Potential Herbs as Eco-green Drugs for Aquaculture: A Review

S. Bharathi¹, Cheryl Antony², A. Uma¹, C. Sudhan³, J. Praveenraj⁴, Phibi Philip Naduvathu³

Abstract

Floral resources are abundant across the globe as it forms a key role in an ecological pyramid and enriched with a bunch of medicinal properties. Historical statue reveals various plants and its materials were used for treatments of different ailments and injuries and also used as nutraceuticals in humans and animals and also used for pest control in agriculture. The practice of using plants in aquaculture started in early 1990’s for various purposes by traditional farmers. Of late, due to overuse of fertilizers, antibiotics and other chemicals in aquaculture that created the environmental issues. As an alternative to chemicals and drugs, herbal based products can be used for eco and green aquaculture for safe and healthy fish productions. There are many potential herbal plants that have been identified and used in aquaculture and we focused on a few highly important herbal plants used in aquaculture. The potential herbal plants such as Aloe vera, Phyllanthus niruri, Azadirachta indica, Curcuma longa, Allium sativum, Ocimum sanctum, Zingiber officinale, Eclipta alba, Cissus quadrangularis, Acalypha indica could be used in fish farming. These herbal plants have versatile medicinal and therapeutic properties in fish, antioxidant, antifungal, antibacterial, antioxidant and immuno-stimulant. This review article gives information about the application of herbal plants in Aquaculture as a sustainable solution for safe and healthy fish productions.

Key words: Aquaculture, Environment, Herbal plants, Medicinal properties, Sustainability.

The study of naturally occurring compounds from herbal plants has progressed at a significant level. Plants have been used for the purpose of healing and in treatment of various diseases from time immemorial. Even when modes of medicines have changed from time to time, plants continue to be the mainstay of medicines (Kumar et al. 2007). Plants play an important role in drug discovery and many approved therapeutics as well as drugs has been derived from natural sources. They have been the source of most of the active ingredients in medicines. The valuable therapeutic impacts of plant materials normally result from the mixes of optional items present in the plant. These secondary metabolites constitute the medicinal value of a drug plant, which produces a definite physiological action on the human body and also finds application in fisheries and aquaculture (Wal et al. 2013). The World Health Organization encourages using medicinal herbs and plants to substitute or minimize the use of chemicals and go back to nature (Kaur and Shah 2017). The excess use of antibiotics in the management of disease in aquaculture has resulted in serious health and environmental problems. Consequently, the need for safe and effective alternatives to antibiotics is required (Shakya 2015). Phytobiotics can be defined as plant derived products used to progress the presentation of an animals. The phytobiotics have a wide variety of properties such as: antioxidant, antimicrobial, anti - carcinogenic, analgesic, insecticidal, anti - parasitic, anti - coccidial, growth promoter appetite enhancement and stimulant of secretion of bile and digestive enzyme activity (Kaur and Shah 2017). The assessment of phytobiotics in aquaculture is a generally new zone of research demonstrating promising outcomes. Expansion of various single herbal extracts (Massa medicata, Crtategi fructus, Artemisia capillaries and Cnidium officinale) or a combination of all the herbs promoted increase and improved a few non-specific immunity indicators of fish (Kaur and Shah 2017). Although interest in the use of medicinal plants and plant extracts in aquaculture has been explored recently, medicinal plants have long been used by rural fish farmers. In maximum cases, fresh plants had been without delay introduced into the rearing water and used to improve water quality, reduce fish stress, increase fish resistance to pathogens and treat fish diseases. Plants have been accounted for to deliver different impacts,such as anti - stress, growth promotion, appetite stimulation, immunostimulation, aphrodisiac and to have anti - pathogen properties in fish and shrimp aquaculture due to their varied active principles such as alkaloids, terpenoids, tannins, saponins and flavonoids (Reverter et al. 2017).
Commonly used medicinal plants in Aquaculture are present in Table 1.

**Aloe vera (L.) Burm. f.**

Aloe vera under the family of Asphodelaceae. Aloe has very good anti – fungal, anti – inflammatory, anti – mutagenic, wound healing and anti–oxidant properties (Joseph and Raj 2010). It has several health benefits, viz., it improves digestion, energy levels, builds immunity and detoxifies the body (Rajeswari et al. 2012b). It was effective against V. alginolyticus in juvenile rockfish (Sebastes schlegeli) at 0.5% level. Aloe vera showed only 1.7% of the mortality (Kim et al. 1999). It has anti-bacterial properties. It was active and effective against the *A. hydrophila* in goldfish (Carassius auratus). This increased the growth and survival rate was 80% at 1.5 % concentration, 75% at 1.0% concentration (Ahilan and Jeyaseelan 2010). It improves the specific and non-specific defence mechanism through increasing the lysozyme activity, serum bacterial power, total protein and IgM levels in common carp and also it shows disease resistance against *A. hydrophila* (Alishahi et al. 2010). Aloe vera leaf extract helped to improve the respiratory activity of leucocytes in *Brycon amazonicus* during (Zanuzzo et al. 2012). It has good antibacterial and disease healer against *A. hydrophila* especially EUS in Striped murrel (Hanif et al. 2013). It acts as a good protective agent against WSSV and *V. parahaemolyticus* in cultured shrimps (Trejo-Flores et al. 2016). Aloe vera in fish diets at 4%, showed higher sex reversal rate in GIFT Nile tilapia, *Oreochromis niloticus* (Gabriel et al. 2017).

