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Turmeric- A Versatile Multipotential Medicinal Plant in Aquaculture

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ABSTRACT

Natural compounds with immune-stimulating and antibacterial capabilities have attracted a great interest from aquaculture point of view. In the recent past, aquaculture has gained popularity around the globe to enhance productivity. Further to meet the huge demand by the alarmingly increasing population, culture intensification has become a popular method in both finfish and shellfish production. Amongst several factors to increase the productivity high stocking densities has become classic practices along with applications of various chemicals and drugs which in turn increase the production cost. Therefore, studies on applications of herbs are essential. Diseases of microbial aetiology of economic relevance have surfaced in rearing and grow out ponds as a result of increased culture methods, posing a threat to the aquaculture industries. To inevitably enhance the productivity, fish and shrimp farming systems have been treated with synthetic chemicals and antibiotics, with diverse degrees of certainty in order to overcome the disease issues. Additionally, the uses of various immune boosters natural and synthetic are also being considered as an alternative approach. These compounds, known as immunostimulants and are thought to be an appealing and promising agent for disease prevention. Beneficial effects of herbs and particularly turmeric have pushed its use in disease management practices in aquaculture. In the current review, it is highlighted the nutritional properties and applications of turmeric utilization which could contribute to future research on aquaculture nutritional sciences.

Keywords Aquaculture, Immunostimulants, Immune system, Medicinal plant, Turmeric.

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INTRODUCTION

Aquaculture is one of the fastest growing sectors producing high protein food and a primary food supplier for growing population. However, in the last two decades, the intensification of aquaculture production has had a significant impact on farming. Evidently, the chances of disease outbreaks are more likely to occur as a result of environmental deterioration and stressful situations caused by either viruses, bacteria or protozoan, which have gained advantage

Fig. 1. Turmeric plant, rhizome and powder.

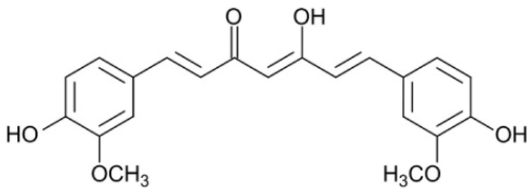

Fig. 2. Chemical structure of curcumin (Source: Mulec and Gorjanc 2015).

due to poor water quality management. To prevent the disease outbreaks, the use of antibiotic infusions as a preventative as well as therapeutic medicines have unintended negative environmental consequences, raising food safety issues. Consequently, diseases have become a major limiting issue leading to significant economic loss (Khan *et al.* 2005). Therefore, chemical based medications are most commonly used for disease treatment, but on the other hand, they have major detrimental effects on the aquatic environment.

Considering this, environmentally safer herbal medicinal plants are best alternatives. Amongst them, turmeric is being utilized as an immunoprophylactic, which can stimulate growth and act as disease resistance due to their immune-stimulatory and other significant features and also cure a variety of diseases for thousands of years and they are now being employed more frequently in aquaculture (Kaur *et al.* 2020 and 2021). As a result, a surge of interest in using medicinal plants has evolved, attracting a lot of global attention and becoming the focus of active systematic investigation in several nations such as India (Dey and Chandra 1995). Thailand (Direkbusarakom *et al.* 1996), Egypt (Ahmad *et al.* 2011), Japan (Takaoka *et al*. 2011), Indonesia (Caruso *et al.* 2013), Iran (Mousavi *et al.* 2011), Korea (Harikrishnan *et al.* 2010a), Nigeria (Okeke *et al.* 2001) because they are (i) cheap, (ii) easy to prepare and (iii) are effective with no side effects during the treatment of diseases and without any environmental hazardous (Jian and Wu 2003), (iv) available throughout the year.

