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Nanocomposite Microspheres for Nasal Delivery of Deferiprone in Neurodegenerative Conditions

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Introduction

Nanotechnology has revolutionized drug delivery systems by enabling targeted and efficient delivery of therapeutic agents. Among the promising innovations in this field are nanocomposite microspheres, which have emerged as an advanced platform for delivering drugs to specific sites within the body. In the context of neurodegenerative conditions, where traditional drug delivery methods often face challenges such as crossing the Blood-Brain Barrier (BBB), nanocomposite microspheres present a transformative solution. This article explores the potential of nanocomposite microspheres for nasal delivery of deferiprone, a chelating agent, in managing neurodegenerative conditions characterized by abnormal iron accumulation. Neurodegenerative disorders such as Alzheimer's disease, Parkinson's disease and Huntington's disease are often associated with dysregulated iron metabolism. Excessive iron accumulation in the brain leads to oxidative stress, mitochondrial dysfunction and neuronal damage, exacerbating disease progression [1].

Description

Deferiprone, an FDA-approved iron chelator, has shown promise in reducing iron overload and mitigating oxidative damage in these conditions. However, its systemic administration is often limited by poor bioavailability, side effects and inefficiency in crossing the BBB. A targeted delivery system that bypasses these limitations is crucial to maximize the therapeutic potential of deferiprone in neurodegenerative diseases. The nasal route for drug delivery has gained attention as a non-invasive, efficient pathway for targeting the Central Nervous System (CNS). Unlike oral or intravenous routes, nasal delivery allows drugs to bypass the BBB through the olfactory and trigeminal neural pathways. This direct route to the brain minimizes systemic exposure, reduces potential side effects and enhances the drug's bioavailability.

Despite these advantages, nasal delivery presents its own challenges, such as mucociliary clearance, enzymatic degradation and limited retention time in the nasal cavity. To address these issues, nanocomposite microspheres have been developed as a robust drug delivery platform. Nanocomposite microspheres are microscopic particles that integrate nanoscale materials with microscale carriers. They combine the benefits of nanoparticles, such as high surface area and targeted delivery, with the advantages of microspheres, including sustained drug release and enhanced stability. In the context of nasal drug delivery, these microspheres are designed to adhere to the nasal mucosa, protect the drug from enzymatic degradation and release the drug in a controlled manner, ensuring prolonged residence time and efficient absorption [2,3].

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The formulation of nanocomposite microspheres for deferiprone involves several critical components, including the core drug, polymeric matrix and nanomaterials. Biodegradable polymers such as chitosan, poly(lactic-co-glycolic acid) (PLGA), or alginate are commonly used to form the microsphere matrix. These polymers provide mucoadhesive properties, enhancing the microspheres' ability to adhere to the nasal epithelium. Chitosan, in particular, is a popular choice due to its biocompatibility, biodegradability and ability to open tight junctions in the nasal epithelium, facilitating drug absorption. Nanomaterials such as silica nanoparticles, magnetic nanoparticles, or lipid-based nanoparticles are incorporated into the microspheres to improve their functional properties. These nanomaterials can serve as carriers for deferiprone, protect the drug from degradation and enable precise control over its release profile.

Additionally, surface modifications, such as the addition of Polyethylene Glycol (PEG) or targeting ligands, can enhance the microspheres' stability, bioavailability and targeting efficiency. The manufacturing process of nanocomposite microspheres typically involves techniques such as solvent evaporation, spray drying, or ionic gelation. Solvent evaporation is widely used for PLGA-based microspheres, where the polymer and drug are dissolved in a volatile organic solvent, emulsified in an aqueous phase and solidified by evaporating the solvent. Spray drying involves atomizing the polymer-drug solution into fine droplets, which are rapidly dried to form microspheres. Ionic gelation is a milder technique often used for chitosan-based microspheres, where the polymer and drug are crosslinked with ionic agents to form stable particles. These methods are optimized to achieve uniform particle size, high drug loading efficiency and controlled release properties [4,5].

Conclusion

Despite their potential, several challenges must be addressed to translate nanocomposite microspheres from the laboratory to clinical practice. Regulatory approval processes for nanotechnology-based drug delivery systems can be complex, requiring comprehensive evaluation of their safety, efficacy and biocompatibility. Additionally, large-scale manufacturing of nanocomposite microspheres with consistent quality and performance poses technical challenges. Addressing these hurdles will require interdisciplinary collaboration among researchers, clinicians and regulatory agencies. Nanocomposite microspheres represent a cutting-edge approach for nasal delivery of deferiprone in neurodegenerative conditions. By leveraging the advantages of nanotechnology and mucoadhesive delivery systems, these microspheres overcome the challenges of traditional drug delivery methods, enabling efficient and targeted delivery of deferiprone to the brain. As research in this field progresses, nanocomposite microspheres have the potential to transform the management of neurodegenerative diseases, improving outcomes for patients and advancing the frontier of drug delivery science.

Acknowledgement

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Conflict of Interest

None.

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