

# Papaya Power: Growth Promotion and Sex Reversal

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## Abstract

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Aquaculture is an emerging sector that significantly contributes to the food security worldwide through its supply of sustainable protein sources. However, its development presents challenges, most prominently on the environmental and health front with synthetic additives, for instance, antibiotics and growth promoters. Researchers have investigated the use of natural alternatives like plant-based extracts that are biodegradable and multi-functional without causing harm as by-products. Of these, *Carica papaya* (papaya) has been identified to hold a lot of promise due to its antimicrobial, antioxidant and growth-promoting effects. Papaya contains bioactive compounds like papain, phenolics and flavonoids that enhance digestion, improve growth performance and provide immune support in aquatic species. It is one of the plants that represent a major source of bioactive substances that are cheaper and non-toxic, compared to synthetic additives. The chapter discusses the potential of papaya extracts in aquaculture, emphasizing its advantages for improved immunity, growth promotion, sex reversal and environmental sustainability.

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**Keywords** Antioxidant, *Carica papaya*, Growth promotion, Papain, Sex reversal, Sustainability

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## 1. Introduction

Currently, aquaculture is the fastest-growing food production sector, greatly contributing to food security and providing a sustainable source of protein. While the industry is growing at an incredible rate, it still has several challenges that have to be overcome in order to ensure its continued

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sustainability and development. One of the primary concerns about aquaculture is its environmental impact. Aquatic organism farming tends to the release of nutrients, chemicals and waste into surrounding waters, which consequently result in waste pollution as well as habitat destruction affecting the local ecosystems negatively. Furthermore, the use of antibiotics and chemicals in fish aquaculture can encourage the development of antibiotic-resistant bacteria, providing additional health hazards (Ipinge *et al.*, 2023). In the last few years, natural extracts in aquaculture have gained popularity as a more sustainable and environmentally friendly alternative to synthetic chemicals and antibiotics. They have several advantages including antimicrobial, antioxidant and growth-promoting properties. Researchers are increasingly investigating the potential of these extracts to improve fish health and growth rates and minimizes adverse environmental impacts (Reverter *et al.*, 2014).

Natural extracts are rich in bioactive compounds, such as phenolics, flavonoids, saponins and alkaloids, which have antibacterial, antifungal, antiviral and antioxidant properties. In addition, using natural extracts can prevent the rise of antibiotic-resistant bacteria which is one of the threats in aquaculture (Nek Rahimi *et al.*, 2022). Additionally, they are cheaper and readily available, hence natural extracts are of interest to aquaculture farmers looking for the sustainable solutions. The key advantage in using natural extracts over synthetic chemicals is that it has a minimal environmental impact as these extracts are biodegradable and less likely to produce harmful residues in the environment (Reverter *et al.*, 2014). By fostering a healthier, more sustainable farming environment, natural extracts support the overall well-being of aquatic ecosystems.

Recently, *Carica papaya*, or papaya, has been recognized as a valuable natural resource in aquaculture due to its diverse bioactive properties. It has various therapeutic and nutritional effects, which have been attributed to its specific profile of bioactive compounds like papain, phenolics and flavonoids, which together exhibit antimicrobial, antioxidant and growth-enhancing properties. In light of the increasing demand for sustainable, health-promoting interventions in aquaculture, *Carica papaya* warrants comprehensive exploration. This chapter delves into the potential of papaya as a functional additive in aquaculture, exploring its bioactive composition and mechanisms of action while highlighting its potential applications in aquaculture, particularly as growth promoter, sex reversal agent and a natural alternative to synthetic additives.

## **2. Overview of Papaya (*Carica papaya*) and its Potential Benefits**

Papaya is known for its bright orange flesh, black seeds and high concentration of vitamins, minerals and bioactive substances. Health benefits of papaya are attributed to the presence of antioxidants in the form of carotenoids, particularly lycopene, which protects the fruit from oxidative stress (Spritzler, 2023). It is majorly cultivated in the tropics and subtropics in various parts of the world because of its nutrient and medicinal value (Alara *et al.*, 2020).

