

Supplementary Material

Recent developments in the bio-mediated synthesis of CoFe_2O_4 nanoparticles using plant extracts for environmental and biomedical applications

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Table S1. Green synthesis of CoFe₂O₄ nanoparticles using plant extracts and several physicochemical properties (particle size, morphology, bandgap, surface chemistry, magnetization) of green CoFe₂O₄ nanoparticles.

Plant species	Plant tissues	Heating treatment	Calcination time	Surface area (m ² /g)	Particles size (nm)	Morphology	Band gap (eV)	Magnetization (emu/g)	Ref.
<i>Okra (A. esculentus)</i>	Fruit	1000 °C	3 h	-	55	Spherical	1.96	65.31	¹
<i>Okra (A. esculentus)</i>	Fruit	Microwave heating	15 min	-	47	Spherical	2.09	65	¹
<i>Olea europaea</i>	Leaf	700 °C	3 h	-	15–30	Spherical	-	58.55	²
<i>Hibiscus rosa-sinensis</i>	Flower	800°C	1 h	-	18.8	-	-	37.19	³
<i>Verjuice</i>	Fruits	600-800 °C	3 h	-	8-42	Polyhedral	-	81.2	⁴
<i>Hibiscus rosa-sinensis</i>	Flower	1000 °C	3 h	-	56	Spherical	2.06	56.43	⁵
<i>Hibiscus rosa-sinensis</i>	Flower	Microwave heating	15 min	-	43	Spherical	1.87	55.29	⁵
<i>Hibiscus rosa-sinensis</i>	Leaf	300 °C	2 h	-	-	Spherical	2	104.2	⁶

sinensis
fresh

<i>Syzygium aromaticum</i>	Leaf	600 °C	2 h	-	75	Bipyramid	-	-	7
<i>Aloe vera</i>	Leaf	400 °C	3 h	-	50-65	Bud-like	-	72.23	8
<i>Opuntia dilenii haw</i>	-	1000 °C	3 h	-	59	Spherical	2.01	68.76	9
<i>Opuntia dilenii haw</i>	-	Microwave heating	15 min	-	48	-	1.93	77.29	9
<i>Hibiscus rosa-sinensis</i>	Leaf and flower	800 °C	2 h	-	23.85	Spherical	-	-	10
<i>Tamarindus indica</i>	Fruit	500 °C	1 h	-	13	-	-	52.12	11
<i>Aloe Vera</i>	Leaf	220 °C	12 h	-	8	Spherical	-	33.43	12
<i>Moringa Oleifera</i>	Leaf	600 °C	5.5 h	-	6.4	Spherical	3.5	37.6	13
<i>Ginger</i>	Root	800 °C	1 h	-	20–50	Spherical	1.44	-	14
<i>Cardamom</i>	Seeds	800 °C	1 h	-	20–50	Spherical	1.36	-	14

<i>Alhagi maurorum</i> (<i>camelthorn</i>)	-	600-800 °C	-	-	27-58	Bipyramid	3.78- 4.24	66.5- 81.1	15
<i>Lemon</i>	Fruits	700 °C	3 h	-	50-100	Semi- spherical	-	75.7	16
<i>Okra (A. esculentus)</i>	Fruits	600 °C	3 h	-	32-58	-	-	55.8	17
<i>Aloe vera</i>	Leaf	500 °C	2 h	72.1	27	Flake-like	2.1	25.46	18
<i>Aloe vera</i>	Leaf	Microwave heating	10 min	93.5	15	Spherical	2.1	77.62	18
<i>Carissa carandas</i>	Stem	500 °C	2 h	136.0	35	Spherical	4.5	-	19
<i>Erythrina variegata</i>	Leaf	900 °C	3 h	-	30-38	Cubic	1.86	-	20
<i>Bean Pods</i>	Fruit	180 °C	6 h	-	1.8	Spherical	-	-	21
<i>Pedaliium murex</i>	Leaf	Microwave heating	12 min	157.7	42	Spherical	1.76	84.1	22

Table S2. Microbial performance of green CoFe₂O₄ nanoparticles.

