Fisheries Journal, 14 (2), 657-672 (2024)
http://doi.org/10.29303/jp.v14i2.816

POTENTIAL USE OF FENNEL (FOENICULUM VULGARE) AS FISH IMMUNOSTIMULANT: ARTICLE REVIEW

Potensi Tanaman Adas (*Foeniculum Vulgare*) sebagai Imunostimulan pada Ikan: Artikel Reviu

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(Received April 23th 2024; Accepted June 4th 2024)

ABSTRACT

The development of aquaculture systems from traditional to intensive has the potential to increase environmental pollution and other problems such as the emergence of disease. One of the fish health management that can be applied to control disease attacks is by taking action to prevent fish disease by administering immunostimulants. Sources of natural immunostimulants can come from plants. Ingredients in natural plants can be immunostimulants for fish, one of which is the fennel (Foeniculum vulgare). Fennel is generally known as a raw material for making bitter herbal medicine which has many benefits for the human body because of its content. Therefore, the aim of this literature review research is to provide a clear picture of the potential of the fennel as an immunostimulant in fish. The method used is a systematic literature review with stages of taking data from the library, then continuing with reading, taking notes and processing research material from articles resulting from research on the potential of fennel as an immunostimulant in fish. The results showed that fennel contain various bioactive compounds with the largest content being flavonoids which can be used as immunostimulants in aquaculture. Fennel have great potential for further research development in an effort to make this material an immunostimulant in large-scale aquaculture.

Key words: Fennel, Aquaculture, Immunostimulant

ABSTRAK

Perkembangan sistem budidaya ikan dari tradisional ke intensif memiliki potensi terhadap peningkatan pencemaran lingkungan dan permasalahan lain seperti munculnya penyakit. Manajemen kesehatan ikan yang dapat diterapkan dalam mengendalikan serangan penyakit salah satunya dengan melakukan tindakan pencegahan penyakit ikan melalui pemberian imunostimulan. Sumber imunostimulan alami dapat berasal dari tanaman. Kandungan dalam tanaman alami dapat menjadi imunostimulan bagi ikan, salah satunya adalah tanaman adas (*Foeniculum vulgare*). Adas umumnya diketahui sebagai bahan baku pembuatan jamu pahitan yang memiliki banyak manfaat untuk tubuh manusia karena kandungannya. Oleh karena itu tujuan dari penelitian studi literatur (*literature review*) ini adalah agar dapat memberikan

gambaran yang jelas mengenai potensi dari tanaman adas sebagai imunostimulan pada ikan. Metode yang digunakan yaitu *systematic literature review* dengan tahapan mengambil data di pustaka, lalu dilanjutkan dengan membaca, mencatat, dan mengolah bahan penelitian dari artikel hasil penelitian tentang potensi tanaman adas sebagai imunostimulan pada ikan. Hasilnya diketahui bahwa tanaman adas memiliki berbagai kandungan senyawa bioaktif dengan kandungan terbesarnya adalah flavonoid yang dapat digunakan sebagai imunostimulan pada budidaya ikan. Tanaman adas sangat berpotensi untuk dilakukan pengembangan penelitian lebih lanjut dalam upaya untuk menjadikan bahan tersebut sebagai imunostimulan pada budidaya ikan dengan skala besar.
Kata Kunci: Adas, Budidaya Ikan, Imunostimulan.

INTRODUCTION

Aquaculture or fisheries cultivation is one of the subsectors that contributes to the value of fisheries and marine production globally. This subsector also plays a role in providing food and protein sources globally which continue to increase (Adharani *et al.,* 2024; Muahiddah & Affandi, 2023). Aquaculture itself is a fishing activity that produces aquatic biota (organisms) in a controlled environment with the aim of making a profit (Affandi & Setyono, 2023). This has resulted in the emergence of great enthusiasm in the community to develop fish farming businesses. Of course, this production growth refers to increasing market demand (Netrawati *et al.,* 2021).

