P-ISSN 2349–8528
E-ISSN 2321–4902
IJCS 2015; 3(2): 83-87

Received: 20-06-2015
Accepted: 21-07-2016

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Medicinal uses of ginger (*Zingiber officinale* Roscoe) improves growth and enhances immunity in aquaculture

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Abstract
Medicinal plants are of great use in pharmaceutical, cosmetic, agricultural and food industry. The efficacy of some herbal products is beyond doubt. The most recent examples being *Silybum marianum* (Linn.), *Artemisia annua* Linn. (Artemesinin) and *Taxus baccata* Linn. (taxol). Randomized controlled trials have proved the efficacy of some established remedies, for instance *Zingiber officinale* Roscoe commonly known as ginger. Ginger contains natural organic materials beneficial to health and enhances resistance to infectious diseases by increasing non-specific and specific immune mechanisms. The rhizome of ginger has shown to be effective in the control of a range of bacterial, viral, fungal and parasitic diseases in humans, poultry and aquaculture owing to its antimicrobial, antioxidant, growth promoter and as immunostimulant properties to health. Hence, this review focuses on the use of ginger as growth promoter, antimicrobial agent, antioxidant and as immunostimulant in aquaculture.

Keywords: Ginger, *Zingiber officinale*, gingerols, antioxidant, aquaculture.

1. Introduction
The world trend to improve food security and to use natural products will drive the chemically synthesized antibiotics and growth promoters out of use. Aquaculture is therefore an emerging industrial sector which requires continued research with scientific technical development and innovations [1]. Extensive use of antibiotics in aquaculture leads to the emergence of antibiotic-resistant bacteria and generation of toxicants, which may cause risks to the environment [2], and immunosuppression in the host [3]. There are a large number of feed additives available to improve fish growth performance. Some of these additives used in feed mill are chemical products, especially hormones and antibiotics, which may cause unfavorable side effects. To alleviate these problems, increasing attention is being given to the use of natural feed additives such as ginger for disease-control strategies in aquaculture. Ginger enhances resistance to infectious disease by increasing non-specific and specific immune mechanisms [4]. Ginger contains natural organic materials that facilitate growth, anti-stress, environmentally friendly and antimicrobial properties in fish [5].

Ginger as a natural antibiotic is the earliest known medicinal plant. It has shown to be effective in treating diseases in humans, poultry and aquaculture owing to its antimicrobial, antioxidant, growth promoter and immunostimulant properties. An optimized dose of ginger is recommended in the diet. Ginger (*Zingiber officinale* Roscoe) has been used as a spice for over 2000 years [6]. It is also called "*The Great Medicament*" in Ayurvedic medicines [7] and is generally considered as a safe herbal medicine [8].

Ginger (*Zingiber officinale* Roscoe) is a creeping perennial underground rhizome belonging to family Zingiberaceae [9]. Nepal is the third biggest producer of ginger in the world [10]. In the first year, a green, erect reed like stem about 60 cm high grows from this rhizome. The plant has narrow; lanceolate to linear-lanceolate, 15-30 cm long leaves, which die off each year. The odour and taste are characteristic, aromatic and pungent. Ginger as a spice has been used through ages in almost all systems of medicine against many maladies [11].

The plant is indigenous to Southeast Asia [12] and is cultivated in a many countries including Nepal. The smell and taste of the medicine are typical and aromatic. The medicinal part of the herb is dried rhizomes. It is now recognized as a drug of choice for nausea and vomiting. It has also been found useful in pregnancy related morning sickness [11]. In rheumatoid arthritis and osteoarthritis, ginger is used as a natural pain reliever and as an anti-inflammatory agent. It is also useful in curing ulcer and preventing heart attack and stroke [11]. Many active constituents and medicinal properties have been reported from the ginger during the last three decade. Thus, the present article provides a comprehensive account of important medicinal properties of this versatile herb.

1.1. Nutrient Composition

Fresh ginger contains 80.9% moisture, 2.3% protein, 0.9% fat, 1.2% minerals, 2.4% fibre and 12.3% carbohydrates. The minerals present in ginger are iron, calcium and phosphorous. It also contains vitamins such as thiamine, riboflavin, niacin and vitamin C. The composition varies with the type, variety, agronomic conditions, curing methods, drying and storage conditions [13, 14].

