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Utilizing Camellia Sinensis Extract for the Biosynthesis of Iron Oxide Nanoparticles and Assessing their Antibacterial Effectiveness

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ABSTRACT: In this study, an extract from green tea leaves (Camellia sinensis) was prepared using 5 grams of leaves in 100 ml of distilled water, then the mixture was heated to 80 °C using a magnetic stirrer to obtain the extract for half an hour. After cooling, iron oxide particles were synthesized by adding 0.01 molar iron chloride to 100 ml of distilled water and using a magnetic stirrer for half an hour. The extract was mixed in ratios of 1:1, 1:2, and 2:3 with iron chloride, and the mixture immediately turned black. The results showed that the light absorption of iron oxide particles decreased with increasing ratios, resulting in a shift towards longer wavelengths. The indirect band gap increased from 3.2 eV at a 1:1 ratio to 3.3 eV at a 2:3 ratio, which may be attributed to the confinement effect. X-ray diffraction (XRD) patterns show the amorphous nature of the particles, and crystal sizes were estimated using the Scherrer formula. In terms of surface properties, particle aggregation was observed in the 1:1 and 2:3 ratios, while the 1:2 ratio had a more uniform distribution. The results showed that iron oxide particles have antibacterial activity against Staphylococcus aureus, with a highest inhibition zone at a ratio of 3:2. This indicates their potential in managing infections caused by these organisms.

KEYWORDS: Inhibition of bacterial, iron oxide, green method, tea extract, Gram-positive S. aureus, Optical characteristics, Structural characteristics.

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1. INTRODUCTION

One of the most important technologies of the twenty-first century is nanotechnology. One important advancement in the science of nanotechnology is the creation of new nanomaterials with a variety of uses. Nanoparticles and nanomaterials are produced using both top-down and bottom-up approaches [1,12]. By using a range of mechanical processes to divide the bulk material into nanoscale size, the top-down process produces metal nanoparticles. Metal nanoparticles are produced bottom-up from atoms or molecules to molecular structures of nanoscale size using a range of chemical or biological processes [3,4]. Numerous disciplines, including optics, mechanics, biotechnology, engineering, remediation, microbiology, environmental medicine, and electronics, can make use of these nanoparticles. They range in size from 1 to 100 nm and have a large surface area to volume ratio. [5]. It is interesting to note that because nanoparticles are non-toxic, non-immunogenic, and can be altered to target certain uses, they have a wide range of applications [6]. Bio-nanotechnology techniques have emerged as the main focus of numerous research disciplines in recent years in an effort to create safe nanomaterials with a variety of applications, particularly in a pharmaceutical and biomedical industries [7–9]. As a result, biological methods have been developed where green synthesis offers greater benefits than traditional techniques. According to numerous studies, metal nanoparticles produced using green methods are simple, quick, affordable, nontoxic, environmentally benign, and easily scalable for large-scale synthesis [10–14]. Because iron oxide nanoparticles may interact with a variety of bacterial compounds and prevent the growth of microorganisms, they offer a viable approach to reducing pathogenicity and resistance to antimicrobial drugs [15]. The most stable of the many iron oxide polymorphs is hematite (α-Fe_2O_3), which has strong chemical stability, biocompatibility, tuneable optical and magnetic properties, and anti-corrosive properties that make it affordable and appropriate for a variety of technological applications. Novel nanotechnologies for gas sensors, water splitting, water purification, anticorrosive agents, high-density magnetic storage medium, catalysts, and solar energy conversion were made possible by hematite's advantages [16-18]. In addition, because of their great chemical stability, low toxicity, and biocompatibility, α-Fe_2O_3 nanoparticles are better suited for biomedical applications [19]. Aim of the work biosynthesis of Iron Oxide nanoparticles using Camellia sinensis Extract and evaluation of their antibacterial efficiency.

