PEGylated magnetic nanoparticles conjugated with curcumin for biomedical applications

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Abstract:
Magnetic nanoparticles (MNPs), particularly iron oxides like magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3), and hematite (α-Fe_2O_3), are widely used in biomedical applications due to their biocompatibility, low toxicity, and magnetic properties. Surface modification with polyethylene glycol (PEG) enhances their colloidal stability and hemocompatibility, enabling their use as efficient carriers for magnetically guided drug delivery. This study presents the synthesis and characterization of curcumin-loaded PEGylated MNPs via three distinct wet chemical routes—utilizing one and two-step processes. Curcumin, a pleiotropic bioactive compound with antioxidant, anti-inflammatory, and anticancer properties, was used as the therapeutic model drug. Structural and surface characterizations were performed using XRD, FTIR, and DLS, confirming crystallinity, PEGylation, curcumin loading, and good colloidal stability (zeta potential >30 mV). VSM analysis demonstrated superparamagnetic behavior. In vitro drug release reached 100% within 24 hours for the first two protocols and 36% for the third, while loading capacities were 33%, 7%, and 20%, respectively. Oxidative stress was evaluated through intracellular/extracellular ROS and MDA assays, and low hemolysis tests confirmed hemocompatibility. The integration of mitochondrial activity (MTT assay), lipid peroxidation (MDA levels), and ROS measurements provides a comprehensive understanding of the metabolic and oxidative responses elicited by these nanoparticles. MTT assays indicated high cell viability, while PEGylated curcumin formulations effectively reduced ROS and MDA levels; they also induced a corresponding decrease in mitochondrial activity, particularly at higher concentrations and longer exposure durations. These findings demonstrate the potential of PEGylated, curcumin-loaded MNPs for safe and efficient targeted drug delivery and therapeutic applications.

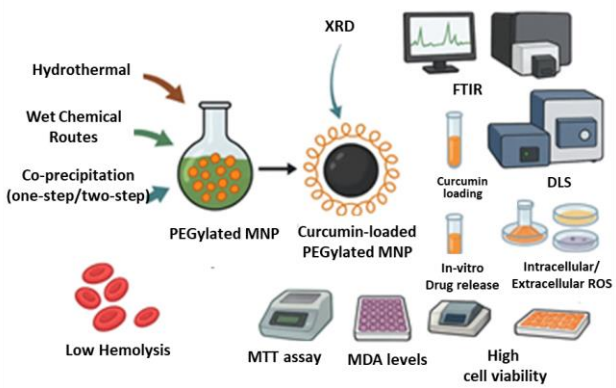

Figure 1: Schematic representation of pegylated magnetic nanoparticles with curcumin.

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