### 2.1. Medicinal Properties

Traditionally, different parts of papaya are used in medicine because of their therapeutic properties from its fruit, leaves, seeds and latex. Papain, an enzyme extracted from papaya latex, is known to play a role in digestion processes and is commonly used as a meat tenderizer (Kong *et al.*, 2021). Different parts of the papaya, such as leaves and seeds, contain alkaloids and flavonoids that play an antimicrobial and anti-inflammatory role, thus granting health benefits (Spritzler, 2023).

### 2.2. Health Benefits

a) *Antioxidant and Anti-inflammatory Activities:* *Carica papaya L.* extracts have drawn a lot of attention for their antioxidant, anti-inflammatory and anticancer activities. The extract's ability to mitigate oxidative stress and inflammation, which are intricately linked to the development and progression of chronic diseases such as cardiovascular disorders and cancer, is aided by the presence of essential vitamins, particularly A and C, as well as various other antioxidants (Kong *et al.*, 2021).

b) *Gastrointestinal Health:* It enhances digestion and helps in relieving diseases including indigestion and constipation (Spritzler, 2023).

c) *Immune Support:* Papaya's high vitamin C content boosts the immune system, helping the body to fight infections more effectively (Spritzler, 2023).

d) *Skin Health:* Papaya is used in skin creams due to its ability to exfoliate dead skin cells and promote a healthy (Rodrigo and Perera, 2018).

### 2.3. Antimicrobial Properties

The recent scientific research has proved that papaya extracts possess broad-spectrum antimicrobial activities. Different studies have confirmed that the growth of a number of pathogenic bacteria like *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis* can be inhibited by using of extracts from the leaves and fruits of papaya (Emeruwa *et al.*, 1982). The antimicrobial properties of papaya are mainly due to its high content of phenolic compounds, including protocatechuic acid and caffeic acid, which have been reported to be strong antibacterial agents (Dwivedi *et al.*, 2020). The bioactive compounds may interfere with vital biological functions and inhibit the growth of microorganisms by interacting with the cell structures and metabolic pathways of bacteria.

### 2.4. Aquaculture Applications

In the field of aquaculture, papaya extracts are currently being investigated determine their potential for growth promotion and sex reversal in fish species. Papaya contains bioactive compounds such as saponins and flavonoids that have been proven to offer potential in enhancing fish health and improving growth performance (Alara *et al.*, 2020).

## 3. Papaya Extract Composition and Properties

The presence of bioactive compounds in papaya extracts contributes to

its health benefits and antimicrobial properties. These extracts contain a wide variety of phytochemicals, such as phenolics, flavonoids, saponins, tannins and carotenoids, which all play an important role in the promotion of health (Nagarathna *et al.*, 2021). The chemical composition of papaya (*Carica papaya* L.) shows high variability among the different parts of the plant. The bioactive compounds show notable richness in leaves, fruits and seeds. Papaya leaves contain phytochemicals like alkaloids, flavonoids, saponins and tannins are (Khor *et al.*, 2021). These compounds contribute to the leaves' potential therapeutic applications, which remain a subject of on-going research in various fields of medicine.

Papaya fruits are nutrient-rich, especially inessential micronutrients. These are recognised as well-known sources of vitamin C, vitamin A and carotenoids (Jeon *et al.*, 2022). Papaya seeds have been found underutilized for its phytochemical profile but gained much attention recently. They possess notable amounts of phenolic acids, flavonoids and saponins (Dwivedi *et al.*, 2020). This composition of the papaya seeds suggests potential medicinal value and there is the need to investigate its pharmacological properties. Papaya's diverse chemical composition makes it a suitable species for bioactive component sources. Variability in composition underscores the importance of considering specific plant parts of papaya when researching or using it for nutritional and therapeutic goals (Goriainov *et al.*, 2023).

