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Review

Impact of plant products on innate and adaptive immune system of cultured finfish and shellfish

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ABSTRACT

Aquaculture is one of the fastest growing food-producing sectors around the world. Among various kinds of cultivated organisms many marine and freshwater finfish and shellfish species constitute an important industry with their production increasing every year. Recently due to intensive farming practices infectious diseases pose a major problem in aquaculture industry, causing heavy loss to farmers. A number of approaches have been made to control diseases including sanitary prophylaxis, disinfection, and chemotherapy with particular emphasis on the use of antibiotics. However, the application of antibiotics and chemicals in culture is often expensive and undesirable since it leads to antibiotic and chemical resistance and consumer reluctance. Therefore immunostimulants such as glucan, chitin, lactoferrin, levamisole, and some medicinal plant extracts or products have been used to control fish and shellfish diseases. In this regard the medicinal plant extracts and their products act as immunostimulants modulating the immune response to prevent and control fish and shellfish diseases. The immunostimulants mainly facilitate the function of phagocytic cells, increase their bactericidal activities, and stimulate the natural killer cells, complement, lysozyme activity, and antibody responses in fish and shellfish which confer enhanced protection from infectious diseases. Currently increased consumer demand for perfection in fish and shellfish farms has put new dimensions to the quality, safety, elimination of concomitant pollutants, antibiotics, and carcinogens during the production process. In this context plants or their byproducts are preferred since they contain several phenolic, polyphenolic, alkaloid, quinone, terpenoid, lectine, and polypeptide compounds many of which have been shown to be very effective alternatives to antibiotics, chemicals, vaccines, and other synthetic compounds. In aquaculture the herbal medicines are also known to exhibit anti-microbial activity, facilitate growth, and maturation of cultured species; besides under intensive farming the anti-stress characteristics of herbs will be of immense use without posing any environmental hazard. Administration of herbal extracts or their products at various concentrations through oral (diet) or injection route enhance the innate and adaptive immune response of different freshwater and marine fish and shellfish against bacterial, viral, and parasitic diseases. Even an overdose of immunostimulants may induce immunosuppression without side effects but helps to reduce the losses caused by disease in aquaculture. The present review describes the role of medicinal herbs and their products on innate and adaptive immune response of finfish and shellfish.

Contents

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1. Introduction

The world's total production of fish and shellfish (including molluscs and crustacea) was 99 mt in 1990 and it increased to 122 mt in 1997 (www.agriculture.de/acms1/conf6/ws9fish.htm). According to Food and Agriculture Organization (FAO) of the United Nations, the global aquaculture production has increased from about 28.3 million tons to 40 mt in 2009 (FAO, 2009). Aquaculture fish production increased significantly over the past few decades necessitating intensive fish culture practices. Fishes are usually cultured in enclosed spaces such as ponds or net cages and efforts have been made to increase productivity per unit space by increasing the rearing density. Due to this practice a number of associated stressors like overcrowding, transport, handling, grading, and poor water quality tends to adversely affect the health of cultured fish (Li et al., 2004). These conditions produce poor physiological environment increasing their susceptibility of fish to infectious agents paving the way for the outbreak of a number of diseases due to an increasing range of pathogens. The stressful environment also leads to the consequent suppression of the immune system, increasing the susceptibility of fish and shellfish to infectious diseases; such events routinely occur in aquaculture and lead to substantial economic losses. The estimated annual economic loss due to diseases in aquaculture is more than US$ 400 million in China (1993), US$ 17.6 million in India (1994), and over US$ 500 million in Thailand (1996) (www.agriculture.de/acms1/conf6/ws9fish.htm) despite the partially successful preventive measures including sanitary prophylaxis, disinfection, antibiotics, vaccines, and chemotherapy for the last 20 years.

2. Prophylatic measures

2.1. Chemotherapy

Chemotherapy is widely applied to control or prevent infectious parasitic, bacterial, and fungal diseases. Several antibiotics have been used successfully to control fish and shellfish diseases, including amoxicillin, enrofloxacin, erythromycin, furazolidone, and oxytetracycline (Agnew and Barnes, 2007; Smith et al., 1994). However, application with overdoses of chemotherapeutants leads to fish mortality and other detrimental side-effects (Chong and Chao, 1969). For example, an overdose of formalin resulted in severe gill damage and repeated treatments with nitrofurazone resulted in ulcerative dermatitis (Punitha et al., 2008). In aquaculture disease control using chemotherapeutants has been complicated by the misleading advice provided to the farmers by feed and chemical companies regarding the use of antibiotics and other therapeutic drugs. In the intensive aquaculture system, application of antibiotics and chemotherapeutics as prophylactic measures has been widely criticized for their negative impacts like immunosuppression and residue accumulation in tissues (Rijkers et al., 1980; Harikrishnan et al., 2009a, 2009b; FAO, 2003); besides this leads to the development of drug resistant pathogens (Smith et al., 1994). The accumulation of chemicals in the environment and in the fish have led to the imposition of stringent regulations that limit the use of antibiotics and a number of chemicals (Alderman and Hastings, 1998; Treves-Braun, 2000) and harmful to the environment as well as consumers (Smith et al., 1994). International agencies recommend that the use of antibiotics be restricted to therapeutic purposes only, and that in fish disease management the preventative approaches should be preferred over costly post effect treatments (GESAMP, 1997; FAO 2005).

The massive use of antimicrobials for disease control has suppressed the growth in aquatic animals. Indeed food-producing animals are one of several potential sources of antibiotic-resistant bacteria which may spread from animals to man via the food chain. Many countries refuse to import farmed fish and their byproducts treated with antibiotics and chemicals; hence to comply with the restrictive measures the producing countries have imposed regulations against the use of many antimicrobial substances. For example, in Norway, the use of antimicrobial drugs has decreased from approximately 50 mt in 1987 to 746.5 kg in 1997 (Verschuere et al., 2000; Norwegian Scientific Committee for Food Safety, 2009). Further the use of disinfectants and antimicrobial drugs had limited success in the prevention or cure of aquatic diseases (Salisbury et al., 2002; Gulliver et al., 1999; Sakai et al., 1991; Sakai, 1999; Michael, 2001; Tuan and Yukihiro, 2004). The pathogens may also transfer their antibiotic-resistance genes into human pathogenic bacteria thus posing a threat to human health and environment problems (Alderman and Hastings, 1998; Cabello, 2006; Abutbul et al., 2004; Smith et al., 1994; MacMillan, 2001), leading to failure of antibiotic treatment in some life-threatening conditions which limits the use of traditional chemotherapeutic substances (Miranda and Zimelman, 2001; Radu et al., 2003). To reduce or avoid the dependence of aquaculture on antibiotics, vaccines have been considered as an effective alternative to control bacterial and viral infections.

2.2. Vaccination

Fish and shellfish culture have been reported as the main causative agents for parasitic, bacterial, and viral diseases; the common control strategy adopted in the control of fish and shellfish disease till date is the use of antimicrobial compounds (Adams et al., 1995; Austin and Austin, 2007). Pathogenic bacteria and virus cause severe economic losses in hatchery and grow-out culture systems, which are usually related to poor management, water quality, and feeds. Till recently the main focus in intensive rearing was on feed hygiene and enhancement of immunity. Vaccination may be the most effective prophylactic measure of controlling fish and shellfish diseases. However they are relatively expensive and pathogen specific (Sakai, 1999; Robertsen, 1999; Raa et al., 1992). A number of vaccines are already commercially available against some bacterial and viral diseases. Vaccines for