

IMPACTS OF USING *ALOE VERA* AS A FEED ADDITIVE IN AQUATIC ANIMALS FEEDING TRIALS: A MINI-REVIEW

Seong Wei Lee^{1*}, Albaris B. Tahliluddin^{2,3}, Hadiana Hadiana^{4*}, Ahmad Syazni Kamarudin⁵, Arifullah Mohammed⁶, Nor Azra Mohamad⁷, Lau Kia Kian⁸, Wendy Wee^{9*}

¹Department of Agricultural Sciences, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia

²College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao, Tawi-Tawi 7500, Philippines

³Department of Aquaculture, Institute of Science, Kastamonu University, Kastamonu 37200, Türkiye

⁴PSDKU Aquaculture, Faculty of Fisheries and Marine Science, Brawijaya University, Jl. Pringgodani, Kel. Mrican, Kec. Mojoroto, Kediri City, East Java 64111, Indonesia

⁵School of Animal Science, Aquatic Science and Environment, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, Besut, Terengganu 22200, Malaysia

⁶KL College of Agriculture, Koneru Lakshmaiah University, Vaddeswaram Campus, Guntur 522 302, India

⁷Institute of Climate Adaptation and Marine Biotechnology (ICAMB), Universiti Malaysia Terengganu (UMT), Kuala Nerus, Terengganu 21030, Malaysia

⁸Faculty of Pharmaceutical Sciences, UCSI University Kuala Lumpur Campus, No. 1, Jalan UCSI, UCSI Height, Cheras, Kuala Lumpur 56000, Malaysia

⁹Center for Fundamental and Continuing Education, Universiti Malaysia Terengganu, Kuala Nerus, Terengganu 21030, Malaysia

*Corresponding authors: S.W. Lee: leeseong@umk.edu.my; H. Hadiana: hadiana23@ub.ac.id; W. Wee: wendy@umt.edu.my

Abstract

Aquaculture is the world's fastest-growing food production sector. To ensure sustainable practices in this vital industry, integrating green feed additives is crucial. This review aims to recapitulate and discuss the current research on the effects of *Aloe vera* (AV) as a feed additive on the growth and health of various aquatic animals. AV has emerged as a promising green feed additive in aquaculture due to its multifaceted benefits. These benefits include enhanced growth performance, improved flesh quality, modulated hematological parameters, stimulated disease resistance, stress mitigation, and even masculinization effects in certain species. The review further elaborates on the sources and beneficial effects of AV's bioactive compounds. A key focus is understanding the mechanisms of action of AV and its derivatives, alongside determining optimal dietary inclusion levels for aquatic animals. Previous studies indicate that optimal dietary doses of AV and its derivatives range from 0.0005% to 6% of the diet, while a concentration of 0.005% is recommended for bathing treatments. These beneficial effects are attributed to AV's rich array of bioactive compounds, including phenolic acids, glucomannan, acemannan, emodin, and anthraquinone. Overall, the findings suggest that the dietary inclusion of AV and its derivatives at low levels holds significant promise for promoting growth and enhancing the health of farmed aquatic animals. However, it is equally important to note that excessive doses of AV and its derivatives can negatively affect aquatic animal production.

Key words: growth performance, flesh quality, hematological alteration, disease resistance stimulation, stress mitigation, masculinization effect

The escalating global population has dramatically increased the demand for affordable protein, making aquaculture as a critical sector for food security. Aquatic animal production, primarily through aquaculture, has seen substantial growth, evidenced by a trading value of USD 296 billion in 2022, representing 65% of the total global fish trading value (USD 452 billion) (FAO, 2024). Projections even indicate that aquaculture production is poised to surpass capture fisheries production by 2050 (FAO, 2022). However, meeting this burgeoning demand has led to the overexploitation of wild fish stocks, causing alarming declines in natural populations. Recognizing this urgent issue, international efforts like the 2022

World Trade Organization (WTO) Agreement on Fisheries Subsidies (FSA) have been implemented to curb overfishing and protect marine resources (Soeparna and Taofiqurohman, 2024). Consequently, the limitations of capture fisheries necessitate a heightened reliance on sustainably supplying fish protein.

To meet this demand, intensive aquaculture practices have been adopted to maximize production. Yet, these intensive systems often induce stress, negatively impacting the growth and health of farmed species (Mohamed et al., 2025). Historically, antibiotics were used as feed additives to mitigate these adverse effects. Nevertheless, the widespread use of antibiotics

in aquaculture has contributed to the proliferation of antibiotic resistance in pathogenic bacteria, environmental accumulation of antibiotic residues, and potential threats to public health (Kari et al., 2024). Moreover, residual antibiotics in fish tissues have eroded consumer confidence in aquaculture products. In response to these significant drawbacks, many countries have banned antibiotic use in aquaculture, prompting the search for cost-effective, reliable, and environmentally sustainable alternatives.

Phytobiotics have emerged as a promising alternative feed additive in aquaculture. Over the past decade, their popularity has surged due to their demonstrated beneficial effects on fish growth and health. Numerous studies have explored the potential of phytobiotics to enhance growth performance, digestive enzyme activity (Ahmadifar et al., 2022), immune function, antioxidative responses, and disease resistance in fish (Ashour et al., 2020). Furthermore, research indicates that phytobiotic application can upregulate growth and immune-related gene expression (Ahmadifar et al., 2021; Hoseinifar et al., 2015), thereby boosting aquaculture production. Examples of phytobiotics demonstrating significant potential in tilapia and African catfish include fenugreek (*Trigonella foenum-graecum*) (Moustafa et al., 2020), *Ginkgo biloba* leaf (Abdel-Latif et al., 2021), tamarind (*Tamarindus indica*) pulp (Adeniyi et al., 2022), ginger (*Zingiber officinale*) (Ahmad et al., 2024), *Mitracarpus scaber* leaf (Adeshina et al., 2024), kaffir lime leaf (*Citrus hystrix*) (Wei et al., 2024), *Ficus deltoidea* (Abdul Kari et al., 2024), and *Moringa oleifera* leaf and seed (Gaber et al., 2025). These studies highlight the role of bioactive compounds, particularly polyphenols, in promoting growth and modulating immune responses in fish.

Aloe vera (AV), a plant rich in bioactive compounds, has garnered significant attention across various industries, including aquaculture. Recent research has explored the potential of AV and its derivatives as feed additives and solutions to enhance aquaculture production. Studies have demonstrated that AV can improve growth performance, hematological profiles, immune function, and disease resistance in a variety of aquatic animals. Furthermore, AV has shown promise in mitigating stress and facilitating sex reversal for all-male tilapia production. This review aims to provide a comprehensive overview of the history of *Aloe* species, the bioactive compounds present in AV, and their beneficial effects in aquaculture. Specifically, this work recapitulates and discusses the potential of AV to promote growth, improve flesh quality, enhance health, stimulate disease resistance, and mitigate stress in aquatic animals. Finally, this review paper explores potential of AV used as a solution for sex reversal in all-male tilapia production.

