Facile Formation of Medium-Chain-Length Poly-3-Hydroxyalkanoates (mcl-PHA)-Incorporated Nanoparticle Using Combination of Non-Ionic Surfactants

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Abstract The assembly of nanoparticles incorporating bacterial medium-chain-length poly-3-hydroxyalkanoates (mcl-PHA) via phase inversion emulsification (PIE) was investigated. Sequential addition of water into an agitated mixture of carrier oil (jojoba oil), nonionic surfactants (Cremophor EL and Span 80) and melted mcl-PHA triggered phase inversion of water-in-oil (W/O) to oil-in-water (O/W) emulsion. The emulsion inversion point (EIP) at 30% w/w of water content was determined by abrupt changes in viscosity and conductivity of the suspension. Concurrently, infrared transmittance of the O–H group of water, the C–O–C group of surfactants and the C–H group of alkane chain were practically identical while Small Angle X-ray Scattering indicated the presence of a bi-continuous/lamellar structure. The morphology of the emulsion changed, with increasing water content, from W/O to bi-continuous/lamellar structure and finally to O/W. mcl-PHA appears to form a bridging polymeric network, covering the nanoparticle with a protective layer for enhanced protection of the encapsulated compound. A hypothetical mechanism for the mcl-PHA-based nanoparticle assembly is also proposed.

Keywords Nonionic surfactant mixture · Polymeric nanoparticle · Biodegradable polymer · Medium-chain-length poly-3-hydroxyalkanoates · Phase inversion emulsification

Introduction

Emulsification technology has been widely used to produce emulsions in various fields especially in the pharmaceutical, food and cosmetic industries [1]. Normally, emulsions with small droplets (<0.1 μm) and narrow size distribution are desired in those applications. For instance, nano-sized emulsions could help to improve the delivery of active molecules through oral [2], intranasal [3], intravenous [4] and topical [5] routes. Generating nano-emulsions using conventional emulsification, which involves vigorous agitation of an immiscible binary mixture, is strenuous, as it requires substantial energy to overcome a huge Laplace pressure. The use of surfactants helps to reduce the Laplace pressure considerably, where only a fraction of the energy required in direct emulsification is needed to form micro- and nanoemulsions [6].

One of the most common emulsification techniques is phase inversion emulsification (PIE), a low energy technique featuring a transition from a water-in-oil (W/O) emulsion to an oil-in-water (O/W) emulsion or vice versa [6, 7]. PIE is widely used in industry because of its ability to generate emulsions with nano-sized droplets [6, 7]. It can be sub-categorized as catastrophic and transitional [8, 9]. Catastrophic phase inversion is initiated by changing the system composition (water-to-oil ratio) through

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