**Phyllanthus niruri L.**

It comes under the Euphorbiaceae family. It has anti-viral and hepato-protective properties. When fed in the goldfish (Carassius auratus) it increased the specific growth rate and the survival rate also increased. 1.0% concentration increased the survival rate to 75% and at 1.5% concentration increased the survival rate to 70 (Ahilan and Jeyaseelan 2010). This *Phyllanthus* showed a good antibacterial activity against the bacteria strains *V. harveyi*(JR4). *V. harveyi* (JR7), *V. harveyi* ATCC 35084, *V. parahaemolyticus* ATCC 17802, *V. alginolyticus* ATCC 17749, *Y. ruckeri* ATCC 29473, *E. tarda* ATCC 15947, *P. fluorescense* ATCC 13252, A. hydrophila ATCC 7965, A. cavie ATCC 15468 (Albert and Ransangan 2013). *Phyllanthus niruri* incorporated diets had high growth rate, higher blood parameters (lymphocytes, neutrophils, eosinophils and monocytes) efficiencies compared to control (Hanif and Margaret 2014). 5% incorporation in feed reduced the stress of the *Oreochromis niloticus* by reduction of glucose level in blood (Ibrahim et al. 2015). It improved the primary and secondary antibody response of the *Oreochromis mossambicus* (Muthulakshmi et al. 2016). In *cyprinus carpio*, *Phyllanthus niruri* incorporated diets increased the specific growth rate, food consumption, assimilation rate and efficiency, metabolic rate, serum protein, glucose and cholesterol level and immune-stimulatory effect against *A. hydrophila* (Sunitha et al. 2017).

**Table 1: Commonly used medical plants and its properties.**

| Scientific Name         | Pharmacological properties                                         | References                      |
|-------------------------|-------------------------------------------------------------------|---------------------------------|
| Aloe vera (Aloe)         | Anti-fungal, anti-inflammatory, anti-mutagenic, anti-oxidant,      | (Joseph and Raj 2010)           |
|                         | wound healing capacity                                            |                                 |
| *Phyllanthus niruri*     | Anti-viral, hepatoprotective, anti-bacterial                      | (Bagalkotkar et al. 2006;      |
| (Stonebreaker)           |                                                                   | Albert and Ransangan 2013)      |
| *Azadirachta indica*    | anti-inflammatory, anti-bacterial, anti-viral, anti-fungal,      | (Biswa 2002)                    |
| (Neem)                  | anti-ulcer, anti-pyretic, anti-malarial                           |                                 |
| *Curcuma longa*         | Anti-inflammatory, anti-microbial, anti-oxidant, hepatoprotective, | (Labban 2014)                   |
| (Turmeric)              | anti-carcinogenic, anti-diabetic, anti-depressant, wound healing  |                                 |
|                         | activity                                                           |                                 |
| *Allium sativum*        | Anti-microbial, anti-viral, anti-bacterial, anti-parasitic         | (Kyang 2012)                    |
| (Garlic)                |                                                                   |                                 |
| *Ocimum sanctum*        | Anti-bacterial, anti-viral, anti-fungal, anti-oxidant,             | (Devi 2001; Mohan et al. 2011)  |
| (Tulsi)                 | anti-carcinogenic, radioprotective, adaptogenic activity,         |                                 |
|                         | hypoglycemic, hypolipidemic, hepatoprotective, neuroprotective,   |                                 |
|                         | renoprotective                                                     |                                 |
| *Zingiber officinalis*  | anti-fungal, larvicidal activity, cytotoxic activity, anhelmitic  | (Kumar 2011)                    |
| (Ginger)                | activity, analgesic activity, anti-fungal, anti-inflammatory,     |                                 |
|                         | anti-diarrhoea, anti-diabetic, hepatoprotective, nephroprotective  |                                 |
| *Eclipta alba* (False daisy) | Anti-bacterial, anti-hepatotoxic, anti-hyperlipidemic, anti-oxidant, | (Mithun et al. 2011)           |
| (Veld grape)            | immunomodulatory, analgesic, anti-inflammatory, anti-diabetic,     |                                 |
|                         | anti-cancer, alopecia property                                   |                                 |
| *Cissus quadrangularis* | healing activity, analgesic, anti-osteoporotic, anti-oxidant,     | (Mishra et al. 2010)           |
| (Indian copper leaf)    | para sympathimetic, anabolic androgenic, anti-inflammatory,       |                                 |
|                         | anti-hemorrhoidal, gastroprotective property                      |                                 |
| *Acalypha indica*       | Anti-bacterial, anti-fungal, anti-inflammatory, anti-oxidant      | (Jagatheswari et al. 2013)      |
**Azadirachta indica A. Juss.**

It comes under the family, Meliaceae. The Neem has been reported to have anti-inflammatory, anti-ulcer, antipyretic, anti-malarial, antibacterial, antifungal and antiviral properties. (Mukherjee 1996) reported that application of neem extract to the pond soil reduced the virulence in White Spot Syndrome (WSD). Aquaneem commercial product of neem extracts effectively suppressed the growth of A. hydrophila, P. fluorescenes, E. coli and myxobacteria. 10ppm of this extract controlled the fin rot, tail rot, bacterial gill disease, haemorrhagic septicemia and dropsy when reared in a pond (Das et al. 1999). Neem possesses a triterpenoid called Azadirachtin which is derived from neemseed, it enhances the enhanced respiratory burst activities, the leucocyte count and the primary and secondary antibody response against SRBC (sheep erythrocytes) in tilapia (Oreochromis mossambicus) (Logambal and Michael 2000). 90mg/l of neem oil effectively reduced the Total Ammonia Nitrogen level of 0.45mg/l in 96 hours in brackishwater and application of commercial neem products (neemazal, neemgold) showed reduction in the TAN level respectively as 69% and 79% in brackish water (Krishnani et al. 2002). Neem leaf extract was used as bio pesticide to control the unwanted organisms in the pond and is eco-friendly (Mousa et al. 2008). 100% neem juice incorporation proved higher antibacterial activity and inhibition of Vibrio against shrimp (Banerjee et al. 2013). Neem leaf extract added per kilogram of feed used in Lates calcarifer showed increase in the specific growth, survival rate and improved the non-specific mechanism of seabass against V.harveyi (Talpur et al. 2013). Neem seed oil and neem leaf extract showed better recovery against EUS and red spot disease (Alam et al. 2014).

