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Plant-Derived Bioactive Compounds as a Potential Substitute for Drugs in Aquaculture

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SUMMARY

Aquaculture stands to gain significantly from incorporating medicinal plants and plant-derived compounds as natural and safe alternatives to antibiotics. They are cost-effective, easily available, renewable, and have no negative impacts on animals and the environment. They harvest various bioactive compounds which possess antimicrobial activities. Recent researches are focusing on isolating active components from herbs and adopting them to replace chemotherapeutics in aquaculture.

INTRODUCTION

Disease outbreaks in aquaculture have caused considerable losses. While antibiotics can effectively treat fish diseases, they risk creating antibiotic-resistant strains and accumulating in the environment. Vaccines are often too expensive and slow for broad use, and they target only specific pathogens. Medicinal plants, used for thousands of years as immunostimulants, offer a natural and safe alternative to antibiotics in aquaculture. Their active compounds such as alkaloids, terpenoids, pigments, polyphenols, quinones, lectins, tannins, essential oils, and polypeptides demonstrate antimicrobial properties including antibacterial, antiviral, antifungal and antiparasitic, enhance growth, boost the immune system, stimulate appetite, and alleviate stress in fish. These attributes make medicinal plants a promising substitute for antibiotics, chemicals, and vaccines in aquaculture.

Bioactive compounds in plants

Bioactive compounds in plants are secondary metabolites that have pharmacological effects on humans and animals. Nutrients such as vitamins and minerals are not included in the term bioactive compounds. Key categories of these secondary metabolites are briefly discussed below.

Polyphenols

Polyphenols are produced by plants as secondary metabolites to defend against pathogenic bacteria, fungi, viruses, and various types of abiotic stress. In recent years, numerous studies have explored the use of polyphenols and polyphenol-rich additives as functional feed supplements in aquaculture. Major types of polyphenolic compounds include flavonoids, phenolic acids, polyphenolic amides, lignans, and stilbenes. These compounds are recognized for their positive effects on fish performance and immunity, leading to improved health and productivity in fish farming operations.

Phenols

Plant-derived phenolic compounds are a diverse group of phytochemicals distinguished by their phenolic structure, which includes at least one benzene ring with one or more hydroxyl groups. The simplest example is phenol, or monohydroxy benzene. These compounds, which are prevalent in many organic compounds, are crucial in various fields including medicine, pharmacy, agriculture, and the polymer industry. In plants, phenols are secondary metabolites with important roles in development, biosynthesis, UV protection, and defence. They can be classified into monocyclic (e.g., catechol, resorcinol) or polycyclic types (e.g., resveratrol, curcumin, delphinidin, quercetin). Plant phenols are categorized by complexity into five main classes: monomeric, dimeric, oligomeric, polymeric, and hybrid phenols, with further subdivisions based on the number of benzene rings and attached carbon atoms. Among these, monomeric phenols are the most common and abundant, encompassing a wide range of derivatives such as benzoic acid, benzaldehyde, hydroxycinnamic acids, cinnamic aldehyde, coumarins, isocoumarins, chromones, xanthonoids, stilbenoids, anthraquinones, anthrones, diarylheptanoids, and flavonoids.

In aquaculture, phenolic compounds are used as multifunctional feed supplements. They are valuable for improving industry practices, particularly in disease control and prevention, and are considered safer alternatives to antibiotics and other antimicrobials. With their unique properties, these phytochemicals can enhance various aspects of aquaculture, serving as immunostimulants, antioxidants, and agents with antibacterial, antiviral, antifungal, and antiprotozoal activities.

Flavonoids

Flavonoids are the largest class of polyphenolic compounds and are widely found in various plants, fruits, vegetables, and leaves. They are classified into several subgroups based on their chemical structure, including isoflavonoids, neoflavonoids, flavones, flavonols, flavanones, flavanols, catechins, anthocyanins, and chalcones. Flavonoids are known for their medicinal properties, which include anticancer, antioxidant, anti-inflammatory, and antiviral effects. Recent medical research has focused on specific flavonoids such as Quercetin, Kaempferol, Curcumin, Epigallocatechin Gallate, Hesperidin, Apigenin, Lutein, and Zeaxanthin due to their notable health benefits. In Aquaculture, studies have demonstrated that diets rich in these flavonoids could improve growth, enhance antioxidant status, and boost immune function in fish.