Materials	Plant	Applications	Findings	Ref.
CoFe ₂ O ₄	<i>Okra extract</i>	Antimicrobial	Zone of inhibition: <i>Staphylococcus aureus</i> (14 mm), <i>Micrococcus luteus</i> (8 mm), <i>Enterobacter aerogenes</i> (9 mm), <i>Yersinia enterocolitica</i> (16 mm), <i>Aspergillus aureus</i> (9 mm), <i>Candida Krusei</i> (15 mm)	1
CoFe ₂ O ₄	<i>Hibiscus rosa-sinensis</i>	Antimicrobial	Zone of inhibition: <i>Escherichia coli</i> ATCC 8739 (8 mm), <i>Enterococcus faecalis</i> ATCC 29212 (10 mm), <i>Bacillus subtilis</i> ATCC 6633 (6 mm), <i>Candida albicans</i> ATCC 26790 (6 mm) Minimum inhibitory concentration: <i>Escherichia coli</i> ATCC 8739 (62.0 µg/ml), <i>Enterococcus faecalis</i> ATCC 29212 (62.0 µg/ml), <i>Bacillus subtilis</i> ATCC 6633 (62.0 µg/ml), <i>Candida albicans</i> ATCC 26790 (62 µg/ml)	3
CoFe ₂ O ₄	<i>Hibiscus rosa-sinensis</i>	Antimicrobial	Zone of inhibition: <i>Staphylococcus aureus</i> (9 mm), <i>Escherichia coli</i> (12 mm)	6

CoFe ₂ O ₄ @ Ag	<i>Carissa carandas</i>	Antimicrobial	Zone of inhibition: <i>Bacillus subtilis</i> (24 mm), <i>Staphylococcus aureus</i> (17 mm), <i>Pseudomonas aeruginosa</i> (20 mm), <i>Escherichia coli</i> (19 mm)	19
CoFe ₂ O ₄ @ Ag	<i>Piper chaudocanu m</i>	Antimicrobial	Zone of inhibition: <i>Pseudomonas aeruginosa</i> (18 mm), <i>Escherichia coli</i> (20 mm), <i>Staphylococcus aureus</i> (19 mm)	23
CoFe ₂ O ₄ @ Ag	<i>Moringa oleifera</i>	Antimicrobial	Zone of inhibition: <i>Staphylococcus aureus</i> (15 mm), <i>Pseudomonas aeruginosa</i> (17 mm), <i>Bacillus subtilis</i> (22 mm), <i>Escherichia coli</i> (22 mm) Minimum inhibitory concentration: <i>Staphylococcus aureus</i> (25.5 µg/mL), <i>Pseudomonas aeruginosa</i> (28.1 µg/mL), <i>Bacillus subtilis</i> (16.2 µg/mL), <i>Escherichia coli</i> (20.5 µg/mL)	24
CoFe ₂ O ₄	<i>Eucalyptus globulu</i>	Antimicrobial	Zone of inhibition: <i>Staphylococcus aureus</i> (8.5 mm), <i>Pseudomonas aeruginosa</i> (8 mm), <i>Escherichia coli</i> (7.5 mm), <i>Candida albicans</i>	25

(8.5 mm)

Graphite@C oFe ₂ O ₄	<i>Rutin extract</i>	Antimicrobial	Minimum inhibitory concentration: <i>Staphylococcus aureus</i> (6,800 µg/mL), <i>Escherichia coli</i> : 6,900 µg/mL Minimum bactericidal concentration: <i>Staphylococcus aureus</i> (9,400 µg/mL), <i>Escherichia coli</i> (9,100 µg/mL)	26
CoFe ₂ O ₄	<i>Aloe vera</i>	Antimicrobial	Minimum inhibitory concentration: multidrug-resistant <i>Pseudomonas aeruginosa</i> (250 µg/mL), <i>Pseudomonas aeruginosa</i> (500 µg/mL), <i>Escherichia coli</i> (500 µg/mL), <i>Staphylococcus aureus</i> (500 µg/mL), Methicillin-resistant <i>Staphylococcus aureus</i> (500 µg/mL), <i>Candida albicans</i> (750 µg/mL), <i>Candida parapsilosis</i> (1,000 µg/mL)	27
CoFe ₂ O ₄	<i>Sesamum indicum</i>	Antimicrobial	Minimum inhibitory concentration: <i>Enterococcus faecalis</i> (250 µg/mL), <i>Staphylococcus aureus</i> (1,000 µg/mL), <i>Escherichia coli</i> (1,000 µg/mL), <i>Pseudomonas aeruginosa</i> (125 µg/mL), <i>Candida albicans</i> (> 1,000 µg/mL)	28

