Chapter 08

Balancing Act: Essential Oils as Cost-Effective and Eco-Friendly Disease Control in Aquatic Environments

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ABSTRACT

Aquatic environments, critical to both ecological balance and human industry, face significant threats from pathogenic microorganisms. Conventional chemical treatments, though effective, often lead to environmental degradation and high costs, prompting the need for sustainable alternatives. This study explores the potential of essential oils as cost-effective and eco-friendly agents for disease control in aquatic systems. Essential oils, derived from various plants, exhibit potent antimicrobial properties against a broad spectrum of pathogens. Our research focuses on evaluating the efficacy of essential oils such as tea tree, eucalyptus and thyme in controlling common aquatic pathogens, including Vibrio spp., Aeromonas spp., and Pseudomonas spp.

KEYWORDS			
Conventional, Sustainable, Degradation, Microorganisms, Pathogens	Received: 13-June-2024 Revised: 18-July-2024 Accepted: 10-Aug-2024		A Publication of Unique Scientific Publishers

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INTRODUCTION

The farming of aquatic plants and animals, at a 4.5% annual growth rate, has established aquaculture as a rapidly expanding industry and its yearly value is put at $243.26 billion. Aquaculture is important in meeting the high protein requirements of the world's increasing population, contributing to 50% of the total fish used globally and at the same time is a source of employment and income. Nevertheless, super-intensive techniques have led to the environment being destroyed in aquatic ecosystems because they use much more stock densities and provide more artificial feed (Dawood et al., 2021). Medicinal plants are used in more quantities for aquaculture due to their biodegradability, accessibility, and lack of residues in animal tissues. Essential oils are secondary metabolites of plants that have bioactive qualities that make them excellent phytotherapeutic agents for sustainable aquaculture (Magouz et al., 2021).

Both specialized and generalist parasites inherently live in fish hosts; certain parasites can easily adapt to aquaculture environments and present health problems when infection levels are high. Furthermore, the problem becomes more complex when these parasites find their way into wild stocks after first being reared in captivity as in aquaculture (Buchmann 2022). Since parasitic infections affect the entire population in addition to the individual, the community as a whole must be the target of the response, not the individual. These issues have prompted research into using herbal plants as a substitute for treating parasite illnesses in fish kept in aquaculture. Fish aquaculture may benefit from herbal medicine as an alternative, since it may be less expensive and more efficient than chemotherapy (Soares et al., 2017).

Essential oils are any volatile oil or oils with aromatic elements that can alter a plant's flavor, odor, or scent. The phrase "Essential Oil" was first used by Swiss medical reformer Paracelsus von Hohenheim. It comes from the Latin "Quinta essentia," which refers to a potent medicinal ingredient. These oils are mostly found in glandular hairs or secretory cavities inside plant cells, as fluid droplets at different plant parts like roots, stems, barks, leaves as well as fruits or flowers. They are made up of terpenes comprising monoterpenes, diterpenes, and sesquiterpenes as well as terpenoids but also oxygenated derivatives such as phenolic compounds alcohols, ketones, esters, aldehydes, ethers, or oxides. Moreover, they have compounds belonging to phenylpropanoid and phenolic groups of chemicals, whose biosynthesis starts with the acetate-mevalonic and the shikimic acid pathways, respectively (Sil et al., 2020).

To fight infections and boost immune responses, antibiotics are widely used in aquaculture. However, this approach carries several concerns, such as the emergence of drug-resistant microbes and environmental dangers. This procedure may result in microbial population imbalances, weakened host immunity, and bacterial resistance, all of which could harm aquatic animals' general health. In fish farming, the use of chemicals like formalin, sodium chloride, and copper sulfate could lead to the selection of resistant organisms as well as the accumulation of dangerous residues that put the environment and human health at risk. Therefore, there is a need for sustainable alternatives in aquaculture given the high cost of conventional anthelmintic medicines. It is well-recognized that medicinal herbs are a good, sufficient, and environmentally safe substitute for antibiotics.

Biological and chemical methods to control diseases, for example, probiotics or prebiotics; also, medicinal plants are used. Keeping certain disease-causing agents out of a specific system is made possible by aquaculture biosecurity measures. It's common for Aquafeed to include a variety of supplements such as prebiotics, probiotics, or herbal ingredients aimed at promoting animal health and well-being. Incorporating medicinal plants and their extracts into Aquafeed serves multiple physiological purposes due to the active metabolites they contain acting as functional components (Dawood et al., 2022).

This chapter will delve into essential oils as a potential solution, exploring research findings, their effectiveness, and the mechanisms by which they act on pathogens. Additionally, it will discuss future directions for safely utilizing essential oils on aquatic organisms.

