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ESSENTIAL OILS FOR THE CONTROL OF BACTERIAL DISEASES IN AQUACULTURE: A NATURAL ALTERNATIVE

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The aquaculture sector is experiencing substantial growth, with production surpassing that of wild fishing in 2024 and becoming the first industry to produce fish animal protein for human consumption, accounting for over 51%. Despite this economic golden age for the sector, the increased production of goods and farmed animals leads to heightened demand for artificial feed supplies, water treatment, environmental degradation, and disease outbreaks. Specifically, ponds can lose over 60% of their annual production due to the spread of diseases, causing high mortality rates and consequential economic loss, which is reported to be globally around 1.05 to 9.58 billion USD/year.

One of the most significant threats to aquaculture facilities and fish is bacteriological disease caused by *Aeromonas* spp., *Streptococcus* spp., *Lactococcus* spp., *Vibrio* spp., *Pseudomonas* spp., and other related genera. These bacteria are commonly treated with synthetic antibiotics, vaccines, and chemotherapies to enhance the immune response. Nevertheless, the over- and uncontrolled use of antibiotics has led to the emergence of multidrug-resistant pathogens and an imbalance in the microbial population, with consequences for the host immune system and the environment.

Consequently, the researcher has sought to identify alternative, more natural solutions to replace antibiotics, either partially or completely, in aquaculture. One valuable and rising option is the inclusion of essential oils (EOs) in the feed used for farmed fish.

Extracted from various parts of medicinal plants (flowers, leaves, seeds, roots, fruits, wood and bark), EOs consist of aromatic and volatile compounds that are insoluble in water. They have been described as regulating quorum-sensing systems, biofilm formation, and the expression of virulence factors. EOs have been shown to possess bioactive properties with phytotherapeutic activity against various bacteria, especially Gram-positive bacteria. This phenomenon can be attributed to the presence of lipoteichoic acids in cell membranes that might facilitate the penetration of substances. Moreover, EOs have demonstrated a variety of favourable functions in farmed fish, such as appetite stimulation, growth promotion, and stress reduction.

In this context, various *in vitro* studies have been conducted to assess the effects of EOs on several bacterial species. The research focuses on groups that mainly affect water and aquaculture facilities, causing death in farmed fish. EOs derived from, for example, *Origanum* spp., *Piper* spp., *Cinnamomum* spp., *Lavandula* spp., and *Eucalyptus* spp. demonstrated growth-inhibitory effects on *Aeromonas* spp. (the most studied bacterial species, such as *A. salmonicida*, *A. veronii*, *A. hydrophila*) in several MIC ranges, from 3 µL/mL to 3628 µL/mL. Similarly, inhibitory effects from diverse EOs were observed for *Vibrio* spp., with MIC ranges from 0.244 µL/mL to 320 µL/mL, *Pseudomonas* spp. (MIC from µL/mL to 640 µL/mL), *Lactococcus* spp. (MIC 4 µL/mL to 1280 µL/mL), *Citrobacter* spp. (MIC > 1600 µL/mL) and others.

To conclude, the *in vitro* tests highlighted positive inhibitory effects of EOs on both Gram-positive and Gram-negative bacteria, suggesting their possible incorporation into aquaculture feed as an ecological and "Green" alternative to antibiotics. Nevertheless, the number of studies conducted on fish affected by these diseases remains limited, underscoring the necessity for further research in this field. Consequently, experimental trials in which farmed fish are fed pellets with different percentages of EOs inclusion would be required in order to enhance comprehension of animals' health status and to verify whether there is an improvement in immunological response.

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