) leaf extract, Common water hyacinth (*Eichhornia crassipes*) leaf extract,

and flavonoids from *Allium mongolicum* in various concentrations in different periods used to improve CAT and SOD activities, as well as dormant oxidative stress in *O. niloticus*, *C. carpio*, *O. mykiss*, and Snakehead (*Channa argus*) (Li et al., 2019; Mirghaed et al., 2020; Rufchaei et al., 2020; Ghafarifarsani et al., 2022e). Dietary feed inclusion of Milky mushroom (*Calocybe indica*) extracts at 6% for 90 days significantly improves Spiral Babylon (*Babylonia spirata*) growth (shell length and body weight and antioxidant levels (CAT and SOD) and reduced mortality compared to the control group (Chelladuraia &Maran, 2019). Dietary inclusion of feed additives 1.76 and 1.79% *A. vera* /kg diet notably enhanced growth specifications (i.e., specific growth ratio, absolute growth rate, final weight, and weight gain), protein efficiency, hemato biochemical indices, and inferior feed conversion percentage of *C. gariepinus* fingerlings (Gabriel et al., 2019). Dietary incorporation of feed supplements in barberry root (*Berberis vulgaris*) extracts 250 mg/kg significantly enhanced the growth activity, digestive enzymes, whole-body composition, and muscle fatty acids form of *O. mykiss* for 56 days trial period (Ramezanzadeh et al., 2020).

Applications herbal dietary feed supplements role in aquatic animals diseases

Dietary inclusion of feed supplement in Ashwagandha (*Withania sominefera*) root powder at 5% for 6 weeks of feeding showed that notable improvement in the antioxidant and immune system activity against *A. hydrophila* infection in *O. niloticus* (Zahran et al., 2018). A dietary combination of feed supplements in Spatholobus Stem (*Spatholobus suberectus)* Birthwort (*Aristolochia debilis*) and Asian ginseng (*Panax ginseng*) are helpful to improve infection confrontation against *Streptococcus agalactiae* infection in *O. niloticus* and good antibacterial effects *in vitro* method (Guo et al., 2019). Dietary feed additives of *M. piperita* essential oil (0.25%) for 50 days of feeding showed improved survival and infection tolerance against *Streptococcus agalactiae* infection in *O. niloticus* (de Souza Silva et al., 2019). Dietary feed supplementation of *S. rosmarinus* 16% notably reduced mortalities following infections of *S. agalactiae* and *S. iniae* bacterial disease in Tilapia (*Oreochromis sp.*) (Van Doan et al., 2022). Dietary inclusion of fish-fed pellet containing 0.75% of *Z. officinale* extract for 8-week feeding in Juvenile Black Rockfish (*Sebastes schlegelii*), survival challenge observed 8 days after challenge in *A. hydrophila* infection differentiated to the test group, finally, *Z. officinale* extract improved the survival ratio in Juvenile *S. schlegelii* (Oh et al., 2022).

Dietary incorporation of combined herbal feed supplements in Arjun tree (*Terminalia arjuna*), 12.3 g/kg for 90 days of feeding showed enhanced growth and disease confrontation against *A. hydrophila* disease in *L. rohita* (Meena et al., 2022). Dietary incorporation of feed supplements in Cape Jasmine (*Gardenia jasminoides*) extract shows that to improved survival and reduced mortalities against WSSV infection in Crayfish (*Procambarus clarkii*) (Huang et al., 2019a). Dietary incorporation of feed supplements in various plants' methanolic extract like Indian Acalypha (*Acalypha indica*), Bermuda grass (*Cynodon dactylon*), Katuka (*Picrorrhiza kurrooa*), *W. somnifera,* and *Z. officinale* in fed diet to shrimp for 60 days, the study showed that to an improved immune response against *White spot syndrome virus* (WSSV) disease in Tiger shrimp (*Penaeus monodon*) (Ghosh et al., 2023).

