Iron oxide nanoparticles synthesized from mixing iron (iii) nitrate salt (Fe2NO3) with (curcumin) herbs extract for antibacterial activity

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Abstract

Curcumin extract and iron (III) nitrate (Fe2NO3) salt were employed in the chemical procedure to create iron oxide nanoparticles (IONPs) at 200 oC for two hours. The environment therapies for hazardous bacteria are the main goal of this study. This research succeeded in synthesis IONPs from mixing iron (iii) nitrate (Fe2NO3) salt with curcumin extract by a chemical method. Moreover, the prepared of the IONPs were applied in the antibacterial activity. Curcuma longa, a medicinal plant and a spice in Asia, has a long history in the region. An ingredient in the C. longa rhizome known as curcumin (diferuloylmethane) is hydrophobic and has been shown to have beneficial effects on the human body. Since then, it has received a lot of attention for its diverse biological and pharmacological effects. X-ray diffraction (XRD) analysis, scanning electron microscopy (SEM), and photoluminescence (PL) spectra were used to characterize IONPs in order to investigate their structural and optical features. In areas inhibition (41) mm reveal the produced IONPs antibacterial activity for negative-gram bacteria (E. coli) and (41) mm negative-gram (K. pneumonia) bacteria.

Keywords: *IONPs; Curcumin herbs extract; Antibacterial activity; Green synthesis.*

1. INTRODUCTION

Pollution, especially after the evolution of life, are one of the difficulties facing humanity and the environment Pollution occurs in its various forms, whether it is air, water or soil pollution as a result of the presence of some materials noxious or organic materials or because the ratio of certain basic substances in the environment is increased or decreased This occurs due to human interference or certain natural events, due to its natural proportions [1-2].

One of the most significant types of nanoparticles is thought to be iron oxide, which has small particle size, vast surface areas, and strong magnetic characteristics. Moreover, photocatalytic for pigment degradation, antibacterial, anti-cancer, antifungal, medicines for delivery, gas sensing and antibiotics are widely applied to iron oxide nanoparticles [3-7].

A reduction, stabilization, and clumping agent, the curcumin extract in the fruit's qualities is a plant-flavonoid called quercetin that is as abundant as curcumin and allows for the

synthesis of a lot of nanoparticles. These herbs can be utilized for environmental therapy and water purification because they contain iron and magnesium as well [8-11]. In Asia, India, China, and other tropical regions, Curcuma longa L. is a rhizomatous herbaceous perennial herb that can grow to a height of three to five feet. Glucosidases have been inhibited by naturally occurring Curcumin, demethoxycurcumin, and bisdemethoxycurcumin [12]. Bisdemethoxycurcumin is the most potent of these naturally occurring chemicals and has an IC50 value of 23 M, two times lower than that of acarbose. According to these findings, the manner of inhibition is noncompetitive. When utilizing p-nitrophenylglycoside as a substrate, the enzyme inhibition activity was measured [13].

In order to create nanoparticles that are affordable, safe, socially acceptable, and economically accessible, scientists have recently found green synthesis and linked it to chemical and physical procedures. The green synthesis technique makes use of biological systems, particularly plant extracts, which are completely toxin-free, yield large quantities of nanoparticles, are quick to synthesize, and don't leave toxic residues behind after use. These include herbs, leaves, seeds, stems, fruits, peels, etc [14-17].

The use of curcumin as a capping and reducing agent for the green iron oxide NPs could open a new door for producing less expensive, cleaner, and more ecologically friendly NPs. Additionally, green synthesis is now given more attention in the business due to the widespread availability of plant materials and their significant therapeutic value. Nanotechnology is projected to be a crucial component in the biomedical sector by preventing and combating diseases via materials on an atomic basis. Iron oxide NPs have recently been shown to demonstrate outstanding biocidal and biostatic effect against bacteria that are gram-positive and gram-negative [18-19].

In this study, iron (III) nitrate (Fe2NO3) salt solution was used to chemically synthesis IONPs from curcumin extract at 300 °C for an hour at (1 and 0.5) M. The Nanotechnology Laboratory and Advanced Materials / Department of Materials Research / The Ministry of Science and Technology used XRDs (XRD6000 Shimadzu, Company / Japan) to characterize the IONPs. SEM via (JAEL JSM-6460LV) and PL spectra are examined using a Jobin Yvon HR800UV spectrometer. Environmentally safe bacterial IONPs were used in a diffusion procedure to further clean the environment.

