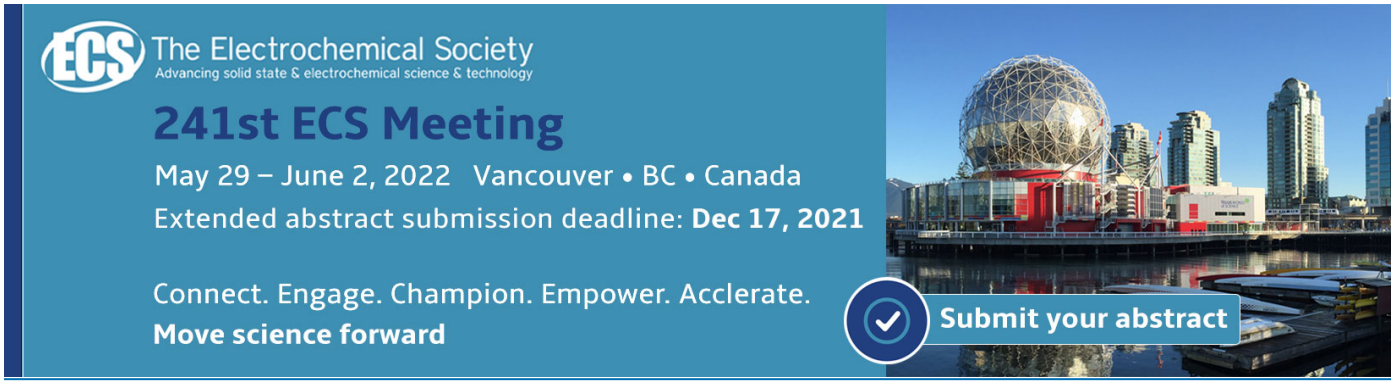
Application of herbal plants in giant freshwater prawn: A review on its opportunities and limitation



Application of herbal plants in giant freshwater prawn: A review on its opportunities and limitation

W Muhammad Amiruddin[1], S A M Sukri[1], S M Al-Amsyar [1], N D Rusli [1,2], K B Mat[1,2], M Mohd[1,2], and H C Harun[1,2,*]

[1]Faculty of Agro-Based Industry, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia.
[2]Institute of Food Security and Sustainable Agriculture, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia.

*E-mail: hasnita@umk.edu.my

Abstract. *Macrobrachium rosenbergii* can be found in northwest India's freshwater to Southeast Asia, Papua New Guinea, and Northern Australia. Nowadays, it becomes the most commercially crucial freshwater crustacean species cultured in many countries in the Asia region and beyond its natural distribution. On the other hand, feed additives are one of the feed ingredients that significantly improve the immune system, enhance the ingestion of feed, stress resistance, and reproduction. There are also many challenges in feed additives, i.e., high price, water-soluble, food safety, environmental issue, and the ban of nutritive antibiotics. Intensified research is devoted to exploiting natural products such as herbs in developing herbal feed additives to enhance cultured aquatic species' performance. Herbs are cheap, safe, effective, easily prepared, biodegradable resources, and a high potential for mass production. Herbs contain many beneficial ingredients that can help as a growth promoter and immunostimulants for animals. However, herbal plants' application to the animal must be in the right dosage to prevent toxicity. This review discusses the findings from different studies related to the *in-vitro* and *in-vivo* applications of herbs as a growth promoter, antimicrobial, and immunostimulant agent besides its opportunity and limitations in applying herbs focusing on *M. rosenbergii* culture.

1. Introduction

In the last decades, it is known that aquaculture production showed impressive growth to meet the increasing global demand for a protein source and to overcome the production limits of capture fisheries [1]. Besides, aquaculture activities have contributed significantly to increase the economics of the middle group. In 2016, *Macrobrachium rosenbergii* had been reported to have an estimated market value that exceeds USD 1.9 billion with 0.23 million tons productions. More than half of its production was produced in China [2].