**Curcuma longa L.**

Turmeric supplemented diet fed gold fish exhibited yellow pigmentation, enhanced growth rate, alkaline protease, lipid activity and had highest acid protease (Pransin 2006). It showed better antibacterial effect, antimicrobial peptides (Crustin and lysozyme) and survival against Vibrio alginolyticus in Macrobrachium rosenbergii (Alambrá et al. 2012). Turmeric extract incorporated at 25% had antibacterial activity against Vibrio harveyi in black tiger shrimp Penaeus monodon and normally turmeric incorporated diets increased the total haemocyte count, phenol oxidase activity, phagocytic activity and bacterial activity against the control (Malar and Charles 2013). (Mahmoud et al. 2014) reported that 0.5% of turmeric powder increased the immunity against Pseudomonas fluorescens in Nile tilapia (Oreochromis niloticus). It also increased the survival rate and growth performance in tilapia. 200ml/kg of garlic extract effectively controls the Acanthocephala in Clarias batrachus (Rosny et al. 2016). Turmeric powder improved the growth rate, survival rate and immunity in common carp (Cyprinus carpio) when challenged with F. Columnaris (Al-Faragi and Hassan 2017). 2g/kg of turmeric in fish diets stimulates the growth parameters, long intestinal fold length and lower bacterial counts in the intestine of Nile tilapia Oreochromis niloticus (Yusuf et al. 2017). 2% incorporation in fish diet improved the growth, haematological indices, immunity and antioxidant capacity of O. mykiss (Yonar et al. 2019).

**Allium sativum L.**

Garlic comes under the family Alliaceae. It has anti-microbial, anti-viral, anti-bacterial, anti-fungal, anti-parasitic properties (Kyung 2012). Garlic incorporated diets increased the haematological parameters (leucocyte, thrombocytes, haemoglobin, erythrocytes and hematocrit values) in fish (Martins et al. 2002). It enhanced the feeding efficiency, survival rate, bacterial activity, lysozyme activity, haemoglobin content in Labeo rohita affected by A. hydrophila when compared to control (Sahu et al. 2007). Garlic incorporated diets develop the immune response of Nile tilapia (Aly et al. 2008). Significant changes in growth performance, antibacterial activity, serum total protein and globulin in rainbow trout — Oncorhynchus mykiss were observed (Nya and Austin 2009a). The garlic in extract or in powder form was used as an antibacterial compound which was used to control the black gill disease in Peneaus indicus (Vaseeharan et al. 2011). The literature review reveals that garlic can effectively eliminate principal pathogenic bacteria such as Pseudomonas fluorescens, Myxococcus piscicola, Vibrio anguillarum, Edwardsiella tarda, Aeromonas punctata, Fibrobacter intestinalis and Yersinia ruckeri in freshwater fishes. It also proved effective against different protozoans that include Opalina ranarum, Opalina dimidicida, Balantidium entozoon, Entamoeba histolytica, Trypanosoma, Leishmania, Leptomonomas and Crithidia (Shakya and Labh 2014). Garlic powder acts as a good growth promoter in common carp (Manoppo et al. 2016).

** Ocimum sanctum L.**

Tulsi belongs to Family Lamiaceae. It has antibacterial, anti-viral, anti-fungal, anti-oxidant, anti-carcinogenic, radio-protective, adaptogenic activity, hypoglycemic, hypolipidemic, hepato-protective, neuro-protective and reno-protective properties (Devi 2001b; Mohan et al. 2011). Diet contained 0.01 and 0.02% of tulsi and ashwagandha proved increase in the specific growth, survival rate and antibacterial activity, serum total protein and globulin in Rainbow trout — Oncorhynchus mykiss were observed (Nya and Austin 2009a). The garlic in extract or in powder form was used as an antibacterial compound which was used to control the black gill disease in Peneaus indicus (Vaseeharan et al. 2011). The literature review reveals that garlic can effectively eliminate principal pathogenic bacteria such as Pseudomonas fluorescens, Myxococcus piscicola, Vibrio anguillarum, Edwardsiella tarda, Aeromonas punctata, Fibrobacter intestinalis and Yersinia ruckeri in freshwater fishes. It also proved effective against different protozoans that include Opalina ranarum, Opalina dimidicida, Balantidium entozoon, Entamoeba histolytica, Trypanosoma, Leishmania, Leptomonomas and Crithidia (Shakya and Labh 2014). Garlic powder acts as a good growth promoter in common carp (Manoppo et al. 2016).