Overview of Common Diseases Affecting Aquatic Environments

Certain diseases are specific to aquatic organisms, for instance, fish, but other diseases are widespread within the entire aquatic environment (Stuart et al., 2018). Common diseases that affect aquatic environments are;

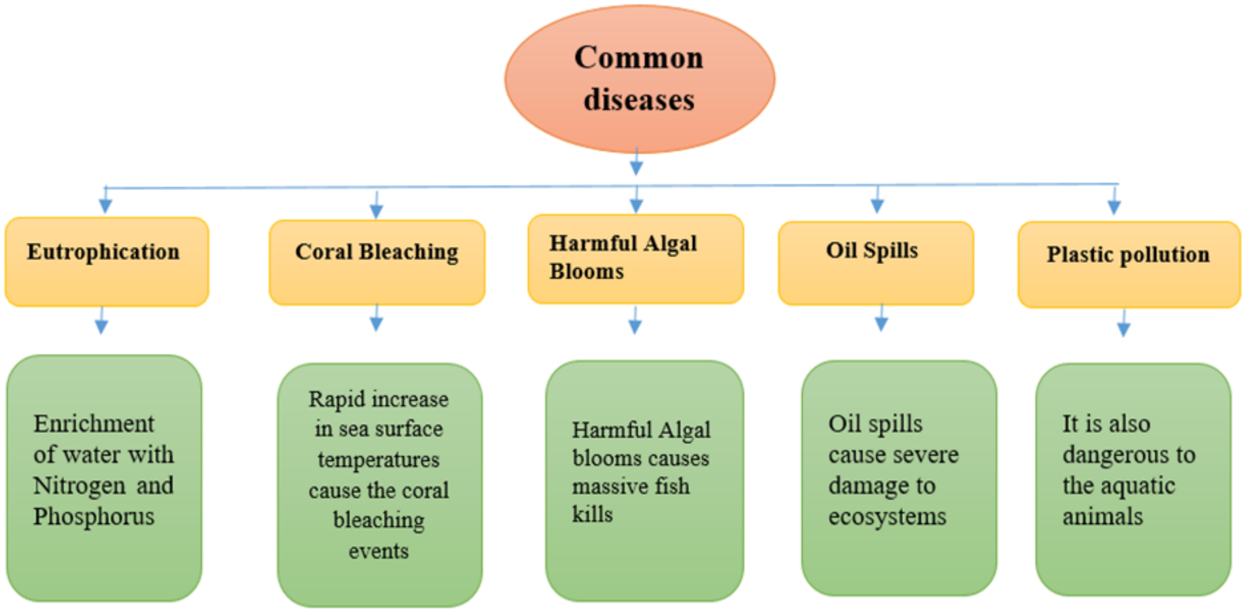

Fig. 1: Overview of common diseases

Impact of Diseases on Aquatic Ecosystems and Industries

The environment in the aquatic system is very complex since all food resources are supplied in the same system where waste and by-products of excretion are also present. Aquatic environments are not static because they are affected by changes that may happen both "within and without." Especially "Physico-chemical changes" make fish diseases complex as the fish environment is dependent on several other factors like plants, soil, and other animals living in the water. The most common cause of environmentally induced diseases is "poor water quality" because changes in water parameters result in direct or indirect effects on fish.

The aquatic ecosystems are ultimate absorbers of contaminants. Water pollution is caused by human actions like urbanization, industrialization, and agriculture. Abundant application of pesticides and fertilizers as well as sewage leads to infections that include "dysentery, diarrhea, and jaundice".

In the ecosystem of water, contamination is one of the types of pollution that is extremely detrimental to human health concerns. "Water is naturally capable of neutralizing contamination", but when pollution is beyond our control, water loses its ability to self-generate. Industrial spills and leakages contribute to the initiation of the process of "water pollution". Most aquatic ecosystems have a "natural ability to dilute pollution" but severe pollution leads to a change in the "fauna and flora" of a community.

Current Methods of Disease Control and their Limitations

Pharmaceutical products are a major factor in "the improvement of quality of life". Many active organic and inorganic compounds have been used for the "treatment and cure of numerous diseases".

The risk of "epidemic transmission" especially due to global warming has heightened. Identifying the "pathogen types, epidemic season, temperature variations, and environmental conditions" that cause the transmission of diseases is critical for prevention or treatment strategies (Jiang et al., 2023).

Methods of Disease Control

The prevention and control of aquaculture health by a single approach is not successful in itself. The mixture of different strategies, rather than the usage of a single strategy, is effective. Establishing a national or regional information exchange between farmers and responsible parties might be advisable. "Prevention is often better than treatment", thus it is recommended to concentrate on the prevention of disease rather than treatment. These are methods of controlling aquatic diseases;

- Antibiotics
- Vaccination

Antibiotics are "chemotherapeutic agents" that prevent or inhibit the growth of microorganisms, such as bacteria, viruses, and fungi. These are used as "antibacterial or antifungal". Their frequent release in water becomes the main concern in the continuing spread of "multi-resistance" in bacteria, which is a precursor for serious health-related problems (Torres et al., 2017).