Dietary inclusion of feed supplements in polyvinylpyrrolidone from Snake grass (*Clinacanthus*) beans shows that to significantly improved infection resistance against *Yellow head virus* (YHV) infection in *P. monodon* (Effendi et al., 2022). Dietary feed inclusion of essential oil and organic acids combinations 0.3 g/kg for 8 weeks of ruminating significantly improved immune activity, intestinal environment, and infection resistance against *Vibrio parahaemolyticus* in *L. vannamei* (Sivakumar et al., 2022; Vijayaram et al., 2022). Dietary feed additives of epigallocatechin-3-gallate (EGCG) 1% had significantly improved the innate immune activity against *A. hydrophila* and *cyprinid herpesvirus 2* disease in Gibel carp (*Carassius auratus gibelio*) (Shen et al., 2022). Dietary inclusion of feed supplements in Chaga mushroom (*Inonotus obliquus*) ethanolic extract 1% and 2% significantly enhanced anti-protease, respiratory burst, and phagocytic activity, activities lysozyme and serum antibacterial activity reduced mortalities against *V. harveyi* disease in Kelp grouper (*Epinephelus bruneus*) (Varalakshmi et al., 2022).

Applications herbals dietary feed supplements role in the immune system of aquatic animals

Dietary incorporation of feed supplements in various medicinal plants such as Astragalus (*Radix astragalin*), Astragalus (*Astragalus radix*), *A. membranaceus*, Baical Skullcap Root (*Scutellaria radix*), Common nettle (*Urtica dioica*), Chaff-flower (*Achyranthes aspera*), Duhuo (*Radix angelicae*), European mistletoe (*Viscum album*), False daisy (*Eclipta alba*), *Z. officinale*, Ganoderma (*Ganoderma lucidum*), Indian rhubarb (*Rheum officinale*), and Japanese honeysuckle (*Lonicera japonica*) are used to 0.1% to 1% level of feedings notably improved immune system and immune gene expression in diverse fish species (Zoral, 2022; Hu et al., 2022; Ren et al., 2022; Sattanathan et al.,2022; Kumar et al.2023; Mohanasundari et al., 2022; Gabr et al., 2023; Ridwanudin et al., 2022). Dietary medicinal herbs feed supplements play a main function in the fish immune system by way of phagocytosis, respiratory burst activity, complement, reactive nitrogen species, reactive oxygen species, total hemocytes, lysozyme, antiprotease, myeloperoxidase, nitric oxide, glutathione peroxidase, and phenoloxidase challenged with, fungal, viral, and parasitic diseases in *C. batrachus* fry (Sharma et al., 2021). Phagocytic cells are the mainly crucial cellular mechanism in the fish immune system; phagocytic action is the main protection mechanism and significant feature of the fish immune system, as well as phagocytes, fabricate toxic oxygen formation through the development of respiratory bursts (Das & Salinas, 2020). Dietary inclusion of feed supplements in Origanum essential oil (1 g/kg) for 15 days trial period demonstrated that notably improved natural immune system activity and plasma bactericidal activity against *Vibrio anguillarum* infection in Red belly tilapia (*Tilapia zillii*) (Mabrok & Wahdan, 2018). Dietary feed additives of 1% *P. guajava* leaf extract (PGE) for 84 days of experimental analysis demonstrated that enhanced growth response, antioxidant, nutrient utilization, immune system reaction, and infection resistance against *A. hydrophila* infection in *O. niloticus* fingerlings (Omitoyin et al., 2019). Dietary feed supplementation of 2 g/kg *C. sinensis* extract for 8 weeks of feeding shows that significantly enhanced humoral (phagocytosis, respiratory burst activities, alternative complement