**Curcuma longa L.**

Turmeric supplemented diet fed gold fish exhibited yellow pigmentation, enhanced growth rate, alkaline protease, lipid activity and had highest acid protease (Pransin 2006). It showed better antibacterial effect, antimicrobial peptides (Crustin and lysozyme) and survival against Vibrio alginolyticus in Macrobrachium rosenbergii (Alambrá et al. 2012). Turmeric extract incorporated at 25% had antibacterial activity against Vibrio harveyi in black tiger shrimp Penaeus monodon and normally turmeric incorporated diets increased the total haemocyte count, phenol oxidase activity, phagocytic activity and bacterial activity against the control (Malar and Charles 2013). (Mahmoud et al. 2014) reported that 0.5% of turmeric powder increased the immunity against Pseudomonas fluorescens in Nile tilapia (Oreochromis niloticus). It also increased the survival rate and growth performance in tilapia. 200ml/kg of garlic extract effectively controls the Acanthocephala in Clarias batrachus (Rosny et al. 2016). Turmeric powder improved the growth rate, survival rate and immunity in common carp (Cyprinus carpio) when challenged with F. Columnaris (Al-Faragi and Hassan 2017). 2g/kg of turmeric in fish diets stimulates the growth parameters, long intestinal fold length and lower bacterial counts in the intestine of Nile tilapia Oreochromis niloticus (Yusuf et al. 2017). 2% incorporation in fish diet improved the growth, haematological indices, immunity and antioxidant capacity of O. mykiss (Yonar et al. 2019).
parameters (WBC count, RBC count and Haemoglobin level) (Das et al. 2015). Ocimum sanctum leaves extract improves the Survival, growth performance, Immunological and haematological characters in Clarius batrachus (Nakah and Sahu 2014).

**Zingiber officinale Roscoe**

Ginger under the Zingiberaceae family has proved to exhibit anti-fungal activity, larvicidal activity, cytotoxic activity, anthelmintic activity, analgesic activity, anti-fungal activity, anti – inflammatory activity, anti-diarrhoea, anti-diabetic activity, hepatoprotective and nephron productive properties (Kumar et al. 2011). Ginger increased the disease resistance against V.harveyi in Lates calcarifer. It also showed higher survival rate at 5 and 10g/kg. (Hemapiya et al. 1997) reported ginger contained a polyphenol compound (6-gingerol and its derivatives) which have a high antioxidant activity. Zinger extract had increased the blood extracellular activity of phagocytic cells in rainbow trout (Dugenci et al. 2003). It increased the weight and specific growth rate in Peneaus monodon postlarvae (Venkatramalingam et al. 2007). Ginger extract controls the growth of certain pathogenic organisms like Escherichia coli, Proteus vulgaris, Staphylococcus aureus, Streptococcus pyogenes and Salmonella (White 2007). It showed an increase in the growth rate of grouper around 41% compared to control (Punitha et al. 2008). Talpur et al. (2013) reported that when ginger was incorporated at 5 and 10g/kg of feed increased the specific growth rate and feed conversion ratio (FCR), erythrocytes (RBC), leucocytes (WBC), reduced the glucose level in blood. Ginger powder enhances the immuno-specific defence mechanism in Rainbow trout (Haghighi and Rohani 2013) and it improves the immunity against Aeromonas hydrophila (Nya and Austin 2009b). Zinger powder incorporated feed improved diseases resistant and immunity against Aeromonas hydrophila in Oreochromis niloticus (Hassanin et al. 2014; Payung et al. 2017). The ginger extract also effectively control the monogenean flatworms Gyrodactylus turnbulli in guppy – Poecilia reticulata (Levy et al. 2015). The proximate composition of fresh ginger contains 80.9% moisture, 2.3% protein, 0.9% fat, 1.2% minerals, 2.4% fibre and 12.3% carbohydrates. It also contains minerals like iron, calcium and phosphorus and vitamins such as thiamine, riboflavin, niacin and vitamin C. Gingerols are the major active components in the fresh ginger rhizome (Shakya 2015). It also resulted in 100% survival rate, growth performance and improved the nutritional composition in Cyprinus carpio body (Abbasi Ghadikolaie et al. 2017). 2.5g/Kg and 5g/kg of ginger extract increase the skin mucus, alkaline phosphate activity, weight gain, protein activities and total protein levels in rainbow trout (Shaluei et al., 2017).

**Eclipta alba L.**

False daisy has anti-bacterial, anti-hepatotoxic, anti-hyperlipidemic, anti-oxidant, immunomodulatory, analgesic, anti-inflammatory, anti-diabetic, anti-cancer, alopecia properties (Mithun et al. 2011). Serum lysozyme activity of O. mossambicus fed with Eclipta leaf extract (1%) supplemented-diet increased 770-3000 units/ml. The incorporation of 1% of Eclipta leaf extract in the supplemented diet gave highest protection against A. hydrophila and it increased the survival (Christybapita et al. 2007). Eclipta alba incorporated diets increased the growth rate and improved the immunological parameters and reduced the viral loads in Peneaus monodon (Radhakrishnan et al. 2015). Its root extracts help in improving the haematological characters (RBC, haemoglobin, white blood cells, PCV) in Clarius batrachus (Preeti and Seema 2014).

**Cissus quadrangularis L.**

Veld grape under the family Vitaceae has healing activity, analgesmic, anti-osteoporotic, anti-ulcer, anti-oxidant, parasympathomimetic, anabolic androgenic, anti-inflammatory, anti-hemorrhoidal and gastroprotective properties. It increased the glycogen content in Oreochromis mossambicus (Aruldoss et al. 2014). According to (Radhakrishnan et al. 2014) it improved specific growth, food conversion ratio and survival in Macrobrachium rosenbergii post larva. It increased the growth performance and energy utilization in Macrobrachium malcomsonii post-larvae. Cissus quadrangularis contained feed fed Macrobrachium malcomsonii had improved proximate and amino acid compounds in their body and it showed higher growth and survival rate, digestive enzyme activities and total haemocytes count (Radhakrishnan et al. 2015).