The development of fish farming systems from traditional to intensive has the potential to increase environmental pollution and other problems such as the emergence of disease (Affandi *et al.,* 2023). Over the past few decades, the world's aquaculture sector has faced disease outbreaks caused by viruses, bacteria, fungi and parasites, resulting in enormous economic losses both in terms of quantity and quality of production (Muahiddah *et al.,* 2023; Sookying *et al.,* 2023). Fish are susceptible to disease because fish are aquatic animals that are always in contact with the water environment so they are very easy to become infected by pathogens in the water (Rahmadani *et al.,* 2023). Fish health management that can be applied to control disease attacks is by taking preventive measures for fish diseases. One technology that has evolved in response to these problems is immunostimulants. Immunostimulants are an important strategy and an appropriate alternative to antibiotics to prevent and control disease in fish (Affandi & Diamahesa, 2023; Yeganeh *et al.,* 2024).

Immunostimulants are described as chemicals, drugs, or actions that increase immune responses or defense mechanisms so that animals are more resistant to pathogens (Mbokane & Moyo, 2024). Sources of immunostimulants for aquaculture can be produced chemically or biologically. These immunostimulant ingredients can be grouped according to their function and source, consisting of various groups such as bacteria and bacterial products, yeast, complex carbohydrates, animal extracts and synthetic drugs (Affandi *et al.,* 2019). Herbal plants that have bioactive components can also act as immunostimulants and influence several pathways related to the immune system (Ahmadifar *et al.,* 2021).

Active secondary metabolite compounds contained in herbal plants have immunomodulatory effects. These compounds are flavonoids, phenols, alkaloids, terpenoids, polysaccharides, glycosides, saponins, tannins and sterols (Sianipar, 2021). The use of herbal plants as a natural and risk-free substitute for antibiotics and immunostimulants in aquaculture has proven to be beneficial. This is because herbal plants are easy to prepare, cheap, and have little negative impact on animals and the environment, so they are gaining increasing attention throughout the world. Herbal plants mainly function as immune boosters, growth promoters, antibacterial, antifungal and antiviral agents against the host's immune system (Dev *et al.,* 2024). Providing immunostimulants from natural ingredients to fish is expected to overcome

the problem of disease in fish by increasing fish immunity and being environmentally friendly. (Muahiddah *et al.,* 2022).

Salah satu alternatif sumber imunostimulan dari tanaman yang dapat digunakan untuk improving the fish's body's defense system is fennel (*Foeniculum vulgare*). Fennel is generally known as a raw material for making bitter herbal medicine which has many benefits for the human body because of its content. Apart from fennel, the raw materials for bitter herbal medicine can be made from ingredients such as bitter, brotowali, lempuyang, meniran leaves, lemongrass, galangal, temu ireng, sea widoro, and white widoro. Therefore, it is necessary to carry out this literature study (literature review) in order to provide a clear picture of the potential of the fennel plant as an immunostimulant to aquaculture stakeholders, especially researchers who will conduct further research related to the potential of this material..

METHODS

Place and Time

This literature review research was conducted from March to April 2024 in Mataram.

Tools and Materials

Tools and materials used in this literature study research (literature review) include laptops, laptop chargers, mice, scientific articles in soft file form..

Procedurs

Access to relevant information for the preparation of this article was obtained from Google Scholar, Proquest, and Elsevier. The articles used were 68 journals, 1 proceeding, and 2 books. The method used in this article is a systematic literature review. Systematic literature study is a series of activities relating to methods of collecting library data, reading and taking notes, and managing research data objectively, systematically, analytically and critically about the potential of fennel plants as an immunostimulant in fish. This article with a literature study has the same preparation as other articles, but the source and method for collecting data is by taking data from the library, then continuing with reading, taking notes and processing research material from articles resulting from research on the potential of fennel as an immunostimulant in fish. This literature study analyzes it in detail and in depth in order to obtain objective results regarding the potential of fennel plants as an immunostimulant in fish. The data collected and analyzed is secondary data in the form of research results such as books, journals and relevant articles (Affandi & Diamahesa, 2023).

Data Analysis

The data analysis technique in this article uses content analysis techniques. Data analysis begins by analyzing research results from the most relevant, relevant, and quite relevant. Researchers then read the abstract of each study to provide an assessment of whether the problems discussed are in accordance with the problems to be solved in this research. Next, note down the important and relevant parts of the research problem and end with drawing conclusions (Affandi & Setyono, 2023, 2024).

