Herbal medicine in aquaculture

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With the continued expansion of cultured fish and shellfish species, aquaculture has become a key component of the animal health industry. Aquaculture is the fastest growing industry around the world with around 80 million tonnes produced annually. With an average annual growth rate of 7 percent, more then 60 percent of the global seafood is currently supplied from aquaculture. However, this growth is not without its problems, as demonstrated by the latest outbreak of Early Mortality Syndrome (EMS) in the shrimp industry, sea lice in the salmon industry and an array of other diseases.

Disease in aquaculture

Due to the intensification of rearing methods and systems, diseases and pathogens have been an integral part of, and a formidable obstacle to, the aquaculture industry worldwide. Moreover, antibiotic resistance has become a major issue affecting the aquaculture industry.

Already in 1994, the American Society of Microbiology stated that 'the increasing problems associated with infectious diseases in fish, the limited number of drugs available for treatment and prevention of these diseases, and the rapid increase in resistance to these antibiotics represent major challenges for this source of food production worldwide' (ASM 1994).

Currently, almost every sector of the aquaculture industry, from fish to crustaceans and shellfish, is using some sort of chemotherapeutic agents including antibiotics and many other chemicals. Although the use of drugs such as Fluoroquinolones, Nitrofurans, Chloramphenicol are prohibted in many countries, the use of these these drugs is still a common practice.

Banning and rejection of seafood imported to the United States or EU countries due to antibiotic or other chemotherapeutics residues are an almost daily occurrence, and yet there is currently no alternative solution to antibiotics and other chemotherapeutics.

During the past decade, several outbreaks of disease devastated the aquaculture industry around the world. In the past three years, the Southeast Asian and Mexican shrimp industries were affected by EMS outbreaks. The Chilean salmon industry suffered (and still does) a devastating outbreaks of sea lice and the infectious salmon anaemia (ISA) virus, causing losses of hundred of millions of dollars. These outbreaks drove the authorities to review and revise the use of chemotherapeutics in this industry.

Misuse of antibiotics

This misuse of antibiotics in all areas – human medicine, veterinary medicine, animal production and plant protection – led the FAO to write a 2005 paper, 'The responsible use of antibiotics in aquaculture', to raise awareness of the antibiotic resistance problem in fish farming and related sectors.

The document focuses on antibiotics misuse and the concomitant threat of resistance development, which is seen as a public health concern affecting the population worldwide.

In its opening statement the authors remarked: 'Antibiotic resistance as a phenomenon is, in itself, not surprising. Nor is it new. It is however, newly worrying because it is accumulating and accelerating, while the world's tools for combating it decrease in power and number.'

Diseases and pathogens are part of all intensive farming. In aquaculture a 'natural mortality' of 10-25 percent is considered to be normal in grow-out systems. Marine finfish larvae (such as sea bream, sea bass, yellowtail kingfish etc) survival in intensive hatcheries is 5-40 percent (Kolkovski, personal comment).

These low survival rates are usually the result of combined factors, such as environmental conditions, non-specific pathogens, larvae susceptibility and low immune system development. In fact, this situation is true to most marine and freshwater organisms reared in intensive systems. Although banned in most countries, in many cases antibiotics are used to combat this problem, whether as growth promoters or specifically against bacterial infection (Hernández Serrano, 2005).

Alternative therapy

Phytotherapy (the use of herbal extracts in human medicine) has been known for thousands of years. In China, India, Southeast Asia and some countries in South and Central America, phytotherapy is considered mainstream, while in the West naturopathy and herbal medicine are becoming more and more acknowledged.

Different medicinal plants and herbs, and/or combinations of them, are known to have various health benefits, including antibacterial and antifungal properties, hormonal balancing and support for the immune and digestive systems. The world market for herbal medicine has been estimated to have an annual growth rate between 5 and 15 percent, with an estimated value of US$62 billion (Citarasu, 2009).

Strategies for prophylaxis and control of pathogens include improvement of environmental conditions, stocking of specific pathogen free (SPF) shrimp post-larvae, and enhancement of disease resistance with immunostimulants such as glucans. Immunostimulants are substances that enhance the non-specific defence mechanism and provide resistance against pathogenic organisms (Citarasu *et al.*, 2006).

Many plant-derived compounds have been found to have non-specific immunostimulating effects in animals, of which more than a dozen have been evaluated in fish and shrimp (Citarasu *et al.* 2002, 2006, Sakai, 1999). Many herbs and plants have been used as home remedies in cultures around the world for millennia, for human and animal consumption.

