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Utilization of Garlic (*Allium sativum*) as a Functional Supplement to Enhance the Health and Performance of Cultured Fish: A Systematic Literature Review

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ABSTRACT

Background: The increasing demand for aquaculture production requires the use of foods that not only meet nutritional needs but also promote fish health. The use of natural food additives has become an important alternative to reduce dependence on synthetic antibiotics. One of the most extensively studied natural food additives is garlic (Allium sativum). Garlic has been found to eliminate major pathogenic bacteria, strengthen immunity, improve health status, enhance growth, and increase flesh quality in freshwater fish. With its multifunctional properties, garlic represents a promising functional feed additive to enhance growth performance, food utilization, and stress resistance in cultured fish.
Aims: This article was prepared using a systematic literature-review approach on the effects of garlic supplementation in aquaculture feeds.
Methods: A systematic literature search was conducted for articles published within the last ten years in Scopus-or SINTA-indexed journals. The review included: (1) experimental studies investigating the effects of garlic supplementation in fish feed or rearing media; (2) studies involving growth, physiological, immune, or water quality parameters; and (3) articles focusing on aquaculture species such as tilapia (Oreochromis niloticus), common carp (Cyprinus carpio), rohu (Labeo rohita), rainbow trout (Oncorhynchus mykiss), and groupers (Epinephelus spp.).
Results: The evidence has been shown that garlic can enhance growth performance, food efficiency, and immune response in fish, particularly in species such as tilapia, carp, rainbow trout, rohu and grouper. The effective dosage generally ranges between 0.5–3% garlic powder in food, with variations depending on species and application methods.
Conclusion/ Recommendation: Future studies should focus on developing probiotic–herbal feed products based on fermented garlic and assessing the economic and social feasibility of natural phytobiotic applications in intensive aquaculture systems.

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1. Introduction

The increasing demand for aquaculture production requires the use of foods that not only meet nutritional needs but also promote fish health. The use of natural food additives has become an important alternative to reduce dependence on synthetic antibiotics, which pose risks of antimicrobial resistance and environmental pollution. One of the most extensively studied natural additives is garlic (*Allium sativum*), a herbal plant rich in bioactive compounds that has long been used in human health applications and is now being developed for aquaculture purposes (Adineh *et al.,* 2020; Valenzuela-Gutiérrez *et al.,* 2021).

Garlic can enhance the immune system to combat diseases and maintain overall health by increasing monocyte activity and phagocytic function (Papu *et al.,* 2014; Erguig *et al.,* 2015). Garlic contains at least 33 sulfur compounds, 17 amino acids, several enzymes, minerals, and vitamins (Kaur & Ansal, 2020). Extracts and isolated compounds of *A. sativum* have been evaluated for various biological activities, including antibacterial, antiviral, antifungal, antiprotozoal, antioxidant, anti-inflammatory, and anticancer properties (Batiha *et al.,* 2020).

The primary active compound in garlic, allicin (allyl 2-propenethiosulfinate or diallyl thiosulfinate), exhibits strong antibacterial, antiviral, and antifungal activity (Adineh *et al.,* 2020). Allicin can activate the non-specific immune system by upregulating cytokine gene expression, thereby enhancing host defense mechanisms when garlic extract is incorporated into fish feed (Fall & Tanekhy, 2015; Erguig *et al.,* 2015). Allicin is recognized as the most potent organosulfur component in garlic, capable of eliminating pathogenic bacteria and parasites, regulating oxidative stress, and improving immune competence. It also enhances gastrointestinal motility and modulates enzyme secretion, which collectively improves digestion and nutrient absorption (Kaur & Ansal, 2020). In addition, other components such as 1-propenyl allyl thiosulfonate, allyl methyl thiosulfonate, (E,Z)-4,5,9-trithiadodeca-1,6,11-triene 9-oxide (ajoene), and γ-L-glutamyl-S-alkyl-L-cysteine function as antioxidants and immunostimulants that enhance non-specific immune responses in fish (Bayan *et al.,* 2014; Valenzuela-Gutiérrez *et al.,* 2021; Bhatwalkar *et al.,* 2021).