(ACH50), peroxidase, and serum lysozyme) and mucosal immunity (peroxidase activities and lysozyme), growth, infection resistance against *S. agalactiae* infection in *O. niloticus* (Van Doan et al., 2019). Dietary incorporation of feed supplements in 5 g/kg Elephant foot (*Elephantopus scaber*) extract for 8 weeks of feeding showed that improved humoral (phagocytosis (PI), respiratory burst (RB), alternative complement (ACH50), serum peroxidase (SP), and serum lysozyme (SL)) and mucosal immunity (skin peroxidase (SMPA) and mucus lysozyme (SMLA)), growth and infection tolerance against *S. agalactiae* infection in *O. niloticus* (Doan et al., 2019). Dietary additives of herbs and spices feed supplements in 15 g/kg for 60 days of feeding trial shows that to notably improved some immunological and serum biochemical status (albumin, globulin, and total protein) and plasma lysozyme action of *O. mossambicus* as well as the highest level of concentration lesser standards of respiratory burst action and red blood cell count in fish (Garnier and Shahidi, 2021).

Dietary incorporation of feed supplements in Thai ginseng (TG) (*Kaempferia parviflora*), Chinese ginger (*Boesenbergia rotunda*), powder 10 g/kg for 8 weeks of feeding trial shows that to notably improved peroxidase and lysozyme activities in tilapia skin mucus, as well as phagocytosis index (PI), respiratory burst activities (RB) serum lysozyme (SL), alternative complement (ACH50), and serum peroxidase (SP), and disease resistance against *S. agalactiae* in *O. niloticus* (Van Doan et al., 2019). Dietary feed supplementation of Wolfberry (*Lycium barbarum*) polysaccharides powder notably improved complement 3 (C3) action stimulated interleukin IL-1β gene expression in spleen tissue, considering turning down apoptosis in spleen tissue, and no changes in malondialdehyde (MDA), serum alkaline phosphatase (AKP), and superoxide dismutase (SOD), apoptosis, blood constituents or gene expression of IL-1β in liver tissue in *O. niloticus* (Zhang et al., 2020). Dietary feed supplementation of 1.5% Borage (*Borago officinalis*) Powder for 2 weeks of feeding trial shows that significantly improved white blood cells and no changes in hemoglobin, hematocrit, and red blood cells and also increased leucocyte count before and after *A. hydrophila* disease in *C. carpio* fingerlings (Cheraghi, et al., 2022). Dietary feed additives of 2 g/kg Turmeric powder (TP) (*C. longa*) for 10 weeks of feeding period show significantly improved fish performance, innate immunity, and challenge against *A. hydrophila* infection in Grass carp (*Ctenopharyngodon idella*) (Ming et al., 2020). Dietary feed supplementation of 1% Loquat (*Eriobotrya japonica*) leaf extract (LLE) for 7 week feeding period significantly improved immune-associated gene (TNF-alpha, IL1B, IL8, and LYZ) and downregulated gene (TGF-β) in the bowel and also improved innate immune activation in the early stage of *C. carpio* culture (Hoseinifar et al., 2018). Dietary incorporation of feed supplements in *Z. officinale* extract (6 or 10 g/kg) for 56 days of feeding trial showed that to a notable improvement in phagocytic activity, antibacterial, antioxidant enzymes activity, together with lysozyme activity, Total serum protein, and total serum immunoglobulin and have no changes in lactate dehydrogenase, alanine aminotransferase, and aspartate aminotransferase activities and infection resistance against *Y. ruckeri* disease in *O. mykiss* (Soltanian et al., 2019). Dietary feed supplementation of Garlic peel (0.5%) for 20 days feeding trial shows significantly improved hematological parameters (white blood cells and

red blood cells) biochemical (albumin, globulin, and serum total protein), and more resistance against *A. hydrophila* disease in *C. gariepinus* fingerlings (Hamza et al., 2021).