2. Method and materials

On a local market of the iron (III) nitrate (Fe2NO3) salt solution and the helps (curcumin) from (Baghdad, Iraq). The synthesis of enormous quantities of nanoparticles is made possible by the curcumin extract, which acts as a reduction, stabilization, and clumping agent. All solutions made using distilled water. All the glassware used in this research are made of Borosil.

2.1 Prepared of the (curcumin) herbs extract.

Dishwater washing the herbs (curcumin) and then drying for 2 days under the sunshine. Afterwards, with an electric grinder, the herbs (curcumin) were crushed. In a blending of 5 grams of curcumin the powder will be peeled at 60 oC for 1 hour with 100 ml of distilled water. At room temperatures, the finished solution is cooled and filtered on which type of filter paper [20]. The processes for transferring the herbs

(curcumin) into the extract are explained in figure 1 (A-B).

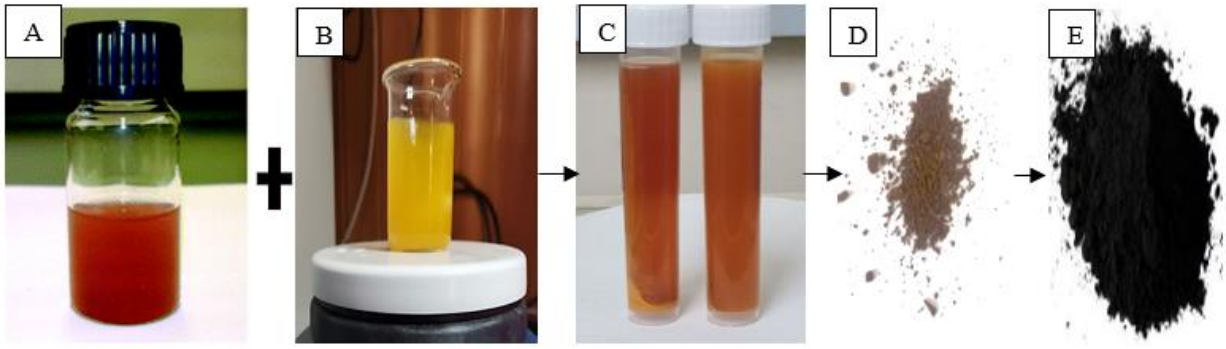
Figure 1 : The explains the phases to prepared of extract, A) curcumin herbs, B) curcumin extract.

A B

2.2 Prepared of IONPs using (curcumin) herbs extract with iron (III) nitrate (Fe2NO3) salt at (1 and 0.5) M.

IONPs are made from mixing the 100 ml of curcumin extract with 100 ml (1 and 0.5) M of iron (III) nitrate (Fe2NO3) salt solution. After that, the solution was heated to 80 °C on a hot plate stirrer for 50 minutes. As the extract (curcumin) is being created, the solution notices how the color swiftly changed from translucent yellow to dark brown, suggesting the IONP form. The end result was a chilled solution that was at room temperature. To create the nano-powder of IONP solutions, the 20 ml IONP solutions have now been placed in pottery with steamed wine and baked at 300 °C for 3 hours. Lastly, the IONP solutions were kept in a sealed serum tube for future analysis. Figure 2 depicts the phases that will be created when (curcumin) herb extract is combined with iron (III) nitrate Fe2NO3 salt solution to create IONPs (A-E).

Figure 2: The explains the phases to prepared of IONPs, A) Fe2NO3 salt solution, B) curcumin extract, C) IONPs (1 and 0.5) M, D) Fe916O NPs (1M) powder, and E) Fe3O4 NPs (0.5M) powder.



2.3 Characterization of IONPs using (curcumin) herbs extract.

The IONPs were characterization for study the crystallite size, pure, and phases by XRD "(XRD6000 Shimadzu, Company/ Japan)" Measures at Iraq's Ministry of Science and Technology's Advanced Materials Department, Materials Research Department, and Nanotechnology Laboratory. The SEM analysis by (JOEL JSM-6460LV) for determined the average grain size and morphology. The edge near band gap was determined by PL measurements are performed at room temperature by using a Jobin Yvon HR800UV spectrometer system. A He-Cd laser

(325 nm) was used as an excitation source for PL for samples that prepared by a simple chemical method using curcumin extract at different conctration (1 and 0.5) M.