Garlic has been found to eliminate major pathogenic bacteria, strengthen immunity, improve health status, enhance growth, and increase flesh quality in freshwater fish such as common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus*), rainbow trout (*Oncorhynchus mykiss*), and african catfish (*Clarias gariepinus*) (Hai, 2015; Erguig *et al.,* 2015). Moreover, several studies have demonstrated the immunostimulatory role of garlic in larval and juvenile stages of various fish species, including striped catfish (*Pangasius hypophthalmus*), silver barb (*Barbonymus gonionotus*), and african catfish (*Clarias gariepinus*), resulting in improved survival and growth performance (Andriani *et al.,* 2017; Hismah *et al.,* 2022; Pangaribuan *et al.,* 2022). With its multifunctional properties, garlic represents a promising functional food additive to enhance growth performance, food utilization, and stress resistance in cultured fish. This review aims to summarize recent scientific findings on the utilization of garlic (*Allium sativum*) as a functional supplement to enhance the health and performance of cultured fish. *This review provides a comprehensive and up-to-date synthesis of recent evidence highlighting garlic (Allium sativum) as a multifunctional, antibiotic-free functional feed additive that simultaneously enhances immunity, growth performance, nutrient utilization, and stress resistance across multiple cultured fish species and life stages.*

2. Methods

This article was prepared using a systematic literature review approach. The review included: (1) experimental studies investigating the effects of garlic supplementation in fish feed or rearing media; (2) studies involving growth, physiological, immune, or water quality parameters; and (3) articles focusing on aquaculture species such as tilapia (*Oreochromis niloticus*)*,* common carp (*Cyprinus carpio*)*,* african catfish (*Clarias gariepinus*), rohu (*Labeo rohita*)*,* rainbow trout (*Oncorhynchus mykiss*), and groupers (*Epinephelus* spp.).

Literature selection criteria

Articles were included if they met the following criteria: (i) published within the last ten years (2015–2025); (ii) original research or literature review articles; and (iii) published in peer-reviewed scientific journals indexed in national databases (e.g., Sinta) or international databases (e.g., Scopus, Web of Science, DOAJ).

Search strategy

Relevant literature was retrieved from Google Scholar, ScienceDirect, SpringerLink, and Researchgate using combination of keywords such as "garlic", "*Allium sativ*um", "fish growth", "aquaculture", and "immunity". The identification, screening, and eligibility process of systematic literature review approach can be seen in figure 1.

