Eco-friendly fabrication and biomedical evaluation of phytocapped iron oxide nanoparticles synthesised using *Morus alba* leaf extract

L. R. Rakshita[1] and Gomathy Baskar[2,*]

[1]Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai 602 105, India

[2]Department of Obstetrics and Gynaecology, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai 602 105, India

Green synthesis of nanoparticles using medicinal plants provides a sustainable and biocompatible route for biomedical applications. *Morus alba* leaves, rich in polyphenolic phytochemicals, act as natural reducing and capping agents, enabling the synthesis of iron oxide (Fe_3O_4) nanoparticles with potential therapeutic properties. Characterisation was conducted using UV-visible spectroscopy, energy-dispersive X-ray spectroscopy (EDX), transmission electron microscopy (TEM), X-ray diffraction (XRD), and Fourier-transform infrared spectroscopy (FTIR). The 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) test was used to assess anticancer activity against the cell lines HepG2 (liver cancer) and MDA-MB-231 (triple-negative breast cancer). Antioxidant potential was assessed by free radical scavenging, and antimicrobial activity was tested against bacterial and fungal pathogens. UV-visible spectra exhibited a distinct absorption peak at 352 nm, while FTIR confirmed the presence of functional groups, indicating phytochemical stabilisation. XRD revealed a crystalline structure. TEM images demonstrated spherical nanoparticles with a uniform size of 10–20 nm, and EDX analysis confirmed the elemental composition. The nanoparticles exhibited strong cytotoxicity, with half-maximal inhibitory concentration (IC_{50}) values of 34.11 μg/mL (MDA-MB-231) and 43.52 μg/mL (HepG2). Antioxidant activity peaked at 54.83% inhibition at 50 μg/mL, while antimicrobial assays revealed greater efficacy against bacteria than fungi. *M. alba*-mediated Fe_3O_4 nanoparticles combine eco-friendly synthesis with significant anticancer, antioxidant, and antimicrobial activity. These findings highlight their promise as a biocompatible nanoplatform for therapeutic applications, particularly in cancer treatment.

CANCER remains a leading cause of mortality worldwide, with hepatocellular carcinoma and triple-negative breast cancer accounting for a significant proportion of cancer-related deaths worldwide[1]. The conventional therapeutic methodologies, such as chemotherapy and radiotherapy, although widely used, often exhibit non-specific cytotoxicity, resulting in off-target effects and substantial damage to healthy tissues[2]. Furthermore, the therapeutic efficacy of conventional anticancer treatments is increasingly compromised by the emergence of drug resistance and the complex heterogeneity inherent to most tumors[3]. Tumour heterogeneity involves genetic and phenotypic variability, leading to varied therapy responses and survival of resistant subpopulations. Resistance mechanisms, like enhanced drug efflux and target mutations, worsen treatment outcomes and promote disease recurrence[4]. These limitations underscore the need for alternative therapeutic strategies that not only enhance efficacy but also improve biocompatibility and reduce systemic toxicity[5].

Advances in nanotechnology have opened new avenues to address the intrinsic drawbacks of conventional cancer treatments. Engineered nanoparticles, typically within the 1–100 nm range, exhibit distinct physicochemical characteristics, such as a high surface-to-volume ratio, tunable surface functionality, and efficient cellular uptake, that are not observed in bulk materials. These nanoscale attributes enable precise interactions with biological systems, offering potential for site-specific drug delivery, enhanced bioavailability, and minimised systemic toxicity[6,7].

Inorganic oxide nanoparticles represent a distinctive category of nanomaterials, characterised by adjustable surface chemistry and functional versatility. They exhibit increased surface reactivity, higher adsorption capacity, and strong interactions with cellular and subcellular structures. For biomedical applications, inorganic oxide nanoparticles were studied for anticancer, imaging, antioxidant, and antibacterial actions. Because of their