Anene et al. (2021) reported that the dietary inclusion of feed supplements in Turmeric powder with 4% notable improvement of glucose, serum glutamic pyruvic transaminase, serum glutamic oxaloacetic transaminase, and cholesterol levels and also without any adverse effect on physiological response in *C. gariepinus*. Singh et al. (2019) reported that 0.5% *A. aspera* feed additives show notably increased nitric oxide synthase, myeloperoxidase, and serum lysozyme levels and also reduced carbonyl protein and malondialdehyde content as well as stimulation of IL-1b and TLR 4 and challenged with *A. hydrophila* in *L. rohita*. Jomeh et al. (2021) demonstrated that 1% *H. sabdariffa* extract (RE) feed supplements for 8 weeks of feeding trial show that notably improved RBC, WBC hemoglobin, hematocrit, complement, lysozyme, and up-regulated hepatic tumor necrosis factor-alpha gene expression, as well as 1.5% RE down-regulated interleukin-10 gene expression in *O. mykiss*. Dietary feed additives of five herbal extracts at 0.2% and 1.0%, or Shame plant (*Mimosa pudica*) at 2.0% for 8 weeks feeding period shows that notable improvement of the immune system and infection resistance against *Edwardsiella ictaluri* challenge in *C. gariepinus* (Nhu et al., 2019). Dietary inclusion of feed supplements in (5%) *C. dactylon* for 60 days of feedings period showed that improved biochemical and hematological criteria including red blood cell counts, white blood cell counts, hemoglobin substance, protein, albumin, globulin, albumin/globulin ratio, serum glucose and cholesterol against *A. hydrophila* disease in Giant water prawn (*Macrobrachium rosenbergii*) (Banerjee et al., 2023).

Herbal dietary chasteberry (*Vitex agnus-castus*) feed additives of 15 g/kg for 8 week trial showed notably better hematological parameters (phagocytic activity respiratory burst and lysozyme) and triggered the natural immune system of Goldfish (*C. auratus*) against *A. hydrophila* (Rashmeei et al., 2020). Herbal dietary feed supplement at 1 % *Z. officinale* for 12 weeks feeding trial showed that enhancement in white blood cell (WBC), red blood cell (RBC) values, hematocrit (Htc), lysozyme activity, and respiratory burst activity in *C. carpio* (Arshad et al., 2023). Dietary inclusion of feed supplements in fermented Chinese herbal medicines 1% for 8 weeks of feeding time showed that to improved respiratory burst activity, superoxide dismutase (SOD) activity, white blood cell count (WBC), myeloperoxidase (MPO) activity, and tumor necrosis factor-α (TNF-α) activity, plasma aspartate aminotransferase (AST) and alanine aminotransferase (ALT) activity were examined in juvenile *M. salmoides* fed diet, finally, the study concluded that fermented Chinese herbal medicines supplement is potential immunostimulant in aquaculture (Zhou et al., 2022). Dietary inclusion of herbal feed supplement in aloe-emodin 5 mg/kg for 3 weeks feeding time significantly increased WBC, biochemical parameters, lysozyme activity, phagocytic action, respiratory burst activity, complement activity, and myeloperoxidase activity and infection resistance against *Aphanomyces invadans* in *L. rohita* (Devi et al., 2019).

Chekani et al. (2021) exhibited that dietary herbal feed supplement (dehydrated lemon peel (*Citrus limon*) powder (DLPP)) 1.5 for 45 days feeding trial shows notable improvement of cellular immunity, humoral immunity, and expression of immune-associated genes including Interleukin 1b (il1b), immunoglobulin T heavy chain (igth), natural killer enhancing factor A (nkefa) and colony-stimulating factor receptor 1 (csfr1) and also no elevation of antioxidant enzyme, antioxidant genes, antistress genes activity and expressions after 45 days feeding in *O. mykiss*. Dietary incorporation of feed supplements in herbal *A. membranaceus* and *N. nucifera* leaf powder combinations 1.5% shows that significantly enhanced the immune system function of aquatic animals (Hu et al., 2019). Dietary feed supplementation of herbal Butterfly needles (*Bidens alba*) extract (BAE) and Mexican mint (*Plectranthus amboinicus*) extract (PAE) combinations 20 g/kg for 28 days of feeding trial notably increased natural immune responses, increased total hemocyte count, O^{2-} production ratio, phagocytic activity, PO activity, lysozyme, survival and growth response of *L. vannamei* in aquaculture (Huang et al., 2022).