2.4 Antibacterial activity of IONPs using (curcumin) herbs extract.

The well diffusion technology has been used to assess the antibacterial activity of prepared IONPs against two type negative bacteria (E. coli and K. pneumonia). New 24-hour crop bacterial pathogens have been developed on agar plates. The standardized (McFarland No. 0.5) inoculum was employed for the antibacterial test. The powder from IONPs was dissolved and sonicated in sterile distilled water. The solution IONPs with a concentration of 30 mg/mL was placed into 2 wells on a platform and baked at 37 °C for 24 hours [22].

3. Results and Discussion

The XRD patterns of IONPs (Fe916O and Fe3O4) NPs prepared from mixing the (curcumin) extract with the Fe2NO3 salt solution by a chemical method at 300 oC for 3 hours, as shown in Figure 3 (A-C). The interest point that is explain descripted through at distinct peaks of (111), (200), (220), and (011) is consistence of Fe2NO3 solution only as shown in figure 3 (A). But, in figure 3 (B) shows the peaks of Fe916O NPs using curcumin extract at (1M) are (200), (220), (311), and (222). Figure 3 (C) explains the peaks of Fe3O4 NPs using curcumin extract at (0.5M) are (111), (220), (311), (222), and (400) [23-29]. Table 1 shows the crystallite size and miller index of Fe2NO3 solution and IONPs. The SEM images was used to determine the morphology and average grain size of Fe2NO3 solution and IONPs (Fe916O and Fe3O4) NPs using (curcumin) extract at (1 and 0.5) M for 3 hours as explain in Figure 4. The morphology and average grain size of Fe916O NPs using curcumin extract at 300 oC are nano-balls structure with ranged from (100.6 to 168.2) nm in figure 4 (B-B1) [30-31]. The morphology and average grain size of Fe3O4 NPs prepared using curcumin extract are inverse cubic structure with ranged from (17.68 to 146.9) nm, as explain in figure 4 (C-C1). In figure 4 (A) shows the morphology and average grain size are nanoparticles structure with ranged 280 nm [32-33]. The band edge gap values of Fe2NO3 solution and IONPs (Fe916 and Fe3O4) were determined via PL spectrophotometer as shown in Figure 5 (A-C). The band edge gap values were from (2.16 to 2.74) eV [34-41].

Figure 3: (XRD) from IONPs at 300 oC for 3 hours, A) iron (III) nitrate Fe2NO3 salt solution, B) Fe916O NPs (1M) using curcumin extract, and C) Fe3O4 NPs (0.5) using curcumin extract.

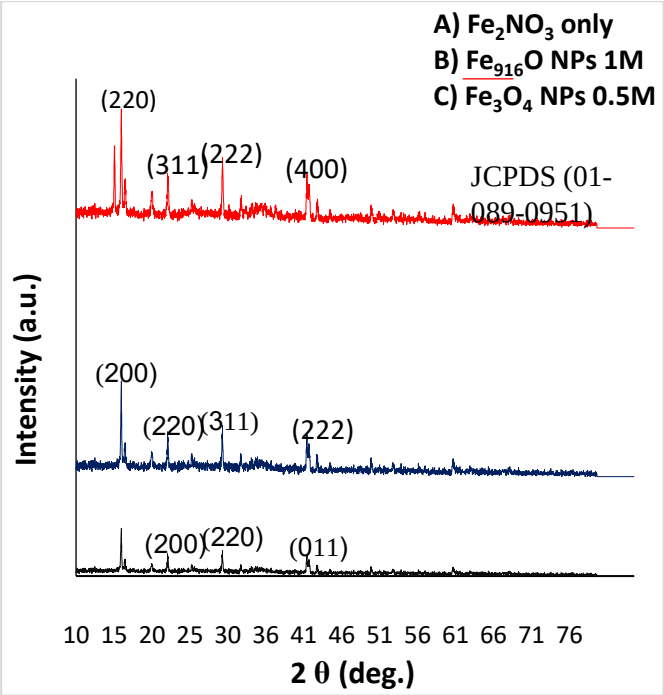


Table 1: X-ray diffraction pattern (XRD) of IONPs (1 and 0.5) M using (curcumin) extract.