In Malaysia, the production of *M. rosenbergii* is just about 361.43 tonnes in 2019, which is relatively unstable [3]. Among limitations in establishing the *M. rosenbergii* industry in Malaysia are high mortality at the larvae stage due to low-quality larvae and limited quality broodstocks. The majority of broodstock used by Malaysian hatcheries reported coming from rivers [4]. In terms of growth rate and immune system, animal performance can be improved by enhancing its nutrition

intake [5]. In usual practice, *M. rosenbergii* larvae mainly depend on the live feed, while post larvae (PL) usually take the different sizes of pellets to rely on age. Besides the price, reports showed that the application of *Artemia nauplii* alone could not provide enough nutrition to fulfil the larvae requirement and serve as a disease vector [6]. Even though *M. rosenbergii* is known to have high resistance towards disease infection, disease outbreaks had been reported, especially at larvae and post-larvae stage of *M. rosenbergii* caused by viruses, bacteria, fungi, yeast, and protists culture [7, 8]. Emerging aquatic diseases, intensification of culture, and declining water quality have contributed to a severe health problem in *M. rosenbergii* farming. These threats have pushed the increased usage of antibiotics that could left drug residues within the aquatic products, thus raising global food safety concerns [9].

Moreover, antibiotics are also known to develop microbial resistance towards antibiotics drugs and increase concerns about utilising non-plants xenobiotics agents in animal diets [10]. The development of better quality feed is indispensable to improve the quality of *M. rosenbergii* larvae. Production of fast growth *M. rosenbergii* larvae to reduce time at the larvae stage might improve the prawn larvae's survivability aside from improving disease infection resistance. This approach could potentially solve current problems in *M. rosenbergii* culture, especially in Malaysia. In recent years, finding natural ingredients as alternatives to antibiotics has gained extensive attention. Previous studies had shown the potential application of herbal feed additives in the aquaculture industry for various purposes, e.g., antiparasitic, appetite stimulator, antioxidant, antimicrobial, growth promoter, antistress, and immunostimulant [1, 11, 12, 13].

This review paper concentrates on the recent studies on the use or combination of various herbs and herbal extracts as partial protein replacement, feed supplement, antimicrobial, growth promoter, and immunostimulants on *in-vitro* and *in-vivo* applications for *M. rosenbergii* farming.

2. Herbal Feed Additives

Many beneficial ingredients in herbs contain tannins, polysaccharides, flavonoids, organic acids, volatile oils, alkaloids, and nutrients, i.e., vitamins, amino acids, minerals, and carbohydrates. These ingredients can promote metabolism, increase appetite, increase enzyme activity, and accelerate protein synthesis [14]. Feed additives are among the essential ingredients required to be included in animal feed to improve the feed quality.

2.1 The usage of herbs as a growth promoter and potential application in M. rosenbergii culture.

Feed additives are proven to significantly improve animal performance, health, and growth promoters [1, 11, 15, 16]. The inclusion of herbal nutrients in the feed enhances the feed's digestibility and palatability [17]. Herbs that significantly affect the growth of *M. rosenbergii* are shown in Table 2.1.1.

The active compounds showed the ability to improve growth by inducing the secretion of digestive enzymes that stimulate appetites and increase food consumption [18, 25]. Several studies reported that when the herbal powder is included in the feed, the *M. rosenbergii* PL activity of digestive enzymes increased [23, 24]. Besides, amino acids are protein precursors that serve as a source of energy [13]. Several studies showed that significantly increased amino acid levels have the potential to produce better muscle composition of *M. rosenbergii* PL [21, 26]. Herbs application also improved the meat qualities of *M. rosenbergii* [26].

Table 2.1.1. Type of herbs applied to *M. rosenbergii*.

