

Topical ophthalmic nanoformulation of astaxanthin: Physicochemical characterization and in vitro intraocular diffusion for retinal therapy

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Oxidative stress is a key driver of retinal neurodegeneration in age-related macular degeneration (AMD), the leading cause of irreversible vision loss in the elderly. Astaxanthin (ASTAX), a potent antioxidant with neuroprotective properties, has demonstrated the ability to mitigate oxidative damage in retinal cells. However, its clinical application is severely hindered by poor aqueous solubility and limited ocular bioavailability. To address these challenges, we developed a topical ophthalmic liposomal nanoformulation of ASTAX designed to enhance corneal permeability and retinal delivery.

The formulation was developed using a self-assembling PEGylated lipid system, achieving an encapsulation efficiency >98%. Physicochemical characterization confirmed a nanoscale particle size, low polydispersity, and near-neutral zeta potential, ensuring stability and minimal electrostatic interactions. The formulation exhibited a physiologically compatible pH and osmolarity, and transmission electron microscopy (TEM) validated its uniform spherical morphology.

In vitro intraocular diffusion studies using excised rabbit corneas demonstrated a significant enhancement in ASTAX permeation with the liposomal formulation compared to free ASTAX, supporting its potential for effective transcorneal transport and retinal bioavailability. These findings establish the feasibility of this nanocarrier system for non-invasive ocular drug delivery, addressing critical limitations in antioxidant-based retinal therapies.

With optimized physicochemical properties and enhanced intraocular permeability, this formulation represents a promising candidate for in vivo pharmacokinetic and therapeutic validation in AMD models, advancing the development of targeted, non-invasive neuroprotective strategies for retinal diseases.

Keywords: Nanoformulation, Astaxanthin liposomes, intraocular diffusion

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