Applications herbals dietary feed supplements role in the digestive physiology and metabolism of aquatic animals

Dietary feed additives of oregano essential oil have remarkable changes in colon morphometry (villus width, villus height, and crypt depth) of *C. carpio* fingerlings (Abdel-Latif et al., 2020). Dietary feed additive of thymol significantly enlarged the height of the villus intestine in *O. niloticus* (Abd El-Naby et al., 2020). Microbial population communities transformed during the earlier development of the fish immune system (Stosik et al., 2023). Microbial populations and their by-products contain numerous favorable impacts on host health through immunomodulatory functions (Salinas et al., 2022). Nutritional feed additives of oregano essential oil showed that modifies the intestinal microbial communities of *Propionibacterium*, *Corynebacterium*, and *Brevinema* in *C. carpio* (Zhang et al., 2020). Dietary feed supplementation of oregano essential oil 50 and 400 mg/ kg show considerably increased surface area of intestinal villi length and Pepsin enzyme level in the intestinal region of Black Sea salmon (*Salmo labrax*) (Özel et al., 2022). Dietary inclusion of feed additives in oregano essential oil 4500 mg/kg showed significantly improved digestive enzyme activity, antioxidant, immunomodulatory, and alteration of the gut microbial community in Koi carp (*C. carpio*) (Zhang et al., 2020). Dietary incorporation of feed supplements in 1% Thyme (*T. vulgaris*) essential oil did not alter *bacillus* sp in the intestinal region and stimulated the cellular and innate immune system response of *O. niloticus* (Valladão et al., 2019). Dietary inclusion of feed additives in Sweet orange (*Citrus sinensis*) 2-6 g/kg for 45 days of feeding trial shows that considerably enhanced the survival rate, growth activity, digestive enzyme activity, muscle biochemical components, and amino acids. The inconsequential modification in metabolic enzyme action in Catla (*Catla catla*) (Shabana et al., 2019).

Significance of herbal feed supplements in aquaculture

Different types of environmental factors (water quality, salinity, temperature, feed quality, and dissolved oxygen content of water) are mainly involved in improved meat conditions and the manufacture of aquaculture. Environmental impact major threatens to decrease aquatic products like rain, floods, landslides, entry of predatory fish in the culture ponds or reservoirs, excessive temperature, algal bloom, etc. The above factors are mainly caused by anxiety and below consumption of normal feed, disease outbreaks are the main problem to affect health and decreases aquatic production. Chemotherapeutics and antibiotics are applied to manage the infections but these methods affect the organs of aquatic animals and also affect humans, different types of natural methods probiotics, prebiotics, and synbiotics are applied to improve healthy aquatic productions. The herbal dietary feed supplement method is the best traditional method and is also low-cost, nontoxic, and environmentally friendly. The herbal dietary feed supplement is an alternative way to enhance healthy aquatic production in aquaculture.

Conclusion

Herbals are the most vital traditional medicines for humans and aquatic animals and also the most important nutrient supplements for food and feed. Herbal dietary feed additives appreciably enhance healthy life for humans and aquatic animals. Herbal dietary feed additives are used to develop different types of products like medicines, cosmetics, foods, and feeds. Herbal products are eco-friendly, nontoxic, inexpensive, and easily handled, these products are more effects compared to other biological methods. Herbal dietary feed supplements are more effective and efficient additives in aquaculture as well as these natural feed additives are helpful to improve the aquatic feed quality and reduce toxins levels. This review concluded that to provide some information regarding herbal dietary feed supplements. Herbals used as a dietary feed supplement for aquatic animals provide some positive effects like enhanced growth activity, disease resistance against aquatic animal diseases, and stimulating the immune system. These review analyses enlighten to improve research based on herbal dietary applications in aquaculture. In the future, identify and use novel herbal medicines and their by-products utilized to improve aquatic dietary feed quality and healthy aquatic production to fulfill human protein needs and improve healthy human life.