2. MATERIALS AND METHODS

Green tea (Camellia sinensis) leaf extract was made by heating 5 grams of leaves in 100 milliliters of distilled water to 80 degrees Celsius for 30 minutes with a magnetic stirrer. After cooling, 0.01 molar iron chloride was added to 100 ml of distilled water, and the mixture was stirred with a magnetic stirrer for 30 minutes to create iron oxide particles. When iron chloride was added to the extract in 1:1, 2:1, and 3:2 ratios, the mixture instantly became black. The hue shift happened right away. The supernatant layer was disposed of once the solution was decanted. To get rid of any contaminants, the particles were cleaned twice more and then decanted once more. They were dried for an hour at 60°C in an electric oven. The produced Fe_2O_3 nanoparticles' antibacterial activity against Gram-positive S. aureus bacteria was assessed using Mueller-Hinton agar medium and the conventional zone of inhibition method. Mueller-Hinton broth was used to cultivate the bacterial strain for 16–20 hours at 37°C.

3. RESULTS AND DISCUSSION

3.1 Optical characteristics

3.1a. The optical absorption

The optical absorption spectra are displayed in Figure 1. of composite Fe_2O_3 nanoparticles at different material ratios. The variation in absorption may result from the variation in the concentration of nanoparticles within the solution. As the absorption decreased with increasing material ratios, the edges of the optical absorption shifted toward longer wavelengths (red shift) this behivour close to obtained by [20].

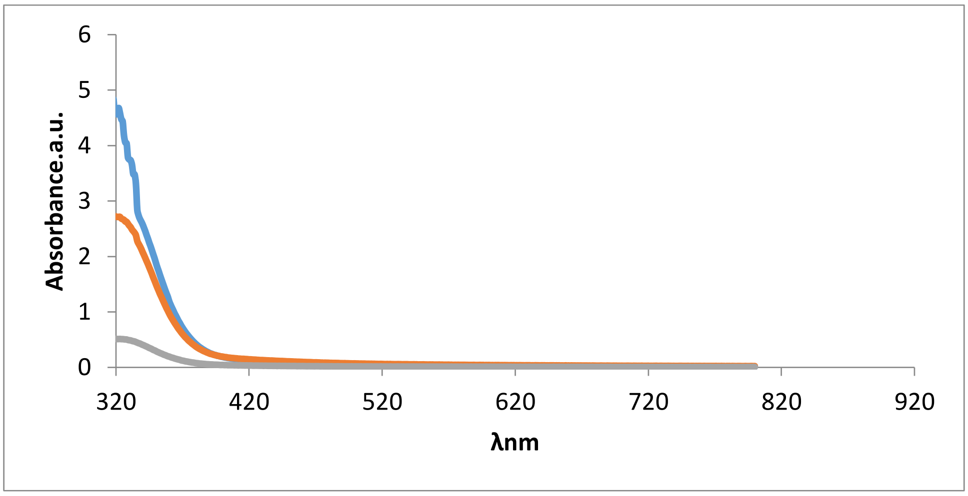

Figure 1: optical absorption spectra of composite Fe_2O_3 nanoparticles at different material ratios

3. 1.b Optical bandgap

The indirect optical bandgap of the Fe_2O_3 NPs shown in Figure 2. was increased from 3.2 in 1:1, 3.25 in 1:2 eV to be 3.3 eV in 2:3. this behivour close to obtained by [20] which might be attributed to the confinement effect [20]. A bandgap of an examined samples can be evaluated by Tauc's relation as following [21]:

$$\alpha h\upsilon = C\,(h\upsilon - E_g)^{x} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

