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Exploring the Vital Role of Essential Oils for Sustainable Aquaculture Management and Fish Welfare – A Review

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Abstract
Aquaculture has been an essential component of global food production, but it faces challenges such as disease outbreaks and environmental sustainability. Throughout history, traditional knowledge has relied on plant-based remedies for treating aquatic animal ailments, with essential oils (EOs) emerging as a prominent solution. Essential oils, lipophilic compounds derived from aromatic plants, exhibit diverse chemical compositions and therapeutic properties. Their constituents, including terpenes and oxygenated molecules, contribute to their antimicrobial, growth-promoting, and stress-alleviating effects on aquatic organisms. Moreover, EOs enhance antioxidative capacity and immune responses in fish, bolstering resistance against infectious diseases. Therapeutic potential of EOs, aquaculture practices can improve sustainability and productivity while minimizing dependency on conventional antibiotics and chemicals. Present study provides a comprehensive overview of the significance of essential oils in enhancing aquaculture sustainability and underscores their role in promoting the health and well-being of aquatic species.

Keywords: Aquaculture, Essential Oils, Health, Fishes

Introduction
In aquaculture use of plants for treating diseases has always been a common practice among indigenous tribes worldwide, and this continues today. It remained active through verbal transmission of knowledge between different generations (Tavares-Dias, 2018). Essential oils (EOs) are one of the phytochemicals used in aquaculture for treating disease and helps in increasing the production. Essential oils are a lipophilic mixture of organic compounds from the secondary metabolism of aromatic plants, which mostly are limpid liquid with an obvious fragrance which are obtained from the plant raw materials (Dawood *et al.*, 2022). There are 20 to 200 different components present in different EOs, which were named according to their mixture of concentration. The major constituents from 20 to 95%, secondary constitutes from 1 to 20%, and trace components are present in <1% (Souza et al., 2019).

EO constituents include two main groups of terpene-derived compounds the first consists of hydrocarbon terpenes/terpenoids derivatives (eg. alcohols, aldehydes, ketones, phenols, acids, and esters), and the second group includes oxygenated molecules (phenylpropanoids and their derivatives) (Carson & Hammer, 2010).

Essential oils, also known as an etheroleum, it has a variety of therapeutic properties, including analgesic, adaptogen, and astringents. It also has potential of growth-promoting, antibacterial, stress reducing and immunostimulant effects for several fish species. Moreover, it also increases the antioxidative capacity and the resistance to infectious diseases of aquatic

animals (Dawood *et al.*, 2022). It enhances the permeability of intestinal barriers and increase intestinal nutrient absorption.

Extraction of Essential Oil

The main methods of EO extraction are steam distillation and its variants, cold pressing, supercritical fluid extraction, and solvent extraction. Once condensed, the clean oil is separated from the aqueous distillation. EOs are volatile compounds therefore it has relative low stability, which may undergo chemical changes. However, various strategies can be observed to prevent their deterioration, including storage in small volume glass containers, maintaining them under low temperatures and protected from light. Once condensed, the clean oil is separated from the aqueous distillation (Souza *et al.*, 2019).

Use of Essential Oil in Different Field of Aquaculture

ESSENTIAL OIL AS STRESS REDUCING AGENT (ANESTHETICS): For minor procedures such as biometry and collection of blood samples, lower concentrations of EOs can be used that induce tranquilization and light sedation, in order to minimize stress and reduce plasma cortisol levels. Several synthetic anaesthetics are aversive which create the undesirable habit to fish even at low concentrations, while EOs are not aversive and found safe for the aquatic uses (Junior *et al.*, 2018). Generally, for stress reduction EOs are applied in water prior to handling. The use of EOs as edatives or anesthetics is to reduce possible damage to fish and overcome them easily from the stress. It may also use in aquaculture industry to facilitate handling, labelling, induced spawning, vaccination, etc.

Live transportation of larvae, juvenile or broodstock is one of the major causes of stress in fish due to the capture, packing, high loading density, and changes in water quality. So, here during transportation EOs play important role to prevent the stress. The effect of the EOs may also change according to the species and the type of application. Mostly select bath treatment for aquatic animal to reduce the stress.

Table 1:- List of essential oils used as an anesthesia in aquatic animals are given below.