Introduction of *Aloe* species

The nomenclature of *Aloe vera* (AV) reflects its historical significance and diverse origins, combining the

Arabic “Alloeh”, meaning “shining bitter substance”, with the Latin “vera”, signifying “true”. Revered in ancient Egypt as the “plant of immortality”, AV has been integral to traditional medicinal practices across numerous cultures, including those of India, China, Japan, and the Americas (Kumar et al., 2019).

The *Aloe* genus, belonging to the Liliaceae family, encompasses over 400 species. These include *A. vera* (L.) Burm. f., *A. barbadensis* Miller, *A. chinensis* Steud. ex Baker, *A. elongata*, *A. flava* Pers., *A. indica* Royle, *A. lanzar* Tod., *A. maculate* Frossk., *A. rubescens* DC, and *A. vulgaris* Lam. Natural hybridization among these species has resulted in the emergence of numerous varieties, such as *A. perfoliate* var. *barbadensis* (Mill.) Aiton, *A. perfoliate* var. *vera* L., *A. vera* var. *chinensis* (Steud. ex Baker) Baker, *A. vera* var. *lanzae* Baker and *A. vera* var. *littoralis* J. König ex Baker. Among these, *A. vera* and *A. barbadensis* are particularly prominent and often considered synonymous, with purported distinctions based on flower color and bioactive compound profiles. However, it is crucial to note that both floral pigmentation and phytochemical composition within *Aloe* species are subject to variation influenced by abiotic factors.

AV is characterized as a stemless plant with elongated, succulent leaves. These leaves serve as water reservoirs and exhibit a distinct three-layered structure. The outermost layer, the thick cuticle, functions as a site for protein, carbohydrate, and lipid biosynthesis. The middle layer, the thin leaf pulp, produces latex. The innermost layer, the primary repository of aloe gel, constitutes the major component of the plant (Boudreau and Beland, 2006; Zhang et al., 2016). Both the latex and gel, along with the whole leaf, are utilized in health supplements due to their rich content of bioactive compounds, contributing to their diverse beneficial effects (Zhang et al., 2016).

Bioactive compounds and beneficial effects of *Aloe vera*

AV is characterized by its high moisture, comprising approximately 99% of the plant’s mass, with the remaining 1% consisting of a complex array of solid constituents. This solid fraction encompasses over 75 distinct compounds, contributing to the plant’s diverse biological activities (Radha and Laxmipriya, 2015). Notably, AV contains essential amino acids, vitamins, minerals, enzymes, lignin, salicylic acid, saponins, hormones, and fatty acids, forming a rich nutritional profile (Surjushe et al., 2008). The AV gel and latex, in particular, are repositories of a wide range of bioactive compounds, including anthraquinones (Cock, 2015), anthrones (Kanama et al., 2015), chromones (Kanama et al., 2015), coumarins, pyrans, pyrones (Cock, 2015), alkaloids, benzene, naphthalene derivatives (Dagne et al., 2000), flavonoids (Lucini et al., 2015), and lipid components (Kumar et al., 2019).

The AV gel, the principal component of the plant, exhibits a mucilaginous texture and comprises a complex mixture of polysaccharides, sugars, minerals, proteins, lipids, and phenolic compounds. Specifically, dried AV gel consists of approximately 55% polysaccharides, 17% sugar, 16% minerals, 7% protein, 4% lipids, and 1% phenolic compounds (Kumar et al., 2019). Among the polysaccharides, polymannan, a linear chain of mannose with glucose residues (Kumar et al., 2019), also known as glucomannan, is a major constituent (Zhang et al., 2016). Additionally, the gel contains other polysaccharides, including cellulose, hemicellulose, pectin, and various mannan derivatives (Kumar et al., 2019).

The AV latex, characterized by its yellow-brown coloration, contains approximately 80 chemical compounds, with anthraquinones and anthrones being predominant (Zhang et al., 2016). Barbaloin, a prominent anthraquinone and anthrone derivative, is present in latex (Boudreau and Beland, 2006) and can exist in various forms, including aloin A, aloin B, aloeresin A, and aloeresin B, depending on its molecular structure (Saccù et al., 2001). It is essential to note that the concentrations of these bioactive compounds are subject to significant variability, influenced by environmental factors, soil conditions, propagation methods, and post-harvest activities (Boudreau and Beland, 2006).

Historically, AV gel has been employed for external applications, including wound healing, dermatological conditions, burns, and ulcerations. Conversely, AV latex has been traditionally recognized for its stress-relieving properties (Zhang et al., 2016). Contemporary scientific literature corroborates these traditional uses, highlighting the diverse biological activities of AV. Studies have demonstrated its antioxidant (Saini and Saini, 2011), anti-inflammatory (Budai et al., 2013), antimicrobial (Hamman, 2008; Sitara et al., 2011), antimalarial (Clarkson et al., 2004; Van Zyl and Viljoen, 2002), antiviral (Olatunya et al., 2012), antidiabetic (Misawa et al., 2012), hepatoprotective (Chandan et al., 2007; Salama et al., 2016), and anticancer properties (Harlev et al., 2012; Shalabi et al., 2015). These biological activities underscore the potential of AV as a valuable source of therapeutic compounds.

Impacts of application of *Aloe vera* on aquatic animals

Growth performance alterations

The incorporation of dietary AV has been explored as a strategy to enhance growth performance across a spectrum of aquatic animals. Studies have demonstrated significant improvements in growth parameters following AV supplementation. For instance, Syed et al. (2022) reported that Nile tilapia (*Oreochromis niloticus*) reared in a closed aquaculture system and fed diets containing 1–3% AV leaf extract for 105 days exhibited enhanced growth performance. Specifically, significant increases were observed in weight gain,

specific growth rate, feed conversion ratio, hepatosomatic index, and viscerosomatic index, with the 3% AV diet yielding the most pronounced effects. Comparing findings were documented in rainbow trout (*Oncorhynchus mykiss*), where 0.1% and 1% AV supplementation for 6 weeks resulted in significant improvements in weight gain, specific growth rate, and feed conversion ratio (Heidarieh, 2013). Similarly, shirbot (*Tor grypus*) fed diets containing 0.1–0.5% AV for 2 months demonstrated significantly higher ($P < 0.05$) weight gain, specific growth rate, and feed conversion ratio compared to the control group (Safari et al., 2019). Furthermore, *Catla catla* fed diets containing 1–5% AV gel for 70 days showed positive impacts on growth performance (Yousaf et al., 2025).

The growth-promoting effects of dietary AV are attributed to several potential modes of action. AV may stimulate appetite and enhance digestive enzyme activity, thereby improving nutrient assimilation (Syed et al., 2022). Additionally, AV has been suggested to improve intestinal morphology by increasing villus length and reducing villus width, thus expanding intestinal surface area and enhancing nutrient absorption (Heidarieh, 2013). Moreover, studies have indicated that AV supplementation can improve feed utilization, contributing to enhanced growth performance (Yousaf et al., 2025).

However, not all studies have reported positive growth effects following AV supplementation. Amri et al. (2022) found no significant differences in growth performance in gilthead seabream (*Sparus aurata*) fed 0.5–5% AV diets for 8 weeks, despite observing the upregulation of growth-related genes. Similar observations were reported in juvenile goldfish (*Carassius auratus*) fed 2% of AV diets for 7 and 30 days (Palermo et al., 2013) and steelhead trout (*O. mykiss*) fed 0.5% AV diets for 42 days (Zanuzzo et al., 2015). These discrepancies may be attributed to insufficient experimental durations, which may not have allowed for the full manifestation of AV's growth-promoting effects.