Vaccination is a major factor in "avoiding and managing infectious disease in fish". There are some recent developments in fish vaccination recently. Vaccination is being used in large numbers for almost all food animals. In fish farming, it can prevent infectious diseases. It also prevents the risk of "drug resistance". Vaccines are so widely accepted because there is no risk of drug resistance development. Modern vaccines are classified as "killed, attenuated, DNA and genetically modified".

Limitations and Challenges

- The important challenge in diagnosing the disease of fish is "the individual fish is the unit of interest". The use of antibiotics is under restriction due to "drug resistance".
- "Formulation of vaccines towards intracellular bacterial and viral pathogens" would be among the major challenges for the next few years.
- Probiotics too can acquire antibiotic resistance because live bacteria are added in high numbers, which have high levels of antibiotic resistance genes (Watts et al., 2017).

Introduction to Essential Oils

Essential oils (EOs) can be defined as any type of volatile oils that contain aromatic components and can give variation in aroma, odor, or flavor to the plant. These are primarily a by-product formed during plant metabolism, also called volatile secondary plant metabolites. The term "Essential Oil" is supposed to be originated in the sixteenth century coined by Paracelsus von Hohenheim, which is a Swiss reformer of medicine, from the term "Quinta essential", which means an effective constituent of a drug (Sil et al., 2020).

In general, EOs account for less than 5% of vegetable dry matter, which is a very small part of the plant's total composition. All plant organs, especially the buds, flowers, leaves, stems, seeds, and fruits, synthesize EOs. EOs can be stored in secretory cells, cavities, epidermal cells, or glandular trichomes. EOs are usually liquid, volatile, colorless at ambient temperature, highly soluble in fixed oils, organic solvents, and alcohol but poorly soluble in water. A total of 3000 types are identified as EOs, from which only 300 are found to be of industrial importance for use in the food industries, often for the fragrances and flavors market. For plants, EOs perform many important functions in nature, particularly chemical and aromatic characteristics, such as

- Attracting beneficial pollinators and insects
- Protecting plants from environmental stress (cold, heat, etc.)
- Shielding plants from microorganisms and/or pests

EOs are globally known for their biological activities, including antifungal, antioxidant, antiviral, antimicrobial, insecticidal, antiparasitic, and antimycotic properties. Due to these activities, many EOs are used in agriculture (repellent and bio-pesticide), in cosmetics (make-up products and perfumes), as natural remedies in aromatherapy and sanitary products (aromas in cleaning products for household) (Falleh et al., 2020). EOs can be used as food additives in industry and bioactive packaging due to their antimicrobial properties, especially for the preservation of cereal grains, fruits, legumes, and meat products (Almeida et al., 2024).

Previous research has revealed that essential oils and their major components, such as carvacrol and thymol, are active against *Salmonella* spp. *Staphylococcus aureus*, *Escherichia coli,* and *Bacillus cereus* but are less efficient against *Pseudomonas* spp. due to the formation of exopolysaccharides that increase resistance to these compounds. Due to variations in the composition of cell membranes, most EOs have a greater bactericidal impact on Gram-positive bacteria than on Gram-negative. For example, an experiment revealed that the administration of essential oils (such as carvacrol, thymol, anethole, and limonene) as feed additives offer protection in Rainbow Trout against *Aeromonas salmonicida* infection. Higher survival rates in White Shrimp post-larvae were shown by dietary supplementation of neem (*Azadirachta indica*) or oregano (*Lippia berlandieri Schauer*) extracts when exposed to *Vibrio parahaemolyticus* infection as compared to the control group (Perez-Sanchez et al., 2018).

The Efficacy of Essential Oils in Disease Control

EOs are intricate blends made up of more than 300 distinct substances. They are made up of organic volatile substances, most of which have small molecular weights. EOs are generally found in the vapor state at room temperature and atmospheric pressure due to their suitably high vapor pressure (Dhifi et al., 2016).

Bacterial membranes and their cytoplasm can both be impacted by EOs. The breakdown of cell walls, harm to membrane proteins and the cytoplasmic membrane, as well as decreased ATP production and proton motive force, are some of the pathways of action of EOs. Because EO chemicals are lipophilic, they can pass through cell membranes and stay in the space between phospholipids. EOs primarily enter bacterial membranes and operate on their cytoplasm and membranes to change the morphology of their cells and the abnormalities of their organelles, thereby blocking their action mechanisms. The heightened sensitivity of gram-positive bacteria to essential oils (EOs) compared to gram-negative bacteria often stems from the presence of lipoteichoic acids in their cell membranes. These acids may facilitate the penetration of the hydrophobic compounds found in essential oils (Zanetti et al., 2015).