**Acalypha indica L.**

Indian copperleaf under Euphorbiaceae family has anti-bacterial, anti-fungal, anti-inflammatory, anti-oxidant properties (Jagatheeswari et al. 2013). The leaf of the Acalypha indica used for asthma (Vaishnava et al. 1993). The leaf extract of Acalypha indica, enhanced the antibody response in tilapia against sheep red blood cells (Hemapiya et al. 1997). This plant extract control the Aeromonas hydrophila in in-vitro condition (Bhuvaneswari and and Balasundaram 2006). Acalypha indica contained diets enhance the immunity, haematological and growth performance in Peneaus indicus against Vibrio harveyi (Rajeswari et al. 2012a). (Yogeeswaran et al. 2012) has proved that Acalyph aindica with Cynodon dactylon, Withania somnifera, Zinger officinalis and Picrorhiza kurrooa increased the survival rate, growth performance and immunostimulation against the WSSV in P. monodon juveniles. (Reverter et al. 2017) have also reported that Acalypha has anti-bacterial, anti-viral and good immunostimulant activity.

**CONCLUSION**

Herbal remedies have potent anti-viral as well as anti-bacterial and anti-fungal properties. Moreover, these substances also possess other valuable properties as they are non-biodegradable and biocompatible. They are eco-
friendly and easily available. But the use of herbs in aquaculture is still in laboratory level only. Working in medicinal plants is a huge field and many investigations remain necessary to discover the secrets behind these field especially proper investigations that need to be done and standardized for commercialisation of products.

**Conflicts of Interest**

Authors don't have any conflict of interest.

**REFERENCES**

Abbasi, G. H., Kamali, A., Soltani, M. and Sharifian, M. (2017). Effects of Zingiber officinale powder on growth parameters, survival rate and biochemical composition of body in juvenile common carp (Cyprinus carpio). Iranian Journal of Fisheries Sciences, 16: 57-85.

Ahlil, B. and Jeyaseelan, M.J.P. (2010). Influence of certain herbal additives on the growth survival and disease resistance of goldfish, Carassius auratus (Linnaeus), Tamil Nadu J. Veterinary and Animal Sciences, 6 (1): 5-11.

Alam, M.N., Ahmed, G.U. and Chowdhury, M.B.R. (2014). Performance of herbal extracts on diseased fish. Bangladesh Journal of Veterinary Medicine, 12: 225-230.

Alamba, J.R., Alenton, R.R.R., Gulpeo, P.C.R., et al. (2012). Immunomodulatory effects of turmeric, Curcuma longa (Magnoliophyta, Zingiberaceae) on Macrobrachium rosenbergii (Crustacea, Palamonidae) against Vibrio alginolyticus (Proteobacteria, Vibrionaceae). Aquaculture, Aquarium, Conservation and Legislation, 5:13-17.

Albert, V. and Ransangan, J. (2013). Antibacterial potential of plant crude extracts against Gram negative fish bacterial pathogens. International Journal of Research in Pharmaceutical and Biosciences, 3: 21-27.

Al-Faragi, J.K. and Hassan, M.A.H. (2017). Efficiency of dietary turmeric on growth performance, hematological and survival rate in common carp Cyprinus carpio challenged with Flexibacter columnaris. Kufa Journal for Veterinary Medical Science, 8: 130-140.

Alishahi, M., Ranjbar, M.M., Ghorbangerpour, M., Peyghan, R., Mesbah, M. and Razi, J.M. (2010). Effects of dietary Aloe vera on some specific and nonspecific immunity in the common carp (Cyprinus carpio). International Journal of Veterinary Research. 4(3): 189-195.

Aly, S.M., Atti, N.A., Mohamed, M.F. (2008). Effect of garlic on the survival, growth, resistance and quality of Oreochromis niloticus. In: From the pharaohs to the future. Eighth Collaborative Research Support Program, pp 277-296.

Aruldoss, K., Kannan, R., Divya, S. (2014). Effect of Cissus quadrangularis on the biochemical parameter in the fresh water fish, Oreochromis mossambicus. International Journal of Modern Research and Reviews, 2: 178-182.

Bagalkotkar, G., Sagineedu, S.R., Saad, M.S. and Stanslas, J. (2006). Phytochemicals from Phyllanthus niruri Linn. and their pharmacological properties: a review. Journal of Pharmacy and Pharmacology, 58: 1559-1570.

Banerjee, S., Kim, L.M., Shariff, M., et al. (2013). Antibacterial activity of neem (Azadirachta indica) leaves on Vibrio spp. isolated from cultured shrimp. Asian J. Anim. Vet. Adv. 8: 355-361.

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. International Journal of Biological Research and Development, 1: 34-53.

Bhuvaneswari, R. and Balasundaram, C. (2006). Traditional Indian herbal extracts used in vitro against growth of the pathogenic bacteria-Aeromonas hydrophila. The Israeli Journal of Aquaculture-Bamidgeh, 58(2): 89-96.

Biswas, K., Chattopadhyay, I., Banerjee, R.K. and Bandyopadhyay, U. (2002). Biological activities and medicinal properties of neem (Azadirachta indica). Current Science 82: 10.

Christybasita, D., Divyaganeswari, M. and Michael, R.D. (2007). Oral administration of Eclipta alba leaf aqueous extract enhances the non-specific immune responses and disease resistance of Oreochromis mossambicus. Fish and Shellfish Immunology, 23: 840-852.