Furthermore, Quirós-Pozo et al. (2021) reported no significant differences in growth performance in golden mullet (*Liza aurata*) fed 2% and 4% of AV diets for 60 days. Conversely, a 6% AV diet significantly enhanced growth performance, suggesting a dose-dependent effect. This observation contrasts with studies on common carp (*Cyprinus carpio*) and tilapia, which reported beneficial growth effects at lower doses (2%) (Gabriel et al., 2015; Mahdavi et al., 2013). These findings underscore the species-specific responses to AV supplementation, highlighting the need for tailored dietary formulations based on the physiological requirements of individual species.

Flesh quality alteration

The inclusion of AV in fish diets has been shown to influence flesh quality, with several studies reporting positive outcomes. For instance, Yousaf et al. (2025)

demonstrated that *Catla catla* fed AV gel diets for 70 days exhibited significant improvement in crude protein and ash content in their flesh, particularly at a 3% AV gel inclusion. Concurrently, a significant decrease in moisture and crude fat content was observed in these fish compared to the control groups. These findings are consistent with observations in Nile tilapia, where dietary AV extract enhanced crude protein and ash content in the flesh (Syed et al., 2022).

However, the literature is not without its discordant notes. Gabriel et al. (2017) found that AV extract supplementation did not significantly impact the flesh quality of GIFT tilapia. Furthermore, a 2% AV extract diet resulted in lower crude protein levels in the flesh of these fish. These discrepancies across studies may be attributed to a multitude of factors, including species-specific responses, variations in water quality, differences in AV dosage, and the overall health status of the fish (Yousaf et al., 2025).

Hematological profile alteration

Numerous studies have reported that dietary AV can positively influence the hematological profiles of aquatic animals, suggesting its potential as a functional feed additive. For example, Syed et al. (2022) observed that Nile tilapia fed 1–3% AV dried leaf extract for 105 days exhibited enhanced levels of hemoglobin, neutrophils, lymphocytes, monocytes, eosinophils, and white blood cells. However, red blood cell counts remained unchanged. Similarly, Safari (2019) reported that shirbot fed 0.1–0.5% AV diets showed significant ($P < 0.05$) increases in red blood cell count, white blood cell count, hemoglobin, and hematocrit compared to the control group. This positive effect was also reported in Nile tilapia post-infection with *Streptococcus iniae*, where AV supplementation at 0.5–4% improved hematological parameters (Gabriel et al., 2015). Furthermore, studies on African catfish (*Clarias gariepinus*) demonstrated that a combination of AV and *Allium sativum* in the diet enhanced red blood cell and platelet counts (Gabriel et al., 2021), and AV paste alone elevated the hematological profile (Adegbesan et al., 2018). Consistent with these findings, red hybrid tilapia fed a herbal mixture containing *Vitex trifolia*, *Strobilanthes crispus*, and AV showed improved hematological profiles after 60 days of feeding (Manaf et al., 2016). The observed enhancements in hematological profiles are likely attributed to the polysaccharides present in AV, which may stimulate erythropoiesis and hematopoiesis processes (Gabriel et al., 2015; Safari et al., 2019).

However, some studies have indicated that the beneficial effects of AV on hematological parameters are more pronounced under conditions of stress or infection. Gabriel et al. (2015) reported that AV diets enhanced white blood cell count, neutrophil and eosinophil levels in GIFT tilapia only after *S. iniae* infection, with no significant differences observed in unaffected

fish. Similarly, Farahi et al. (2012) found that 0.5% AV diets did not enhance the hematological parameters in common carp under normal conditions but significantly improved them following *Aeromonas hydrophila* infection. These findings suggest that bacterial infection activates erythropoiesis and hematopoiesis as a physiological response to pathogen invasion, potentially amplifying the effects of AV (Ali and Ansari, 2012; Sebastião et al., 2011).

Interestingly, high doses of AV have been reported to exert adverse effects on hematological profiles in aquatic animals. For example, GIFT tilapia fed 4% AV diets developed anemia, whereas lower doses (0.5% and 1%) enhanced hematological parameters (Gabriel et al., 2015). Similarly, negative effects on gill, heart, liver, and kidney tissues in fish fed high doses were reported (Jegade, 2011). These observations suggest that high concentrations of plant extracts, including AV, may disrupt erythropoiesis and hematopoiesis, potentially leading to anemia and other toxic effects (Jenkins et al., 2003; Palanisamy et al., 2011). Therefore, careful consideration of AV dosage is crucial in aquaculture practices, with lower doses generally recommended to maximize benefits and minimize potential adverse effects.

Disease resistance stimulation

The inclusion of AV in aquatic animal diets has demonstrated significant potential for enhancing disease resistance. For instance, Heidarieh (2013) observed a significant reduction ($P < 0.05$) in mortality rates of rainbow trout challenged with *Streptococcus agalactiae* after six-week feeding regimen incorporating 0.1% and 1% AV. Similarly, Kim et al. (1999) reported enhanced resistance to *Vibrio alginolyticus* in juvenile rockfish (*Sebastes schlegeli*) fed 0.5% of AV leaf powder. This immunostimulatory effect extends to fungal pathogens, with studies indicating that AV supplementation can bolster resistance against *Aphanomyces invadans* and *Saprolegnia parasitica* in rainbow trout (Mehrabi et al., 2019) and rohu (Devi et al., 2019), respectively. Furthermore, investigations in white-leg shrimp (*Litopenaeus vannamei*) have revealed that dietary AV can offer protection against white spot syndrome virus and *V. parahaemolyticus*, accompanied by the upregulation of immune-related gene expression (Trejo-Flores et al., 2018, 2016). These findings collectively suggest AV holds promise as a valuable immunostimulant in shrimp aquaculture.

The immunostimulant effects of AV are multifaceted. Notably, dietary AV has been shown to increase intestinal villus height in fish, leading to an expanded gut mucosal surface area, which facilitates pathogen elimination (Heidarieh, 2013). Additionally, a significant increase in total goblet cells within the fish epithelium, a crucial component of the mucosal defense system, was observed in AV-fed individuals. Kim et al. (1999) fur-

ther reported that AV supplementation activates kidney leukocytes and fortifies non-specific immunity against bacterial infection. The presence of bioactive compounds, such as phenolic acids, in AV likely contributes to the stimulation of the non-specific immune system in aquatic animals (Heidarieh, 2013). Specifically, glucomannan and acemannan, two key components of AV, have been documented to possess medicinal properties, including wound healing, immune system modulation, macrophage activation, and antiviral and antibacterial properties (Dotta et al., 2014). Moreover, aloe-emodin and anthraquinone, other bioactive constituents, have demonstrated virus inhibitory effects by interfering with viral adsorption and replication (Hu et al., 2003; Reynolds and Dweck, 1999).