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Conflict of interest

The authors declare no conflict of interest.

Compliance with ethical standards

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Data Availability Statements

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Table 1. Herbals feed supplements role in aquatic animals health.

Herbals Local Name	Herbals Scientific Name	Aquatic Animals Local Name	Aquatic Animals Scientific Name	Administration/ Dosages	Duration of Treatment	Response	References
Turmeric and Clove	*Curcuma Longa* & *Syzygium aromaticum*	Nile tilapia	*Oreochromis niloticus*	Oral, 0, 2, 4, and 8 g/kg	Dietary Turmeric, 8 weeks	NO, Leukocytes, Ly,IL-4, Lymphocyte proliferation index	Abdel Rahman et al. (2020)
Thyme	*(Zataria multiflora)*	Rainbow trout	*Oncorhynchus mykiss*	Oral, 0, 1, 2.5, and 5 g/kg of Ginger extract	Ethanolic Ginger, 45 days	WG, FCR, Ly, ALP, ACP	Mirghaed et al. (2020)
Pumpkin seed meal	*Cucurbita mixta*	Mozambique tilapia	*Oreochromis mossambicus*	Oral, 0, 2, 4 and 6 g/kg	*C. mixta* seed meal diet, 4 weeks	WG, FCR, SGR, Co, Ly, RBA, Pa	Musthafa et al. (2017)
Velvet bean	*Mucuna pruriens*	Mozambique tilapia	*O. mossambicus*	Oral, 0, 2, 4, and 6 g/kg	*M. pruriens* seed meal diet, 4 weeks	WG, SGR, FCR, Ly, RBA, Co, Pa	Saiyad Musthafa et al. (2018)
Ashwagandha	*Withania somnifera*	Nile tilapia	*O. niloticus*	Oral, 0, 2.5%, and 5%	Dietary *W. somnifera* Root Powder, 6 weeks	CAT, GST, GSH,SOD, TAC	Zahran et al. (2018)
Aloe vera	-	Pacu	*Piaractusmesopotamicus*	Oral, 0, 0.5%, 1%, and 2%	Dietary *Aloe vera* extract, 10 days	Ly, Co, RBA	Zanuzzo et al. (2017)
Lemon verbena	*Aloysia citrodora*	Siberian sturgeo	*Acipenser baerii*	Oral, 0, 300, 500, and 800	leaf extract, 90 days	WBC, HCT, HIS, VSI	Adel et al.

		n		mg/kg			(2020)
Lemon peel	*Citrus limon*	Rainbow trout	*O. mykiss*	1.5%	Lemon peel powder/ 45 days	Immunostimulant, Cytotoxic, Bactericidal and Antioxidant	Chekani et al. (2021)
Spade flower	*Hybanthus enneaspermus*	Rohu	*Labeo rohita*	Oral, 0, 1, 2,3, and 4 g/kg	Aqueous extract, 6 weeks	Ly, Pa, RBA, RBC, WBC, SOD, Neutrophil, Protein, ALP, Amylase, Lipase, Protease	Giri et al. (2017)
Chaff flower	*Achyranthes aspera*	Rohu	*L. rohita*	Oral, Control Diet, 0.5% seeds (D1) and leaves (D2)	Dietary seeds and leaves, 80 days	Me, Nitric Oxide Synthase, Lysozyme C and G, TNF-A, IL-10 and IL-1b	Kumar et al. (2019)
Ginseng	*Araliaceae*	Nile tilapia	*O. niloticus*	200 mg/kg	17 week	Enhanced growth performance, diet utilization efficiency, and hematological Indices	Mansour et al. (2022)
Wood betony	*Stachys lavandulifolia*	African cichlid	*Sciaenochromis fryeri*	8%	10 week	Improve liver function and response to acute Stress	Mohammadi et al. (2019)
Garlic	*Allium*	Nile	*O. niloticus*	0.5%	5 week	Improved	Mekawe