RESULT

Active Compound Content in Fennel Plants

In general, all parts of herbal plants such as leaves, stems, roots, fruit, buds and flowers are rich sources of natural bioactive compounds such as carotenoids, phenolic acids, flavonoids, coumarins, alkaloids, polyacetylenes, tannins, saponins and terpenoids. This bioactive compound provides a myriad of biological effects, including antioxidant,

antibacterial, antiviral, antifungal, anti-parasitic, anti-inflammatory, anti-allergic, and others (Chandrasekara & Shahidi, 2018). One example of a herbal plant that is rich in active compounds is the fennel plant (Foeniculum vulgare). Based on the literature study that has been carried out, in detail the content of active compounds in fennel plants is summarized in Table 1.

Tab*le* 1. Active Compound Content in Fennel Plants

Compounds in Fennel Plants	**Reference**
Lignans, phenolic acids, flavonoids, phenylpropanoids, and tannins	(Noreen *et al.,* 2024)
α-Pinen, kampen, sabinen, β-Pinen, myrsen, felandren, p-Cymene, sylvestrene, 1,8-Cineole, cis-Ocimene, trans-Ocimene, γ-Terpinen, fenkon, Allo-Ocimene, camphor, Terpinen- 4-ol, methyl chavicol, octanol acetate, endo-Fenchyl acetate, exo-Fenchyl acetate, cis-p-Anetol, p-Anisaldehyde, trans-Anetol, Germakren D	(Salama & Al-Maharik, 2024)
Phenolics (especially vanillic acid) and flavonoids (especially kaempferol)	(Barakat *et al.,* 2022, 2023)
Flavonoids, phenolics and phenolic glycosides	(Jadid *et al.,* 2023)
Flavonoids, glycosides, D-arabitol, octadecenoic acid, methyl pyrrolidine, guanosine, xanthine riboside, palmitic acid, oleamide, trimesic acid, linoleic acid, diterpenes, sesquiterpenes, cannabinoids, pheromones, lignin, essential oils, sterols, fumaric acid, and pinacol	(Mehra *et al.,* 2023)
Flavonoids, glycosides, tannins, coumarins, hydroxycinnamic acids, phenolic acids, petrosylic acid, oleic acid, linoleic acid, palmitic acid, terpenes (trans-anetol and limonene)	(Noreen *et al.,* 2023)
α-Pinen, kampen, sabinen, β-Pinen, myrsen, p-Cymene, limonene, cineol, γ-Terpinen, camphor, trans-Anetol, estragol, fenkon, borneol, fenchyl acetate, apiol, thymol, cis-Ocimene, linalool, α-Felandren, karyophyllene, Germakren D, and spathulenol	(Sabzi-Nojadeh *et al.,* 2023)
Isoflavon	(Safaei *et al.,* 2023)
Phenolic acids (neochlorogenic acid and ferulic acid), flavonoids, kaempferol, isorhamnetin, and quercetin glucuronide	(Crescenzi *et al.,* 2022)
Essential oils, estragol, limonene, anetol, fenkon, felandren, anisic acid, camphen, palmitic acid, oleic acid, linoleic acid, pinin, petroselenic acid, flavonoids, cisocimene, para-cymene, gamma-terpinen, alpha-pinene, sabinen, beta-myrcene, safrole, beta-pinene, and camphor	(Khan *et al.,* 2022)
Aromatic compounds ((E)-anetol and methyl chavicol) and monoterpenes	(Milenković *et al.,* 2022)
Monoterpene hydrocarbons (α-pinene, β-pinene, myrsen, 3-carene, and γ-terpinene), phenylpropanoids (estragol and (E)-anetol), and oxygenated monoterpenes (fencon and trans-sabinol)	(Napoli *et al.,* 2022)
Polyphenols, estragol, anethol, and oleic acid	(Shahsavari *et al.,* 2022)
Phenolic compounds, flavonoids, tannins, saponins, steroids, glycosides and terpenoids	(Suleiman & Helal, 2022)
Flavonoids, tannins, saponins, steroids, terpenoids, alkaloids, glycosides, 1,4 cyclohexadiene, and metronidazole	(Abubakar *et al.,* 2021)