Aloe vera relieves stress of aquatic animals

Preliminary investigations have indicated that dietary administration of AV leaf powder may attenuate transport-induced stress in matrinxã (*Brycon amazonicus*) and pacu (*Piaractus mesopotamicus*) through immersion treatments (Zanuzzo et al., 2012). Specifically, a significant increase ($P < 0.05$) in respiratory burst activity of leukocytes was observed in the fish exposed to 0.002% of AV leaf powder solution during transportation, relative to untreated controls. Notably, plasma glucose concentrations did not differ significantly between treatment groups. This initial study suggests the potential utility of AV leaf powder as an aquatic additive to mitigate stress in fish during fish transport (Zanuzzo et al., 2012).

Subsequent research by Zanuzzo et al. (2017) further demonstrated that dietary supplementation with AV, at levels ranging from 0.5% to 2% for 10 days, effectively reduced stress responses in pacu subjected to transportation, injection, and bacterial challenge. The stress-mitigating effects of AV were particularly pronounced following intraperitoneal injection of heat-killed *A. hydrophila*. Mechanistically, AV was shown to modulate glucose and cortisol levels, preventing stress-induced elevations. Specifically, cortisol levels in AV-treated fish returned to levels comparable to unstressed controls. Consequently, future studies are warranted to elucidate the precise pathways through which AV modulates cortisol and mitigates stress in aquatic animals.

Masculinization effect

Dietary administration of AV has been reported to induce masculinization effect on Nile tilapia (*O. niloticus*) fry, with doses ranging from 0.5% to 4% for 30 days (Gabriel et al., 2017). This study demonstrated a dose-dependent masculinization, wherein higher AV concentrations resulted in a more pronounced phenotypic shift. However, a significant decline in survival rates was also at higher AV dosages. Similar masculinization effects have been documented in tilapia fed diets supplemented with other plant-based additives,

such as *Tribulus terrestris* (Omitoyin, 2013), soapbark tree (*Quillaja saponaria*) (Francis, 2002), soybean (*Glycine max*) (El-Sayed, 2012), and Ceylon spinach (Ghosal, 2014). Conversely, extracts from Chinese hibiscus (*Hibiscus rosa*) (Jegade, 2010) and papaya (*Carica papaya*) (Abdelhak, 2013) have been reported to disrupt gonadal development and maturation in tilapia, indicating the potential for both masculinizing and feminizing effects depending on the plant species.

The observed masculinization effects of AV may be attributed to its diverse array of bioactive compounds, such as flavonoids, saponin, tannins, alkaloids, and anthraquinones, which have been implicated in fertility modulation (Langmead et al., 2004; Vogler, 1999). For instance, AV extracts have been shown to disrupt sex hormone profiles in the green terror cichlid (*Aequidens rivulatus*) (Norouzi, 2014) and gonad development in tilapia (Jegade, 2010). Moreover, saponins, a constituent of AV (Kumar, 2012), are recognized for their ability to elevate testosterone production in animal models (Ganzer, 2001). Conversely, isoflavonoids and genistein, found in other plant sources, have demonstrated inhibitory effects on masculinization in Nile tilapia (El-Sayed, 2012), Japanese medaka (*Oryzias latipes*) (Zhang, 2002), and rainbow trout (*O. mykiss*) (Bennetau-Pelissero, 2001). However, the precise molecular mechanism underlying AV-induced masculinization in fish remains unexplored. Therefore, further investigations are warranted to elucidate the pathways through which AV modulates sex differentiation in aquatic species.

Conclusion

In summary, dietary *Aloe vera* (AV) and its derivatives have demonstrated a range of beneficial effects on aquatic animal growth and health. These encompass improvements in growth performance, flesh quality, hematological parameters, disease resistance stimulation, and stress mitigation. Notably, masculinization effects have also been observed in certain species. However, it is crucial to acknowledge that excessive application of AV and its derivatives can induce adverse effects. Furthermore, the variability in reported outcomes across studies may be attributed to factors such as species-specific responses, water quality, AV dosage, and the initial health status of the experimental animals. The observed beneficial activities are likely mediated by AV's diverse bioactive compounds, including phenolic acids, glucomannan, acemannan, emodin, and anthraquinone. While the application of AV and its derivatives holds considerable promise, further research is imperative. Future studies should focus on evaluating cost-effectiveness, optimizing dosage, refining application methods, and elucidating the precise mechanisms of action. This will ensure the safe and effective utilization of AV in aquaculture practices.

Table 1. The impacts of *Aloe vera* and its derivatives as feed additive in aquatic animals

<i>Aloe vera</i> and its derivatives	Aquatic animal – age/weight	Dose and duration	Impacts	References
1	2	3	4	5
<i>Aloe vera</i> leaf powder	Juvenile rockfish, <i>Sebastes schlegeli</i> – 25 g	0.5% of diet – 6 weeks	↑disease resistance to <i>Vibrio alginolyticus</i>	(Kim et al., 1999)
<i>Aloe vera</i> leaf powder	Matrinxã, <i>Brycon amazonicus</i> – 84.7 g	0.002% – bathing treatment – 2 h	↑mitigate stress due to transportation	(Zanuzzo et al., 2012)
<i>Aloe vera</i> gel	Rainbow trout, <i>Oncorhynchus mykiss</i> – 50.3 g	0.1–1% of diet – 6 weeks	↑growth performance ↑skin alteration ↑gastrointestinal ↑disease resistance to <i>Streptococcus agalactiae</i>	(Heidarieh, 2013)
<i>Aloe vera</i> and propolis mixture (1:1)	Juvenile Nile tilapia, <i>Oreochromis niloticus</i> – 54.3 g	0.5–2% of diet – 14 days	= hematological profile ↑monocyte and neutrophil phagocytic activity	(Dotta et al., 2014)
<i>Aloe vera</i> leaf powder	GIFT tilapia, <i>Oreochromis niloticus</i> – 4.83 g	1–2% of diet – 60 days	↑hematological profile ↑growth performance = disease resistance to <i>Streptococcus iniae</i> cause anemia	(Gabriel et al., 2015)
<i>Aloe vera</i> leaf powder	Steelhead trout, <i>Oncorhynchus mykiss</i> – 133.9 g	4% of diet – 60 days 0.5% of diet – 6 weeks	= growth performance = antioxidative responses = regulate immune-related genes expression	(Zanuzzo et al., 2015)
<i>Aloe vera</i> leaf powder	Whiteleg shrimp, <i>Litopenaeus vannamei</i> – Bioassay 1 – 80 mg Bioassay 2 – 104 mg Bioassay 3 – 110 mg	0.1–0.4% of diet – 26 days 11 days 7 days	↑disease resistance to <i>Vibrio parahaemolyticus</i> + white spot syndrome virus (WSSV)	(Trejo-Flores et al., 2016)
<i>Aloe vera</i> leaf powder	GIFT tilapia, <i>Oreochromis niloticus</i> – 4.83 g	1–4% of diet – 42 days	↑masculinization effects	(Gabriel et al., 2017)
<i>Aloe vera</i> leaf powder	Pacu, <i>Piaractus mesopotamicus</i> – 71.3 g	0.5–2% of diet – 10 days	↑mitigate transportation stress ↑immune system ↑disease resistance to <i>Aeromonas hydrophila</i>	(Zanuzzo et al., 2017)
<i>Aloe vera</i> leaf powder	Whiteleg shrimp, <i>Litopenaeus vannamei</i> – 2.9 g	0.1% of diet – 72 h	↑upregulate immune-related genes expression	(Trejo-Flores et al., 2018)
<i>Aloe vera</i> polysaccharides	African catfish, <i>Clarias gariepinus</i> – 3.1 g	0.5–2% of diet – 60 days	↑growth performance ↑resistance to low pH environment	(Gabriel et al., 2019)
<i>Aloe</i> -emodin	Rohu, <i>Labeo rohita</i> – 27.8 g	0.5–1% of diet – 60 days 0.0005% of diet – 8 weeks	↑hematological profile ↑immune system ↑disease resistance to <i>Aphanomyces invadans</i> ↑upregulate immune-related genes expression	(Devi et al., 2019)
<i>Aloe vera</i> leaf powder	Rainbow trout, <i>Oncorhynchus mykiss</i> – 10.89 g	1.5% of diet – 8 weeks	↑growth performance ↑immunological parameters ↑upregulated immune-related genes expression ↑disease resistance to <i>Saprolegnia parasitica</i>	(Mehrabi et al., 2019)
<i>Aloe vera</i> leaf powder	Common carp, <i>Cyprinus carpio</i> – 1.73 g	0.2–1.6% of diet – 90 days	↑growth performance ↑flesh quality	(Khanal et al., 2021)
<i>Aloe vera</i> and <i>Allium sativum</i> mixture (1:1)	African catfish, <i>Clarias gariepinus</i> – 12.28 g	1% of diet – 60 days	↑growth performance ↑hematological profile ↑resistance to low pH environment ↑flesh quality – lipid content	(Gabriel et al., 2021)

