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RESEARCH PAPER

Developing heatable microfluidic chip to generate gelatin emulsions and microcapsules

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Abstract The heatable microfluidic chip developed herein successfully integrates a microheater and flow-focusing device to generate uniform-sized gelatin emulsions under various flow rate ratios (sample phase/oil phase, Q_s/Q_o) and driven voltages. The gelatin emulsions can be applied to encapsulate vitamin C for drug release. Our goal is to create the thermal conditions for thermo-sensitive hydrogel materials in the microfluidic chip and generate continuous and uniform emulsions under any external environment. The gelatin emulsion sizes have a coefficient of variation of <5 % and can be precisely controlled by altering the flow rate ratio (Q_s/Q_o) and driven voltage. The gelatin emulsion diameters range from 45 to 120 μm. Moreover, various sizes of these gelatin microcapsules containing vitamin C were used for drug release. The developed microfluidic chip has the advantages of a heatable platform in the fluid device, active control over the emulsion diameter, the generation of uniform-sized emulsions, and simplicity. This new approach for gelatin microcapsules will provide many potential applications in drug delivery and pharmaceuticals.

Keywords Heatable microfluidic chip · Microheater · Uniform · Gelatin emulsions · Vitamin C

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1 Introduction

In conventional drug release models, drugs are absorbed quickly by the human body, causing the drug concentration in the blood to be higher than the expected dose. The drug concentration in the blood changes dramatically, which can cause the drug concentration to be higher or lower than the effective treatment ranges. Thus, the development of controlled-release drug delivery systems is very important. The use of microparticles with large size distributions can restrict potential applications (Wang et al. 2005; Kikuchi and Okano 2002). Because the microcapsule size and distribution influence the clearance rate from the body and ultimately determine the drug dosage, their control is important for controlled-release drug delivery system (Kikuchi and Okano 2002; Gombotz and Wee 1998). Many biomaterials have been used to form emulsions and microcapsules for the controlled release of drugs, including alginate (Hoesli et al. 2011; Huang et al. 2006a, b; Yeh et al. 2009; Liu et al. 2006), chitosan (Choi et al. 2007; Lan et al. 2010; Yang et al. 2007), poly(lactide-co-glycolides) (PLGA) (Yeh et al. 2012; Hung et al. 2010; Xu et al. 2009), and others (Yeh and Lin 2009). Gelatin is a natural material derived from collagen and is commonly used for pharmaceutical and medical applications because of its biocompatibility, biodegradability, non-toxicity, high drug loading capability, and easy removal in a physiological environment (Kushibiki et al. 2003; Young et al. 2005). To date, gelatin microparticles are mainly generated by spray-drying (Sivakumar and Rao 2003), coacervation (Bruschi et al. 2003), and emulsification (Vandervoort and Ludwig 2004). However, these methods have some disadvantages, including complicated procedures, toxic cross-linking agents, material denaturation due to heat treatment, and a large particle size distribution. Thus, heatable microfluidic