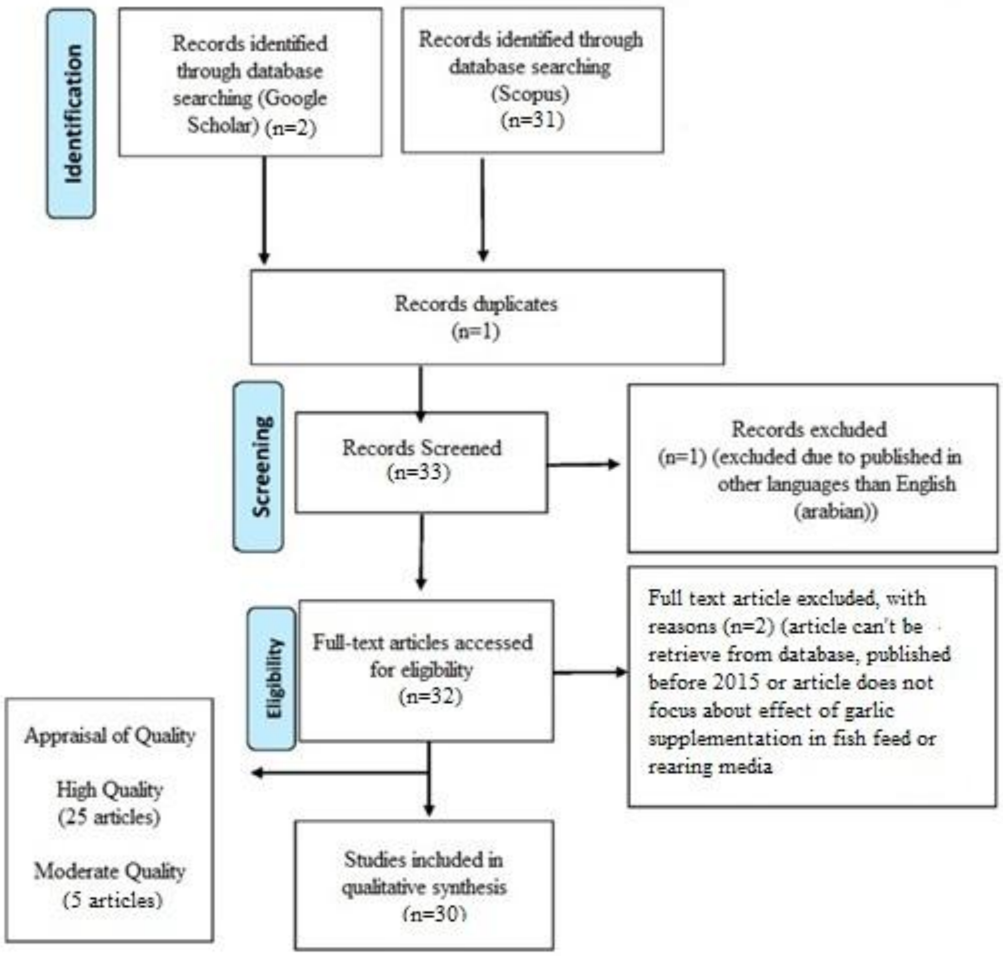

Figure 1. The identification, screening, and eligibility process of systematic literature review approach

Data analysis

Eligible publications were analyzed qualitatively. Findings and conclusions were critically examined and descriptively synthesized to provide an integrated overview of how garlic act as antibacterial agents, immunostimulants, and antioxidants that can improve fish growth and resistance to environmental stress and pathogenic infections. This qualitative-descriptive synthesis forms the scientific basis for developing natural feed additives strategies in intensive aquaculture systems.

3. Results and Discussion

3.1 Effects of Garlic on Fish Growth

Most studies reported that garlic supplementation in fish diets can enhance growth performance and food conversion efficiency. Based on references found that adding garlic oil (0,5-2%) or garlic extract (1 g/kg) to the diet of *Oreochromis niloticus* improved overall body weight, general health condition, and increased survival rate (Foysal & Javed, 2019; Samson, 2019; Said *et al.,* 2022; Abu-Alya *et al.,* 2022). Other species *Cyprinus carpio*, indicates that adding garlic powder (15 gr/kg), garlic extract (1-5 g/kg) enhanced growth performance, specific growth rate, increased body weight and food efficiency (Manoppo *et al.,* 2016; Karimi Pashaki *et al.,* 2018; Al-Noor *et al.,* 2025). Nyadjeu *et al.,* (2021) and Ukenye *et al.,* (2023) reported that dietary garlic powder (1-2%) of *Clarias gariepinus* improved growth, weight gain, and food utilization.

The growth-promoting mechanism of garlic is closely associated with the stimulation of digestive enzyme secretion and improvement of intestinal morphology. Huang *et al.* (2020) reported that dietary allicin at levels of 0.005–0.01% enhanced intestinal villi development in *Larimichthys crocea* larvae, thereby improving nutrient absorption. In addition, the antimicrobial properties of garlic help stabilize the intestinal microbiota, which plays a vital role in improving food utilization efficiency (Bhatwalkar *et al.,* 2021; Delgado *et al.,* 2023). Guroy states that adding garlic powder (1%) enhanced specific growth rate (SGR) and weight gain of rainbow trout (*Oncorhynchus mykiss*). The effects of garlic on fish growth can be seen in table 1.