Table 1 – contd.

1	2	3	4	5
<i>Aloe vera</i> by-product	Golden mullet, <i>Liza aurata</i> – 8.93 g	2–6% of diet – 91 days	= growth performance = flesh quality ↑immunological parameter at 2% only = antioxidative response	(Quirós-Pozo et al., 2021)
<i>Aloe vera</i> leaf gel	Atlantic salmon, <i>Salmo salar</i> – 75 g	0.04% – 28 days	↑relieve inflammation induced by soybean meal	(Fehrmann-Cartes et al., 2022)
<i>Aloe vera</i> leaf powder	Gilthead sea bream, <i>Sparus aurata</i> – 138.35 g	0.5–5% of diet – 60 days	= growth performance ↑antioxidative response ↑upregulate growth-related genes expression ↓downregulate lipid metabolism-related genes expression ↑hepatic steatosis	(Amri et al., 2022)
Methanolic <i>Aloe vera</i> leaf extract	Nile tilapia, <i>Oreochromis niloticus</i> – 4.04 g	1–3% of diet – 105 days	↑growth performance ↑hematological profile	(Syed et al., 2022)
<i>Aloe vera</i> gel	Mori fish, <i>Catla catla</i> – 10 g	1–3% of diet – 70 days	↑growth performance ↑flesh quality ↑hematological profile ↑antioxidative response	(Yousaf et al., 2025)

↑ positive impact; ↓ negative impact; = no impact.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

All authors declare that they have unknown competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- Abdel-Latif H.M.R., Hendam B.M., Nofal M.I., El-Son M.A.M. (2021). *Ginkgo biloba* leaf extract improves growth, intestinal histomorphometry, immunity, antioxidant status and modulates transcription of cytokine genes in hapa-reared *Oreochromis niloticus*. *Fish Shellfish Immunol.*, 117: 339–349.
- Abdelhak M.E., Madkour F. F., Ibrahim M. A., Sharaf M.S., Sharaf M.M., Mohammed D.A. (2013). Effects of pawpaw, *Carica papaya* seeds meal on the productive performance and histological characters of gonads in Nile tilapia, *Oreochromis niloticus*. *Int. J. Adv. Res.*, 3: 34–37.
- Abdul Kari Z., Sukri S.A.M., Téllez-Isaías G., Bottje W.G., Khoo M.I., Guru A., Tayyeb J.Z., Kabir M.A., Eissa E.S.H., Tahiluddin A.B., Wei L.S. (2024). Effects of dietary powdered *Ficus deltoidea* on the growth and health performance of African catfish, *Clarias gariepinus* production. *Fish Physiol. Biochem.*, 50: 2563–2582.
- Adegbesan S.I., Obasa S.O., Abdurraheem I. (2018). Growth performance, haematology and histopathology of African catfish (*Clarias gariepinus*) fed varying levels of *Aloe barbadensis* leaves. *J. Fish.*, 6: 553–562.
- Adeniyi O.V., Olaifa F.E., Emikpe B.O. (2022). Effects of dietary tamarind pulp extract on growth performance, nutrient digestibility, intestinal morphology, and resistance to *Aeromonas hydrophila* infection in Nile tilapia (*Oreochromis niloticus* L.). *J. Appl. Aquacult.*, 34: 43–63.
- Adeshina I., Tihamiyu L.O., Abubakar M.I., Ogundayomi O.O., Adesanmi O. (2021). Effects of dietary *Mitracarpus scaber* leaves extract on growth, physiological, antioxidant, and mucosal immune profiles of North African catfish, *Clarias gariepinus*, and resistance against *Edwardsiella tarda* infection. *Trop. Anim. Health Prod.*, 53: 541.
- Ahmad I., Irm M., Ahmed I., Haoran Y., Taj S., Bhat T.A., Khan S.K., Puswal S.M., Khalil H.S., Sopjani M., Peres H., Faggio C., Rather M.A., Amin A. (2024). Role of ginger in fish nutrition with special emphasis on growth, health, gut and liver morphology. *J. World Aquacult. Soc.*, 55: e13101.
- Ahmadifar E., Mohammadzadeh S., Kalhor N., Yousefi M., Moghadam M.S., Naraballoh W., Ahmadifar M., Hoseinifar S.H., Van Doan H. (2022). Cornelian cherry (*Cornus mas* L.) fruit extract improves growth performance, disease resistance, and serum immune- and antioxidant-related gene expression of common carp (*Cyprinus carpio*). *Aquaculture*, 558: 738372.
- Ahmadifar E., Pourmohammadi Fallah H., Yousefi M., Dawood M.A.O., Hoseinifar S.H., Adineh H., Yilmaz S., Paolucci M., Doan H.V. (2021). The gene regulatory roles of herbal extracts on the growth, immune system, and reproduction of fish. *Animals*, 11: 2167.

