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In-gel study of the effect of magnetic nanoparticles immobilization on their heating efficiency for application in Magnetic Fluid Hyperthermia

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ABSTRACT

Recent studies on magnetic nanoparticles (MNPs) used for Magnetic Fluid Hyperthermia treatments have shown that Brownian rotation is suppressed when they are confined within a cell. To investigate this effect we conducted a systematic study of the Specific Absorption Rate (*SAR*) of a colloidal suspension of MNPs in water and gels at different agarose concentration. *SAR* measurements were conducted by varying the frequency (f = 110 – 990 kHz) and amplitude (up to 17 kA/m) of the applied alternating magnetic field (AMF). MNP samples with different diameter (d = 10, 14, and 18 nm) were used. Our results show that Néel relaxation dominates *SAR* with negligible contribution from Brownian motion for smaller MNPs (d = 10 nm). For the largest MNPs (d = 18 nm) we observed a more significant *SAR* decrease in gel suspensions as compared to those in solution. In particular, when applying AMFs as the ones used in a clinical setting (16.2 kA/m at f = 110 kHz), we measured *SAR* value of 67 W/g in solution and 25 W/g in gel. This experimental finding demonstrates that investigation of MNPs properties should be conducted in media with viscosity similar to the one found in mammalian tissues.

KEYWORDS

Magnetic Fluid Hyperthermia; Magnetic nanoparticles; Superparamagnetism;
Specific Absorption Rate; Relaxation Times; Brownian motion

1. INTRODUCTION

Hyperthermia is an antitumoral therapy consisting in a temperature rise up to 43°C, with the aim of damaging cancer cells by denaturating their basic molecular structures, such as DNA or enzymes [1, 2]. This aim is achieved for instance by the so-called Magnetic Fluid Hyperthermia (MFH), that employs magnetic nanoparticles (MNPs), with the advantage of producing the temperature rise only within the neoplastic region where they are located. In this technique, colloidal solutions of biocompatible MNPs dispersed in physiological liquids and injected e.g., directly inside the tumour, release heat once exposed to an alternating magnetic field (AMF) operating at safe values of frequency and amplitude [3, 4].
In most cases, for *in vivo* applications, MNPs consist of a magnetic core made of iron oxides, known to have a low toxicity [3, 5], coated by organic biocompatible moieties. The core size is generally so small (the equivalent diameter typically is less than 20 nm) that the MNPs result to be superparamagnetic [1, 6, 7]. In the superparamagnetic regime the MNPs magnetization, also called superspin, can fluctuate between the two opposite directions of the easy axis determined by the magnetic anisotropy, with a characteristic relaxation time, τ_N. According to the Néel model for non-