Chitin plays a vital role in constructing the fungal cell wall, which is indispensable for fungal survival. This cell wall is crucial for the growth and vigor of fungi. Inhibiting chitin polymerization can impede cell division and growth, affecting the maturation of cell walls, septum development, and bud ring formation. Essential oils (EOs) emerge as one of the most promising natural products for inhibiting fungi. Similarly, arginine is converted into nitric oxide (NO) by bacterial nitric oxide synthases (bNOS). The NO produced by bNOS gives bacteria a wider range of antibiotic resistance, enabling the bacteria to coexist and share environments with microorganisms that produce antibiotics. NO-mediated resistance is attained by reducing the oxidative stress that many antibiotics inflict, as well as by chemically altering harmful substances. EO oil has the potential to be used in the treatment of oxidative damage since it can lower nitric oxide levels, restrict the synthesis of H2O2, and inhibit NO synthase (Nazzaro et al., 2017).

Research on the utilization of herbal remedies as additives in aquatic feeds for the prevention and treatment of illnesses has seen significant growth since the 1990s (Valladao et al., 2015). By adding myrcene, menthol, and 1, 8-cineole to its diet, the growth performance, immune status, antioxidant status, and resistance to environmental ammonia of Common Carp *(Cyprinus carpio)* were improved. Furthermore, Dawood et al. (2020) showed that Nile Tilapia-fed diets supplemented with carob syrup *(Ceratonia siliqua)* exhibited improved immunity, tolerance to ammonia exposure, and growth performance. Lately, exposure to dietary menthol essential oil has had a positive impact on the growth rate and anti-oxidative capability, as well as an anti-inflammatory response among Nile tilapia suffering from chlorpyrifos toxicity.

Several studies have highlighted the antimicrobial efficacy of essential oils and their primary *constituents, such as thymol and carvacrol, against Salmonella spp., Bacillus cereus, Staphylococcus aureus*, and *Escherichia coli*. However, their impact on Pseudomonas species is less pronounced due to the development of exopolysaccharides, which enhances tolerance to certain substances. Due to alterations in the structure of cell membranes, most essential oils exert a stronger bactericidal effect on Gram-positive bacteria compared to Gram-negative bacteria, although the specific mechanism of action varies depending on their chemical composition (Perez-Sanchez et al., 2018).

A new study has proven that Channel Catfish *(Ictalurus punctatus)* increases feed intake and growth as well as mean corpuscular hemoglobin (MCH) content when reared in low temperatures with flax seed oil supplementation as opposed to the supplemented diet (Thompson et al., 2015). A comparative study has further revealed that administrating dietary extract of papaya *(Carica papaya)* significantly increases the growth rate and helps in the maturation of gonads in both male and female Tilapia.

Economic Considerations of Using Essential Oils for Disease Control

The considerations that comprise all the factors like money-making, presence of resources, prices, etc. which were involved in the act of deciding by the individuals which are the basis of elevation of good economic outcomes are called economic considerations.

Some essential oils have attributes to curb parasitic diseases in fish, to test these attributes, in vitro studies were used. The main factors of utilizing in vitro studies are:

- Their cheap price.
- Their speedy outcomes.
- Their eventuality of an apparent act of screening.
- Presence of certain essential oils (Tavares-Dias, 2018).

Potential Cost Savings of Using Essential Oils

A remarkable number of plants were required to extract essential oils in minute quantities. For example, one drop of Rose Otto essential oil is formed by using rose petals of thirty to fifty roses.

While buying essential oils, some of the points given below assist in money saving:

- A small quantity of essential oil lasts for a long time because of its concentrated appearance.
- Prefer to buy essential oil aggregates than a single particular aromatic oil.
- Buying pre-diluted aromatic oils.

➢ When well-known companies or brands offer discounts, it is better to purchase essential oils from those brands or companies.

Examples of Essential Oils and Benefits of Using These Essential Oils
Example no. 1, Thymol Essential Oil

Thymol essential oil is given to fish and poultry animals because of its numerous advantageous components that are beneficial for the body of the animals. The Thymol essential oil is used to ameliorate:

- Functionality variables
- Sexual performances
- Utilization of nutrients
- Working of immunity cells of the body
- Prohibiting the body from pathogenic agents and diseases.