- Ali H., Ansari K.K. (2012). Comparison of haematological and biochemical indices in healthy and monogenean infected common carp, *Cyprinus carpio*. *Ann. Biol. Res.*, 3: 1843–1846.
- Amri A., Bouraoui Z., Balbuena-Pecino S., Capilla E., Gharred T., Haouas Z., Guerbej H., Hosni K., Navarro I., Jebali J. (2022). Dietary supplementation with *Aloe vera* induces hepatic steatosis and oxidative stress together with a disruption of cellular signaling pathways and lipid metabolism related genes' expression in gilthead sea bream (*Sparus aurata*). *Aquaculture*, 559: 738433.
- Ashour M., Mabrouk M.M., Ayoub H. F., El-Feky M.M.M.M., Zaki S.Z., Hoseinifar S.H., Rossi W., Van Doan H., El-Haroun E., Goda A.M.A.S. (2020). Effect of dietary seaweed extract supplementation on growth, feed utilization, hematological indices, and non-specific immunity of Nile tilapia, *Oreochromis niloticus* challenged with *Aeromonas hydrophila*. *J. Appl. Phycol.*, 32: 3467–3479.
- Bennetau-Pelissero C., Breton B., Bennetau B., Corraze G., LeMenn E., Davail-Cuisset B., Helou C., Kaushik S.J. (2001). Effect of genistein-enriched diets on the endocrine process of gametogenesis and on reproduction efficiency of the rainbow trout *Oncorhynchus mykiss*. *Gen. Comp. Endocrinol.*, 121: 173–187.
- Boudreau M.D., Beland F.A. (2006). An evaluation of the biological and toxicological properties of *Aloe barbadensis* (Miller), *Aloe vera*. *J. Environ. Sci. Health, Part C*, 24: 103–154.
- Budai M.M., Varga A., Milesz S., Tozsér J., Benko S. (2013). *Aloe vera* downregulates LPS-induced inflammatory cytokine production and expression of NLRP3 inflammasome in human macrophages. *Molecular Immunol.*, 56: 471–479.
- Chandan B.K., Saxena A.K., Shukla S., Sharma N., Gupta D.K., Suri K.A., Suri J., Bhadauria M., Singh B. (2007). Hepatoprotective potential of *Aloe barbadensis* Mill. against carbon tetrachloride induced hepatotoxicity. *J. Ethnopharmacol.*, 111: 560–566.
- Clarkson C., Maharaj V.J., Crouch N.R., Grace O.M., Pillay P., Matsabisa M.G., Bhagwandin N., Smith P.J., Folb P.I. (2004). *In vitro* antiparasmodial activity of medicinal plants native to or naturalised in South Africa. *J. Ethnopharmacol.*, 92: 177–191.
- Cock I.E. (2015). The genus aloe: Phytochemistry and therapeutic uses including treatments for gastrointestinal conditions and chronic inflammation. *Progress Drug Res.*, 70: 179–235.
- Dagne E., Bisrat D., Viljoen A., Van Wyk B.E. (2000). Chemistry of *Aloe* species. *Curr. Organic Chem.*, 4: 1055–1078.
- Devi G., Harikrishnan R., Paray B.A., Al-Sadoon M.K., Hoseinifar S.H., Balasundaram C. (2019). Effects of aloe-emodin on innate immunity, antioxidant and immune cytokines mechanisms in the head kidney leucocytes of *Labeo rohita* against *Aphanomyces invadans*. *Fish Shellfish Immunol.*, 87: 669–678.
- Dotta G., de Andrade J.I.A., Tavares Gonçalves E.L., Brum A., Mattos J.J., Maraschin M., Martins M.L. (2014). Leukocyte phagocytosis and lysozyme activity in Nile tilapia fed supplemented diet with natural extracts of propolis and *Aloe barbadensis*. *Fish Shellfish Immunol.*, 39: 280–284.
- El-Sayed M.A.B., Abdel-Aziz H.E.S., Abdel-Ghani M.H. (2012). Effects of phytoestrogens on sex reversal of Nile tilapia (*Oreochromis niloticus*) larvae fed diets treated with 17 α -methyltestosterone. *J. Aquaculture*, 360: 58–63.
- FAO (2022). The State of World Fisheries and Aquaculture. <https://openknowledge.fao.org/items/11a4abd8-4e09-4bef-9c12-900fb4605a02>
- FAO (2024). The State of World Fisheries and Aquaculture 2024. 10.4060/cd0683en
- Farahi A., Sudagar M.K.M., Soleimani I.M., Zorriehzahra S.M.J. (2012). Effect of dietary supplementation of *Melissa officinalis* and *Aloe vera* on haematological traits, lipid oxidation of carcass and performance in rainbow trout (*Oncorhynchus mykiss*). *Online J. Anim. Feed Resour.*, 1–5.
- Fehrmann-Cartes K., Vega M., Vera F., Enríquez R., Feijóo C.G., Al-lende M.L., Hernández A.J., Romero A. (2022). *Aloe vera* reduces gut inflammation induced by soybean meal in Atlantic salmon (*Salmo salar*). *Front. Animal Sci.*, 3.
- Francis G., Levavi-Sivan B., Avitan A., Becker K. (2002). Effects of long-term feeding of *Quillaja* saponins on sex ratio, muscle and serum cholesterol and LH levels in Nile tilapia (*Oreochromis niloticus* L.). *J. Comp. Biochem. Physiol. Part C*, 133: 593–603.
- Gaber H.G., Younis N.A., Saleh S.Y. (2025). Comparative physiological and immunological impacts of *Moringa oleifera* leaf and seed water supplements on African catfish (*Clarias gariepinus*): effects on disease resistance and health parameters. *BMC Vet. Res.*, 21: 320.
- Gabriel N.N., Qiang J., He J., Ma X.Y., Kpundeh M.D., Xu P. (2015). Dietary *Aloe vera* supplementation on growth performance, some haemato-biochemical parameters and disease resistance against *Streptococcus iniae* in tilapia (GIFT). *Fish Shellfish Immunol.*, 44: 504–514.
- Gabriel N.N., Qiang J., Ma X.Y., He J., Xu P., Omoregie E. (2017). Sex-reversal effect of dietary *Aloe vera* (Liliaceae) on genetically improved farmed Nile tilapia fry. *North Am. J. Aquacult.*, 79: 100–105.
- Gabriel N.N., Wilhelm M.R., Habte-Tsion H.M., Chimwamurombe P., Omoregie E. (2021). The effects of dietary garlic (*Allium sativum*) and *Aloe vera* crude extract mixtures supplementation on growth performance, feed utilization, hematological parameters, whole body composition, and survival at low pH in African catfish (*Clarias gariepinus*) juveniles. *Scient. African*, 11: e00671.
- Gabriel N.N., Wilhelm M.R., Habte Tsion H.M., Chimwamurombe P., Omoregie E., Iiping L.N., Shimooshili K. (2019). Effect of dietary *Aloe vera* polysaccharides supplementation on growth performance, feed utilization, hemato-biochemical parameters, and survival at low pH in African catfish (*Clarias gariepinus*) fingerlings. *Int. Aquatic Res.*, 11: 57–72.
- Ganzera M., Bedir E., Khan I.A. (2001). Determination of steroidal saponins in *Tribulus terrestris* by reversed-phase high-performance liquid chromatography and evaporative light scattering detection. *J. Pharm. Sci.*, 90: 1752–1758.
- Ghosal I., Chakraborty B.S. (2014). Effects of the aqueous leaf extract of *Basella alba* on sex reversal of Nile tilapia, *Oreochromis niloticus* L. *J. Pharm. Biol. Sci.*, 9: 162–164.
- Hamman J.H. (2008). Composition and applications of *Aloe vera* leaf gel. *Molecules*, 13: 1599–1616.
- Harlev E., Nevo E., Lansky E.P., Ofir R., Bishayee A. (2012). Anticancer potential of aloes: Antioxidant, antiproliferative, and immunostimulatory attributes. *Planta Medica*, 78: 843–852.
- Heidarieh M., Mirvaghefi A.R., Sepahi A., Sheikhzadeh N., Shahbazfar A.A., Akbari M. (2013). Effects of dietary *Aloe vera* on growth performance, skin and gastrointestinal morphology in rainbow trout (*Oncorhynchus mykiss*). *Turkish J. Fish. Aquac. Sci.*, 13: 367–373.
- Hoseinifar S.H., Khalili M., Rufchaei R., Raeisi M., Attar M., Cordero H., Esteban M.Á. (2015). Effects of date palm fruit extracts on skin mucosal immunity, immune related genes expression and growth performance of common carp (*Cyprinus carpio*) fry. *Fish Shellfish Immunol.*, 47: 706–711.
- Hu Y., Xu J., Hu Q. (2003). Evaluation of antioxidant potential of *Aloe vera* (Miller) extracts. *J. Agric. Food Chem.*, 51: 7788–7791.
- Jegade T. (2010). Control of reproduction in *Oreochromis niloticus* (Linnaeus 1758) using *Hibiscus rosa-sinensis* (Linn.) leaf meal as reproduction inhibitor. *J. Agric. Sci.*, 2: 149–159.
- Jegade T. (2011). Effects of *Aloe vera* (Liliaceae) on the gonad development in Nile tilapia (*Oreochromis niloticus*) (Linnaeus 1758). *Proc. 9th International Symposium on Tilapia Aquaculture*.
- Jenkins F., Smith J., Rajanna B., Shameem U., Umadevi K., Sandhya V., Madhavi R. (2003). Effect of sub-lethal concentrations of endosulfan on hematological and serum biochemical parameters in the carp *Cyprinus carpio*. *Bulletin Environ. Contamin. Toxicol.*, 70: 993–997.
- Kanama S.K., Viljoen A.M., Kamatou G.P.P., Chen W., Sandasi M., Adhami H.R., Van Wyk B.E. (2015). Simultaneous quantification of anthrones and chromones in *Aloe ferox* ("Cape aloes") using UHPLC-MS. *Phytochem. Lett.*, 13: 85–90.
- Kari Z.A., Wee W., Abdul Hamid N.K., Dawood M.A.O., Azwanida Z.N.N., Wei L.S. (2024). The roles of polysaccharides in tilapia farming: A review. *Aquacult. Fish.*, 9: 20–27.
- Khanal M., Lamichhane S., Bhattarai A., Kayastha B.L., Labh S.N. (2021). Extract of *Aloe vera* (*Aloe barbadensis* Miller) enhances the growth, protein contents, and gastrostatic index (GaSI) of common carp *Cyprinus carpio*. *J. Nutr. Metabol.*, 8029413.