Origin and history of turmeric

Turmeric (*Curcuma longa* Linn.) is an herbaceous medicinal plant native to tropical Asia, notably India, and has been used in Indian ayurvedic medicine for thousands of years (Gupta *et al.* 2013). Because of its beautiful yellow color, turmeric is sometimes referred to as "Indian Saffron" (Fig. 1). In turmeric, curcumin is the most significant coloring bioactive compound which is responsible for several features of turmeric (Behera *et al.* 2011). It is now widely cultivated in tropics and is known by various names in different countries. For example, turmeric is known in Northern India as "haldi," derived from the Sanskrit word 'Haridra', and in the South as "Manjal". Turmeric gets its name from the Latin term 'Terra Merita', which relates to the coloration of ground turmeric, which resembles like a mineral pigment (Prasad and Aggarwal 2011, Newman and Cragg 2007). In French, it's known as terremerite, and in many other languages, it's simply referred to as "Yellow Root".

Composition of turmeric powder

Turmeric contains 6.3% protein, 5.1% fat, 3.5% minerals, 69.4% carbohydrate, 3.5% ash and 2.6% fiber (Chattopadhyay *et al.* 2004). In turmeric, curcumin is the most well-known physiologically active component, besides it contains curcuminoids (Toennesen 1992), aromatic turmerones (32.5%), alpha (15.6%), and beta (17.1%) turmerones (Ferreira *et al.* 1992), and curlone are some of the other active ingredients found in turmeric.

Physical and chemical properties

Turmeric ($C_{21}H_{20}O_6$) is a hydrophobic and polyphenolic bioactive compound also known as diferuloylmethane (1,7-bis (4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione), having a melting point of 176–177 °C (Fig. 2). Steam distillation is used to obtain essential oil of *C. longa*, with yields

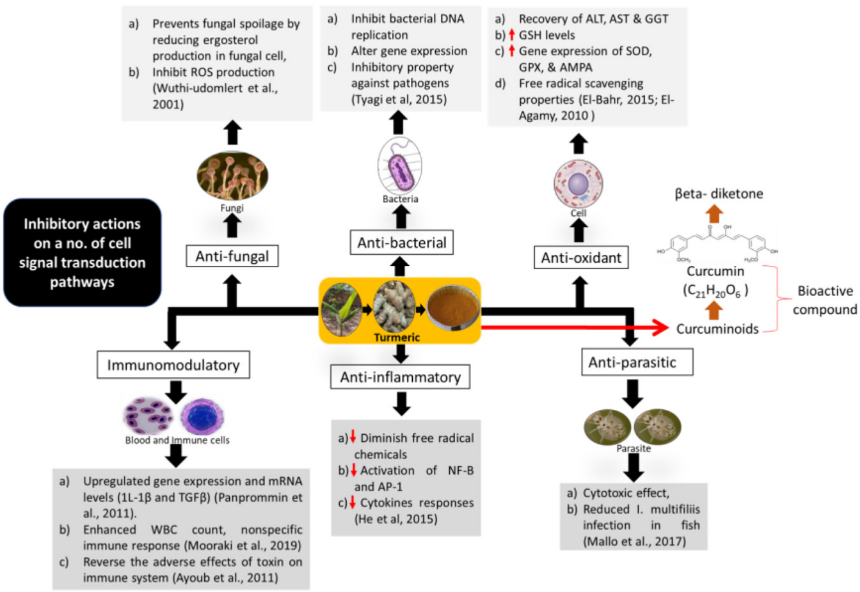

Fig. 3. Mechanism of action of turmeric in fish.

ranging from 1.3 to 5.5%. Turmeric comes from a wide variety of species including *C. xanthorrhyza*, *C. domestica*, *C. zedoafia*, *C. caesia* and *C. amada*. Despite the fact that all of these plants are aromatic, *C. longa* is the one that is utilized as a flavouring agent.

Significant value of bioactive compound – Turmeric

Turmeric finds its application around the world, as it has a wide spectrum of biological properties, including antioxidant, antibacterial, antifungal, antiviral, anti-inflammatory and immunostimulating properties (Masuda *et al.* 2001, Chandra and Gupta 1972).

Antioxidant properties

The presence of antioxidants significantly retards the rate of oxidation by protecting cells from damage caused due to unstable free radicals (Shasha *et al.* 2014). Enzymes control the free radical levels in the body such as superoxide dismutase, catalase and glutathione peroxidase (Gülçin *et al.* 2002). However, oxidative stress occurs when the amounts of free radicals exceed those of the endogenous enzymes responsible for their removal (Agrawal and Goel 2016). The antioxidant activities of curcumin have ability to protect biomembranes from peroxidative damage and scavenge oxygen from free radicals (Sharma 1976).