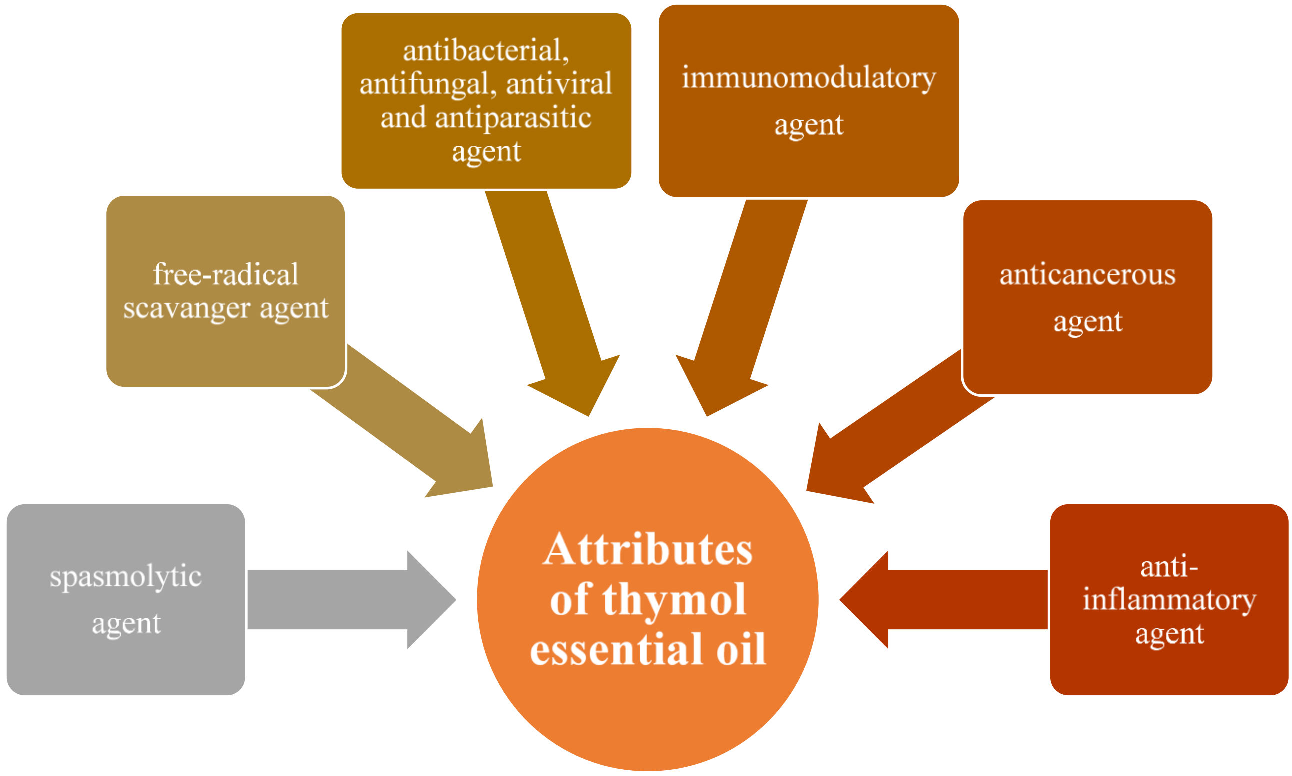

Fig. 1: Some attributes of thymol essential oil (Ezzat Abd El-Hack et al., 2016)

Example no. 2, Clove Oil

To perform small-scale surgical operations on the fish, a small amount of clove oil is applied to anesthetize the fish. Applying this oil in large quantities is responsible for fish assassination.

Comparative Cost Analysis with Conventional Disease Control Measures

The deed of splitting the cost of a summary into its parts and then analyzing and describing every factor is termed cost analysis.

Environmental Impacts of Traditional Disease Control Methods

Specific kinds of physical deeds that cause variations in the man-made and innate environments and these modifications have disastrous impacts on aquatic organisms, terrestrial organisms, birds, mammals, invertebrates, and other residents of the environment are termed as environmental impacts.

➢ The quality of soil is influenced by regular sowing, plucking, and gathering of food crops and many trees were demolished to collect the sap to get the resins which is responsible for the origination of essential oils, so the formation of essential oil is the root cause of removal of trees.

➢ **In vitro studies of using essential oils to control fish parasites**: These studies are used to overcome parasitic diseases in fish due to monogeneans that were the main cause of huge amounts of fish loss.

➢ **In vivo studies of using essential oils to curb fish parasites:** These studies are used to medicate fish infected with external parasites and they are separated from the body of fish by the application of short-duration or long-duration baths in which seeking essential oils were used.

- The quality of water is ameliorated by the insertion of essential oils.
- For the betterment of the physical condition of fish, essential oils were added.
- Parasites were also removed from the body of fish by the inclusion of essential (Tavares-Dias, 2018).