- Kim K.H., Hwang Y.J., Bai S.C. (1999). Resistance to *Vibrio alginolyticus* in juvenile rockfish (*Sebastes schlegelii*) fed diets containing different doses of aloe. *Aquaculture*, 180: 13–21.
- Kumar K.H.N., Chandana E., Preethi S.D., Chauhan B.J. (2012). *In vitro* antimicrobial activity and phytochemical screening of *Aloe vera* Linn. *Int. J. Current Pharm. Res.*, 4: 45–47.
- Kumar R., Singh A.K., Gupta A., Bishayee A., Pandey A.K. (2019). Therapeutic potential of *Aloe vera* – A miracle gift of nature. *Phytomedicine*, 60: 152996.
- Langmead L., Makins R. J., Rampton D.S. (2004). Anti-inflammatory effects of *Aloe vera* gel in human colorectal mucosa *in vitro*. *Alim. Pharmacol. Therap.*, 19: 521–527.
- Lucini L., Pellizzoni M., Pellegrino R., Molinari G.P., Colla G. (2015). Phytochemical constituents and *in vitro* radical scavenging activity of different *Aloe* species. *Food Chem.*, 170: 501–507.
- Mahdavi M., Hajimoradloo A., Ghorbani R. (2013). Effect of *Aloe vera* extract on growth parameters of common carp (*Cyprinus carpio*). *World J. Med. Sci.*, 9: 55–60.
- Manaf S.R.H.M.D., Alimon A.R., Mustapha N.M., Hamdan R.H., Muniand K.G., Hamid N.H. (2016). The effects of *Vitex trifolia*, *Strobilanthes crispus* and *Aloe vera* herbal-mixed dietary supplementation on growth performance and disease resistance in red hybrid tilapia (*Oreochromis* sp.). *J. Aquacult. Res. Dev.*, 7: 425.
- Mehrabi Z., Firouzabakhsh F., Rahimi-Mianji G., Paknejad H. (2019). Immunostimulatory effect of *Aloe vera* (*Aloe barbadensis*) on non-specific immune response, immune gene expression, and experimental challenge with *Saprolegnia parasitica* in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 503: 330–338.
- Misawa E., Tanaka M., Nomaguchi K., Nabeshima K., Yamada M., Toida T., Iwatsuki K. (2012). Oral ingestion of *Aloe vera* phytochemicals alters hepatic gene expression profiles and ameliorates obesity-associated metabolic disorders in Zucker diabetic fatty rats. *J. Agric. Food Chem.*, 60: 2799–2806.
- Mohamed A.H., Eweedah N.M., El-Sharawy M.E., Radwan I.A., Gewaily M.S., Dawood M.A.O. (2025). High stocking density affected the growth performance, digestive enzyme activity, intestinal histology, and immune response of Nile tilapia (*Oreochromis niloticus*) fry grown in brackish water. *Ann. Anim. Sci.*, 25: 353–362.
- Moustafa E.M., Dawood M.A.O., Assar D.H., Omar A.A., Elbialy Z.I., Farrag F.A., Shukry M., Zayed M.M. (2020). Modulatory effects of fenugreek seeds powder on the histopathology, oxidative status, and immune related gene expression in Nile tilapia (*Oreochromis niloticus*) infected with *Aeromonas hydrophila*. *Aquaculture*, 515: 734589.
- Norouzi M., Farrokhriz M. (2014). Effect of *Aloe vera* on growth and sex hormone of the fish *Aequidens rivulatus*. *Biol. Forum Int. J.*, 6: 412–416.
- Olatunya O.S., Olatunya A.M., Anyabolu H.C., Adejuyigbe E.A., Oyelami O.A. (2012). Preliminary trial of aloe vera gel on HIV infection. *J. Alternat. Complem. Med.*, 18: 850–853.
- Omitoyin B.O., Ajani E.K., Sadiq H.O. (2013). Preliminary investigation of *Tribulus terrestris* (Linn, 1753) extracts as natural sex reversal agent in *Oreochromis niloticus* (Linn. 1758) larvae. *Int. J. Aquacul.*, 3: 133–137.
- Palanisamy P., Sasikala G., Mallikaraj D., Bhuvaneshwari N., Nataraajan G.M. (2011). Haematological changes of fresh water food fish, *Channa striata* on exposure to *Cleistanthus collinus* suicidal plant extract. *Res. J. Pharma. Biol. Chem. Sci.*, 2: 812–816.
- Palermo F.A., Cocci P., Angeletti M., Felici A., Polzonetti-Magni A.M., Mosconi G. (2013). Dietary *Aloe vera* components' effects on cholesterol lowering and estrogenic responses in juvenile goldfish, *Carassius auratus*. *Fish Physiol. Biochem.*, 39: 851–861.
- Quirós-Pozo R., Ventura-Castellano A., Ramírez-Bolaños S., Roo-Filgueira J., Robaina L. (2021). Evaluation of *Aloe vera* by-product against cereals in feeds for golden mullet (*Liza aurata*). *Aquacult. Rep.*, 20: 100659.
- Radha M.H., Laxmipriya N.P. (2015). Evaluation of biological properties and clinical effectiveness of *Aloe vera*: A systematic review. *J. Trad. Complem. Med.*, 5: 21–26.
- Reynolds T., Dweck A.C. (1999). *Aloe vera* leaf gel: A review update. *J. Ethnopharmacol.*, 68: 3–37.
- Saccù D., Bogoni P., Procida G. (2001). Aloe exudate: Characterization by reversed phase HPLC and headspace GC-MS. *J. Agric. Food Chem.*, 49: 4526–4530.
- Safari M.C.D., Mesbah M., Jangaran N.A. (2019). Effects of *Aloe vera* extract on growth and some hematological parameters of shirbot, *Tor grypupus* (Heckel, 1843). *Iranian J. Fish. Sci.*, 18: 445–456.
