DOI: 10.1002/chem.200802747

Encapsulation and Sustained Release of Curcumin using Superparamagnetic Silica Reservoirs

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Curcumin is a yellow polyphenol found in the rhizomes of the plant *Curcuma longa.* The compound has shown promise towards wound healing, which is attributed to the presence of myofibroblast, and in enhancing fibronectin and collagen expression.[1] The treatment of wounds with curcumin has been reported to increase the formation of granulation tissue, which includes greater cellular content; neo-vascularisation; and faster re-epithelialisation of wounds.[2] These findings suggest that curcumin may be able to improve radiation-induced wound repair delay. Curcumin has also been reported to show antioxidant,[3] anti-inflammatory,[4] antimicrobial,[5] and anticancer capability.[6] Various animal models or human studies also showed that curcumin is extremely safe even at a dosage as high as 12 g per day.[7] However, all of the above-mentioned properties of curcumin are yet to be fully realised, due to its low water solubility, fast degradation, and poor bioavailability. Oral administration of curcumin at a dose of 2 $g\,kg^{-1}$ to rats, only resulted in a maximum serum concentration of 1.35 (0.23 $\mu g\,mL^{-1}$ after approximately 1 h, whereas in humans the same dose of curcumin resulted in either undetectable or extremely low (0.005 $\mu g\,mL^{-1}$ at 1 h) serum levels.[8] Attempts have been made to encapsulate curcumin in polymeric micelles, lipid-based nanoparticles, and hydrogels in order to improve its water solubility, stability, and bioavailability.[9] However, organic-based carriers such as polymeric nanoparticles, liposomes, and micelles are shown to suffer from poor stability owing to biochemical attack and swelling.[10] On the other hand, silica-based drug-delivery carriers are chemically and thermally more stable, highly hydrophilic, and biocompatible. Furthermore, the high density of silanol groups located at the silica surface (pores and external surface) can be readily treated with coupling agents to provide sites for tethering specific bioactive substrates including antibodies.[11]

Targeted drug delivery offers the advantage to safely and effectively deliver desirable dosages of drugs to specific sites without adverse side effects. One strategy for targeting drug delivery is to use an external magnetic field to guide magnetically labelled drug carriers. For magnetic-targeting drug delivery, a drug or therapeutic molecule is bound to a magnetic material, introduced in the body, and then concentrated in the target area by means of a magnetic field. Such magnetic carriers are an attractive approach for site-specific delivery of drugs with the ability to concentrate them on desired cells or organs by an external magnetic field. They can be subsequently removed after treatment thereby improving the efficiency of the treatment and reducing toxic side effects. Moreover magnetic forces act at relatively long range and magnetic fields do not adversely affect most biological tissues. A few synthetic approaches have been reported for the preparation of magnetic silica particles, such as the use of microemulsions,[12] sol-gels,[13] and backfilling.[14] However, in the case of microemulsions, much effort is required to separate the particles from the large amount of organic surfactants and solvents used. The backfilling method risks clogging the silica pores and consequently resulting in a decrease of available surface area. Block co-polymer templating methods have also been used to develop the internal mesopore structure, while simultaneously incorporating the magnetic nanoparticles into the silica matrix.[15] Here ther-

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Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/chem.200802747.