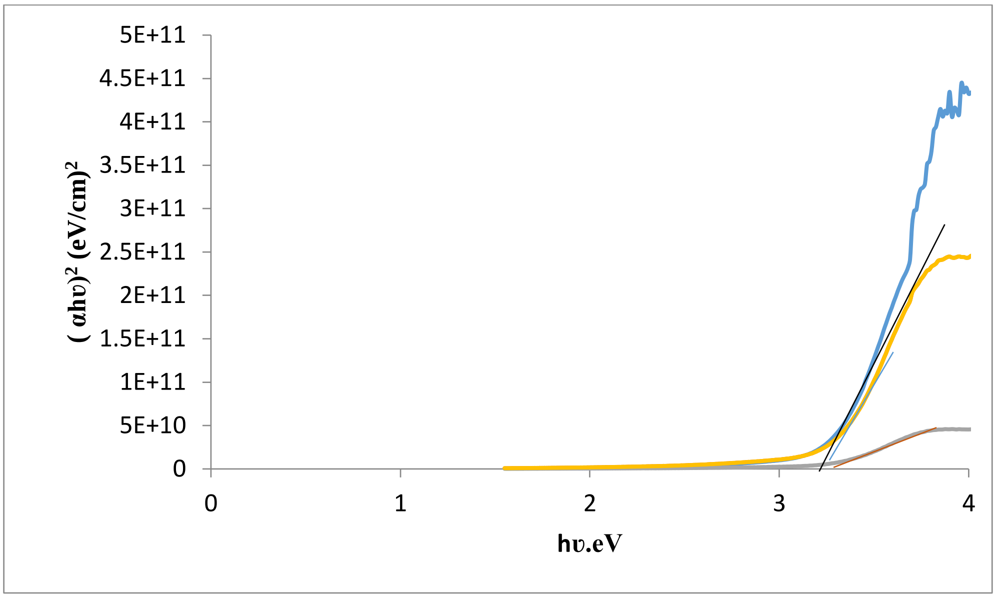

Figure 2: optical bandgap of composite Fe_2O_3 nanoparticles at different material ratios

3.2 Structural characteristics

Figure (3a,3b,3c). The XRD pattern of the sample shows an amorphous nature, characterized by the absence of sharp peaks. This pattern is explained by the tiny size of the nanoparticles formed by the green method and their coating with organic compounds extracted from green tea, which inhibits long-term crystalline arrangement. The crystallite size has been evaluated using Scherrer's formula based on information obtained from the XRD patterns [22,23].

$$D = (K\ \lambda) / (\beta\ COS\theta) \ .... \qquad (2)$$

The size of the crystals varies according to the proportions of the manufactured samples, as shown in Table 1.