Antibacterial properties

In the aquaculture systems, diseases caused by bacteria become discriminant. The primary bacterial infections producing bacteria are *Aeromonas* spp., *Pseudomonas* spp., *Flavobacterium* spp., and *Edwardsiella tarda* which are frequently occurring in the culture system (Kumar *et al.* 1986). Antibiotics are commonly used for treatment of pathogenic bacteria-infected fish, however the sensitivity of bacterial strains to antibiotics varies widely even within the same species. Moreover, antimicrobial medicines and immunizations are being utilized to combat the infection caused by the bacteria. The prolonged use of these medications has resulted in a residual effect and a risk of resistance in all livestock, including humans (Spanggaard *et al.* 1993). Considering this herbal medicinal plant such as turmeric is used in aquaculture operations for the control of infections (Das *et al.* 1999).

Table 1. Summary of literature on turmeric as fish feed ingredient.

Fish/Animal	Turmeric dose	Major effects	References
Rohu (*Labeo rohita*)	5, 10, 15, 20 g kg^{-1}	Enhances the immune protection and pathological damage against pathogenic bacterial infections through immunomodulatory mechanisms	Kaur *et al.* (2020)
Common carp (*Cyprinus carpio*)	120 and 240 mg kg^{-1}	Increased the antioxidant status which protect carp from liver injury induced against carbon tetrachloride	Zhang *et al.* (2021)
Nile tilapia (*Oreochromis niloticus*)	10, 20 g kg^{-1}	Ameliorated negative effects of aflatoxin, improved biochemical, detoxified enzymes, liver and kidney functions and showed down-regulations of GPx gene expression	El-Barbary (2018) Mooraki *et al.* (2019)
Green terror (*Andinocara rivulatus*)	0.1, 0.2, 0.3%	0.3% turmeric had better growth performance, survival rate and improved hematological profile	Mukherjee *et al*. (2009)
Guppy (*Poecilia reticulate*)	45 mg/50 g	Promoted carotenoid pigment deposition on the fantail and muscle with better specific growth rate	Riauwaty *et al.* (2020)
Pangas (*Pangasius hypopthalmus*)	0.5, 0.7, 0.9%	Reduced risk of motile *Aeromonas hydrophila* Septicaemia infection in fish.	Basuki *et al.* (2020)
African catfish (*Clarias gariepinus*)	15 g kg^{-1}	Provide better growth performance	Kumari and Paul (2020)
Walking catfish (*Clarias batrachus*)	100 mg kg^{-1}	Turmeric causes normalization in the hematological and biochemical levels when exposed with fenvalerate	
Asian sea bass (*Lates calcarifer*)	5g kg^{-1}	Improved growth performance and did not affect blood chemistry	Abdelwahab and El-Bahr (2012)
Gilthead seabream (*Sparus aurata*)	0, 1.5, 2, 2.5, 3%	Enhanced phagocytic activity and improved final body weight gain, specific growth rate in fish	Ashry *et al.* (2021)
Rainbow trout (*Oncorhynchus mykiss*)	0.5, 1 %	Reduced oxidative stress in the serum and liver	Şahinöz *et al.* (2019)
White shrimp (*Litopenaeus vannamei*)	7.5, 15 g kg^{-1}	Increased total hemocyte count, phenoloxidase activity and bactericidal activity against shrimp pathogenic vibrio spp.	Lawhavinit *et al.* (2011)

Antifungal properties

Various researches have been conducted in order to explore turmeric with the goal of preventing fungal spoilage and fungal infections due to the widespread traditional usage of turmeric. Turmeric showed anti-fungal activity by decreasing ergosterol content in fungal cell in the presence of curcumin which reduces the ergosterol production and leads to the accumulation of biosynthetic precursors of ergosterol. This eventually results in cell death due to the production of reactive oxygen species (Wuthi-udomlert *et al.* 2001). Furthermore, turmeric has antifungal activities against many different strains of genus Candida including *C. albicans, C. glabrata, C. krusei, C. tropicalis* and *C. guilliermondii* cause fish disease (Moghadamtousi *et al.* 2014) (Fig. 3).

