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RESEARCH PAPER

Synthesis of $FeCoCrO_4$ Nanoparticles Using ginger and Malva sylvestris Extracts as Green Capping Agents: Investigation Their Magnetic Properties

Hazim Saad Jabbar Al-Maliki [1], Ahmed Ramadhan Abood [2], Raed Muslim Mhaibes [3], Huda Hadi Nameh [4], Zaid H. Mahmoud [5]*

[1] Department of Basic Sciences, College of Dentistry, University of Basrah, Basrah 61001, Iraq
[2] Department of Dentistry, College of Dentistry, Ashur university, Iraq
[3] Department of Biochemistry, College of Medicine, Misan University, Misan, Iraq
[4] College of Pharmacy, University of Hilla, Babylon, Iraq
[5] Chemistry Department, College of Sciences, University of Diyala, Iraq

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ABSTRACT

Ternary metal oxide ($FeCoCrO_4$) nanoparticles were synthesized using simple and straightforward co-precipitation method. Different green extracts from *ginger* and *Malva sylvestris* were used as green capping agents. The composition and phase structure of the synthesized nanoparticles were studied using X-ray diffraction pattern (XRD), confirming the formation of cubic structure. The potential of steric stabilization of the nanoparticles using the used green capping agents reflected in reduction of calculated lattice parameters, average crystallite size, and particle size. The magnetic properties of the synthesized nanoparticles were investigated using vibrating sample magnetometer (VSM), which revealed ferromagnetic behavior. The size dependence of magnetic parameters, including saturation magnetization (M_s), coercivity (H_c), remnant magnetization (M_r), anisotropy constant, and magnetic moment, was determined. The reduction in these parameters was observed for the nanoparticles synthesized in the presence of the green capping agents. The M_s for the aqueous-media-synthesized nanoparticle was 88.9 emu/g, which reduced to the 29.5 and 43.4 emu/g for those synthesized in *ginger* and *Malva sylvestris* extracts, respectively. The decrement of H_c and M_r with reducing of the particle size confirmed the decrease in magnetic domain size as the result of using the green capping agents.

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INTRODUCTION

In recent years, metal oxide nanoparticles have received considerable attention due to their unique physical and chemical properties, especially in terms of magnetic, electrical, and catalytic behavior [1-3]. Among these, mixed metal oxides stand out owing to synergistic effects arising from the combination of multiple metal components, which often result in enhanced thermal stability, improved structural integrity, and superior functional performance compared to

* Corresponding Author Email: raid.mcm@uomisan.edu.iq