Table 1. The effects of garlic on fish growth based on references

No	Fish Species	Form and Dosage of Garlic	Main Effects on Growth Performance	References
1	*Cyprinus carpio*	Garlic powder or oil (unspecified dose)	Generally enhanced growth performance	Al-Noor *et al.,* 2025
2	*Oreochromis niloticus*	Garlic oil (5–15 ml/kg)	Positive effects on growth, hematology, blood biochemistry, hepatosomatic index, and histopathology	Oz *et al.,* 2024
3	*Liza ramada*	Fermented garlic (1–2%)	Improved growth and antioxidant activity	Basuini *et al.,* 2024
4	*Oncorhynchus mykiss*	Garlic powder (1%)	Enhanced specific growth rate (SGR) and weight gain	Guroy *et al.,* 2024
5	*Oreochromis niloticus*	Mixture of lemon, onion, garlic (LOG)	Acted as a growth promoter	Abozaid *et al.,* 2024
6	*Clarias gariepinus*	Garlic powder (unspecified dose)	Highest weight gain and best performance	Ukenye *et al.,* 2023
7	Multi-spesies	Various garlic forms	Generally improvement in biology performance	Delgado *et al.,* 2023
8	*Oreochromis niloticus*	Garlic oil (0,5%)	Improved the overall body weight	Abu-Alya *et al.,* 2022
9	*Oreochromis niloticus*	Garlic oil (0,5-1%)	Improved general health condition	Said *et al.,* 2022
10	*Clarias gariepinus*	Garlic powder (1-2%)	Better growth, food utilization and body composition	Nyadjeu *et al.,* 2021
11	*Labeo rohita*	Garlic extract (6.25–25 mg/kg)	Increased SGR and survival rate	Paul *et al.,* 2021
12	*Oncorhynchus mykiss*	Microencapsulated extract (0–2%)	Improved growth, food conversion ratio (FCR), and body protein content	Adineh *et al.,* 2020
13	*Cyprinus carpio*	Garlic powder (1–1.75%)	Optimal dose enhanced specific growth rate (SGR) and food conversion	Mohammad, 2020
14	*Lates calcalifer*	Garlic powder + Ascorbic acid	Improved growth performance, feed utilization, and body composition	Abdelwahab *et al.*, 2020
15	*Larimichthys crocea*	Allicin (0.005–0.01%)	Enhanced intestinal development and larval growth	Huang *et al.,* 2020
16	Multi-spesies	Various phytobiotics (meta-analysis)	Significant improvement in overall growth performance	Reverter *et al.,* 2020
17	*Oreochromis niloticus*	Garlic extract (1 g/kg)	Increased survival rate	Foysal & Javed, 2019
18	*Oreochromis sp*	Garlic powder (1–2%)	Improved survival and growth performance	Samson, 2019
19	*Cyprinus carpio*	Garlic extract (1–5 g/kg feed)	Increased body weight and food efficiency	Karimi Pashaki *et al.,* 2018
20	*Cyprinus carpio*	Garlic powder (15 g/kg)	Increased specific body weight gain	Manoppo *et al.,* 2016
21	*Oreochromis niloticus*	Garlic extract (1%)	Highest weight gain (WG) and specific growth rate (SGR)	Hussein *et al.,* 2016

3.2 Effects of Garlic on the Immune System and Disease Resistance

The immunostimulatory effects of garlic have been the primary focus of most related studies. Based on references that adding garlic extract (0,4 g/L or 1-5 g/kg) preventing *Streptococcus iniae* infection, exhibited antiparasitic activity, and adding garlic oil (0,5-1% or 10 ml/kg) improved hematological parameters and antioxidant activity, acted as an immunostimulant (Foysal & Javed, 2019; Reda *et al*., 2024; Said *et al.,* 2022; Oz *et al.,* 2024). Rezaei *et al.,* (2022) reported increased lysozyme and superoxide dismutase (SOD) activities in crayfish fed diets containing 1% garlic powder. Similarly, Hamed *et al.,* (2020) demonstrated that allicin alleviated liver damage caused by exposure to the pesticide carbofuran in tilapia (*Oreochromis niloticus*) by enhancing the activities of antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT).