Herbs	Effects	Reference
Sessile joyweed (*Alteranthera sessili*), false daisy (*Eclipta alba*), veld grape (*Cissus quadrangularis*)	Enhanced the activities of digestive enzymes (protease, amylase, and lipase), concentrations of biochemical constituents (total protein, amino acid, carbohydrate and lipid, essential amino acids, and unsaturated fatty acids), and haemocytes count and population of *M. rosenbergii*	Subramaniam *et al.* [13], Shanthi *et al.* [18]
Couch grass (*Cynodon dactylon*)	Increase weight gain, survival rate, and contents of essential biochemical constituents (total protein, carbohydrate, lipid, and ash) of muscle in *M. rosenbergii*.	Dhanalakshmi *et al.* [19]
Indian ginseng (*Withania somnifera*), holy basil (Ocimum sanctum)	Increase weight gain, specific growth rate, condition factor, survival rate, energy utilisation (feeding, absorption, conversion, and metabolism), and concentrations of biochemical constituents (total protein, amino acid, carbohydrate and lipid, and profiles of individual amino acids) in *M. rosenbergii*.	Bhavan *et al.* [20]
Fenugreek (*Trigonella foenum-graecum*), garlic (*Allium sativum*), turmeric (*Curcuma longa*), ginger (*Zingiber officinale*)	Increase survival rate, feeding rate, and weight gain, improve the specific growth rate, feed conversion efficiency, protein conversion efficiency, metabolise energy, and gross energy in *M. rosenbergii*.	Poongodi *et al.* [17]
Coriander leaves (*Coriandrum sativum*), mint leaves (*Mentha arvensis*), curry leaves (*Murraya koenigii*)	Improve weight gain, specific growth rate, survival rate, feeding rate, absorption rate, conversion rate, ammonia excretion rate, metabolic rate, activities of digestive enzymes, concentrations of biochemical constituents and levels of non-enzymatic antioxidants in *M. rosenbergii*.	Bhavan *et al.* [21]
Purple fruited pea eggplant (*Solanum trilobatum*), black catnip (*Phyllanthus amarus*)	Improve in survival, growth, digestive enzymes, energy utilisation, and vitamin levels in *M. rosenbergii*.	Muralisankar *et al.* [22]
Nutmeg (*Myristica fragrans*), liquorice (*Glycyrrhiza glabra*), gallnut (*Quercus infectoria*)	Increase in weight gain, survival rate, activities of digestive enzymes (protease, amylase, and lipase), concentrations of total protein, non-enzymatic antioxidants, minerals (Na^+ and K^+), and induce secretion of protease, amylase, and lipase in *M. rosenbergii*.	Bhavan *et al.* [23]
Long pepper (*Piper longum*) and black pepper (*Piper nigram*)	Improve in weight gain, specific growth rate, food conversion ratio, elevation in activities of digestive enzymes (protease, amylase, and lipase), concentrations of total protein, non-enzymatic antioxidants, and mineral (Na^+ and K^+) in *M. rosenbergii*.	Bhavan *et al.* [24]

2.2 The use of Herbs as antimicrobial and immunostimulants agents and potential applications in M. rosenbergii culture.

Herbs are used as alternatives to the control of fish diseases with chemicals, drugs, and antibiotics. Antimicrobial effects of herbs have been investigated for various bacterial fish pathogens [11]. Few studies have shown that herbal plants can be a promising alternative to antibiotics [27, 28]. A study that used turmeric and Moringa [29, 30] showed inhibitory effects to counteract various pathogenic

bacteria in shrimp culture. Another study also showed that garlic usage virtually eliminates pathogenic bacteria in freshwater fish, including *Pseudomonas fluorescens*, *Myxococcus piscicola*, *Aeromonas hydrophila*, *Edwardsiella tarda, A. punctata f. intestinalis*, *Staphylococcus aureus*, *Mycobacterium marinum,* and *Streptococcus agalactiae* [31]. Poongodi *et al*. [17] reported that feed mixed with 1% of turmeric powder and 1 % of garlic showed improved survivability of *M. rosenbergii* to up 70% and 82 %, respectively.

Immunostimulants can also boost both the adaptive and innate immune systems of the cultured organism [32, 33]. Previous studies showed that herbs contain immunostimulants that can enhance innate and adaptive immune parameters [34]. Phagocytic activity is vital in the innate immune system [35]. Fish phagocytosis can be improved when treated with immunostimulants [36]. Pan and Yan [37] stated that traditional Chinese herbal extracts could increase phagocytosis in many fish and shrimp species. Furthermore, Soltani *et al*. [38] reported that herbal plants' immunostimulant effects had been confirmed in several commercial fish species. There were many reports of herbs such as dietary peppermint (*Mentha piperita*), green tea (*Camellia sinensis* L.), Bermuda grass (*Cyanodon dactylon*), and false daisy (*Eclipta alba*) used as immunostimulants in aquatic animals such as Caspian brown trout fish (*Salmo trutta caspius*) [39], Caspian white fish (*Rutilus frisii kutum*) [40], greasy groupers (*Epinephelus tauvina*) [41], Nile tilapia (*Oreochromis niloticus*) [42], Pacific white shrimp *(Litopenaeus vannamei*) [43], and black tiger shrimp (*Penaeus monodon*) [44].