Materials	Crystallite size D (nm)	(hkl)
Fe_2NO_3	79	(*111*)
	74	(*220*)
Fe916O	19	(*200*)
	26	(*311*)
Fe3O4	12	(*111*)
	13	(*220*)

Figure 5: Scanning electron microscopy (SEM) images of IONPs at 300 oC for 3 hours, A) Fe2NO3 salt solution, B-B1) Fe916O NPs (1M) using curcumin extract, and C-C1) Fe3O4 NPs (0.5 M) using curcumin extract.

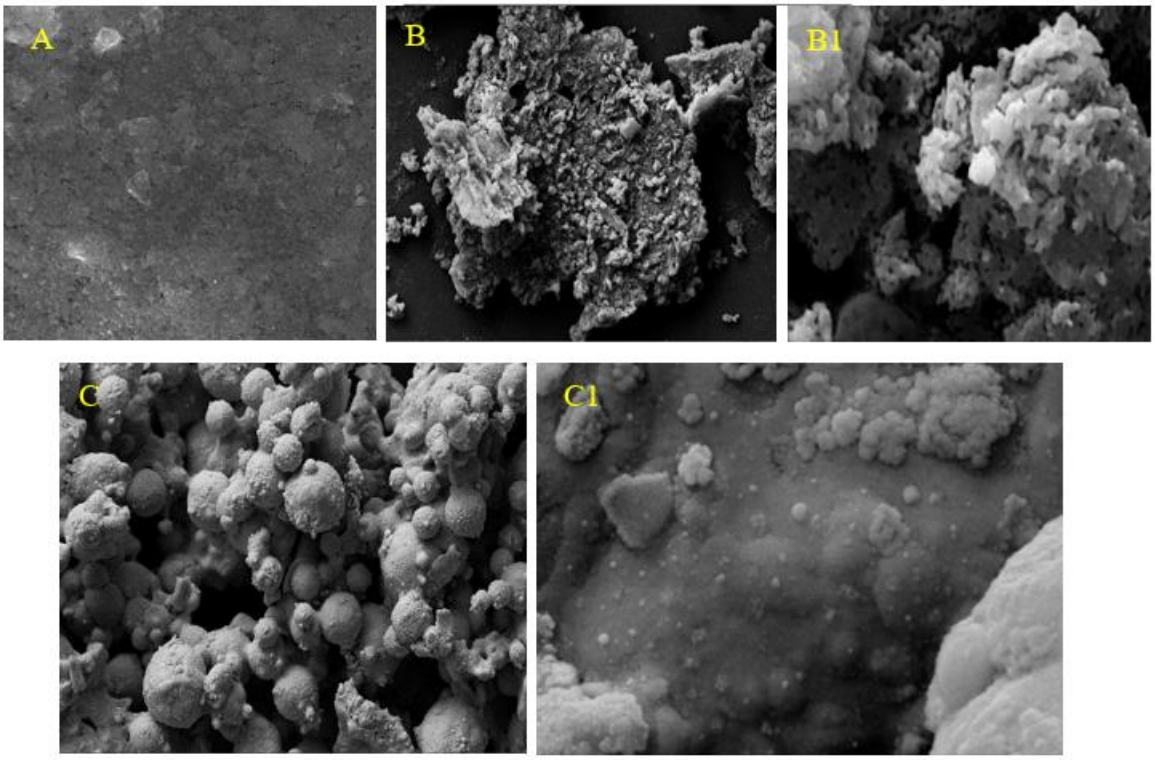
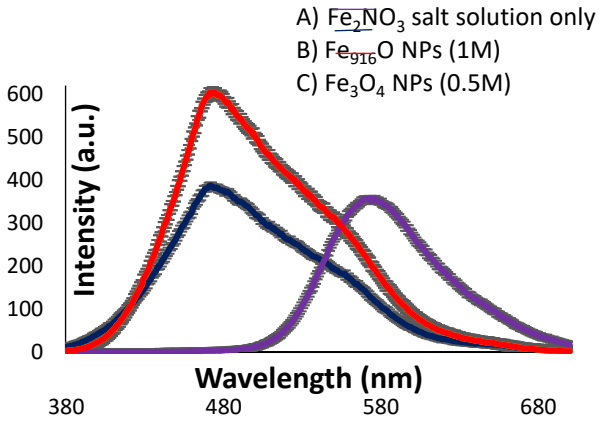