CoFe ₂ O ₄	<i>Sesamum indicum</i>	Anticancer	Cell viability of HCT-8: 14% (1000 µg/mL)	28
CoFe ₂ O ₄	<i>Torajabin</i>	Anticancer	Half-maximal inhibitory concentration: CaCo2 (1095 µg/mL), MCF-7 (1811 µg/mL), mouse embryo fibroblast cell (2502 µg/mL)	15
CoFe ₂ O ₄ @ Ag	<i>Piper chaudiocanum</i>	Anticancer	Half-maximal inhibitory concentration: HepG2 (68.9 µg/mL)	23
CoFe ₂ O ₄ @ Ag	<i>Carissa carandas</i>	Anticancer	Half-maximal inhibitory concentration: MCF-7 (60 µg/mL)	19
CoFe ₂ O ₄ @ Ag	<i>Moringa oleifera</i>	Antioxidant	Inhibition of 69% DPPH (0.1%) by 1,000 µg/mL	24

*Note: DPPH, 2,2-diphenyl-1-picrylhydrazyl.

Table S3. Performance of green CoFe₂O₄ nanoparticles for removal of pollutants.

Materials	Reducing agent	Pollutant	Pollutant concentration (mg/L)	Catalyst dosage (g/L)	Treatment method	Treatment efficiency	Ref.
CoFe ₂ O ₄	<i>Erythrina variegata</i> extract	Crystal violet	25	0.15	Photodegradation	85.18%	20
CoFe ₂ O ₄	<i>Erythrina variegata</i> extract	Congo red	25	0.15	Photodegradation	79.58%	20
CoFe ₂ O ₄	<i>Carissa carandas</i> extract	Rhodamine B	30	0.01	Photodegradation	77.83% in 35 min	19
CoFe ₂ O ₄ @Ag	<i>Carissa carandas</i> extract	Rhodamine B	30	0.01	Photodegradation	97.42% in 35 min	19
CoFe ₂ O ₄	<i>Torajabin</i> extract	Acid orange 7	20	1.0	Photodegradation	92.1% in 120 min	15
CoFe ₂ O ₄ @ZnO@CeO ₂	<i>Crataegus microphylla</i> extract	Humic acid	250	3.0	Photodegradation	97.2% in 100 min	29
CoFe ₂ O ₄	<i>Hibiscus rosa-sinensis</i> extract	Methylene blue	10	-	Photodegradation	84.0% in 120 min	6

CoFe ₂ O ₄ /Ti O ₂	<i>Moringa oleifera</i> extract	Methylene blue	7	1.0	Photodegra dation	98.7% in 20 min	30
CoFe ₂ O ₄ /Ti O ₂ /rGO	<i>Pedaliium murex</i> extract	Tetracyclin e	20	0.3	Sonophoto degradation	92.0% in 90 min	22
CoFe ₂ O ₄ /Ti O ₂ /rGO	<i>Pedaliium murex</i> extract	Ciprofloxa cin	10	0.3	Sonophoto degradation	84.0% in 90 min	22
CoFe ₂ O ₄ @ Nb ₂ O ₅	<i>Tangerine Peel</i> extract	Paracetamo l	20	0.5	Photodegra dation	97.5%	31
CoFe ₂ O ₄	<i>Ginkgo biloba</i> extract	Congo red	50	1.0	Adsorption	45.7 mg/g	32
Ag- CoFe ₂ O ₄	<i>Taxus wallichiana</i> leaf extract	Pb ²⁺	100	-	Adsorption	33.0 mg/g	33
CoFe ₂ O ₄	<i>Ginger</i> extract	Phenol red	-	1.0	Photodegra dation	91.0%	14
CoFe ₂ O ₄	<i>Cardamom</i> extract	Phenol red	-	2.0	Photodegra dation	74.6%	14

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