Compounds in Fennel Plants	Reference
Phenolic acids and flavonoids	(Anka *et al.,* 2020; Castaldo *et al.,* 2021)
Hydroxycinnamic acids, flavonoid glycosides, flavonoid aglycones, phenolic acids, iridoids, lignans, phenylpropanoids, glycolipids and phospholipids	(Crescenzi *et al.,* 2021)
Eucalyptol, terpinen, anisole, camphor, anetol, anisaldehyde, apiol, a-pinene, estragol, fenkon, and limonene	(Ibrahim *et al.,* 2021)
Phenolic compounds and essential oils	(Karakus *et al.,* 2021)
Monoterpenes, phenylpropanoids, trans-anetol, estragol, fencon, and limonene	(Liu *et al.,* 2021)
Flavonoids, glycosides, phenols, trans-anetol, estragol, fenkon, kaempferol, quercetin, and rosmarinic acid	(Mehra *et al.,* 2021)
Phenols, flavonoids, essential oils, estragol, α-pinene, β-pinene, limonene, trans-anetol, and anisaldehyde	(Nada *et al.,* 2022)
Flavonoids (isoquercetin and isorhamnetin) and phenolic acids (gallic acid, chlorogenic acid, syringic acid, ferulic acid, caffeic acid and cinnamic acid)	(Wasli *et al.,* 2021)
Trans-anetol, butanone, fencon, limonene, and estragol	(Barrahi *et al.,* 2020)
Estragol, limonene, fencon, and α-pinene	(Belabdelli *et al.,* 2020)
Estragol, anetol, limonene, and fenkon	(Hajalizadeh *et al.,* 2020; Tabibazar *et al.,* 2020)
Terpenes, coumarins, flavonoids, sterols, estragol, anetol, limonene, fencon, and α-felandren	(Marrelli *et al.,* 2020)
Anetol and estragol	(Masoudzadeh *et al.,* 2020)
Chromones (flavonol glycosides and hydroxycinnamoyl quinic acid), phenolic compounds, and aromatic compounds	(Safaei-Cherehh *et al.,* 2020)

The Role of Active Compounds in Fennel Plants

Researchers have intensified efforts to exploit natural products such as medicinal plants in the development of alternative food supplements that improve the growth, health and immune system performance of farmed fish. Medicinal plants promise to be a source of immunostimulants because they have properties as appetite stimulators, growth promoters, antiparasitic, antimicrobial, antioxidant and immunostimulant agents in in-vitro and in-vivo applications (Syahidah *et al.,* 2015). In this literature study, we summarize the use of fennel plants in fish farming. The role of the active compounds contained in the fennel plant can be seen in Table 2.

Table 2. Active Compound Content in Fennel Plants

Compounds in Fennel Plants	Reference
Antioxidant, anticancer, antiplatelet, hepatoprotective, antihyperlipidemic, chemopreventive, immunomodulatory, neuroprotective, antimicrobial and antithrombotic	(Noreen *et al.,* 2024)