Figure 6: (PL) spectrophotometer of IONPs at 300 oC for 3 hours, A) Fe2NO3 sat solution only, B) Fe916O NPs (1M) using curcumin extract, and C) Fe3O4 NPs (0.5M) using curcumin extract.



3.1 Antibacterial activity test of IONPs using curcumin herbs extract.

The Agar well dissemination technique was used to evaluate the stabilizing anti-bacterial activities of IONPs prepared from mixing Fe2NO3 salt with curcumin extract. Figure 7 shows inhibitory areas for microorganisms. The E. coli and K. pneumonia bacteria, Since they cause foodborne illnesses, pathogenic gram-negative bacteria have been employed to test the antibacterial effectiveness of IONP [36]. For Injected with 30 mg/mL of curcumin extract (1), the Fe2O3 salt solution (2), Fe916O NPs (1M) using curcumin extract (3), Fe3O4 NPs (0.5) (4). Mechanical IONPs are popular with the interaction of bacteria, since the bacterial plasma membrane, negatively charged by electromagnetic attraction, binds to positively charge metal IONPs [37]. Treat the bacteria directly because it oxidizes due to the occurrence of gravity when exposed to IONPs. This method is similar to linking the vesicles' negative loaded lipid membrane to the antimicrobial peptide positively loaded [38-41]. IONPs usually release ions that respond to the bacterial cell membrane and cell lysis with the (-SH) thiol protein groups [25-26]. IONPs that damage their DNA and protein in the bacteria can have antibacterial activity mechanisms through stress oxidation from the oxygen reaction generated by the radicals singlet oxygen (1O2), hydrogen peroxide (H2O2), hydroxyl (-OH) as well as superoxide (O2-) [14, 42-44]. The results from an IONP inhibition zone against 2 bacteria at concentrations of 30 (mg/mL) are shown in Table 2.

Figure 7: Antibacterial activity of IONPs against gram-negative (K. pneumonia) and (E. coli), (1) curcumin extract only (1), Fe2NO3 salt (2), Fe916O NPs (3), and Fe3O4 NPs (4).

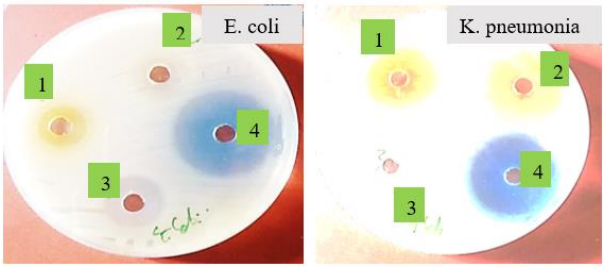


Table (2): results inhibition of zone of IONPs, againts two type nagtive bacteria at 30 (mg/mL) concentrations using curcumin extract.

Material	Gram-negative (-)		Percentage of inhibition zone (%)	
	E. coli	K. pneumonia	E. coli	K. pneumonia
Curcumin	30 mm	23 mm	33.3 mm	25.5 mm
Fe_2NO_3	23 mm	26 mm	25.5 mm	29 mm
$Fe_{916}O$ NPs	29 mm	28 mm	32.2 mm	31 mm
Fe_3O_4	41 mm	41 mm	45.5 mm	45.5 mm

4. Conclusion

Since they cause foodborne illnesses, pathogenic gram-negative bacteria have been employed to test the antibacterial effectiveness of IONP. An ingredient in the C. longa rhizome known as curcumin (diferuloylmethane) is hydrophobic and has been shown to have beneficial effects on the human body. XRD was characterized for the measurements of crystallite size, phase and purity by the iron oxide IONP specimens (Fe916O and Fe3O4) made from curcumin herbs extract. SEM images examination has determined the shape and average size of grain and the aggregation of prepared IONPs. PL spectra show the near band edge values were from (2.16 to 2.74) eV of IONPs (Fe916O and Fe3O4). In areas inhibition (41) mm reveal the produced IONPs antibacterial activity for negative-gram bacteria (E. coli) and (41) mm negative-gram (K. pneumonia) bacteria.