### *3.1. Bioactive Compounds*

The health benefits of papaya extracts are explained by the diversity of bioactive compounds that they contain. Among these compounds, chlorogenic acid, caffeic acid and ferulic acid are the most important phenolic compounds. According to Jeon *et al.* (2022), these are known to be the most active antioxidants present in the extracts. Such compounds can scavenge free radicals and therefore neutralize them, which decreases oxidative stress in biological systems. Other significant phytochemicals that contribute to the extract's bioactivity include flavonoids, which is a subclass in the composition of papaya. The primary reported flavonoids in the composition of papaya are quercetin and kaempferol, also linked with both anti-inflammatory and antioxidant (Dwivedi *et al.*, 2020). The extracts from papaya contain antimicrobial properties due to the saponins and tannins present. These compounds have been shown to inhibit the growth of pathogenic bacteria, which can be used in controlling microbial infections (Nirosha and Mangalanayaki, 2013). The antimicrobial activity of papaya extracts is due to the synergistic effects of different bioactive compounds present in the plant. Its complex phytochemical profile underlies its diverse biological activities, such as phenolic compounds, flavonoids, saponins and tannins found in papaya extracts. Such bioactive compounds can interact with several targets in the cell and thus influencing various physiological processes (Kong *et al.*, 2021).

## 4. Growth Promotion in Fish Using Papaya Extracts

In fish, growth can be promoted using various feed additives. Among the feed additions that can aid in fish growth are exogenous enzymes, amino acids and beneficial bacteria (Kari *et al.*, 2022). The fast growth of the aquaculture sector and the safer method of lowering operating costs have led to a growing use of proteolytic enzymes as additives in fish feed. Microorganisms, plants and animals are all examples of living things from which exogenous proteolytic enzymes can form (Zulhisyam *et al.*, 2020). Exogenous enzymes added to the feed in the right amounts will make up for endogenous enzyme deficiencies and improve growth performance (Zheng *et al.*, 2020). Papain, a proteolytic enzyme found in papayas (*Carica papaya*), aids in better digestion and nutritional absorption. By improving the digestion of proteins, this encourages fish development.

### 4.1. Mechanism of Action

The papain enzyme, which is found in papayas, breaks down proteins into smaller peptides that fish can more easily absorb and use. This increases the fish's efficiency in converting their diet into growth. Because of papain, growth performance is improved by increased activity of digesting enzymes, particularly lipase and protease. Papain is a cysteine protease which is essential for the digestion of proteins because it breaks down lengthy polypeptide chains into smaller peptides and amino acids. In biological systems, this is especially helpful as a growth promoter since it improves nutrient absorption. In its active site, papain deprotonates cysteine-25, which allows it to disrupt peptide bonds in proteins. This activity promotes growth by making it easier to digest and convert proteins into forms that are more effectively absorbed (Isa, 2010).

### 4.2. Growth Performance in Fish

Papaya leaves are frequently thought of as agricultural trash. However, because papain is present, it might be used as a sustainable fish growth enhancer in aquafeed (Vij and Prashar, 2015). Papaya leaf extract used as an aquafeed additive at 1% or 2% inclusion levels in aquafeed led to promotion of better growth performance in red hybrid tilapia without compromising regular digestive enzyme activity blood parameters and biochemistry, or the fish's proximate composition (Hamid *et al.*, 2022). Significant increase in growth performance was observed in Nile tilapia when fed with *C. papaya* extract (Kareem *et al.*, 2016). According to earlier research, adding papain to aquafeed improves feed utilization and growth performance in African catfish (*Clarias gariepinus*; Rachmawati *et al.*, 2020), sterlet (*Acipenser ruthenus*; Wiszniewski *et al.*, 2022), mahseer (*Tor tambra*; Muchlisin *et al.*, 2016) and rohu (*Labeo rohita*; Khati *et al.*, 2015).

## 5. Sex Ratio Control in Fish using Papaya Extracts

### 5.1. Importance of Sex Ratio Control in Aquaculture

Sex Ratio Control in Aquaculture is Important Since it directly influences

reproduction, growth and quality of products, effective sex control is important in commercialization and propagation of fish species. Sex control has become an important feature of research in aquaculture because it influences husbandry, productivity and economics. The farmer can exercise only partial control over breeding events, including sexual differentiation, maturation and reproduction, both at hatchery and grow-out stages. Control of sex and reproduction is essential for large-scale commercial production of aquatic species, which has become commodities traded worldwide. Sex ratio control in fish can be achieved through hormone administration, gene knockout, chromosome manipulation and hybridization, which are all environmentally influenced by temperature and pH (Wang *et al.*, 2018). Even though these methods provide several advantages for fish farming, they also pose some challenges that need to be addressed for sustainable aquaculture.