Compounds in Fennel Plants	Reference
Anti-inflammatory, chemopreventive, and immunotherapy	(Salama & Al-Maharik, 2024)
Hepatoprotective, antioxidant, anti-inflammatory, antibacterial, antifungal, analgesic, antitumor and antimicrobial	(Barakat *et al.,* 2022, 2023)
Antiviral, antimicrobial, antioxidant, anti-inflammatory, gastroprotective, antimutagenic, anticancer, hepatoprotective, antifungal and antibacterial	(Jadid *et al.,* 2023)
Antioxidant, anti-inflammatory and antimicrobial	(Crescenzi *et al.,* 2022; Karakus *et al.,* 2021; Mehra *et al.,* 2023)
Antibacterial, antimicrobial, anticancer, antihyperlipidemic, antioxidant, anti-inflammatory, analgesic, antiulcer, antifungal, gastroprotective and hepatoprotective	(Noreen *et al.,* 2023)
Anti-inflammatory, analgesic and antioxidant	(Sabzi-Nojadeh *et al.,* 2023)
Antioxidant, antifungal, antibacterial, antitumor, anti-inflammatory and antioxidant	(Safaei *et al.,* 2023)
Antioksidan, antimikroba, hepatoprotektif, antibacterial, antifungal, antiviral, anti-inflammatory, and immunostimulant	(Khan *et al.,* 2022)
Antioxidant, antimicrobial, antipyretic, antibacterial, antifungal, anticancer, gastroprotective and hepatoprotective	(Milenković *et al.,* 2022)
Antimicrobial, antibiofilm, antioxidant, antibacterial, antifungal, antiviral, antimycobacterial and anticandidal	(Napoli *et al.,* 2022)
Antioxidant, antimicrobial and antifibrogenic	(Shahsavari *et al.,* 2022)
Antimicrobial, antitumor, antioxidant, antiviral, anticancer, antiplatelet, antibacterial, antifungal, anti-inflammatory and hepatoprotective	(Suleiman & Helal, 2022)
Antioxidant, antifungal, antibacterial, anti-inflammatory, antimutagenic, anticarcinogenic, hepatoprotective, antipyretic, antitumor and anticancer	(Abubakar *et al.,* 2021)
Antioxidant, anti-inflammatory and anticancer	(Castaldo *et al.,* 2021)
Anti-inflammatory, antioxidant, immunomodulatory, antitumor and anticancer	(Crescenzi *et al.,* 2021)
Analgesic, antipyretic, antioxidant, antimicrobial, hepatoprotective and immunostimulant	(Liu *et al.,* 2021)
Antimicrobial, antioxidant, anticancer, anti-inflammatory, antibacterial, antifungal, anticarcinogenic, antimutagenic, antinociceptive, antiplatelet and immunostimulant	(Mehra *et al.,* 2021)
Hepatoprotective, antioxidant, anticancer, chemopreventive, antibacterial, antistress, and antiviral	(Nada *et al.,* 2022)
Antioxidant	(Wasli *et al.,* 2021)
Antioxidant, antitumor, chemopreventive, cytoprotective, hepatoprotective, antiplatelet, antibacterial, antimicrobial, antifungal, antimycobacterial, anticandidal and anti-inflammatory	(Anka *et al.,* 2020)
Antibacterial and antimicrobial	(Barrahi *et al.,* 2020)

Compounds in Fennel Plants	Reference
Antioxidant, antifungal, antibacterial, analgesic, anti-inflammatory, hepatoprotective, neuroprotective, and antimicrobial	(Belabdelli *et al.,* 2020)
Antioxidant and antimicrobial	(Hajalizadeh *et al.,* 2020)
Analgesic, anti-inflammatory, antimicrobial, antiparasitic, anticancer, hepatoprotective and nephroprotective	(Marrelli *et al.,* 2020)
Antioxidant, antimicrobial and hepatoprotective	(Masoudzadeh *et al.,* 2020)
Antibacterial, hepatoprotective, antioxidant, antifungal and antimicrobial	(Safaei-Cherehh *et al.,* 2020)

Use of Fennel Plants in Fish Farming

One of the aquaculture research that is widely discussed is to increase fish immunity by using immunostimulants. Elumalai *et al.,* (2020) stated that among the immunostimulants used in aquaculture, herbs are quite promising because of their tendency to improve growth performance, fish immunity, their antimicrobial properties, as well as being a good alternative to chemical treatment and antibiotics. Medicinal plants are environmentally friendly, cost effective and have minimal side effects. Therefore, this literature study was carried out to determine the prospects of the medicinal plant fennel as an immune system enhancer in farmed fish. So far, 6 recent publications (last 5 years) and 6 previous publications (more than the last 5 years) have been found regarding the use of the medicinal plant fennel in fish farming which can be seen in Table 3.