In pathogen challenge tests, Paul *et al.,* (2021) found that rohu (*Labeo rohita*) fed garlic extract at 6,25-25 mg/kg diet exhibited significantly higher survival rates following infection with *Aeromonas septicemia*. These findings further support the evidence that garlic enhances non-specific immune responses, including increased leukocyte count, phagocytic activity, and serum antibacterial activity in cultured fish (Mahmoud *et al.,* 2019; Abdelwahab *et al.,* 2020; Karimi Pashaki *et al.,* 2018; Rezaei *et al.,* 2022; Delgado *et al.*, 2023; Basuini *et al.*, 2024). The effects of garlic on the immune system and disease resistance can be seen in table 2.

Table 2. The effects of garlic on the immune system and disease resistance based on references

No	Fish Species	Form and Dosage of Garlic	Main Effects on the Immune System and Disease Resistance	References
1	*Cyprinus carpio*	Garlic powder or oil (unspecified dose)	Improved general health and immune condition	Al-Noor *et al.,* 2025
2	*Oreochromis niloticus*	Garlic oil (10 ml/kg feed)	Improved hematological parameters and antioxidant activity	Oz *et al.,* 2024
3	*Oreochromis niloticus*	Garlic extract (0.4 g/L water)	Exhibited antiparasitic activity against *Dactylogyrus* spp.	Reda *et al*., 2024
4	*Oreochromis niloticus*	Fermented garlic powder	Exhibited strong antioxidant and antimicrobial effects	Basuini *et al*., 2024
5	Multi-spesies	Various garlic forms	Enhanced non-specific immune responses	Delgado *et al.,* 2023
6	*Clarias gariepinus*	Garlic powder (unspecified dose)	Immunity and disease resistance	Ukenye *et al.,* 2023
7	*Postantacus leptodactylus*	Garlic powder (1%)	Enhanced immune enzyme activity (lysozyme, phagocytosis)	Rezaei *et al.,* 2022
8	*Oreochromis niloticus*	Garlic oil (0,5-1%)	Promoted growth and acted as an immunostimulant	Said *et al.,* 2022
9	*Oncorhynchus mykiss*	Garlic extract mixture (0–2%)	Increased protein ratio and immune response	Oz & Dikel, 2022
10	*Epinephelus coioides*	Garlic powder (unspecified dose)	High concentrations showed potential toxicity; appropriate dosage is essential	Erazo-Pagador *et al.,* 2022
11	*Seriola dorsalis*	Garlic extract (1, 4, 16 ml/L water)	Reduced parasitic infection caused by *Z. seriolae*	Armuelles-Bernal *et al.,* 2022
12	*Labeo rohita*	Garlic extract (6.25–25 mg/kg feed)	Increased resistance to *Aeromonas septicemia* infection	Paul *et al.,* 2021
13	*Oreochromis niloticus*	Garlic extract bionanocomposite	Enhanced oxidative stability and fillet resistance to oxidation	Youssef *et al.,* 2021
14	*Oreochromis niloticus*	Allicin (0.5–1 g/kg feed)	Increased SOD and CAT enzyme activities; provided hepatic protection against pesticide toxicity	Hamed *et al.,* 2020
15	*Oreochromis niloticus*	Garlic powder + Ascorbic acid	Improved immune status and antioxidant capacity	Abdelwahab *et al.,* 2020
16	*Cyprinus carpio*	Garlic extract (unspecified dose)	Decreased *Gyrodactylus elegans* parasitic infection	Yavuzcan & Bekcan, 2020
17	*Oreochromis niloticus*	Garlic extract (1 g/kg)	Effective in preventing *Streptococcus iniae* infection	Foysal & Javed, 2019