	sativum	tilapia				growth performance	y (2019)
Garlic	*A. sativum*	Cat fish	*Heteroclarias*	2.5%	-	Improved growth performance	Ayanwale et al. (2021)
Black cumin Oil	*Nigella sativa*	Rainbow trout	*O. mykiss*	1%	144 days	Growth performance, body composition and lipid Profile	Öz et al. (2018)
Sabah snake grass	*Clinacanthus nutans*	Giant tiger prawn	*Penaeus monodon*	1 g/kg leaf extract	-	Prevented *Yellow Head Virus* Disease	Tan et al., (2020)
Gallnut(Myrobalan)	*Terminalia chebula*	Common carp	*C. carpio*	0.5% and 1%	-	Prevention of *A. Hydrophila* Infections	Zhu (2020).
Elephant's foot	*Elephantopus scaber*	Nile tilapia	*O. niloticus*	5 g/kg	8 week	Disease Resistance Against *Streptococcus agalactiae* Infections	Doan et al. (2019)
Sweetwormwood	*Artemisia annua*	Goldfish	*Carassius auratus*	20 g/kg	45 days	Prevention of*Ichthyophthirius Multifiliis* and *A. Hydrophila* Infections	Wu et al. (2017)
Ginger	*Zingiber officinale*	Grass carp	*Ctenopharyngodon idella*	4 mg/L	-	Prevention of *Ichthyophthirius Multifiliis*	Fu et al. (2019)
Coriander	*Coriandrum sativum*	Rainbow trout	*O. mykiss*	Seed extract 2%	8 week	Improved hematocrit value, hemoglobin content,	Farsani et al. (2019)

						white blood cells, red blood cells	
Mistletoe	*Viscum album*	Rainbow trout	*O. mykiss*	1.78 to 1.94%.	8 week	Growth performance, innate immune antioxidant systems, promoted bactericidal activity	Yousefi et al. (2021)
Common mallow	*Malva sylvestris*	Common carp	*C. carpio*	0.5 and 1 g/kg	45 days	Non specific immune response,growth Promoter disease Resistance against *A. hydrophila*	Bilen et al. (2020)
Coriander Common mallow Oak acorn	*C. sativum* *M. sylvestris* *Quercus brantii*	Common carp	*C. carpio*	3%	60 days	Growth Immune System, antioxidant, and disease resistance	Raissy et al. (2022)
Tarragon	*Artemisia dracunculus*	Rainbow trout	*O. mykiss*	2%	8 week	Growth performance, haemato-immunological, biochemicalparameters, and mucosal immunity	Gholamhosseini et al. (2021)

Garlic	*A. sativum*	Nile tilapia	*O. niloticus*	1.0 g	-	Upregulation of intestinal gene expression il-10 and IL-17F and prevention of *streptococcus* Infection	Foysal et al. (2019)
Pyrola Common verbena	*Pyrola Calliantha Verbena officinalis*	Giant grouper	*Epinephelus fuscoguttatus* × *Epinephelus lanceolatu*	60 g/kg	60 days	Growth response and immune system	He et al. (2021)
Roth	*Ulva clathrata*	Nile tilapia	*O. niloticus*	0.1, 0.5, 1%/kg	60 days	No changes in weight gain, Specific growth rate,weight gain and feed conversion ratio	Pratiwi & Pratiwy 2022
Moshkoorak	*Oliveria decumbens*	Mozambique tilapia	*O. mossambicus*	0.01, 0.1 and 1%	90 days	Specific growth rate, weight gain and feed conversion ratio	Vazirzadeh et al. (2019)
Shallots	*Allium hirtifolium*	Common carp	*C. carpio*	1.5 %/kg	30 days	WBC, Phagocytic action, globulin, phagocytic index	Mahboub et al. (2022)
A. vera	-	Golden mullet	*Liza aurata*	6%	91 days	Growth promoter	Quirós-Pozo et al. 2021