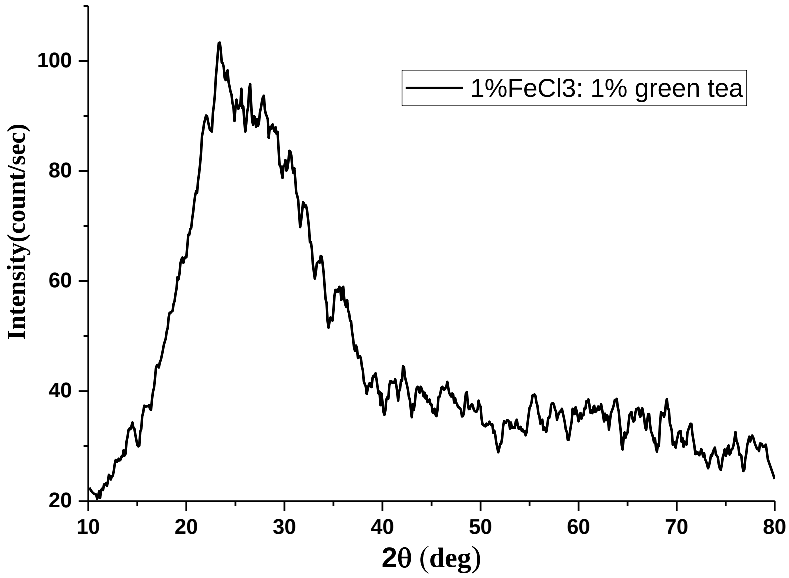

Figure 3a: X-ray diffractograms of the synthesized Fe_2O_3 nanoparticles in 1:1

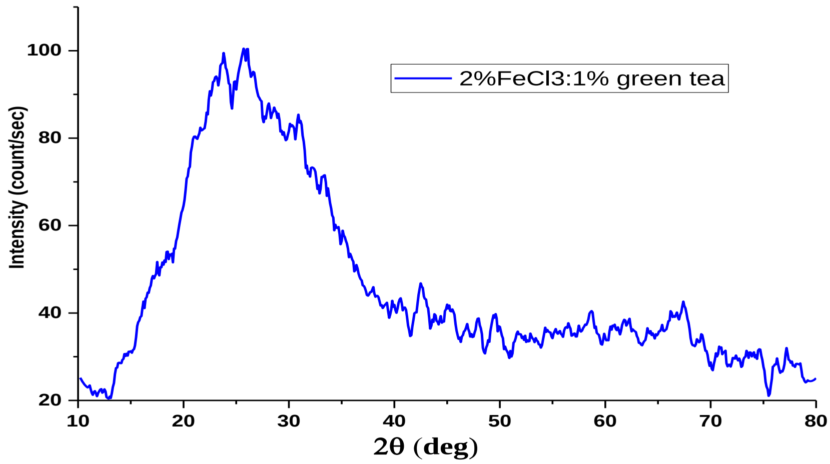

Figure 3b: X-ray diffractograms of the synthesized Fe_2O_3 nanoparticles in 2:1

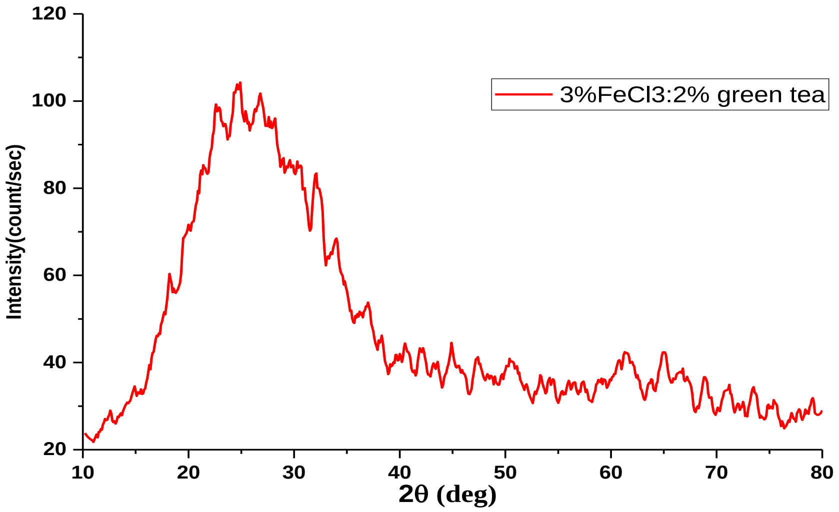

Figure 3c: X-ray diffractograms of the synthesized Fe_2O_3 nanoparticles in 3:2

Table 1: X-ray diffractograms of the synthesized Fe_2O_3 nanoparticles

2Θ	I%	FWHM	D nm	hkl
22.129	94.4	0.195	42.2	012
23.657	100	0.534	15.4	104
28.272	91.6	0.433	19.2	110
43.033	42.1	0.202	42.8	113
43.894	47.7	0.163	53.2	202
55.345	41.1	0.323	28.4	024
66.269	43.9	0.175	55.4	116
77.483	35.5	0.187	55.9	300
23.931	100	0.182	44.6	012
42.104	45.5	0.34	24.9	113
49.800	37.5	0.57	15.3	024
51.750	42	0.159	55.3	116
32.24	100	0.252	32.8	110
33.719	83	0.214	38.7	104

3.3 FESEM of iron oxide nanoparticles

Figure (4a,4b,4c) illustrates the surface morphology of iron oxide nanoparticles synthesized using the green method at different ratios, with the aqueous solution then deposited onto a glass slide by distillation. Figure 4a,4c demonstrates that the iron oxide nanoparticles prepared at 1:1 and3:2 ratios aggregate into larger crystals, and the surface of the samples appears free of any microscopic holes or cracks. In contrast figure 4b, the 1:2 ratio results in a more homogeneous distribution and smaller particle size, this behivour close to obtained by [20].

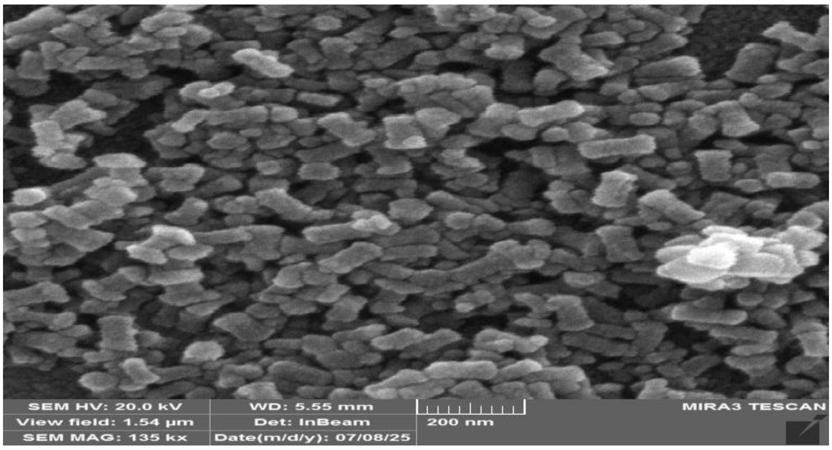

Figure 4a: Surface morphology of iron oxide nanoparticles in 1:1.