18	*Oreochromis niloticus*	Garlic powder (1,5%)	Significantly reduced lipid peroxidation and exhibited antioxidant effects	Mahmoud *et al.,* 2019
19	*Cyprinus carpio*	Garlic extract (1–5 g/kg feed)	Increased WBC count, lysozyme activity, and IgM concentration	Karimi Pashaki *et al.,* 2018
20	*Poecilia reticulata*	Garlic powder (1,25 mg/g feed)	Reduced infection intensity on the caudal fin	Kim *et al.,* 2018
21	*Oreochromis niloticus*	Garlic extract (1%)	Increased erythrocyte (RBC) and leukocyte (WBC) counts	Hussein *et al.,* 2016

3.3 Effects on Food Efficiency and Fish Physiology

Several studies have reported that garlic supplementation improves feed utilization efficiency by enhancing blood biochemical profiles and liver function. Hussein *et al.,* (2016) state that adding garlic oil (5-15 ml/kg) or garlic extract (1%) increased blood protein levels, digestive enzyme activity, and nutrient utilization efficiency. Abdelwahab *et al.,* (2020) found that the combination of garlic and vitamin C produced synergistic effects on food efficiency and oxidative balance in Nile tilapia (*Oreochromis niloticus*). In addition, Öz *et al.,* (2024) demonstrated that dietary garlic oil (5-15 ml/kg) supplementation improved hematological parameters and total serum protein levels in tilapia.

Positive physiological effects have also been observed in fish reared under extreme environmental conditions. For instance, Wijayanto *et al.,* (2023) reported that garlic supplementation enhanced the growth performance and survival rate of grouper (*Epinephelus* spp.) reared in low-salinity environments. These findings indicate the potential application of garlic in promoting fish adaptation to environmental stress conditions. Also, Basuini *et al.,* (2024) state that adding fermented garlic (1-2%) can increased antioxidant activity and more efficient metabolism of grey mullet (*Liza ramada*). The effects on food efficiency and fish physiology can be seen in table 3.

Table 3. The effects on food efficiency and fish physiology based on references

No	Fish Species	Form and Dosage of Garlic	Main Effects on Feed Efficiency and Fish Physiology	References
1	*Cyprinus carpio*	Garlic powder or oil (unspecified dose)	Increased food efficiency	Al-Noor *et al.,* 2025
2	*Oreochromis niloticus*	Garlic oil (5–15 ml/kg)	Increased blood protein levels, digestive enzyme activity, and nutrient utilization efficiency	Öz *et al.,* 2024
3	*Liza ramada*	Fermented garlic 1–2%	Increased antioxidant activity and more efficient metabolism	Basuini *et al.,* 2024
4	*Oreochromis niloticus*	Various garlic forms	Enhanced metabolic efficiency and digestive enzyme activity	Delgado *et al.,* 2023
5	*Cyprinus carpio*	Garlic powder (unspecified dose)	Improved blood and biochemical characteristics	Mohammad MA., 2023
6	*Postantacus leptodactylus*	Garlic powder (1%)	Improved digestive enzyme activity and nutrient absorption	Rezaei *et al.,* 2022
7	*Labeo rohita*	Garlic extract (6.25–25 mg/kg)	Improved food utilization efficiency and reduced oxidative stress	Paul *et al.,* 2021
8	*Oreochromis niloticus*	Garlic powder+ Ascorbic acid (unspecified dose)	Enhanced food efficiency, oxidative balance, and liver health	Abdelwahab *et al.,* 2020
9	*Cyprinus carpio*	Garlic powder (1–1.75%)	Lower feed conversion ratio (FCR) and improved food efficiency	Mohammad, 2020
10	*Oncorhynchus mykiss*	Microencapsulated garlic extract (2%)	Reduced FCR, increased body protein, and enhanced digestive enzyme activity	Adineh *et al.,* 2020
11	*Larimichthys crocea*	Allicin (0.01%)	Enhanced nutrient absorption through improved intestinal morphology	Huang *et al.,* 2020
12	Multi-spesies	Garlic-based phytobiotic (unspecified dose)	Improved average food efficiency by 10–20%	Reverter *et al.,* 2020