ALP: alkaline phosphatase activity; An: antibody; AP: antiprotease; CAT: catalase; Co: complement; FCR: feed conversion ratio; GPx: glutathione peroxidase; GST: glutathione-S-transferase; Hb: hemoglobin; HCT: hematocrit; Ig: immunoglobulin; IL-10: interleukin 10; IL-1 b: interleukin 1 beta; Ly: lysozyme; Lyz cand g: lysozyme c and g gene; Me: myeloperoxidase; NBT: nitroblue tetrazolium; NO: nitric oxide; Pa: phagocytosis; PL: protein level; PO: phenoloxidase; RBA: respiratory burst activity; RBC: red blood cells; ROS: reactive oxygen species; RNS: reactive nitrogen species; SOD: superoxide dismutase; SGR: Specific growth rate; TNF-a: tumor necrosis factor alpha; VSI: viscerosomatic index; WG: weight gain; WBC: white blood cells.

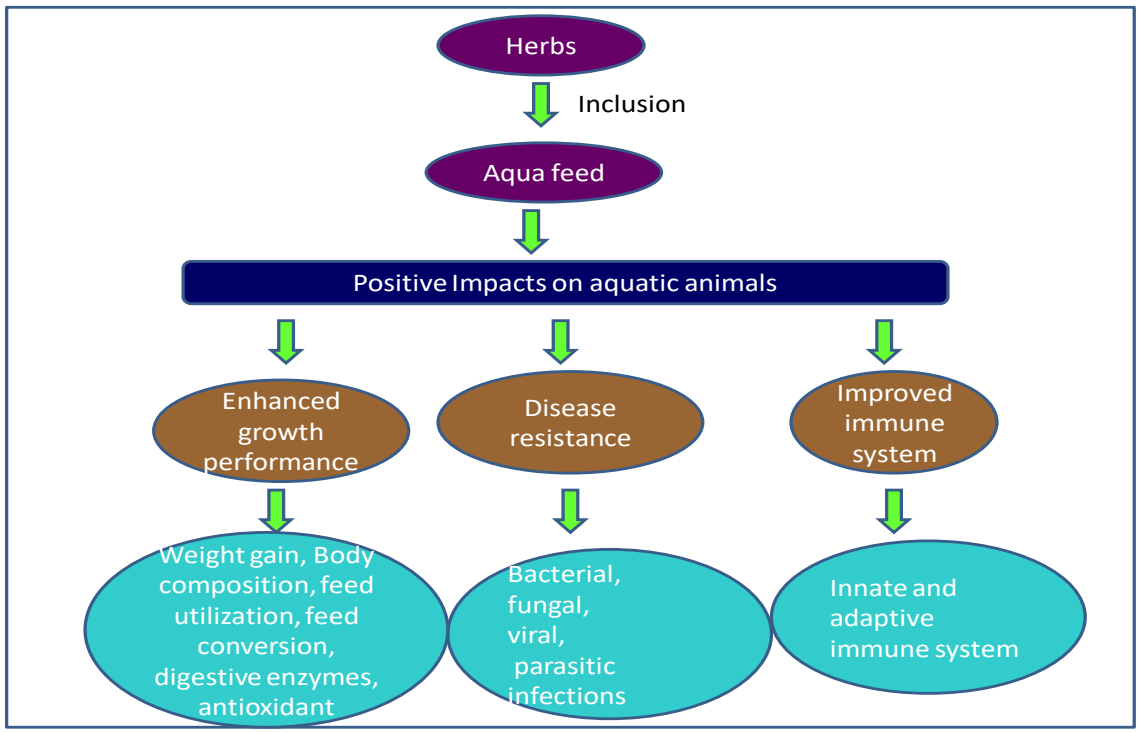

Fig. 1. Applications of herbal supplements in aquaculture.