Table 3. Use of Fennel Plants in Fish Farming

Fish	Method	Result	Resistance to Disease	Reference
Goldfish (*Cyprinus carpio*)	Oral	The best dose is the addition of fennel extract to feed as much as 200 mg/kg which increases: 1. Catalase (CAT) 2. Superoxide dismutase (SOD) 3. Glutathione peroxidase (GPx)	-	(Motlagh *et al.,* 2023)
Black sea salmon (*Salmo labrax*)	Oral	The best dose is the addition of fennel extract to the feed as much as 50 mg/kg by increasing: 1. Survival rate (SR)	-	(Özel *et al.,* 2023)
Guppy fish (*Poecilia reticulata*)	Oral	The best dose is the addition of fennel extract to the feed as much as 100 µl/g by increasing: 1. Survival rate (SR)	-	(Zareen *et al.,* 2023)
Largemouth snapper	Oral	The best dose is the addition of fennel extract to the feed	-	(He *et al.,* 2022)

Fish	Method	Result	Resistance to Disease	Reference
(*Micropterus salmoides*)		as much as 0.05% by increasing: 1. Survival rate (SR) 2. Superoksida dismutase (SOD) 3. Catalase (CAT)		
Parrot fish (*Oreochromis niloticus*)	Oral	The best dose is the addition of fennel extract to the feed as much as 2 ml/kg by increasing: 1. Alanine aminotransferase (ALT) 2. Aspartate aminotransferase (AST) 3. Alkaline phosphatase (ALP) 4. Tumor necrosis factor-alpha (TNF-α) 5. Interleukins-1β (IL-1β) 6. Superoxide dismutase (SOD) 7. Catalase (CAT) 8. Glutathione peroxidase (GPx)	Glyphosate Pesticide	(Abdelmagid *et al.*, 2021)
Goldfish (*Cyprinus carpio*)	Oral	The best dose is the addition of fennel extract to the feed as much as 3 ml/100 g by increasing: 1. Hemoglobin (Hb) 2. Nitroblue tetrazolium (NBT) 3. Total immunoglobulin (TI) 4. Catalase (CAT) 5. Glutathione peroxidase (GPx)	Chlorpyrifos pesticide	(Pala *et al.*, 2021)
African catfish (*Clarias gariepinus*)	Oral	The best dose is the addition of fennel extract to the feed as much as 0.5% by increasing: 1. Limfosit 2. Eosinofil 3. Basofil	*Vibrio vulnificus*	(Emeish *et al.*, 2018)
Caspian whitefish (*Rutilus kutum*)	Oral	The best dose is the addition of fennel extract to the feed as much as 100 mg/kg by increasing: 1. Triglycerides	-	(Mahdavi *et al.*, 2017)

Fish	Method	Result	Resistance to Disease	Reference
		2. Glucosa 3. Cortisol		
Parrot fish (*Oreochromis niloticus*)	Oral	The best dose is the addition of fennel extract to the feed as much as 1 ml/kg by increasing: 1. Alanine aminotransferase (ALT) 2. Catalase (CAT)	Aflatoksin B_1	(Rahman *et al.,* 2017)
Parrot fish (*Oreochromis niloticus*)	Oral	The best dose is the addition of fennel extract to the feed as much as 1 ml/kg by increasing: 1. Survival rate (SR) 2. Hematokrit 3. Hemoglobin (Hb) 4. Red blood cells	-	(Hassaan & Soltan, 2016)
Zebra cichlid fish (*Cichlasoma nigrofasciatum*)	Oral	The best dose is the addition of fennel extract to the feed as much as 150 mg/kg by increasing: 1. Survival rate (SR)	-	(Sotoudeh & Yeganeh, 2016)
Ikan putih Kaspia (*Rutilus frisii kutum*)	Oral	The best dose is the addition of fennel extract to the feed as much as 400 mg/kg by increasing: 1. White blood cell 2. Red blood cell 3. Hematokrit 4. Hemoglobin (Hb)	-	(Mahdavi *et al.,* 2014)

DISCUSSION

Fennel (*Foeniculum vulgare*) is a perennial herb native to Southern Europe and the Mediterranean region that grows upright. This plant has yellow flowers in complex umbels and grows to a height of about 1.5 m. Various forms of fennel plants and their seeds are fennel seed stems, raw fennel fruit, ripe fennel fruit, harvested fennel seeds, fennel powder, and fennel extract (Khan *et al.,* 2022). Fennel in French is called fenouli, in Spanish it is hinojo, in Italian it is called finnochio, in Russian it is fynkhel, in Hindi it is saunf, in German it is fenchel, and in Arabic it is called shamar. This plant has a classification, namely Kingdom: Plantae; Subkingdom: Virideplantae; Superdivision: Embryophyta; Division: Tracheophyta; Subdivision: Spermatophytina; Class: Magnoliopsida; Order: Apiaels; Family: Apiaceae; Genus: Foeniculum; Species: *Foeniculum vulgare*. Fennel was once endemic to Mediterranean countries and Europe but is now widespread in tropical and temperate regions and is therefore widely cultivated. Fennel is a famous and very economical medicinal plant in China. Fennel grows wild through naturalization and cultivation in the eastern, western and northern hemispheres, especially in Asia, Europe and North America (Mehra *et al.,* 2021).

