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Abstract

Nanoparticle-Based Encapsulation of Anaesthetics in Fish Anaesthesia: Advances and Perspectives †

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Abstract

Fish are continuously exposed to stress factors throughout their life cycle, making the use of anaesthetics essential for a wide range of experimental procedures. Currently, the most commonly used and FDA approved anaesthetic for fish research is Tricaine Methanesulfonate (MS-222). However, its use has been associated with several undesirable effects, including hypoxemia, hypercapnia and hypoglycaemia, as well as environmental concerns due to its release through aquaculture effluents. These limitations highlight the need for alternative anaesthetic strategies. Natural compounds such as clove oil, menthol and thymol have been investigated as potential alternatives, demonstrating effective anaesthetic properties. However, their low aqueous solubility, represents a significant challenge, which may be overcome through nanoencapsulation. This approach can enhance solubility, enable controlled release, and reduce the effective dose required. Accordingly, the present study aims to provide an overview of the recent advances in nanoparticle-based encapsulation strategies for anaesthetic delivery in fish, with a focus on their efficacy, safety and environmental impact. Some studies have demonstrated the benefits of nanoencapsulation. In adult zebrafish (*Danio rerio*), lower concentrations of benzocaine were required when encapsulated in chitosan-PLGA nanoparticles, while lidocaine-loaded lipid NPs reduced bradycardia. In Nile Tilapia (*Oreochromis niloticus*), clove oil encapsulated in lipid-based nanocapsules enabled effective anaesthesia and prolonged release of the active compound eugenol. Similarly, mucoadhesive zein NPs, reduced the effective concentration of Eugenol by up to 50%. Monoterpenes such as menthol and thymol also show promise for zebrafish anaesthesia, demonstrating efficacy at 50 mg/L. These findings suggest that nanoparticle-based delivery systems can improve the efficacy and safety of fish anaesthetics while reducing required doses and potential environmental impact. Future research should focus on optimizing nanoparticle-anaesthetic systems by combining natural compounds with biocompatible and biodegradable nanocarriers (e.g., zein, chitosan or PLGA) to achieve controlled release, targeted delivery and minimization of side effects.

Keywords: anaesthesia; nanoparticles; controlled release; aquaculture

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