1.2. Chemical composition

Gingerols are the major active components in the fresh ginger rhizome [15]. The volatile oil components consists mainly of sesquiterpene hydrocarbons, predominantly zingeberene (35%), curcumene (18%) and farnesene (10%) [13]. Non-volatile pungent compounds include gingerols, shogaols, paradols and zingerone. Paradol is similar to gingerol and is formed from hydrogenation of shogoal (phenylalkanones) [16].
Ginger contains fats, waxes, carbohydrates, vitamins and minerals. Ginger rhizomes also contain a potent proteolytic enzyme called zingibain. The pungent taste of ginger is due to nonvolatile phenylpropanoid-derived compounds, particularly gingerols and shogaols. Supplementing ginger in fish diets may enhance disease resistance by reinforcing host innate immune functions that are necessary for protection against infectious diseases. [17, 18, 19, 20, 21].

1.3. Ginger as growth promoter

Ginger extracts have been reported to enhance the growth of teleosts. For instance, rainbow trouts (*Oncorhynchus mykiss*) that were fed ginger had significant increases in growth, feed conversion, and protein efficiency. Supplementing diets with acetone extract from ginger was reported to enhance growth of tilapia (*Oreochromis mossambicus*) [22]. The administration of ginger can produce significantly higher weight gain and specific growth rates in *Penaeus monodon* post larvae [23]. The efficiency of feed proportionately increased with the increased percentage of ginger. Moreover, digestive enzyme activity significantly increased with ginger enrichment [23].

1.4. Ginger as an antioxidant agent

Ginger is a strong antioxidant substance and may either mitigate or prevent generation of free radicals [24, 25]. It is considered to be a safe herbal medicine with only a few insignificant side effects [26]. All major active ingredients of ginger, such as zingerone, gingerdiol, zingibrene, gingerols and shogaols, are known to possess anti-oxidant activities [27]. Ginger oil might act as a scavenger of oxygen radical and might be used as an antioxidant [28]. This antioxidant activity in ginger is due to the presence of polyphenol compounds (6-gingerol and its derivatives) [29]. The total phenolic content in the alcoholic extract of the dried rhizome of ginger is 870.1 mg/g dry extract [20]. Antioxidant property of ginger is extremely significant as it can be used to prevent a number of diseases in aquaculture.

1.5. Ginger as antimicrobial agent

Ginger has some antifungal properties as well [30]. Ginger inhibits *Aspergillus* sp, a fungus known for the production of aflatoxin, a carcinogen [31]. Fresh ginger juice showed inhibitory action against *Aspergillus niger, Saccharomyces cerevisiae, Mycoderma* sp. and *Lactobacillus acidophilus* [32]. It provides protection against invading microorganisms, including bacteria such as *E. coli* and *Staphylococcus aureus* (a common cause of skin infections) and fungi, including *Candida albicans* (33Reference). The benzene extract of *Zingiber officinale* rhizome showed highest antimicrobial activity against drug resistant *Pseudomonas aeruginosa* isolated from wound and pus samples [34]. Melvin *et al*., 2009 [35] also reported that the ginger extract exhibited maximum antimicrobial activity against *P. aeruginosa*. Ginger was also found to be protective against DNA damage induced by hydrogen peroxide and enhanced health [36, 37].The rhizome of ginger (*Zingiber officinale*) has been reported to possess a broad-spectrum of prophylactic and therapeutic activities [38].
Ginger is effective in the control of a range of bacterial, viral, fungal and parasitic diseases [39, 40, and 41]. Cultured fish suffer from a wide variety of bacterial, viral, parasitic and fungal diseases [42]. The application of ginger in aquaculture is an innovative approach to enhance health of fish and to prevent diseases [43]. Numerous evidences suggest that many dietary factors may be used alone or in combination with traditional chemo- therapeutic agents to prevent or treat diseases [44]. Ginger has an excellent antimicrobial activity against various gram positive and gram negative bacteria and fungi. In vitro studies have shown that active constituents of ginger inhibit multiplication of colon bacteria [45]. These bacteria ferment undigested carbohydrates causing flatulence. This can be counteracted with ginger [45]. The extract of ginger inhibits the growth of *Escherichia coli*, *Proteus vulgaris*, *Staphylococcus aureus*, *Streptococcus pyogenes* and *Salmonella* [38, 46]. This plant can be used as one of the best medicinal plants in controlling pathogenic bacteria.