Citarasu, T. (2010). Herbal biomedicines: a new opportunity for aquaculture industry. Aquaculture International, 18: 403-414.

Das, B.K., Mukherjee, S.C., Sahu, B.B. and Murjani G. (1999). Neem (Azadirachta indica) extract as an antibacterial agent against fish pathogenic bacteria. Indian Journal of Experimental Biology, 37: 1097-1100.

Das, R., Raman, R.P., Saha, H. and Singh, R. (2015). Effect of Ocimum sanctum Linn. (Tulsi) extract on the immunity and survival of Labeo rohita (Hamilton) infected with Aeromonas hydrophila. Aquaculture Research, 46: 1111-1121.

Dev, P. N. (2001). Radioprotective, anticarcinogenic and antioxidant properties of the Indian holy basil, Ocimum sanctum (Tulasi).

Dügenci S.K., Arda, N., Candan, A. (2003). Some medicinal plants as immunostimulant for fish. Journal of Ethnopharmacology, 88: 99-106. https://doi.org/10.1016/S0378-8741(03)00182-X

Gabriel, N.N., Qiang, J., Ma X.Y., et al. (2017). Sex-reversal effect of dietary Aloe vera (Liliaceae) on genetically improved farmed Nile tilapia fry. North American Journal of Aquaculture, 79: 100-105.

Haghighi, M. and Rohani, M.S. (2013). The effects of powdered ginger (Zingiber officinale) on the haematological and immunological parameters of rainbow trout Oncorhynchus mykiss. Journal of medicinal Plant and Herbal Therapy Research, 1: 8-12.

Haniifa, M.A., Bharathi, B.K., Margaret, I.V. and Paray, B.A. (2013). Effect of a Probiotic and Herbal Additives on Growth, Survival and Disease Resistance of Striped Murrel. World Aquaculture june: 64-67.

Haniifa, M.A. and Margaret, I.V. (2014). Effect of Dietary Administration of the Herbal Additive Phyllanthus niruri on Growth Performance and Hematological Changes in Striped Snakehead. World Aquaculture. 66-68.

Hassanin, M.E., Hakim, Y. and Badawi, M.E. (2014). Dietary effect of ginger (Zingiber officinale roscoe) on growth performance, immune response of Nile tilapia (Oreochromis niloticus)
and disease resistance against *Aeromonas hydrophila*. Abbassa Int. J. Aqua. 7: 35-52.

Hemapiya, V.S., Logambal, S.M. and Michael, R.D. (1997). Immunostimulation by leaf extracts of a few south Indian medicinal plants in *Oreochromis mossambicus* (Peters). Developmental and Comparative Immunology. 2: 175.

Ibrahim, M., Khan, M., Rinard, J. and Mustafa, A. (2015). Determination of effective dosage of *Phyllanthus niruri* to modulate stress in tilapia, *Oreochromis niloticus*. Bioeng Biosci. 3: 68-71.

Jagatheeswari, D., Deepa, J., Ali, HSJ. and Ranganathan, P. (2013). *Acalypha indica L.* - An important medicinal plant: A review of its traditional uses and pharmacological properties. International Journal of Research in Botany. 3: 19-22.

Joseph, B. and Raj, S.J. (2010). Pharmacognostic and phytochemical properties of *Aloe vera* Linn an overview. International Journal of Pharmaceutical Sciences Review and Research. 4: 106-110.

Kaur, R. and Shah, T.K. (2017). A review on role of plant waste products on fish growth, health and production. Journal of Entomology and Zoology Studies. 5: 583-589.

Kim, K.H., Hwang, Y.J. and Bai, S.C. (1999). Resistance to *Vibrio alginolyticus* in juvenile rockfish (*Sebastes schlegelii*) fed diets containing different doses of aloe. Aquaculture. 180(1-2): 13-21.

Krishnani, K.K., Gupta, B.P., Joseph, K.O. et al. (2002). Studies on the use of neem products for removal of ammonia from backwater. Journal of Environmental Science and Health, Part A. 37: 893-904.

Kumar, B., Vijayakumar, M., Govindarajan, R. and Pushpanganadan, P. (2007). Ethnopharmacological approaches to wound healing-Exploring medicinal plants of India. Journal of Ethnopharmacology. 114: 103-113. https://doi.org/10.1016/j.jep.2007.08.010.

Kumar, G., Karthik, L. and Rao, K.V.B. (2011). A Review on Pharmacological and Phytochemical Properties of *Zingiber officinale* Roscoe (*Zingiberaceae*). Journal of Pharmacy Research. 4(9): 2963-2966.

Kyung, KH. (2012). Antimicrobial properties of *Allium species*. Curr Opin Biotechnol. 23: 142-147. https://doi.org/10.1016/j.copbio.2011.08.004

Labban, L. (2014). Medicinal and pharmacological properties of Turmeric (*Curcuma longa*): A review. Int. J. Pharm. Biomed Sci. 5(1): 17-23.

Levy, G., Zilberg, D., Paladini, G and Fridman, S. (2015). Efficacy of ginger-based treatments against infection with *Gyrodactylus turnbuli* in the guppy [*Poecilia reticulata* (Peters)]. Veterinary parasitology. 209: 235-241.

Logambal, S.M. and Michael, R.D. (2000). Immunostimulatory effect of azadirachtin in *Oreochromis mossambicus* (Peters). Indian Journal of Experimental Biology. 38: 1092-1096.