Essential oil	Species	Reference
Lippa alba	Silver catfish	Becker et al., 2012
	Tambacu	Sena et al., 2016
	Common carp	Mazandarani et al., 2017
Lemon verben *(Aloysia triphylla)*	Silver catfish	Parodi et al., 2014
	Nile tilapia	Teixeira et al., 2018
Myrcia sylvatica	Silver catfish	Saccol et al., 2018
Lippia origanoides	Silver catfish	Becker et al., 2018
Clove oil	*Penaeus vannamei*	Kaewmalun et al., 2022
	Abalon *(Haliotis squamat)*	Fanni et al., 2021
	Carrasius auratus	Abdolazizi et al., 2011
	Macrobrachium rosenbergii	de Souza valnete et al., 2023
Citrus sinesis	*Betta splendens*	da Silva et al., 2023
Lavander oil	Rainbow trout	Yogit et al., 2022
Eucalyptus globulus	Silver kob	Gabriel et al., 2022
Linseed oil	Darkbel fish	Li et al., 2014
Melaleuca alternifolia (Tea tree oil)	Silver catfish	Souza et al., 2017
	Common carp	Hajek et al., 2011
	Brachyuran crab	Souza et al., 2018
White camphor oil	Bighead carp	Krasteva et al., 2022

ESSENTIAL OILS AS FEED ADDITIVES FOR PROMOTING GROWTH: EOs can exert a prebiotic-like effect on the intestinal environment and alter the gut bacterial composition. Depending on the EO compound, the degradation and absorption may occur in different sites of the digestive tract, suggesting that each molecule may have a specific place to act. The EO compounds could be absorbed in the upper digestive tract and metabolized before reaching their optimum site of action. Thus, they would be ineffective and may be necessary to protect the EOs from gastric absorption. The indirect effects of EOs on the intestinal microbiota can occur through changes in the intestinal environment, including changes in pH, and amount of secretions of the intestinal mucosa (Sutili *et al.*, 2018). For growth performance essential oils are given in mixed with feed.

It was noted that the feed consumption is increases and Feed conversion ratio is decreases when EOs are used as a feed dietary supplement. The intestinal villus is increases and nutrient utilization improved due to the EOs, which resulted in high feed consumption and gives better growth rate of fishes (Valladão et al., 2017).

Table 2: - list of essential oils used to increase the growth in different aquatic species

Essential oils	Fish species	Reference
Lemon verben (*Aloysia triphylla)*	Silver catfish (*Rhamdia quelen*)	Zeppenfeld *et al.*, 2017
Mint oil (*M. spicata)*	Rainbow trout	Sönmez *et al.*, 2015
Oregano oil	Common carp	Abdel-Latif *et al.*, 2020
	Koi carp	Zhang *et al.*, 2020
	Yellow tail tetra fish	Ferreira *et al.*, 2016
	Nile tilapia	de Oliveira *et al.*, 2020
	Channel catfish	Zheng *et al.*, 2009
Lemongrass (*Cymbopogon citratus*)	Nile tilapia	Al-Sagheer *et al.*, 2018
EOs of Fennel and Garlic	Nile tilapia	Hassaan & Soltan, 2016
Curcumin	Mosambica tilapia	Midhun *et al.*, 2016
Sweet orange peel	Mosambica tilapia	Acar *et al.*, 2015
Citrus Lemon peel	Mosambica tilapia	Baba *et al.*, 2016
Menthol oil	Nile tilapia	Magouz et al., 2021
Citrus sinensis	*Oreochromis niloticus*	Acar et al., 2015
Thyme oil	*P. vannamei*	Aktaş, et al., 2022
Savory oil	*Caspian roach*	Ghafarifarsani et al., 2022
Rosemary oil	*Huso huso*	Ebrahimi et al., 2020
Cumin Essential Oil	*P. vannamei*	Sheikh et al., 2018
Tea tree oil (*Melaleuca alternifolia)*	Nile tilapia	Valladão et al., 2017
	Macrobrachium rosenbergii	Liu et al., 2022a

AS IMMUNOSTIMULANT: There are two categories of immune responses, the natural (innate) and the acquired (adaptive) immune responses. The innate response represents the first defensive action and a significant part of the immunity system, which includes functions like phagocytosis, cytokine production, the release of inflammatory mediators, and antigen production. While the acquired response employs the production of antibodies/ immunoglobulins (Ig), B cells (plasma cells), and T-cells. In fish, lymphocytes mediate cellular and humoral immune responses, and the primary lymph organs in fish are the kidney, spleen, thymus, and anterior. Functional and nutritional supplements and balanced diets of feed can stimulate immune responses in fish (Dawood *et al.*, 2022).