### 5.2. Papaya Extract in Sex Reversal of Fish

The use of *Carica papaya*, including its seed meal and extracts, has promising results for adjusting the sex ratio in fishes, particularly in the cases of tilapia. However, it has been proven from studies that dietary inclusion with papaya seed meal affects the sex ratio highly significantly in favour of the males, which is favourable and helpful in aquaculture for decongesting overcrowding and fast development. Though its benefits in aquaculture are well documented, there is a need to establish long-term effects and associated risks with dietary supplementation on other fish species.

*Carica papaya* seed meal efficiently skewed the sex ratio of *Oreochromis mossambicus* fry towards males while reaching a maximum population to 77.8%, at optimal inclusion levels. The optimal level of PSM inclusion, which achieved a high male population at 20g PSM/kg basal diet in *O. mossambicus*, was reported as having less adverse effects on growth and survival, thus implying that it is a well-tolerated and effective masculinizing agent (Omeje *et al.*, 2018). Growth, immune response and disease resistance in Nile tilapia was positively affected by the dietary supplementation of papaya seed extract at 2.0 g kg<sup>-1</sup>. Its potential for sex reversal in fish was indicated as male sex ratio of Nile tilapia increased producing a 77% male phenotype (Radwan *et al.*, 2023).

## 6. Challenges and Future Directions

Traditionally, aquaculture has relied on synthetic growth promoters, including antibiotics, hormones and chemical additives, which are used for improving the growth and feed conversion efficiency of fishes and resistance to infections. The recent concerns over the issues of antibiotic-resistant bacteria, contamination of environments and presence of chemical residues in fish have generated high interest in finding natural replacements such as plant-based supplementations. Among these alternatives, *Carica papaya*, or papaya, extracts are of interest and show potential as a natural growth promoter. The presence of residues from synthetic growth promoters in the fish products is a major concern for human health and has led to the stricter

regulation on the use of antibiotics in aquaculture. In contrast, papaya extracts have been deemed safe for human consumption and fish. They do not leave harmful residues in the tissue of fish, making them very suitable for organic and sustainable farming (Kareem *et al.*, 2016).

Moreover, plant-based feed additives fulfil the consumers' demand for green and environment-friendly aquaculture products, which will contribute to increasing market value. Synthetic promoters contribute to environmental pollution through aquaculture effluents containing antibiotics and chemicals, which may disrupt local ecosystems and cause resistant pathogens. Papaya-based feed additives are biodegradable and do not accumulate in water bodies, which makes them an eco-friendly feed additive. Their use reduces the environmental footprint of aquaculture operations (Olusola and Nwokike, 2018).

While papaya has some advantages for aquaculture, the impacts on reproductive functions and health at higher dosages are bad and need further study. The future research should be oriented towards optimizing the use of papaya extracts across species and evaluating their long-term impact on aquaculture systems.

## 7. Conclusion

While synthetic growth promoters are the mainstream in the aquaculture industry, there is a great need for alternatives due to the disadvantages such as antibiotic resistance, environmental pollution and regulatory restrictions. Therefore, sustainable solutions such as papaya extracts offer benefits associated with the growth promotion, feed efficiency and added disease resistance without the potential risks associated with synthetic options. The use of natural extracts, particularly *Carica papaya*, offers a sustainable alternative to synthetic chemicals and antibiotics in aquaculture. Papaya's bioactive compounds, including papain, phenolics and flavonoids, enhance fish growth, improve immune responses and reduce environmental impact. Its proteolytic enzyme, papain, aids in nutrient absorption, while papaya seed extracts contribute to sex ratio control, supporting efficient fish farming. Though its benefits in aquaculture are well documented, there is a need to establish long-term effects and associated risks with dietary supplementation on other fish species.

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