Mahmoud, M.M., El-Lamie, M.M., Dessouki, A.A. and Yusuf, M.S. (2014). Effect of turmeric (*Curcuma longa*) supplementation on growth performance, feed utilization and resistance of Nile tilapia (*Oreochromis niloticus*) to *Pseudomonas fluorescens* challenge. Global Research Journal of Fishery Science and Aquaculture. 1: 026-033.

Malar, H.V. and Charles, P.M. (2013). Effect of Turmeric *Curcuma longa* Linn. Extract on immunity and resistance to Vibrio harveyi in black tiger shrimp *Penaeus monodon*. International Journal of Research in Zoology. 3: 21-26.

Manoppo H., Kolopita M.E., Malatunduh R. (2016). Growth promoter effect of garlic (*Allium sativum*) on carp (*Cyprinus carpio* L.). International Journal of Pharm. Tech. Research. 9: 283-288.

Martins, M.L., Moraes, FR., Miyazaki, DMY., et al. (2002). Alternative treatment for *Anacanthorus penilabialis* (Monogenea: *Dactylogyroidae*) infection in cultivated pacu, *Piaractus mesopotamicus* (Osteichthyes: Characidae) in Brazil and its haematological effects. Parasite. 9: 175-180. https://doi.org/10.1051/parasite/2002092175.

Mishra, G., Srivastava, S. and Nagori, B.P. (2010). Pharmacological and therapeutic activity of *Cissus quadrangularis*: an overview. International Journal of Pharmitech. Research. 2: 1298-1310.

Mithun, N.M., Shashidhara, S. and Vivek Kumar, R. (2011). *Eclipta abia* (L) A review on its phytochemical and pharmacological profile. Pharmacology Online. 1: 345-357.

Mohan, L., Amberkar, M.V. and Kumar, M. (2011). *Ocimum sanctum* Linn (Tulsi)- an overview. Int. J. Pharm. Sci. Res. 7: 51-53.

Ranbar, M., Ghorbanpoor, M., Peyghan, R., Mesbah, M. and Razi Jalali, M. (2010). Effects of dietary Aloe vera on some specific and nonspecific immunity in the common carp (*Cyprinus carpio*). Iranian Journal of Veterinary Medicine. 4(3): 295356. 10.22059/IVM.2010.21352

Mousa, M.A., El-Ashram, A.M. and Hamed, M.O.N.A. (2008). Effect of neem leaf extract on freshwater fishes and zooplankton community. In 8th International Symposium on Tilapia in Aquaculture. pp 307-318.

Mukherjee, S.C. (1996). Training programme on fish diseases, their diagnosis and control. Central Institute of Freshwater Aquaculture (ICAR), Bhubaneswar, India.

Muthulakshmi, M., Subramani, P.A. and Michael R.D. (2016). Immunostimulatory effect of the aqueous leaf extract of *Phyllanthus niruri* on the specific and nonspecific immune responses of *Oreochromis mossambicus* Peters. Iranian Journal of Veterinary Research. 17: 200.

Nahak, G. and Sahu, R. (2014). Immunostimulatory effects of *Ocimum sanctum* Linn, leaf extracts in *Clarias batrachus* Linn. Asian J. Pharm. Clin. Res. 7: 157-163.

Nya, E.J. and Austin, B. (2009a). Use of garlic, *Allium sativum*, to control *Aeromonas hydrophila* infection in rainbow trout, *Oncorhynchus mykiss* (Walbaum). Journal of Fish Diseases. 32: 963-970.

Nya, E.J. and Austin, B. (2009b). Use of dietary ginger, *Zingiber officinale* Roscoe, as an immunostimulant to control *Aeromonas hydrophila* infections in rainbow trout, *Oncorhynchus mykiss* (Walbaum). Journal of Fish Diseases. 32: 971-977.

Payung, C.N., Tumbol, R.A. and Manoppo, H. (2017). Dietary ginger (*Zingiber officinale*) enhance resistance of Nile tilapia (*Oreochromis niloticus*) against *Aeromonas hydrophila*. Aquaculture, Aquarium, Conservation and Legislation. 10: 962-968.

Pransin, M. (2006). Using turmeric (*Curcuma longa*) in goldfish (*Carassius auratus*) feed. Master of Science (Aquaculture), Major Aquaculture, Department of Aquaculture, Kasetsart University 86.
Potential Herbs as Eco-green Drugs for Aquaculture: A Review

Preeti, M. and Seema, G. (2014). Haematological evaluation of Eclipta alba root extract in catfish Clarias batrachus. Journal of Pharmaceutical and Scientific Innovation. 3: 240-244.

Punitha, S.M.J., Babu, M.M., Sivaram, V., et al. (2008). Immuno-stimulating influence of herbal biomedicines on nonspecific immunity in Grouper Epinephelus taurina juvenile against Vibrio harveyi infection. Aquaculture International. 16: 511-523.

Radhakrishnan, S., Bhavan, P.S., Seenivasan, C., et al. (2014). Influence of medicinal herbs (Alternanthera sessilis, Eclipta alba and Cissus quadrangularis) on growth and biochemical parameters of the freshwater prawn Macrobrachium rosenbergii. Aquaculture International. 22: 551-572.

Radhakrishnan, S., Saravana Bhavan, P., Seenivassan, C., et al. (2015). Effects of native medicinal herbs (Alternanthera sessilis, Eclipta alba and Cissus quadrangularis) on growth performance, digestive enzymes and biochemical constituents of the monsoon river prawn Macrobrachium malcolmsonii. Aquaculture Nutrition. 21: 496-506.