Table 1: Cost analysis, dose and duration, and impacts of different essential oils on immunity, growth, and infectious diseases of fish species

Fish species	Essential oils	Dose and Duration	Cost per 10ml (according to Pakistani currency)	Effects (growth, immunity, and infectious diseases)	References
Mozambique tilapia (*Oreochromis mossambicus*)	Bitter lemon (*Citrus limon*)	0.5, 0.75, and 1% for 60 days	*Rs. 690 for 10ml*	Growth indices and feed utilization increase Nitroblue tetrazolium (NBT), white blood cells (WBCs), Blood total protein, lysozyme, and myeloperoxidase activity (↑) – Serum glucose and triglycerides (↓) Resistance against *Edwardsiella tarda* (↑)	(Baba et al., 2016)
O. mossambicus	Sweet orange (*C. sinensis*)	0.1, 0.3, and 0.5% for 60 days	Rs. 550-570 for 10ml	Growth indices and feed utilization (↑) – Lysozyme and myeloperoxidase activity, hematological and biochemical variables, i.e., hemoglobin (Hb), hematocrit (Htc), albumin, and globulin (↑) - Blood glucose and cholesterol (↓) – Resistance against *Streptococcus iniae* (↑)	(Acar et al., 2015)
O. niloticus	*Origanum vulgare*	5 and 10% for 8 weeks	Rs 1,750 for 10ml	Growth indices and feed utilization (↑) Antioxidant activities (↑) Resistance against *Vibrio alginolyticus* (↑)	(Abdel-Latif and Khalil, 2014)

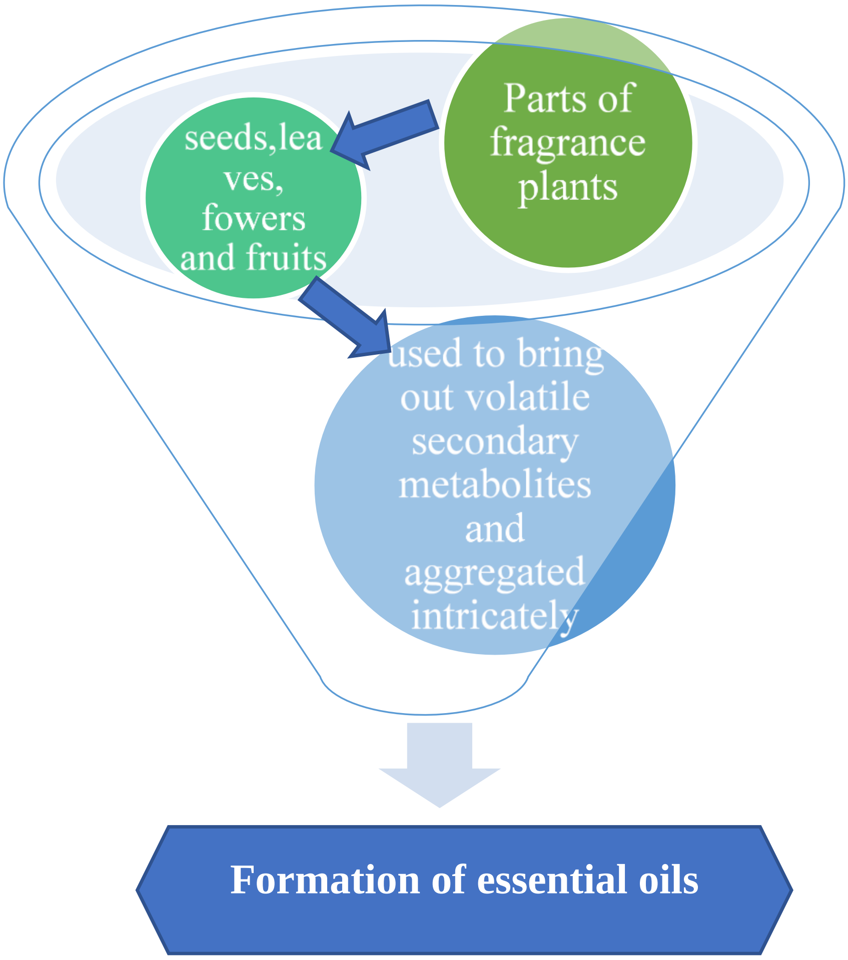

Fig. 2: Extraction of essential oils (Raghuvanshi et al., 2023)

Eco-Friendly Aspects of Essential Oils

Ecologically safe additives were used to keep away from the immediate and non-immediate influences on the aquatic environment and physical condition of humans. Some essential oils were operated as a natural pesticide. To protect the crops from pests, some essential oils worked as preventive and prohibitive agents to keep the insects away from plants.
For humans, essential oils are used for:

- Making skin products
- Betterment of mood and alleviating pain by scent therapy.
- Wiping homes, schools, and offices by using harmless essential oil-based cleaners to prevent these places from air pollution and water pollution.

Lemon and Peppermint essential oils and mixtures of oils like Purification are usually inserted in fish aquariums. These oils are used for the removal of microorganisms and other pathogenic components from the water to shield the fish.