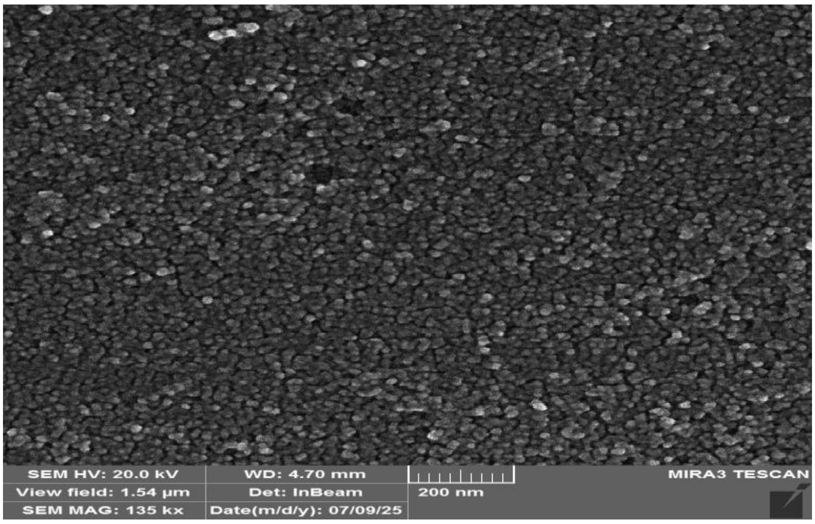

Figure 4 b: Surface morphology of iron oxide nanoparticles in 2:1.

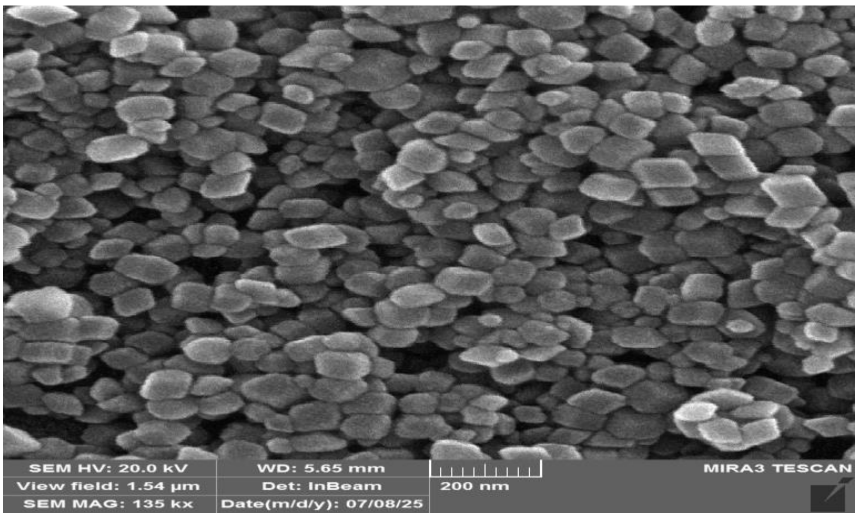

Figure 4c: Surface morphology of iron oxide nanoparticles in3:2.

3.4 The iron oxide nanoparticles' EDS spectrum

Strong oxygen (O) peaks in the EDS spectrum of iron oxide nanoparticles made with green tea extract verify that oxygen (O) is the main element present (Figure 5a,5b,5c). Furthermore, oxidation-induced iron oxide production is suggested by oxygen (O) peaks. O (60.30 wt%) and Fe (39.70 wt%) are shown by EDS quantification.