A study from Liu *et al*. [45] stated that the haemolymph lysozyme activity of *M. rosenbergii* fed with 0.05% anthraquinone extract from *Rheum officinale* was significantly higher than those of the control group. Another study from Alambra *et al*. [27] indicated that dried turmeric powder could modulate the antimicrobial peptides, particularly crustin and lysozyme of the *M. rosenbergii,* when challenged with *V. alginolyticus*. Furthermore, a 2.0 and 3.0 g kg^{-1} *Eichhornia crassipes* leaves incorporated into the diet of adult *M. rosenbergii* showed significantly increased hyaline cell, total haemocyte count, transglutaminase activity, granular cell, glutathione peroxidase activity, respiratory bursts, superoxide dismutase activity, and phenoloxidase activity, and a significantly decreased haemolymph coagulation time against *Lactococcus garvieae* [46]. Application of *W. somnifera* extract on adult *M. rosenbergii* reported an enhanced immune system against *A. hydrophila* [27].

3. Limitation and Suggested Dose in Applying Herbal Plants.

Some herbs, such as Moringa, have high protein content, i.e., 27.51% in the crude protein of the leaves [47], and can be used as protein replacement or partial protein replacement. However, there are some limitations in applying herbs as the primary protein sources. Herbs also need to be added to the right level because they are dose-dependent. After all, only a sufficient dosage would significantly activate the immune response without being harmful that causes toxicity towards animals [48]. Most of the studies reported applying an inclusion rate of a maximum of 7% of the herbs extracts or powder in the feed formulation for PL of *M. rosenbergii* [17, 18, 20, 22, 23, 26].

Many kinds of research had been conducted to study mixed herb feed formulation focusing on producing feed with a level of fibre content less than 10% [17, 22]. The nutrition requirement of crude fibre in the feed of *M. rosenbergii* is 8% for starter and grower and 10% for finisher prawn diet [49]. Bhavan *et al*. [21] stated that if the fibre content was high, which may increase gastric emptying time and interfere in digestive and absorptive processes, and ultimately decrease the growth of *M. rosenbergii* PL. A study by González-Pena *et al*. [50] reported that adult *M. rosenbergii* could tolerate until a 10% level of α-cellulose in the diet.

In addition, all plants produce chemical compounds as part of their regular metabolic activities, and one of them is known as phytochemicals. Phytochemicals are organic chemical compounds that occur naturally in plants and comprise a diverse group of natural products, some of which may be nutritionally essential but many of which have no nutritional value or antinutritional properties [15]. Antinutritional properties could intrusive with food utilisation and affect the health and performance of animals [51]. Phytochemicals such as phytate, lectin, and trypsin inhibitors can decrease feed conversion efficiency and growth [52]. Previous studies showed that using various herb extracts at

higher concentrations may harm the animals due to feeding deterrents such as saponins [25]. Saponins are triterpene glycoside or steroid compounds present in many plants considered to have lower food palatability in insects, decapod crustaceans, and fishes. Besides, saponins are highly toxic to aquatic species due to their adverse effect on the respiratory epithelia [52].

4. Conclusion and Recommendation

Herbal plants show great potential to be applied in aquaculture to improve aquaculture species performance significantly. In *M. rosenbergii* farming, plant herbs' application reduces and solves production, growth, and disease problems. This review shows that plant herbs towards *M. rosenbergii* health, nutrition, and production are still limited. More studies on this subject are required to improve *M. rosenbergii* culture further in the future.