Lavender, orange, and tangerine essential oils are given to fishes. They are sometimes protective but sometimes they are not protective of all fishes. Some of them are responsible for ameliorating and conferring immunity to some infections or diseases when taken up by fish.

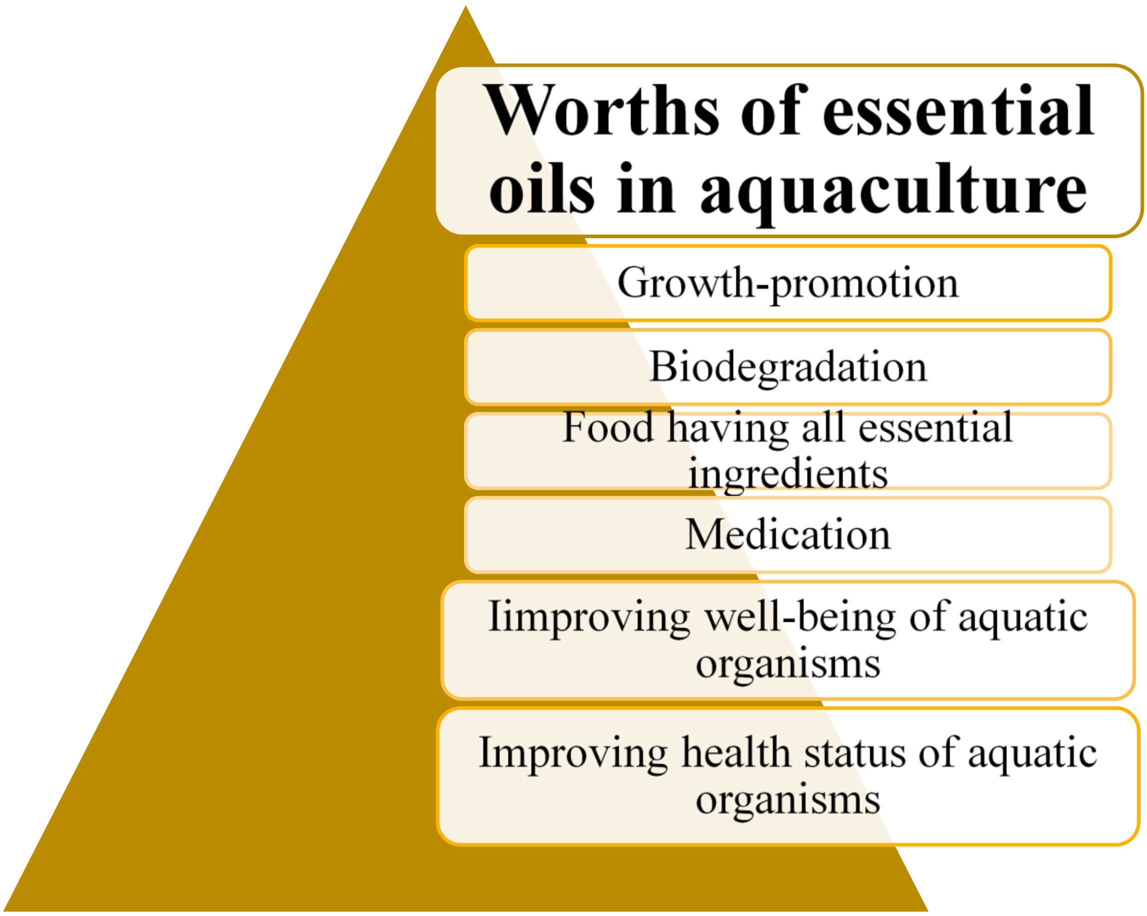

Fig. 3: Usefulness of essential oils for aquatic (Dawood et al., 2022)

Sustainability Aspects of Essential Oil Usage in Aquatic Environment

The potentiality to conserve, restore, or reinforce an activity eventually is known as sustainability. Three fundamental concepts of sustainability are:

1. Profitable
2. Ecological
3. Communal

Using Diffusers

The extremely frequent means to apply essential oils for peacefulness is with a diffuser. To protect the aquatic organisms, it was suggested by the fish owners to place the aquarium away from the diffusers because sometimes specific types of essential oils were harmful to the body of fish so their toxic diffused vapors could become the fundamental cause of death of fish.

Inclusion of Essential Oil in Glass Aquarium

Insertion of essential oils in an aquarium made of glass is much more secure and reliable than adding it in a tank made of plastic because the reaction between the chemicals present in the essential oils and the plastic tank poses disastrous impacts on the fish. Start adding essential oils in small quantities and then increase their quantity with time so that the fish can become habitual of these oils.