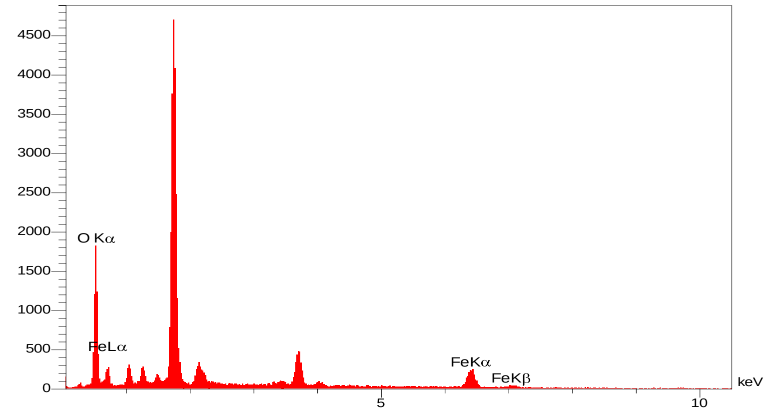

Figure 5a: the EDS spectrum of iron oxide nanoparticles in 1:1.

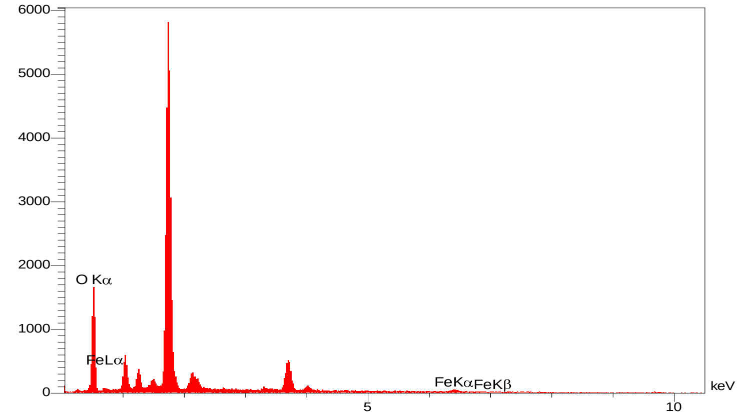

Figure 5b: the EDS spectrum of iron oxide nanoparticles in2:1.

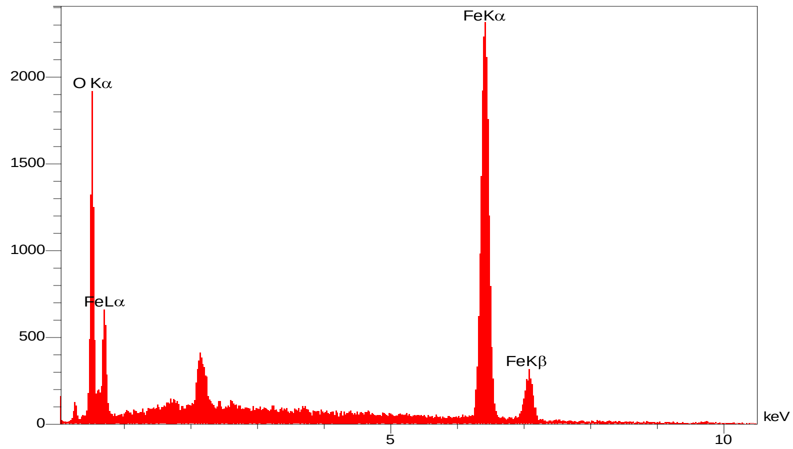

Figure 5c: the EDS spectrum of iron oxide nanoparticles in3:2.

4. ANTIBACTERIAL CHARACTERISTICS

A plate of the Gram-positive bacterial strain Staphylococcus aureus is displayed in Figure 6, along with the organism's zone of inhibition at different iron oxide nanoparticle (IONP) concentrations. Agar diffusion method used to measure an inhibition zones in millimeters. The measured diameters varied overall. The most sensitive Gram-positive bacterium was S. aureus, which showed greater activity for iron oxide nanoparticles made with green tea extract at a 3:2 ratio than for the other ratios. Additionally, it was discovered that the concentration and the inhibition zone were closely proportionate.

Figure 6: zone of inhibition of the strain at varying concentrations of iron oxide nanoparticles

CONCLUSION

Green tea leaves were employed to produce iron oxide nanoparticles. is an economical and ecologically good way to create nanoparticles without harming the environment. S. aureus was prevented from growing by these iron oxide nanoparticles. Consequently, It makes sense to suggest that iron oxide nanoparticles could be used to treat diseases and infections caused by these organisms. A highest differentiation of Fe_2O_3 nanoparticles with green tea was best prepared chemically in a straightforward and understandable manner, and the best suppression of Staphylococcus aureus bacteria was obtained when green tea extract was present at a ratio of 3:2.

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