Reference

Taylor, P., Piedra, E., Álvarez, J. R. & Luque, S. Desalination and Water Treatment Hexavalent chromium removal from chromium plating rinsing water with membrane technology. Desalination Water Treat 3994, 37–41 (2015).

Bide, Yasamin, and Soheila Shokrollahzadeh. "Toward tailoring of a new draw solute for forward osmosis process: Branched poly (deep eutectic solvent)-decorated magnetic nanoparticles." Journal of Molecular Liquids 320 (2020): 114409.

Ansari, Mohd Owais, et al. "Iron oxide nanoparticles-synthesis, surface modification, applications and toxicity: a review." Materials Focus 6.3 (2017): 269-279.

Ali, A., et al. "Synthesis, characterization, applications, and challenges of iron oxide nanoparticles. Nanotechnol Sci Appl 9: 49–67." (2016): 6.

Ai, Zhihui, et al. "Facile microwave-assisted synthesis and magnetic and gas sensing properties of Fe3O4 nanoroses." The Journal of Physical Chemistry C 114.14 (2010): 6237-6242.

Zhu, Shishu, et al. "Enhanced hexavalent chromium removal performance and stabilization by magnetic iron nanoparticles assisted biochar in aqueous solution: mechanisms and application potential." Chemosphere 207 (2018): 50-59.

Jin, Xiaoying, et al. "Removal of Cr (VI) from aqueous solutions via reduction and absorption by green synthesized iron nanoparticles." Journal of Cleaner Production 176 (2018): 929-936.

Slman, Dhuha Kadhem, Raghad Dhyea Abdul Jalill, and Ahmed N. Abd. "Biosynthesis of zinc oxide nanoparticles by hot aqueous extract of Allium sativum plants." Journal of Pharmaceutical Sciences and Research 10.6 (2018): 1590-1596.

Al-Kalifawi, Esam J., et al. "Biosynthesis of silver nanoparticles by using onion (Allium cepa) extract and study antibacterial activity." Journal of Genetic and Environmental Resources Conservation 3.1 (2015): 1-9.

Stan, Manuela, et al. "Enhanced photocatalytic degradation properties of zinc oxide nanoparticles synthesized by using plant extracts." Materials Science in Semiconductor Processing 39 (2015): 23-29.

Magro, Massimiliano, and Fabio Vianello. "Bare iron oxide nanoparticles: Surface tunability for biomedical, sensing and environmental applications." Nanomaterials 9.11 (2019): 1608.

Karłowicz-Bodalska, K. A. T. A. R. Z. Y. N. A., Han, S. T. A. N. I. S. Ł. A. W., Freier, J., Smoleński, M., & Bodalska, A. (2017). Curcuma longa as medicinal herb in the treatment of diabetic complications. Acta Poloniae Pharmaceutica–Drug Research, 74(2), 605-610.

Gupta, R., Bajpai, K. G., Johri, S., & Saxena, A. M. (2008). An overview of Indian novel traditional medicinal plants with anti-diabetic potentials. African Journal of Traditional, Complementary, and Alternative Medicines, 5(1), 1.

Saratale, Rijuta Ganesh, et al. "New insights on the green synthesis of metallic nanoparticles using plant and waste biomaterials: current knowledge, their agricultural and environmental applications." Environmental Science and Pollution Research 25.11 (2018): 10164-10183.

Yi, Yunqiang, et al. "Aging effects on the stabilisation and reactivity of iron-based nanoparticles green synthesised using aqueous extracts of Eichhornia crassipes." Environmental Science and Pollution Research 26.27 (2019): 28361-28371.

Eslami, Shahram, Mohammad Ali Ebrahimzadeh, and Pourya Biparva. "Green synthesis of safe zero valent iron nanoparticles by Myrtus communis leaf extract as an effective agent for reducing excessive iron in iron-overloaded mice, a thalassemia model." RSC advances 8.46 (2018): 26144-26155.