Practical Applications and Case Study

Essential oils have diverse properties that can improve the welfare, growth, and health of animals, as well as lessen the stress processes that's why these are used in aquaculture studies. Recent studies revealed that EOs can reduce or eliminate stress caused by varying stocking densities. In Silver Catfish, exposed to a stressful environment of high stocking density, dietary administration of 0.50mL/kg *Lippia alba* EO prevents the cortisol levels from rising. Similarly, a diet containing *Myrcia sylvatic* (2.0mL/kg) EO for ninety days decreased the levels of cortisol in Gilthead Seabream after 22 days at high stocking density (40kgm^{-3}) (Souza et al., 2019).

Studies demonstrated that the disease resistance to *Vibrio parahaemolyticus* of Pacific White Shrimp remarkably increased by adding 0.3gkg^{-1} essential oils and organic acids blend into the control diet. Similar results were observed in shrimp-fed diets containing plant extracts and citric acid. Also, enhanced disease resistance by dietary essential oils against bacterial pathogens has been reported in Mozambique Tilapia, Rainbow Trout (*Oncorhynchus mykiss*), and Channel Catfish (*Lctalurus punctatus*) (He et al., 2017).

The antimicrobial activity of essential oils from *Mentha piperita, Lippia sidoides, Lippia alba, Zingiber officinale*, and *Ocimum gratissimum* was investigated against *Streptococcus agalactiae*. With minimum bactericidal concentration (MBC) ranging from 416.7-2,500µgmL^{-1} and minimum inhibitory concentration (MIC) ranging from 312.5-2,500µgmL^{-1}, all tested essential oils revealed bactericidal action against *S. agalactiae*. In this study, essential oil *L. sidoides* demonstrated better findings against *S. agalactiae* (Majolo et al., 2018)

Recently, it has been observed in many species that EOs can be used as sedatives or anesthetics to reduce possible harm to fish during handling. Lower levels of EOs can be used that cause light sedation and tranquilization for minor procedures such as collection of blood samples and biometry to reduce stress and minimize cortisol levels of plasma. In handling processes, the suggested concentration is 10-30mgL^{-1} for clove oil (extracted from *Syzygium aromaticum* or *Eugenia aromatica*) (Souza et al., 2019).

Challenges and Limitations

The use of antibiotics or vaccines is an effective way to prevent diseases in the aquaculture industry, but the mass killing of beneficial aquatic bacteria is also involved in it (Ahmad et al., 2021). Several researchers found out that essential oils cause fish toxicity and that affected "its embryotoxicity, mortality, developmental abnormalities, the hatching rate of embryo and swimming activities of fish" (He et al., 2018).

Opportunities for Further Research and Development

Many essential oils are highly instrumental in the process as they "enhance the defense system of the aquatic organisms". The research on the transcriptomic profiles of fish is still ongoing to see the effects of botanical EO concentrations on the immune response or disease resilience (Dawood et al., 2022).

Future Trends and Potential Advancements in the Field

EOs are going to be significant for the creation of products exhibiting "antibacterial characteristics". The essential oils have been examined for their capability to be used as bio-pesticides, which are highly degradable in the environment and comparatively safe (Pintong et al., 2020).

Studies on the "cytotoxic activity" of plant extracts and essential oils in tumor cells have produced promising results for "new cancer therapies or enhancement of the effectiveness of existing cancer drugs". Plant-derived essential oils have surfaced as an "eco-friendlier" method of producing metal nanoparticles in more recent times (Salehi et al., 2020).

New Perspectives on the use of Essential Oils and Plant Extracts

The toxicity of essential oils and plant extracts to insects that damage crops and their potential use as bio-pesticides have been the subject of numerous studies in recent years, making this one of the most researched potential uses of these substances. Utilizing nano-emulsion and essential oils (EOs) or other herbal remedies to treat microbiological illnesses is seen to be "a novel and sustainable aquaculture strategy". EOs serve as "natural preservatives, stress relievers, herbal anesthetics, and immunomodulatory medicinal plants" in the fisheries and aquaculture industries (Gonzales et al., 2020).

Conclusion

The international community acknowledges the existence of alternative approaches to address some of the most prevalent illnesses in fish farming. Nevertheless, the knowledge gained from previous experiences holds valuable insights, and new research has further substantiated the importance of using environmentally sustainable methods to implement disease control measures in aquaculture. Therefore, the task is to accomplish it. Previous encounters with different types of animal husbandry have demonstrated that antiparasitic drug resistance has emerged consistently when stringent control methods have been implemented. This has led to the ineffectiveness of the majority of traditional anthelmintics. Thus, chemotherapeutics will be used less frequently in fish farming as herbal products, including essential oils, are more widely used. The usage of these natural compounds, together with other preventive measures, will gradually rise to decrease disease outbreaks. In addition, fish metabolic pathways often flush EOs out of the body rapidly due to the components' sensitivity and low molecular weight.

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