13	*Cyprinus carpio*	Garlic extract (unspecified dose)	Stress indicators in carp returned to normal after one hour of recovery	Yavuzcan & Bekcan, 2020
14	*Cyprinus carpio*	Garlic extract (1–5 g/kg feed)	Improved blood biochemical profile and liver function	Karimi Pashaki *et al.,* 2018
15	*Cyprinus carpio*	Garlic powder (15 g/kg)	Improved FCR and growth ratio	Manoppo *et al.,* 2016
16	*Oreochromis niloticus*	Garlic extract (1%)	Improved immune factors	Hussein *et al.,* 2016

Overall, dietary garlic supplementation has been shown to consistently improve growth performance, feed utilization, immune function, and stress resistance in various cultured fish species. The effectiveness of garlic is highly dependent on its dosage and form. Across studies, optimal responses were generally observed at 0.5–2% garlic powder, 1–5 g/kg garlic extract, 5–15 mL/kg garlic oil, or 0.005–0.01% allicin, while pathogen resistance was enhanced at lower inclusion levels (6.25–25 mg/kg diet).

These benefits are primarily associated with enhanced digestive efficiency, improved intestinal morphology, modulation of gut microbiota, and stimulation of antioxidant and innate immune responses. When applied within optimal dose ranges, garlic supplementation improved physiological performance without inducing negative effects. Therefore, garlic can be considered an effective natural feed additive for sustainable aquaculture, although further dose–response studies are required to refine species-specific recommendations.

3.4. Environmental and Sustainability Aspects

The use of garlic as a natural food additive aligns with the principles of sustainable aquaculture, as it can reduce dependence on antibiotics and chemicals synthetic. Delgado *et al.* (2023) and Reverter *et al.* (2020), through meta-analysis studies, concluded that the use of herbal plants—including garlic—significantly improves the biological performance of fish without causing toxic effects on the environment. However, Erazo-Pagador *et al.* (2022) cautioned that excessively high doses of garlic may be toxic, as indicated by LC_{50} values demonstrating potential adverse effects at extreme concentrations. Therefore, determining the optimal dosage is a crucial factor for its practical application in aquaculture systems.

Research Gaps and Future Directions

Although numerous studies have demonstrated the beneficial effects of garlic supplementation, several scientific gaps remain to be addressed:

1. Lack of standardized dosage and formulation (powder, oil, extract, fermented form) across studies.
2. Limited research on tropical marine fish species compared to freshwater species such as *Oreochromis niloticus* and *Cyprinus carpio*.
3. Few long-term studies evaluating residue effects, chronic toxicity, and interactions with other feed ingredients.
4. Further molecular investigations are required to elucidate the mechanisms of allicin in modulating immune and antioxidant gene expression.

Future studies should focus on developing probiotic–herbal feed products based on fermented garlic and assessing the economic and social feasibility of natural phytobiotic applications in intensive aquaculture systems.

4. Conclusion & Recommendations

Garlic (*Allium sativum*) has demonstrated considerable potential as a natural food additive in sustainable aquaculture. Based on the review of 30 scientific articles, dietary garlic supplementation at 0.5–2% garlic powder, 1–5 g/kg garlic extract, 5–15 mL/kg garlic oil, or 0.005–0.01% allicin generally enhances growth performance, food efficiency, and fish resilience to stress and diseases. These positive outcomes are attributed to the antibacterial, antioxidant, and immunostimulant activities of allicin and its bioactive derivatives. Also, the use of garlic as a natural food additive can reduce dependence on antibiotics and chemicals synthetic. Therefore, garlic can be considered an effective natural feed additive for sustainable aquaculture, although further dose–response studies are required to refine species-specific recommendations. Future studies should focus on developing probiotic–herbal feed products based on fermented garlic and assessing the economic and social feasibility of natural phytobiotic applications in intensive aquaculture systems.

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