Some of these remedies have potent

Table 1. Plants and herbs with antibacterial effects in aquaculture

Botanical name	Family	Distribution	Useful parts	Biological effects in aquaculture	Reference
Daemia extenas	Asclepiadeae	India	Leaves and roots	Antibacterial amd immunostimulant	*Sivaram et al., 2004; Jinish, 2012*
Psoralea corylifolia	Papilionaceae	India	Seeds	Antibacterial	*Citarasu et al., 2003 b*
Adathoda vasica	Acanthaceae	India	Whole plant	Antibacterial	*Citarasu et al., 2001 Minimol, 2005*
Acalypha indica	Euphorbiaceae	India	Whole plant	Antibacterial	*Citarasu et al., 1999*
Andrographis paniculata	Acanthaceae	India	Whole plant	Antibacterial	*Direkbusarakom, 2004; Citarasu et al., 2003b; Rani, 1999; Jinish, 2002*
Azadirachta indica	Meliaceae	India, Burma	Whole plant	Antibacterial	*Sivaram et al., 2004*
Artemisaia vulgaris	Compositae	India, Japan	Whole plant	Antibacterial, Antiviral	*Shagnliang et al., 1990*
Elephentopus scaber	Compositae	India, Bengal	Roots and leaves	Antibacterial	*Alex Rajan, 2002*
Ixora coccinea	Rubiaceae	India	Root	Antibacterial	*Citarasu et al., 1998 b; Alex Rajan, 2002*
Leucus aspera	Labiatae	Southern India	Whole plant	Antibacterial	*Citarasu et al., 1998; Immanuel et al.,2004b; Jinish, 2002*
Melia azedarach	Meliaceae	India	Whole Plant	Antibacterial	*Citarasu et al., 2001*
Murraya koenji	Rutaceae	India	Leaves	Antibacterial	*Sivaram et al., 2004*
Ocimum sanctum	Labiatae	India	Whole Plant	Antibacterial antiviral, anti stress	*Direkbusarakom, 2004; Citarasu et al., 1998a; Rani, 1999; Praseetha, 2005*
Quercus infectoria	Cupuliferae	Greece, Asia, Syria	Galls and Bark	Antibacterial	*Citarasu et al., 1999*
Solanum surattense	Solanaceae	India	Fruits and Roots	Antibacterial	*Sivaram et al., 2004*

Table 2: Plants and herbs with antiviral effects in aquaculture

Botanical name	Family	Distribution	Useful parts	Biological effect in aquaculture	Reference
Oenothera biennis	Onagraceae	Japan, Eastern N. America, UK	Seeds, flowers and root	Antibacterial and antiviral	*Shangliang et al., 1990*
Solanum trilobatum	Solanaceae	India	Whole plant	Antibacterial and immunostimulant	*Citarasu et al., 2003b*
Stellaria aquatica	Caryophyllaceae	Japan	Whole plant	Antibacterial and antiviral	*Shangliang et al., 1990*
Acorus calamus	Aroideae	India, Burma	Rhizome	Antibacterial and immunostimulant	*Magdelin, 2005; Minomol, 2005; Praseetha, 2005*
Cassia alata	Caesalpiniaceae	Tropics	Leaves	Antiviral	*Direkbusarakom, 2004*
Calophyllum inophyllum	Guttiferae	Sea coast of India	Bark, leaves and seed	Antiviral	*Direkbusarakom, 2004*
Tinospora crispa	Menispermaceae	Tropical, Subtropical India	Root and leaves	Antiviral	*Direkbusarakom, 2004*
Momordica charantina	Cucurbitaceae	India	Fruits, seeds and leaves	Antiviral	*Direkbusarakom, 2004*
Phyllanthus niruri	Euphorbiaceae	India, Sri Lanka	Whole plant	Antiviral	*Rani, 1999; Direkbusarakom, 2004; Immanuel et al., 2004b*
Phyllanthus urinaria	Euphorbiaceae	India, USA	Whole plant	Antiviral	*Direkbusarakom, 2004*
Psidium guajava	Myrtaceae	India, Bengal	Bark, fruit and leaves	Antiviral	*Direkbusarakom, 2004; Anita, 2001*
Ocimum basilicum	Labiatae	India	Whole plant	Antiviral and antibacterial	*Direkbusarakom, 2004; Citarasu et al., 2001*
Tephrosia purpurea	Papilionaceae	Southern India	Leaves and root	Antiviral and antibacterial	*Direkbusarakom, 2004; Rani, 1999*
Tinospora cordifolia	Menispermaceae	Southern India	Leaves and stem	Antiviral and immunostimulant	*Citarasu et al., 1998a; Direkbusarakom, 2004; Jinish, 2002*

antiviral, antibacterial and antifungal effects. Natural plant products have been reported to have various other properties making them useful as anti-stressors, growth promoters, appetizers, tonics and immunostimulants.