1.6. Ginger as an immunostimulant

In aquaculture, the application of dietary medicinal herbs as immunostimulants can elevate the innate defense mechanisms of fish against pathogens during periods of stress, such as, intensive farming practices, grading, sea transfer, vaccination and reproduction [47]. The excess use of antibiotics in the management of disease in aquaculture has resulted in serious health and environmental problems. Consequently, the need of safe and effective alternatives to antibiotics is required. In this context, immunostimulants have attracted significant attention [48]. Ginger as a natural antibiotic is one of the most effective natural immunostimulants. The powdered ginger rhizome is able to enhance non-specific immune response in rainbow trouts [49]. Non-specific immunity plays an especially important role in the defense of fish and is the sole immunological mechanism by which invertebrates protect themselves from diseases [50]. Non-specific defense mechanism plays an important role in all stages of fish infection. Fish particularly depend mostly on these non-specific mechanisms than mammals do [51]. Ginger essential oil showed improvement in humoral and cell mediated immune response in immune-suppressed mice [52]. However, future studies might look into the dose-response, determination of optimal dose, treatment duration, and its use in large scales in fish farms. In

general, this study suggests that ginger can be applied as an alternative diet and a supplement to boost immune system for rainbow trout.

Ginger is effective as an immunomodulatory agent in animals and fish and helps to reduce losses caused by diseases in aquaculture [53, 26, 54, 7]. Rainbow trout on powdered ginger rhizome diet for 12 weeks showed increased haematocrit, haemoglobin, erythrocyte, MCH, MCHC, WBC values and neutrophils percentage in comparison to the control group ($p<0.05$). De Pedro *et al.* (2005) [55] indicated that total and differential leukocyte counts are important indices of non-specific defense activities in fish. Also, they are centrally involved in phagocytic and immune responses to bacterial, viral and parasitic challenges [56].

1.7. Traditional use

Ginger is known as *Sunthi* in Ayurveda and description of the plant appears in the old text like *Charaka*, *Sushruta*, *Vagbhata* and *Chakra-dutta* [12]. The use of drug is mentioned in form of *Trikatu*, a famous Ayurvedic remedy for the treatment of digestive disorders. In *Ashtanga Hridaya*, the plant has been used in *Rasna Saptak Quath* (a decoction based on seven medicinal herbs), and is a traditional remedy of arthritis. Pharmacologically, the drug in Ayurveda has been described as an appetizer. It is also indicated in ointment form for local application in pains.

1.8. Phytochemistry

Ginger is a rich source of volatile oil. Zingiberol, zingiberene, phellandrene and linalool are important constituents of the oil. They account for the aroma of the herb. The pungency of the ginger is due to gingerols and shogaols [57]. Investigations have shown gingerol and shogaols to be mutagenic. In addition, ginger contains a special group of compounds called diarylheptanoids including gingerenone [58]. The standardization of the drug is based on presence of pungent principles of the plant.

2. Conclusion

Medicinal herbs are rich source of synthetic and herbal drugs. They contain a wide range of chemical compounds commonly referred to as phytochemicals. Ginger is an important herb today and a number of studies have shown it to be a useful medicinal agent. Its potential as an effective anti-inflammatory and anti-emetic agent cannot be ruled out. *Zingiber officinale*, ginger, is an important plant with several medicinal, ethno-medicinal and nutritional values used in traditional medicine. Ginger is consumed worldwide as a spice and flavoring agent and is attributed to have many medicinal properties such as cardio-protective, anti-inflammatory, anti-microbial, anti-oxidant, anti-cancer properties, etc. It is used as growth promoter, antimicrobial agent, antioxidant and as immunostimulant in aquaculture. Gingerol, the active constituent of ginger has been isolated and studied for pharmacological and toxic effects. Large-scale clinical studies are required to justify ginger as suitable phytopharmaceutical drug although initial data seems to be promising.

3. Acknowledgements

The Author is highly grateful to Prof. Dr. Shyam Narayan Labh, President of Nepal Aquaculture Society and Professor of Zoology, T. U., Nepal for his cooperation and help while writing this review article.

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