References

[1] Syahidah A, Saad C R, Daud H M, and Abdelhadi Y M 2014 Status and potential of herbal applications in aquaculture: a review *Iran J Fish Sci*. **14(1)** 27–44
[2] Sui J, Luan S, Yang G, Xia Z, Luo K, Tang Q, Lu X, Meng and Kong J 2019 Genetic parameters and selection response for the harvest body weight of the giant freshwater prawn (*Macrobrachium rosenbergii*) in a breeding program in China *PLoS One*. **14(8)** 1–17
[3] Anon 2020 Annual Fisheries Statistics 2019 *Department of Fisheries, Malaysia*
[4] Banu R, and Christianus A 2016 Giant freshwater prawn *Macrobrachium rosenbergii* farming: a review on its current status and prospective in Malaysia *J Aquac Res Dev*. **7(3)** 1–5
[5] Rebecca A A, and Bhavan P S 2014 Growth promotion and survival enhancement of freshwater prawn *Macrobrachium rosenbergii* post larvae fed with *Allium sativum*, *Zingiber officinale* and *Curcuma longa Int. J. Pure Appl. Zool*. **2(2)** 138-149
[6] Nik Sin N N, and Shapawi R 2017 Innovative egg custard formulation reduced rearing period and improved survival of giant freshwater prawn, *Macrobrachium rosenbergii*, larvae *J World Aquac Soc*. **48(5)** 751–759
[7] Pillai D, and Bonami J R 2012 A review on the diseases of freshwater prawns with special focus on white tail disease of *Macrobrachium rosenbergii Aquac Res*. **43(7)** 1029–1037
[8] Bonami J R, and Widada J S 2011 Viral diseases of the giant fresh water prawn *Macrobrachium rosenbergii*: a review *J Invertebr Pathol*. **106** 131–142
[9] Wang W, Sun J, Liu C, and Xue Z 2016 Application of immunostimulants in aquaculture: current knowledge and future perspectives *Aquac Res*. **48(1)** 1–23
[10] Kumar M, Kumar V, Roy D, Kushwaha R, and Vaiswani S 2014 Application of herbal feed additives in animal nutrition - a review *Int J Livest Res*. **4(9)** 1–8
[11] Awad E, and Awaad A 2017 Role of medicinal plants on growth performance and immune status in fish *Fish Shellfish Immunol* **67** 40–54
[12] Ramudu K R, and Dash G 2013 A review on herbal drugs against harmful pathogens in aquaculture *Am J Drug Discov Dev*. **3(4)** 209–219
[13] Subramanian R, Bhavan P S, Seenivasan C, Shanthi R, and Poongodi R 2014 Influence of medicinal herbs (*Alteranthera sessilis* , *Eclipta alba* and *Cissus quadrangularis*) on growth and biochemical parameters of the freshwater prawn *Macrobrachium rosenbergii Aquac Int*. **22(2)** 551–572
[14] Pu H, Li X, Du Q, Cui H, and Xu Y 2017 Research progress in the application of Chinese herbal medicines in aquaculture: a review *Engineering*. **3(5)** 731–737
[15] Hashemi S R, and Davoodi H 2011 Herbal plants and their derivatives as growth and health promoters in animal nutrition *Vet Res Commun*. **35(3)** 169–180
[16] Mo W Y, Lun C H I, Choi W M, Man Y B, and Wong M H 2016 Enhancing growth and non-specific immunity of grass carp and Nile tilapia by incorporating Chinese herbs (*Astragalus membranaceus* and *Lycium barbarum*) into food waste based pellets *Environ Pollut*. **219** 475–482