Rajeswari, P.R., Velmurugan, S., Babu, M.M., et al. (2012a). A study on the influence of selected Indian herbal active principles on enhancing the immune system in Fenneropenaeus indicus against Vibrio harveyi infection. Aquaculture International. 20: 1009-1020.

Rajeswari, R., Uma Devi, M., Rahale, C.S., et al. (2012b). Aloe vera: the miracle plant its medicinal and traditional uses in India. Journal of Pharmacognosy and Phytochemistry. 1: 118-124.

Reverter, M., Tapiessier-Bontemps, N., Sasal, P. and Saulnier, D. (2017). Use of medicinal plants in aquaculture. Diagnosis and Control of Diseases of Fish and Shellfish. 9: 223-261.

Rosny, H.S., Hossain, M.M.M., Hasan-Uj-Jaman, M., et al. (2016). Dietary supplementation of garlic (Allium sativum) to prevent Acanthocephala infection in aquaculture. International Journal of Fisheries and Aquatic Studies. 4: 188-192.

Sahu, S., Das, B.K., Mishra, B.K., et al. (2007). Effect of Allium sativum on the immunity and survival of Labeo rohita infected with Aeromonas hydrophila. Journal of Applied Ichthyology. 23: 80-86.

Shakya, S.R. (2015). Medicinal uses of ginger (Zingiber officinale Roscoe) improves growth and enhances immunity in aquaculture. International Journal of chemical studies. 3: 83-87.

Shakya, S.R. and Labh, S.N. (2014). Medicinal uses of garlic (Allium sativum) improves fish health and acts as an immuno-stimulant in aquaculture. European Journal of Biotechnology and Bioscience. 2: 44–47.

Shalaei, F., Nematozadeh, A., Naderi Farzani, H.R., Rahimi, R. and Kaboutari Kadaji, J. (2017). Effect of ethanolic extract of Zingiber officinale on growth performance and mucosal immune responses in rainbow trout (Oncorhynchus mykiss). Aquaculture Nutrition. 23(4): 814-821.

Shankar, K and Kiran, BR. (2013). Review on usage of medicinal plants in fish diseases. International Journal of Pharma. and Bio Sciences. 4(3): 975-986.

Sivaram, V., Babu, M.M., Immanuel, G., et al. (2004). Growth and immune response of juvenile gready groupers (Epinephelus taurina) fed with herbal antibacterial active principle supplemented diets against Vibrio harveyi infections. Aquaculture. 237: 9-20. https://doi.org/10.1016/j.aquaculture.2004.03.014

Sunita, C., Mettilda, S. and Vinoliya, J. (2017). Effect of dietary intake of Phyllanthus niruri L. on fingerlings of freshwater fish, Cyprinus carpio L. Int. J. Fisheries Aquatic Studie. 5: 352-9.

Talpur, A.D., Ikhwuddin, M., Bolong, A-MA. (2013). Nutritional effects of ginger (Zingiber officinale Roscoe) on immune response of Asian sea bass, Lates calcarifer (Bloch) and disease resistance against Vibrio harveyi. Aquaculture. 400: 46-52.

Trejo-Flores, J.V., Luna-González, A., Álvarez-Ruiz, P., et al. (2016). Protective effect of Aloe vera in Litopenaeus vannamei challenged with Vibrio parahaemolyticus and white spot syndrome virus. Aquaculture. 465: 60-64.

Vaishnava, M.M., Tripathi, A.K. and Gupta, K.R. (1993). Constituents of Cassia fistula roots. Fitorterapi. 64(1): 93.

Vaseeharan, B., Prasad, G.S., Ramasamy, P. and Brennan, G. (2011). Antibacterial activity of Allium sativum against multidrug-resistant Vibrio harveyi isolated from black gill–diseased Fenneropenaeus indicus. Aquaculture International. 19(3): 531-539.

Venkatramalingam, K., Christopher, J.G. and Citarasu, T. (2007). Zingiber officinalis an herbal appetizer in the tiger shrimp Penaeus monodon (Fabricius) larviculture. Aquaculture Nutrition. 13: 439-443.

Wal, A., Wal, P., Gupta, N., et al. (2013). Medicinal value of Euphorbia tirucalli. Int J Pharm Biol Arch. 4(1): 31-40.

White B. (2007). Ginger: An overview. American family physician. 75: 1689-1691.

Yogeeswaran, A., Velmurugan, S., Punitha, S.M.J., et al. (2012). Protection of Penaeus mono don against white spot syndrome virus by inactivated vaccine with herbal immunostimulants. Fish and Shellfish Immunology. 32: 1058-1067.

Yonar, M.E., Yonar, S.M., Ispir, Ü. and Ural, M.Ş. (2019). Effects of curcumin on haematological values, immunity, antioxidant status and resistance of rainbow trout (Oncorhynchus mykiss) against Aeromonas salmonicida subsp. achromogenes. Fish and Shellfish Immunology. 89: 83-90.

Yusuf, M.S., Hassan, M.A., Tag, H.M., et al. (2017) Influence of turmeric (Curcuma longa) on performance, histomorhology and microbiota of intestine in juvenile tilapia (Oreochromis niloticus). Int. J. Agric. Sci. Vet. Med. 5: 7-16.

Zanuzzo, F.S., Biller-Takahashi, J.D. and Urbinati, E.C. (2012). Effect of Aloe vera extract on the improvement of the respiratory activity of leukocytes of matrixa during the transport stress. Revista Brasileira de Zootecnia. 41(10): 2299-2302.