Chitosan-coated nickel-ferrite nanoparticles as contrast agents in magnetic resonance imaging

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Abstract

We report evidence for the possible application of chitosan-coated nickel-ferrite (NiFe$_2$O$_4$) nanoparticles as both T$_1$ and T$_2$ contrast agents in magnetic resonance imaging (MRI). The coating of nickel-ferrite nanoparticles with chitosan was performed simultaneously with the synthesis of the nickel-ferrite nanoparticles by a chemical co-precipitation method. The coated nanoparticles were cylindrical in shape with an average length of 17 nm and an average width of 4.4 nm. The bonding of chitosan onto the ferrite nanoparticles was confirmed by Fourier transform infrared spectroscopy. The T$_1$ and T$_2$ relaxivities were 0.858 ± 0.04 and 1.71 ± 0.03 mM$^{-1}$ s$^{-1}$, respectively. In animal experimentation, both a 25% signal enhancement in the T$_1$-weighted mage and a 71% signal loss in the T$_2$-weighted image were observed. This demonstrated that chitosan-coated nickel-ferrite nanoparticles are suitable as both T$_1$ and T$_2$ contrast agents in MRI. We note that the applicability of our nanoparticles as both T$_1$ and T$_2$ contrast agents is due to their cylindrical shape, which gives rise to both inner and outer sphere processes of nanoparticles.

Keywords: Ni-Fe$_2$O$_4$ nanoparticles, Chitosan coating, Contrast agent for MRI

1. Introduction

Recently, magnetic nanoparticles have attracted a great deal of attention in nanoscience and nanotechnology due to their nanoscale dimensions, nontoxic nature, and superior magnetic properties. Potential applications of magnetic nanoparticles in the field of biomedical sciences, such as protein and enzyme immobilization, bioseparation, immunoassay, drug delivery, and magnetic resonance imaging have been extensively studied [1–7].

For biomedical applications, magnetic nanoparticles must be coated with substances that assure their stability, biodegradability, and non-toxicity in the physiological medium. The surfaces of these particles can be modified through a coating process with biocompatible polymers. The polymer coating is not only responsible for the creation of more hydrophilic nanostructures, but also leads to a variety of surface functional groups to bind drug molecules, inhibit aggregation, and increase stability [8–12].

Chitosan is a natural poly-cationic polymer, which is non-toxic, hydrophilic, biocompatible, biodegradable, and anti-bacterial. It is composed of $\alpha$-glucosamine and N-acetyl-$\alpha$-glucosamine linked by b-(1,4)-glycosidic bonds, and thus has one free amino group and two free hydroxyl groups in the repeating unit. Chitosan and its derivatives have been widely used in many biomedical fields [13–17]. It is being investigated in the pharmaceutical industry for its potential in the development of drug/gene delivery systems [18,19]. In particular, its use in bioimaging applications is gaining much attention. The incorporation of imaging agents enables its use for bioimaging. Several inorganic materials including metals are being incorporated into chitosan composite preparations and their combined characteristics are proving beneficial for biomedical applications [20,21]. Recently the potential of chitosan as a delivery vehicle for a biocompatible MRI contrast agent has been explored. MRI contrast agents enhance the tissue contrast of the area of interest by increasing the relaxation rates of water protons [22–24].

In this paper, we prepared chitosan-coated nickel-ferrite (Ni-Fe$_2$O$_4$) nanoparticles in an aqueous system by chemical co-precipitation. This method is similar to that for coating iron oxide (Fe$_3$O$_4$) with chitosan [21,25]. Our synthesized sample showed good colloidal stability and no precipitate was observed even 30 months after synthesis. We evaluated these coated particles as potential T$_1$ and T$_2$ contrast agents for MRI. We studied T$_1$ and