Moreover, these substances also possess other valuable properties: they are non-toxic, biodegradable and biocompatible. No herbal-resistance immunity has been found by any pathogen to date.

Although the properties of herbs and plants are well known, documented, and in use in human medicine around the world, currently very few commercial remedies exist for use in large-scale aquaculture.

Medicinal plants in aquaculture

It is well known and documented that medicinal plants have strong antibacterial effects. Phenolics, polysaccharides, proteoglycans and flavonoids are known to play an important role in preventing and controlling bacterial infections. Herbs such as *S. triblobatum*, *A. paniculata* and *P. corylifolia* were found to reduce vibrio in *P. monodon* by a third when supplied in enriched Artemia (Citrasu *et al.* 2002, 2009).

Several plant products have been found to have potent antiviral effects against fish and shrimp viruses. For example, Direkbusarakom *et al.* 1996 found that shrimp fed ethanol extract of *Clinacanthus nutans* had 95 percent survival rates when exposed to yellow head virus (YHV), compared to only 25 percent survival in control group of black tiger shrimp.

Several species of Indian herbs and plants such as *A. marmelos*, *C. dactylon*, *L. camara*, *M. charantia* and *P. amarus* showed strong antiviral activity against white spot syndrome virus (WSSV) when extracted with organic solvents such as ether, chloroform, ethyl acetate, methanol and ethanol. Many other studies have been published looking at the antibacterial and antiviral effect of herbal extracts with different species (see Table 1).

Herbal extracts are also known to have antifungal and antiparasitic properties. Adiguzel *et al.* (2005) controlled infection of *Aspergillus flavus* and *Fusarium oxyspoum* with extract of *O. basilicum*. A novel anti-fungal molecule, was isolated from the plant *Datura metel L.* (Dabur, 2004). This molecule was shown to have anti-Aspergillus properties, as well as acting against 10 clinical isolates of Candida, 19 clinical isolates of Aspergillus and a few marine fungi.

The herbal extracts involve the fungal cell wall lysis, altering the permeability, affecting the metabolism and RNA and protein synthesis, and ultimately leading to death (Citarasu, 2009).

Herbal extracts have been used for centuries against internal and external parasites in humans, through direct effect on the parasite and/or by strengthening the immune system. For example, garlic was used against skin parasites, with sweat containing the garlic's active ingredients acting as a repellent.

Similarly, a mix of herbal extracts added to fish feed assists with gill and skin flukes such as *Benedenia seriolae*. It is assumed that the mucus on the fish skin containing the herbal active ingredients acts as repellent, and reduces parasitic infection.

Herbal compounds have the ability to inhibit the generation of oxygen anions and scavenge free radicals, hance reducing stress effects. Herbal antioxidant effects were demonstrated by Citrasu *et al.* (2006) when *P. kurroa* (picrorhiza) was used as an antistress compound for black tiger shrimp. Other herbs including *Astragalus membranaceus, Portulaca oleracea, Flavescent ophora* and *A. paniculata* are known to have specific and non-specific antistress effects.

Medicinal plants are also known to have hormonal boosting effects with some herbs being used in herbal medicine as natural 'viagra' and in hormonal replacement therapy for menopausal woman. Significant increases in fecundity and gonadal weight and reduced intermoult period in *P. monodon* were observed when the shrimp were fed a maturation diet containing *W. somnifera*,

Table 3: Plants and herbs used as growth promoters and immunostimulants in aquaculture