Alkaloids

Alkaloids are present in plant tissues primarily as water-soluble salts of organic acids, esters, or sugars, rather than as free bases. These compounds often contain various protein bands that play a significant role in enhancing the immune system and increasing resistance to infections in fish. Alkaloids are known for their potent effects and bitter taste, though they are relatively rare across the plant kingdom. They are classified into several groups, including Tropane Alkaloids, Pyridine and Piperidine Alkaloids, Isoquinoline Alkaloids, Methylxanthine Alkaloids, Quinoline Alkaloids, Indole Alkaloids, Imidazole Alkaloids, Steroidal Alkaloids, and alkaloid derivatives. Some plants produce pseudoalkaloids, which share similar chemical properties with true alkaloids. Each class of alkaloids has distinct properties and uses, ranging from medicinal applications to toxic effects.

Glycosides

Glycosides are secondary metabolites that consist of a mono- or oligosaccharide, or uronic acid, attached to another compound. The sugar or uronic acid component is known as the glycone, while the non-sugar part is called the aglycone. The primary categories of glycosides include cardiac glycosides, cyanogenic glycosides, glucosinolates, saponins, and anthraquinone glycosides. Additionally, flavonoids also often exist in the form of glycosides.

Tannins

Tannins are categorized into two main types: condensed tannins and hydrolysable tannins. Condensed tannins are large polymers made up of flavonoid units, while hydrolysable tannins consist of a monosaccharide core, typically glucose, with several catechin derivatives attached. Although both types share many properties, hydrolysable tannins are less stable and have a higher potential for toxicity. Condensed tannins can have both positive and negative effects on feed digestibility and animal performance, depending on their concentration and biological activity. Even though some studies revealed negative impacts of dietary condensed tannins when given in high concentration, several researchers also found that these tannins could exhibit positive effects on antioxidant status, growth and immune function in fish and shrimp. In *Lateolabrax japonicus*, it was also found beneficial for the lipid metabolism without affecting the growth and digestion upto 1 g/kg. Pacific white shrimp had shown increased resistance to vibrio infection when supplemented with limited dose of tannin in diet.

Terpenoids

Terpenoids, also known as isoprenoids, are the largest and most varied class of compounds produced by plants. While plants use terpenoid metabolites for essential functions related to growth and development, they predominantly employ these compounds for specialized chemical interactions and protection against environmental factors. Terpenoids, which are derived from the isoprene unit, are recognized for their broad range of biological activities and applications. They are classified based on the number of isoprene units they contain, including monoterpenoids, sesquiterpenoids, diterpenoids, triterpenoids, tetraterpenoids, and polyterpenoids. Historically, terpenoids derived from plants have been utilized in the food, pharmaceutical, and chemical

industries. Research involving oral administration in carp has shown that plant-derived terpenoids and phenolic fractions can enhance the immune response.

Carotenoids

Carotenoids are natural pigments found in various organisms, including plants, algae, fungi, bacteria, and animals. Since animals cannot produce carotenoids on their own, they must obtain them through their diet. Carotenoids are crucial for human health, contributing to antioxidant defense and vitamin A synthesis. They are broadly classified into two groups: Carotenes and Xanthophylls. Carotenes include Beta-Carotene, Alpha-Carotene, and Lycopene, while Xanthophylls encompass Lutein, Zeaxanthin, and Astaxanthin. Carotenoids are important for the pigmentation of aquatic animals, affecting consumer acceptability. In aquaculture, carotenoids are included in the diets of salmonids, crustaceans, and other farmed fish primarily to enhance coloration. Additionally, they are used as immunostimulants to promote health in these cultured species.

CONCLUSION

Integration of bioactive compounds obtained from plants in aquaculture feeds is one way to increase the sustainability and productivity. Aquaculture can meet the increasing demand for quality fish while also improving the health of fish and minimising its negative effects on the environment by utilising the inherent advantages of these phytochemicals. The use of these bioactive compounds in aquaculture is anticipated to grow as more study is done to fully understand their potential. This will lead to further improvements in the sector, eliminate the use of environmentally unsafe drugs and support the sustainability and long-term viability of aquaculture operations.

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