Based on the results of the literature study in Table 1, it is known that fennel plants contain various bioactive compounds, but the compounds that are always mentioned in all the literature are flavonoids. According to Ponomarev *et al.,* (2021), flavonoids are low molecular weight substances that are often found in vascular plants. These compounds are found in all parts of plants, especially in photosynthetic cells and have a wide spectrum of action as antioxidants, enzymatic inhibitors, precursors of toxic substances, protection against ultraviolet radiation, and also participate in energy conversion. Other functions include providing color, taste and texture to food. W. Wang *et al.,* (2016) added that various complex components are found in medicinal plants, one of which is flavonoids which can play a series of important roles in nutrition, antiviral and bactericidal activity, as well as fish immune defense. Herbal extracts show potential for application as immunostimulants in fish farming mainly because they are easy to obtain and act against a broad spectrum of pathogens.

Based on the results of the literature study in Table 2, the content of bioactive compounds in fennel plants is known to have various roles such as antibacterial, antiviral, antifungal, antiparasitic, and others. Based on these results, it can be said that fennel plants can be used as an immunostimulant ingredient in fish farming. According to Almarri *et al.,* (2023), one of the compounds that can help increase fish immunity is flavonoids. To fight various diseases, these compounds play an important role in controlling a number of physiological and biochemical factors, including enzyme activity, cell differentiation, signal transduction mechanisms, and cellular redox potential. Flavonoids also have anti-inflammatory effects because they play a role in inhibiting the activity of the cyclooxygenase enzyme which is involved in the inflammatory process. Q. Wang *et al.,* (2020) also added that flavonoids have been proven to perform various functions in the aquaculture industry such as increasing growth, antimicrobial effects, and stimulating fish immunity. Immunity itself according to Fauziah *et al.,* (2023) is often associated with the organism's ability to respond to attacks from outside the body, whether pathogens or other foreign compounds (antigens) that cause a response in the body.

Based on the results of the literature study in Table 3, there are 12 publications regarding research on the use of the medicinal plant fennel in fish farming. The test fish used in the research as a result of literature studies were carp, black sea salmon, guppy, largemouth snapper, tilapia, African catfish, Caspian whitefish, and zebra cichlid. The flavonoid content in fennel plants can function as an immunomodulator to influence non-specific immune responses and increase the body's resistance to pathogens through its ability to increase phagocytosis. Active compounds such as flavonoids can play a role in stimulating leukocytes as a non-specific defense so that they function as immunostimulants (Nurkartika *et al.,* 2023). Flavonoids can directly activate Th1 and Th2 effector cells to produce cytokines without any immune response to intracellular or extracellular antigens. Cytokines produced by Th1 and Th2 cells can also increase macrophage activity. Thus, flavonoid compounds can increase the ability of phagocytosis quickly to destroy intracellular antigens and microorganisms and increase defense against extracellular antigens. The presence of these compounds in the fennel plant makes it effective as an immunostimulant (Maryani *et al.,* 2020). From the results of the literature study that has been carried out, it can be said that further research needs to be carried out on other fish species to determine the effectiveness of fennel as an immunostimulant in fish so that later it can be used on a larger scale and can be mass produced.

CONCLUSION

The fennel plant (*Foeniculum vulgare*) has great potential for further research development in an effort to make this material an immunostimulant in fish farming at the right dose and can then be applied on a field scale.

ACKNOWLEDGEMENT

The author would like to thank the Aquaculture Study Program, Department of Fisheries and Marine Sciences, Faculty of Agriculture, Mataram University for providing support in the form of facilities and infrastructure in writing this scientific article.

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