El-Kassas, Hala Y., Mohamed A. Aly-Eldeen, and Samiha M. Gharib. "Green synthesis of iron oxide (Fe 3 O 4) nanoparticles using two selected brown seaweeds: characterization and application for lead bioremediation." Acta Oceanologica Sinica 35.8 (2016): 89-98.

Ebrahiminezhad, A., Taghizadeh, S., Ghasemi, Y. & Berenjian, A. Green synthesized nanoclusters of ultra-small zero valent iron nanoparticles as a novel dye removing material. Sci. Total Environ. 621, 1527–1532 (2018).

Machado, S., Grosso, J. P., Nouws, H. P. A., Albergaria, J. T. & DelerueMatos, C. Utilization of food industry wastes for the production of zero-valent iron nanoparticles. Sci. Total Environ. 496, 233–240 (2014).

Abid, Muslim A.; Kadhim, Duha A. (2020). Novel comparison of iron oxide nanoparticle preparation by mixing iron chloride with henna leaf extract with and without applied pulsed laser ablation for methylene blue degradation. Journal of Environmental Chemical Engineering, 8(5), 104138–. doi:10.1016/j.jece.2020.104138

Mariam, B.M.B., Devi, U.C.: Chemical and shelf life analysis of dry garlic powder: a golden herb. Int. J. Agric. Food Sci. Technol. 7(1), 1–6 (2016)

Abid, M. A., Kadhim, D. A., & Aziz, W. J. (2020). Iron oxide nanoparticle synthesis using trigonella and tomato extracts and their antibacterial activity. Materials Technology, 1-8.

Badeenezhad, Ahmad; Azhdarpoor, Aboalfazl; Bahrami, Shima; Yousefinejad, Saeed (2019). Removal of methylene blue dye from aqueous solutions by natural clinoptilolite and clinoptilolite modified by iron oxide nanoparticles. Molecular Simulation, (), 1–8. doi:10.1080/08927022.2018.1564077

Štengl, V., Bakardjieva, S., Grygar, T. M., Bludská, J. & Kormunda, M. TiO2-graphene oxide nanocomposite as advanced photocatalytic materials. Chem. Cent. J. 7, 41–53 (2013).

Shah M. S. A. S., Park, A. R., Zhang, K., Park, J. H. & Yoo, P. J. Green synthesis of biphasic TiO2-reduced graphene oxide nanocomposites with highly enhanced photocatalytic activity. ACS Appl. Mater. Interfaces 4, 3893–3901 (2012).

Song, P., Zhang, X. Y., Sun, M. X., Cui, X. L. & Lin, Y. H. Graphene oxide modified TiO2 nanotube arrays: Enhanced visible light photoelectrochemical properties. Nanoscale 4, 1800–1804 (2012).

Lin, S. X., Shen, C. M., Lu, D. B., Wang, C. M. & Gao, H. J. Synthesis of Pt nanoparticles anchored on graphene-encapsulated Fe3O4 magnetic nanospheres and their use as catalysts for methanol oxidation. Carbon 53, 112–119 (2013).

Krishna R., Titus E., Krishna R., Bardhan N., Bahadur D., Gracio J. Wet-chemical green synthesis of L-lysine amino acid stabilized biocompatible iron-oxide magnetic nanoparticles. J. Nanosci. Nanotechnol. 2012;12:6645–6651. doi: 10.1166/jnn.2012.4571.

Sun X., Zheng C., Zhang F., Yang Y., Wu G., Yu A., Guan N. Size-controlled synthesis of magnetite (Fe3O4) nanoparticles coated with glucose and gluconic acid from a single Fe(III) precursor by a sucrose bifunctional hydrothermal method. J. Phys. Chem. C. 2009;113:16002–16008. doi: 10.1021/jp9038682.

Dorniani D., Hussein M.Z., Kura A.U., Fakurazi S., Shaari A.H., Ahmad Z. Preparation of Fe3O4 magnetic nanoparticles coated with gallic acid for drug delivery. Int. J. Nanomed. 2012;7:5745–5756. doi: 10.2147/IJN.S35746.