[17] Poongodi R, Bhavan P S, Muralisankar T, and Radhakrishnan S 2012 Growth promoting potential of garlic, ginger, turmeric and fenugreek on the freshwater prawn *Macrobrachium rosenbergii*. *Int J Pharma Bio Sci*. **3(4)** 914–926
[18] Shanthi R, Saravana Bhavan P, and Radhakrishnan S. 2012 Influence of medicinal herbs, *Andrographis paniculata*, *Cissus quadrangularis* and *Eclipta alba* on growth, digestive enzymes, biochemical constituents and protein profile of the freshwater prawn *Macrobrachium rosenbergii Bio Technol*. **42** 6478–6484
[19] Dhanalakshmi K, Bhavan P S, Rajkumar G, Nathiya V, Srinivasan V and Satgurunathan T 2016 Phytochemical characterisation of couch grass (*Cynodon dactylon*) and its growth promoting potential on the freshwater prawn *Macrobrachium rosenbergii* post-larvae. *Br Biotechnol J*. **14(2)** 1–24
[20] Bhavan P S, Jeyanthi S and Rebecca A A 2011 Growth performance of the freshwater prawn *Macrobrachium rosenbergii* post larvae fed with *Ocimum sanctum* (Tulsi) *and Withania somnifera* (Ashwagandha) incorporated feeds *Int J Biol Res Dev*. **1(1)** 34–53
[21] Bhavan P S, Manickam N and Radhakrishnan S 2012 Influence of herbal greens, *Murraya koenigii*, *Coriandrum sativum* and *Menthe arvensis* on growth performance of the freshwater prawn *Macrobrachium rosenbergii* post larvae *Res J Biotechnol*. **7(4)** 149–157
[22] Muralisankar T, Bhavan P S, Radhakrishnan S, and Santhanam P 2018 Dietary supplement of medicinal herbal leaf powder on growth performance, digestive enzymes activities, energy utilisation and vitamin levels of the freshwater prawn *Macrobrachium rosenbergii Proc Zool Soc*. **71** 265–271
[23] Bhavan P S, Muralisankar T and Subramanian R 2013 Effects of *Myristica fragrans*, *Glycyrrhiza glabra* and *Quercus infectoria* on growth promotion in the prawn *Macrobrachium rosenbergii Int J Life Sci Biotechnol Pharma Res*. **2(3)** 169–182
[24] Bhavan P S, Saranya C, Manickam N, Muralisankar T, Radhakrishnan S and Srinivasan V 2013 Effects of *Piper longum* , *Piper nigram* and *Zingiber officinale* on survival, growth, activities of digestive enzymes and contents of total protein, vitamins and minerals in the freshwater prawn *Macrobrachium rosenbergii Bio Technol*. **58** 14824–14828
[25] Kawamura G, Yong K A S, Au H L, Doison A, Ooi S Y and Lim L S 2019 Malaysian herbs as feeding attractants and enhancers for the giant freshwater prawn (*Macrobrachium rosenbergii*) and the whiteleg shrimp (*Litopenaeus vannamei*) *Borneo J Mar Sci Aquac*. **3(2)** 57–67
[26] Muralisankar T, Bhavan P S, Radhakrishnan S, Santhanam P, and Jayakumar R 2016 Growth performance, muscle biochemical constituents, amino acid and fatty acid compositions of the giant freshwater prawn, *Macrobrachium rosenbergii*, fed with herb-incorporated diet *Aquac Nutr*. **23(4)** 766–776
[27] Alambra J R, Alenton R R R, Gulpeo P C R, Christine L, Miranda A P, Thomas R C, Velando M K S, Vitug L D, and Maningas M B B 2012 Immunomodulatory effects of turmeric, *Curcuma longa* (*Magnoliophyta*, *Zingiberaceae*) on *Macrobrachium rosenbergii* (*Crustacea*, *Palaemonidae*) against *Vibrio alginolyticus Int J Bioflux Soc*. **5(1)** 13–17
[28] Harikrishnan R, Balasundaram C, Jawahar S, and Heo M S 2012 Immunomodulatory effect of *Withania somnifera* supplementation diet in the giant freshwater prawn *Macrobrachium rosenbergii* (*de Man*) against *Aeromonas hydrophila Fish Shellfish Immunol* **32(1)** 94–100
[29] Mohmad Noor B N A, Abdul Rojab N N, Wahab M A, Mat K, Rusli N D, Al-Amsyar S M, Mahmud M, and Harun H C 2020 Feed formulation of improved egg custard formulation using Response Surface Methodology (RSM). *IOP Conf Ser Earth Environ Sci*. **596**.
[30] Lawhavinit O, Kongkathip N, and Kongkathip B 2010 Antimicrobial activity of curcuminoids from *Curcuma longa* L. on pathogenic bacteria of shrimp and chicken *Kasetsar J* (*Natural Sci*.) **44** 364–371
[31] Lee J Y, and Gao Y 2012 Review of the application of garlic, *Allium sativum*, in aquaculture. *J World Aquac Soc*. **43(4)** 447–458