Botanical name	Family	Distribution	Useful parts	Biological effects in aquaculture	Reference
Hygrophila spinosa	Acanthaceae	India, Sri Lanka	Whole plant	Growth promoter	*Citarasu et al., 2002*
Ipomea digitata	Convolvulaceae	Hotter part of India	Root	Growth promoter and immunostimulant	*Citarasu et al., 1999*
Solanum nigrum	Solanaceae	India	Berries	Growth promoter	*Jeyaprakash and Euprasia, 1996*
Terminaelia arjuna	Combretaceae	India, Burma, Sri Lanka	Bark	Growth promoter	*Jeyaprakash and Euprasia, 1996*
Boerhaevia diffusa	Nyctaginaceae	India, Tibet	Leaf and root	Growth promoter and appetizer	*Jeyaprakash and Euprasia, 1996*
Carica papaya	Caricaceae	India	Fruit	Growth promoter and appetizer	*Balakrishnan, 1999; Penaflorida, 1995; Rheka, 1997*
Eclipta erecta	Compositae	India	Whole plant	Hepeto tonic, immunostimulant and antistress	*Citarasu et al., 1998a*
Eclipta alba	Compositae	India	Whole plant	Hepeto tonic, immunostimulant, antiviral and antistress	*Direkbusarakom, 2004; Citarasu et al., 1998a; Rani, 1999*
Cymodon dactycon	Gramineae	India	Leaf and root stalk	Immunostimulant and antibacterial	*Minomol, 2005; Citarasu et al., 2006; Immanuel et al., 2007; Praseetha, 2005*
Emblica officinalis	Euphorbiaceae	India	Whole plant	Immunostimulant and antibacterial	*Minomol, 2005; Praseetha, 2005*
Urtica dioica	Urticaceae	Europe, Turkey, India	Whole plant	Immunostimulant	*Dugenci et al., 2003*
Vernonia cinera	Compositae	India	Whole plant	Immunostimulant	*Citarasu et al., 1998b; 1999*
Viscum album	Loranthaceae	India, Himalayas, Turkey	Berries and leaves	Immunostimulant	*Dugenci et al., 2003*
Zingiber officinale	Scitaminaceae	India, China, Bengal	Rhizome	Immunostimulant	*Citarasu et al., 2001; 2002; Immanuel et al., 2007*
Picrorrhiza kurvooa	Scrophulariaceae	India	Rhizome	Immunostimulant and antistress	*Citarasu et al., 1998a; 2006*
Withania somnifera	Solanaceae	India	Root	Immunostimulant and growth promoter	*Citarasu et al., 1998a; Jinish, 2002; Immanuel et al., 2007*

Mucuna pruita, *Ferula asafoetida* and *Piper longum* extracts (Babu, 1999).

Currently, several hatcheries around the world are using the herbal extract mix NutraBrood Enhance specifically designed to boost and modulate the hormonal system in aquatic animals. The herbal extracts are used with out-of-season broodstock and/or species with fertilization and gonadal development problems such as groupers (low sperm motility and volume) and many other species (Table 2).

Another commercial semi-moist maturation diet, NutraFeed, that included herbal extracts was fed to *P. vanamei*, resulting in a more than 40 percent increase in total nauplii produced, with a 44 percent reduction in mortality compared to the normal fresh feed and nutritional boosters used (Kolkovski *et al.*, 2013). Similar results were found with the Black tiger prawn *P. monodon* (Kolkovski *et al.*, 2010).

Issues

Although herbal remedies have been used in human therapy for millennia, there has been relatively little research into the use of medicinal plants in aquaculture.

Standardisation is an issue when the whole plant or herb is used during the extraction process. Moreover, in many countries including the United States, Australia and the EU, the same herbal and plant extracts approved for use in human naturopathy and herbal medicine are treated as drugs when used in aquaculture.

This means herbal remedies have to be registered, a process that can take years, and costing hundreds of thousands or even millions of dollars. A review of this legislation needs to be carried out, taking into account the benefits of herbal remedies over currently used chemotherapeutic agents.

Herbal extracts can be used not only as remedies, but even moreso as growth promoters, stress resistance boosters and preventatives for infections. Therefore, the use of herbal extracts as feed additives can significantly benefit any organism reared under intensive conditions. Legislation needs to be reviewed and the use of herbal extracts as feed additives allowed.

Conclusion

The development of drug-resistant pathogens has been reported from all areas of aquaculture. Treating microbial infections in fish and crustaceans involves dissolving high quantities of broad-spectrum chemotherapeutic agents in the culture medium, or supplying it in the food. Most of these antibiotics and drugs are now banned for use in the EU, United States and many other countries.

Natural plant products present a viable alternative to antibiotics and other banned drugs, being safer for the reared organism and humans, as well as for the environment. Authorities should review the current legislation regarding the use of herbal and natural remedies in aquaculture, taking the above issues into consideration and allowing more flexibility in the use of herbal medicine in aquaculture.

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