Mahdavi M., Namvar F., Ahmad M.B., Mohamad R. Green biosynthesis and characterization of magnetic iron oxide (Fe3O4) nanoparticles using seaweed (Sargassum muticum) aqueous extract. Molecules. 2013;18:5954–5964. doi: 10.3390/molecules18055954.

Awwad A.M., Salem N.M. A green and facile approach for synthesis of magnetite nanoparticles. Nanosci. Nanotechnol. 2012;2:208–213. doi: 10.5923/j.nn.20120206.09.

Senthil M., Ramesh C. Biogenic synthesis of Fe3O4 nanoparticles using Tridax procumbens leaf extract and its antibacterial activity on Pseudomonas aeruginosa. Dig. J. Nanomater. Biostruct. 2012;7:1655–1660.

Makarov V.V., Makarova S.S., Love A.J., Sinitsyna O.V., Dudnik A.O., Yaminsky I.V., Taliansky M.E., Kalinina N.O. Biosynthesis of stable iron oxide nanoparticles in aqueous extracts of Hordeum vulgare and Rumex acetosa plants. Langmuir. 2014;30:5982–5988. doi: 10.1021/la5011924.

Kah Aik Tan; Norhashimah Morad; Tjoon Tow Teng; Ismail Norli; P. Panneerselvam (2012). Removal of Cationic Dye by Magnetic Nanoparticle (Fe3O4) Impregnated onto Activated Maize Cob Powder and Kinetic Study of Dye Waste Adsorption. , 1(none), –. doi:10.1016/j.apcbee.2012.03.015.

Abid, M. A., & Kadhim, D. A. (2021). Synthesis of iron oxide nanoparticles by mixing chilli with rust iron extract to examine antibacterial activity. Materials Technology, 1-10.

Abid, M. A., Latif, L. A., Kadhim, D. A., & Aziz, W. J. (2021, May). Antimicrobial activity by diffusion method using iron oxide nanoparticles prepared from (Rose plant) extract with rust iron. In Journal of Physics: Conference Series (Vol. 1879, No. 3, p. 032068). IOP Publishing.

Aziz, W. J., Abid, M. A., Kadhim, D. A., & Mejbel, M. K. (2020, July). Synthesis of iron oxide (β-fe2o3) nanoparticles from Iraqi grapes extract and its biomedical application. In IOP Conference Series: Materials Science and Engineering (Vol. 881, No. 1, p. 012099). IOP Publishing.

Aziz, W. J., Abid, M. A., & Hussein, E. H. (2020). Biosynthesis of CuO nanoparticles and synergistic antibacterial activity using mint leaf extract. Materials Technology, 35(8), 447-451.

Wu, S., Rajeshkumar, S., Madasamy, M., & Mahendran, V. (2020). Green synthesis of copper nanoparticles using Cissus vitiginea and its antioxidant and antibacterial activity against urinary tract infection pathogens. Artificial Cells, Nanomedicine, and Biotechnology, 48(1), 1153-1158.

Naika, H. R., Lingaraju, K., Manjunath, K., Kumar, D., Nagaraju, G., Suresh, D., & Nagabhushana, H. (2015). Green synthesis of CuO nanoparticles using Gloriosa superba L. extract and their antibacterial activity. Journal of Taibah University for Science, 9(1), 7-12. Shaymaa N. Ismail, Ehab.m. Ali, Bahaa Jawad Alwan, and Ahmed N. Abd," Potassium Chloride Nanoparticles: Synthesis, Characterization, and Study the Antimicrobial Applications" Macromole cular symposia, DOI:10.1002/masy.202100312, Macromol. Symp. 2022, 401, 2100312.

Shaymaa N. Ismail, Bahaa Jawad Alwan, Ehab M. Ali, et al." Preparation of cadmium oxide nanoparticles by green synthesis method for against grampositive and gram-negative bacterial strains" AIP Conference Proceedings 2398, 020053 (2022); Published Online: 25 October 2022.

Shaymaa N. Ismail, Ahmed N. Abd , Osama Abdul Azeez Dakhil " Preparation of ZnO nanoparticles by Electrolysis and evaluation of their antibacterial activity" First International Virtual Conference on Environment & Natural Resources, IOP Publishing, IOP Conf. Series: Earth and Environmental Science 790 (2021) 012081 doi:10.1088/1755-1315/790/1/012081.

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