Anti-inflammatory properties

Turmeric's efficacy as an anti-inflammatory drug has been proven in several scientific reports and showed great potential as a therapeutic agent for a variety of inflammatory conditions Jurenka (2009). Curcuminoids in turmeric contain benzene rings and hydroxyl groups that diminish the concentration of free radical chemicals such as hydroxyl and superoxide radicals when these free radicals cause oxidative stress at the cellular level, which can induce inflammation. However, turmeric oil also contains sesquiterpenes which known for possessing anti-inflammatory properties (Roy 2012).

Antiparasitic properties

The turmeric showed antiparasitic activity against the *Leishmania, Trypanosoma, Schistosoma* and other parasites such as nematodes, Candida, Giardia, Babesia, Coccidia and Sarcoptes (Haddad *et al.* 2011). Mallo *et al.* (2017) observed turmeric cytotoxic effect against parasite and inhibited the growth of parasite, *Philasterides dicentrarchi* in turbot. Likewise, turmeric showed the strongest anti- *Ichthyophthirius multifiliis* activity on theronts infectivity thereby reducing *I. multifiliis* burdens in fish. Similarly, Liu *et al.* (2017) observed turmeric at concentrations of 2 mg/L or less may protect both infected and naive fish from *I. multifiliis* infection with prolonged treatment duration in the fish farming industry (Liang *et al.* 2015).

Immunostimulatory properties

Turmeric feeding may elevate the non-specific immune system and give long term protection (Sahu *et al.* 2008) and as per several studies *C. longa* have the ability to modulate the immune response in fish, chick and prawn. Moreover, turmeric enhanced the white blood cell count (Mooraki *et al.* 2019), non-specific immune response in *Cirrhinus mrigala* (Sivagurunathan *et al.* 2011) immune response in prawns (*Macrobrachium rosenbergii*) and host defense in fish when *C. longa* fed to the fish and challenged with *Pseudomonas aeruginos*, *Vibrio alginolyticus* and *Aeromonas hydrophila* respectively. However, extensive cellular and animal studies have been performed to evaluate the immunomodulatory effects of turmeric by using various immune cells such as macrophages, monocytes, neutrophils, lymphocytes and natural killer cells.

Efficacy of turmeric utilization in aquaculture

Turmeric enhanced growth performance in rohu, *L. rohita* and Nile tilapia (Sahu *et al.* 2008, Mahmoud *et al.* 2014; Kaur *et al.* 2020) respectively, diet digestion and nutrient digestibility, leading to improved nutrient utilization, which in turn would improve fish growth and feed utilization of common carp (Table 1). Growth inducing properties of turmeric could be due to antioxidant activity (Osawa *et al.* 1995), which triggers synthesis of protein by enzymatic system. A report on goldfish has suggested higher acid and alkaline protease and lipase, improved the growth rate along with yellow pigmentation (Pransin 2006). Moreover, turmeric powder may inhibit potential pathogens in the digestive tract and enhance the population of beneficial microorganism and microbial enzyme activities that consequently improve feed digestibility and nutrient absorption. Besides, turmeric also protects the fish which are infected by the pathogenic bacteria such as *A. hydrophila* and *A. veronii* (Islam *et al.* 2008, Kaur *et al.* 2020) because of its antimicrobial properties.

CONCLUSION

Turmeric possesses polyphenolic properties having curcumin as the most active ingredient. Dietary turmeric is a potential alternative solution and aids to improve growth and reproductive performance, immune response, disease resistance, and increased digestive efficiency and metabolic and excretory pathways of monogastric farm animals, poultry and fish. The beneficial effects of turmeric are traditionally achieved through dietary consumption, even at low levels, over a long period of time. However a precise understanding of effective dose, safety, and mechanism of action is required for the use of turmeric. Turmeric, however, has significant limits due to its lipophilic and hydrophobic characteristics; therefore further research is warranted to understand its mechanism. As such, the scopes of future studies are still vast when it comes to the use of nano-technological tools to advance turmeric research in animal science.

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