The various research of EOs indicated that activities like increases resistivity against the pathogens, maintain homeostasis of blood, elevate respiratory burst activity and hematological parameters, etc are responsible for the immunity boosting in aquatic animals. In shrimps it also induces the prophenol oxidase.

Table 3: - List of essential oils for immunostimulant properties in several aquatic animals

Essential oils	Fish species	Reference
Basil (O. Gratissimum) and ginger (*Z. officinale*)	Nile tilapia	Brum *et al.*, 2017
Cinnamon oil (*Cinnamomum* sp.)	Nile tilapia	M. Dos Santos *et al.*, 2016
C. limon peel	*O. mossambicus*	Baba *et al.*, 2016
Sweet orange peel	*O. mossambicus*	Acar *et al.*, 2015
T. vulgaris	Rainbow trout	Giannenas *et al.*, 2012
Zaatar (*Zataria multiflora*) and blue gum (*Eucalyptus globolus*)	Common carp	Sheikhzadeh *et al.*, 2011
Cinnamon oil	Nile tilapia	Rattanachaikunsopon & Phumkhachorn, 2010
Melaleuca alternifolia (Tea tree oil)	Largemouth bass (*Micropterus salmoides*)	Liu *et al.*, 2022
	Macrobrachium rosenbergii	Liu et al., 2022a
Citrus lemon	*Labeo victorianus*	Ngugi et al., 2017
Cumin Essential Oil	*P. vannamei*	Sheikh et al., 2018

AS ANTIOXIDANT: Oxidative stress is caused by an imbalance in antioxidant supply Oxygen reactive species (ROS). The antioxidative defense system is composed of antioxidant enzymes [catalase (CAT), glutathione-S-transferase (GST), glutathione peroxidase (GPx), and superoxide dismutase (SOD)] and non-enzymatic antioxidants [non-protein thiols (NPT)]. The antioxidant activity is mediated by the reductive structure of the compound, which contains aromatic rings, phenolic compounds, and a high concentration of hydroxyl groups. When EOs are used as an anesthetic, it improving the antioxidant activity of fish (Dawwod et al., 2022).

Table 4: - List of essential oils to increase the capacity of antioxidant in aquatic animals.

Essential oil	Fish species	Reference
Oregano EO	Koi carp	Zhang et al., 2020
	Nile tilapia	*Abdel-Latif et al., 2014*
	Rainbow trout	*Giannenas et al., 2012*
	Channel catfish	*Zheng et al., 2009*
A. triphylla	Silver catfish	Zeppenfeld et al., 2017
Sage, thyme, and mint oil	Rainbow trout	Sönmez et al., 2015
L. alba	Silver catfish	Saccol et al., 2013
Tea tree oil (M. alternifolia	Silver Catfish	Souza et al., 2017
	Silver catfish	Baldissera et al., 2017
	M. rosenbergii	Liu et al., 2022b
Sweet basil oil	*P. vannamei*	Abdel-Tawwab et al., 2021
Cumin essential oil	*P. vannamei*	Sheikh et al., 2018
Savory oil	*Caspian roach*	Ghafarifarsani et al., 2022
Thyme oil	*Cyprinus carpio*	Ghafarifarsani et al., 2022

Conclusion

In conclusion, essential oils have proven to be valuable in aquaculture and offer health benefits without causing adverse side effects. It shows their effects on various aquatic animals, including freshwater fish, marine water fish, ornamental fish, and shellfishes. It demonstrating effectiveness in promoting growth, boosting immunity, reducing stress, enhancing disease resistance, and maintaining antioxidant capacity. The versatility of administration methods, whether orally, through bath treatment, or mixed in feed. Notably, the absence of reported side effects, in contrast to synthetic drugs, makes essential oils a favorable and commercially advisable option for promoting the health and well-being of aquatic organisms in aquaculture.

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