[32] Reverter M, Bontemps N, Lecchini D, Banaigs B, and Sasal P2014 Use of plant extracts in fish aquaculture as an alternative to chemotherapy: current status and future perspectives *Aquaculture* **433** 50–61
[33] Vaseeharan B and Thaya R 2014 Medicinal plant derivatives as immunostimulants: an alternative to chemotherapeutics and antibiotics in aquaculture *Aquac Int*. **22** 1079–1091
[34] Harikrishnan R, Balasundaram C, and Heo M S 2011 Impact of plant products on innate and adaptive immune system of cultured finfish and shellfish *Aquaculture*. **317** 1–15
[35] Neumann N F, Stafford J L, Barreda D, Ainsworth A J, and Belosevic M 2001 Antimicrobial mechanisms of fish phagocytes and their role in host defense *Dev Comp Immunol*. **25** 807–825
[36] Sakai M 1999 Current research status of fish immunostimulants *Aquaculture*. **172** 63–92
[37] Pan T, and Yan M 2020 The screening of traditional Chinese herbs on nonspecific immune response and protection of Pacific white shrimp (*Litopenaeus vannamei*) from *Vibrio harveyi* infection *Aquac Int*. **28** 767–776
[38] Soltani M, Lymbery A, Song S K, and Hosseini S P 2019 Adjuvant effects of medicinal herbs and probiotics for fish vaccines *Rev Aquac*. **11(4)** 1325–1341
[39] Adel M, Safari R, Pourgholam R, Zorriehzahra J, and Esteban M Á 2015 Dietary peppermint (*Mentha piperita*) extracts promote growth performance and increase the main humoral immune parameters (both at mucosal and systemic level) of Caspian brown trout (*Salmo trutta caspius Kessler*, 1877) *Fish Shellfish Immunol*. **47(1)** 623–629
[40] Adel M, Abedian Amiri A, Zorriehzahra J, Nematolahi A, and Esteban M Á 2015 Effects of dietary peppermint (*Mentha piperita*) on growth performance, chemical body composition and hematological and immune parameters of fry Caspian white fish (*Rutilus frisii kutum*) *Fish Shellfish Immunol*. **45(2)** 841–847
[41] Sivaram V, Babu M M, Immanuel G, and Citarasu T 2004 Growth and immune response of juvenile greasy groupers (*Epinephelus tauvina*) fed with herbal antibacterial active principle supplemented diets against *Vibrio harveyi* infections *Aquaculture*. **237** 9–20
[42] Abdel-Tawwab M, Ahmad M H, Seden M E A and Sakr S F M 2010 Use of green tea, *Camellia sinensis* L., in practical diet for growth and protection of Nile tilapia, *Oreochromis niloticus* (L.), against *Aeromonas hydrophila* infection. *J World Aquac Soc*. **41(S2)** 203–213
[43] Wu Y S, Lee M C, Huang C T, Kung T C, Huang C Y, and Nan F H 2017 Effects of traditional medical herbs "minor bupleurum decoction" on the non-specific immune responses of white shrimp (*Litopenaeus vannamei*) *Fish Shellfish Immunol* **64** 218–225
[44] Citarasu T, Sivaram V, Immanuel G, Rout N, and Murugan V 2006 Influence of selected Indian immunostimulant herbs against white spot syndrome virus (WSSV) infection in black tiger shrimp, *Penaeus monodon* with reference to haematological, biochemical and immunological changes *Fish Shellfish Immunol*. **21** 372–384
[45] Liu B, Ge X, He Y, Xie J, Xu P, He Y, Zhou Q, Pan L, and Chen R 2010 Effects of anthraquinones extracted from *Rheum officinale* Bail on the growth, non-specific immune response of *Macrobrachium rosenbergii Aquaculture*. **310** 13–19
[46] Chang C C, Tan H C, Cheng W 2013 Effects of dietary administration of water hyacinth (*Eichhornia crassipes*) extracts on the immune responses and disease resistance of giant freshwater prawn, *Macrobrachium rosenbergii Fish Shellfish Immunol*. **35** 92–100
[47] Oduro I Ellis W O and Owosu D 2008 Nutritional potential of two leafy vegetables: *Moringa oleifera* and *Ipomoea batatas* leaves *Sci. Res. and Essays*. **3(2)** 057-060
[48] Bulfon C, Volpatti D, and Galeotti M 2015 Current research on the use of plant-derived products in farmed fish *Aquac Res*. **46(3)** 513–551
[49] Paul B N and Giri S S 2015 Fresh water aquaculture nutrition research in India *Indian J Anim Nutr*. **32(2)** 113–125
[50] González-Pena M D C, Gomes S Z, and Moreira G S 2002 Effects of dietary fiber on growth and gastric emptying time of the freshwater prawn *Macrobrachium rosenbergii* (*De Man*,

1879). *J World Aquac Soc*. **33(4)** 441–447
[51] Francis G, Makkar H P S, and Becker K 2001 Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish *Aquaculture*. **199** 197–227
[52] Makkar H P S, Francis G, and Becker K 2007 Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems *Animal*. **1(9)** 1371–1391