- Saini D.K., Saini M.R. (2011). Evaluation of radioprotective efficacy and possible mechanism of action of *Aloe* gel. *Environ. Toxicol. Pharmacol.*, 31: 427–435.
- Salama R.A., Mohamed M.M., Abd Elwahab M.B., Shakweer M.M. (2016). Assessment effect of *Aloe vera*, *Azadirachta indica* and *Moringa oleifera* aqueous extracts on carbon tetrachloride-induced hepatotoxicity in rats. *Int. J. Pharm. Pharmaceut. Sci.*, 8: 83–89.
- Sebastião F.A., Nomura D., Sakabe R., Pilarski F. (2011). Hematology and productive performance of Nile tilapia (*Oreochromis niloticus*) naturally infected with *Flavobacterium columnare*. *Brazilian J. Microbiol.*, 42: 282–289.
- Shalabi M., Khilo K., Zakaria M.M., Elsebaei M.G., Abdo W., Awadin W. (2015). Anticancer activity of *Aloe vera* and *Calligonum comosum* extracts separately on hepatocellular carcinoma cells. *Asian Pacific J. Trop. Biomed.*, 5: 375–381.
- Sitara U., Hassan N., Naseem J. (2011). Antifungal activity of *Aloe vera* gel against plant pathogenic fungi. *Pakistan J. Botany*, 43: 2231–2233.
- Soeparna I.I., Taofiqurohman A. (2024). Transversal policy between the protection of marine fishery resources and fisheries subsidies to address overfishing in Indonesia. *Marine Policy*, 163: 106112.
- Surjushe A., Vasani R., Saple D. (2008). *Aloe vera*: A short review. *Indian J. Dermatol.*, 53: 163–166.
- Syed R., Masood Z., Ul Hassan H., Khan W., Mushtaq S., Ali A., Gul Y., Jafari H., Habib A., Ishaq Ali Shah M., Gabol K., Gul H., Ullah A. (2022). Growth performance, haematological assessment and chemical composition of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fed different levels of *Aloe vera* extract as feed additives in a closed aquaculture system. *Saudi J. Biol. Sci.*, 29: 296–303.
- Trejo-Flores J.V., Luna-González A., Álvarez-Ruiz P., Escamilla-Montes R., Fierro-Coronado J.A., Peraza-Gómez V., Flores-Miranda M.d.C., Diarte-Plata G., Rubio-Castro A. (2018). Immune-related gene expression in *Penaues vannamei* fed *Aloe vera*. *Latin American J. Aqua. Res.*, 46: 9.
- Trejo-Flores J.V., Luna-González A., Álvarez-Ruiz P., Escamilla-Montes R., Peraza-Gómez V., Diarte-Plata G., Esparza-Leal H.M., Campa-Córdova Á.I., Gámez-Jiménez C., Rubio-Castro A. (2016). Protective effect of *Aloe vera* in *Litopenaeus vannamei* challenged with *Vibrio parahaemolyticus* and white spot syndrome virus. *Aquaculture*, 465: 60–64.
- Van Zyl R.L., Viljoen A.M. (2002). *In vitro* activity of *Aloe* extracts against *Plasmodium falciparum*. *South African J. Botany*, 68: 106–110.
- Vogler B.K., Ernst E. (1999). *Aloe vera*: a systematic review of its clinical effectiveness. *British J. Gen. Prac.*, 49: 823–828.
- Wei L.S., Hooi K.Y., Khoo M.I., Azra M.N., Wee, W. (2024). Effects of dietary kaffir lime, *Citrus hystrix* DC, leaf powder on the growth performance, digestive enzyme, hematology, antioxidant response, and disease resistance against *Edwardsiella tarda* infection in African catfish, *Clarias gariepinus*. *Aqua. Int.*, 32: 7469–7485.
- Yousaf Z., Hussain S.M., Ali S., Kucharczyk D., Nowosad J., Turkowski K., Paray B.A., Naeem A. (2025). *Aloe vera*: A promising natural herbal supplement for enhancing growth, physiology, antioxidant activity and immunity in *Catla catla*. *Aquacult. Rep.*, 41: 102662.
- Zanuzzo F.S., Biller-Takahashi J.D., Urbinati E.C. (2012). Effect of *Aloe vera* extract on the improvement of the respiratory activity of leukocytes of matrinxã during the transport stress. *Revista Brasileira de Zootecnia*, 41: 2299–2302.
- Zanuzzo F.S., Sabioni R.E., Montoya L.N.F., Favero G., Urbinati E.C. (2017). *Aloe vera* enhances the innate immune response of pacu (*Piaractus mesopotamicus*) after transport stress and combined heat killed *Aeromonas hydrophila* infection. *Fish Shellfish Immunol.*, 65: 198–205.

- Zanuzzo F.S., Urbinati E.C., Rise M.L., Hall J.R., Nash G.W., Gamperl A.K. (2015). *Aeromonas salmonicida* induced immune gene expression in *Aloe vera* fed steelhead trout, *Oncorhynchus mykiss* (Walbaum). *Aquaculture*, 435: 1–9.
- Zhang L., Khan I.A., Foran C.M. (2002). Characterization of the estrogenic response to genistein in Japanese medaka (*Oryzias latipes*). *Comp. Biochem. Physiol. Part C*, 132: 203–211.
- Zhang Z., Mei N., Chen S., Guo L., Guo X. (2016). Chapter 62 – Assessment of genotoxic effects of selected herbal dietary supplements. In *Nutraceuticals*, Gupta R.C. (ed.). Academic Press, pp. 883–892.

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