Journal of Optoelectronic and Biomedical Materials Vol. 17, No. 1, January - March 2025, p. 25 - 34

A comparative study of nickel oxide prepared by beta vulgaris extract and chemical method as antibacterial and antifungal

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The green synthesis method and the simple chemistry method, these two different ways were both successful in making nickel oxide (NiO) nanoparticles. X-ray diffraction, SEM, AFM, UV–vis absorption spectroscopy, and Fourier transform infrared spectroscopy were used to describe the NiO samples. The films had a pure cubic shape, and their average size was about 16.80 nm for NiO (green method) and 29.61 nm for NiO (simple chemical method). According to the data, the different methods had a real effect on the surface shape of the films. The NiO film made with the green method is denser and has smaller grains than the NiO film made with the chemical method. By using a green synthesis and a chemical method, the NiO particles were found to be 29.36 nm and 38.09 nm in size as appear SEM. It was found that the energy gap for NiO NPs was 3.75 eV for the plant extract method and 3.5 eV for the chemistry method. At 524,672 cm^{-1}, the band can be found Ni–O is stretching, . Finally, the antimicrobial activity study showed that NiO NPs are very good at killing germs. As a result, this study shows strong antimicrobial action that could be looked into further in future clinical interventions.

(Received November 20, 2024; Accepted February 4, 2025)

Keywords: NiO, Beta vulgaris, Simple chemical method, Green synthesis, Anti-bacterial Activity, Candida

1. Introduction

Many biomedical experts are very interested in materials made from nanoparticles (NPs). NPs that can be used as antimicrobial agents are very important because they can kill harmful microorganisms [1]. . Nanoparticles can be used to make medical devices like biosensors, wound dressings, and carriers for medications. NPs are also very small particles. A bigger surface area-to-volume ratio makes a big difference in how well they conduct electricity, biologically, mechanically, and electrochemically. Because of these traits, metal oxide nanoparticles (NPs) can be used for many applications [2,3]. Nickel oxide nanoparticles (NiO NPs) also have unique electrical, magnetic, and chemical properties. The band gap for NiO is between 3.6 and 4.0 eV, and it is a p-type semiconductor transition metal (TM) oxide. NiO nanoparticles are also good at killing germs. Many physical and chemical methods can be used to make NiO NPs, such as electrospray synthesis, anodization, galvanostatic, laser ablation, the sole-gel method, and electro-deposition. Green synthesis methods are being looked into as a possible way to reach this goal. Compared to the traditional physical and chemical methods we've already talked about [4-6], green synthesis techniques are better for the environment, don't produce waste, and use less energy. Scientists are interested in green synthesis of nanoparticles because it is quick, cheap, safe for the environment, and can be used for a long time [6–10]. In the green method, the Beta vulgaris was used as reducing and capping agents. As far as we know, no one has written about the green synthesis of NiO NPs using Beta vulgaris in this setting. The type of plant Beta vulgaris is in the Chenopodiaceae family. Beta vulgaris is a plant that has been used to treat heart problems and has been known to fight cancer, make you feel full, help with menstruation, stop bleeding, and protect your kidneys. It can lower blood sugar, lower blood pressure, and fight free radicals. A lot of study has been done on beta vulgaris's ability to protect the liver and reduce inflammation [11]. In this paper, also we report on the preparation of NiO nanocrystals by a green synthesis and simple chemical method using aqueous

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https://doi.org/10.15251/JOBM.2025.171.25

solution of nickel Nitrate and sodium hydroxide, in order to compare between results green synthesis and simple chemical method.

2. Experimental

The Beta vulgaris plant was bought in Baghdad, Iraq, at the Al-Adhamiya market. This plant was cleaned with pure water and then cut up into small pieces. An orbital shaker was used to mix 14 grams of Beta vulgaris with 100 millilitres of distilled water and stir it for one hour. The mixture was filtered through a Whatman filter paper No. 1 to get the watery extract, which is also called the filtrate. It was then kept at 4°C until it was needed [22]. 1.82 grams of $Ni(NO_3)_2.6H_2O$ was mixed with in 100 millilitres of distilled water, and then it was put on a magnetic mixer that was set to 70°C for one hour. Add beta vulgaris extract until the colour stops changing. Twenty millilitres of extract is the right amount to stop the colour change. For the easy chemistry method, 0.1 M of Ni $(NO_3)_2.6H_2O$ and 0.1 M of NaOH pellets were dissolved in 100 mL of distilled water, one after the other. The $Ni(NO_3)_2.6H_2O$ solution was put on a hot magnetic stirrer that was set to 70°C, adding 20 millilitres of NaOH solution for hour until the solution became cloudy. . So, the green solution was made, and the salts were taken out by washing it with distil water over and over again.

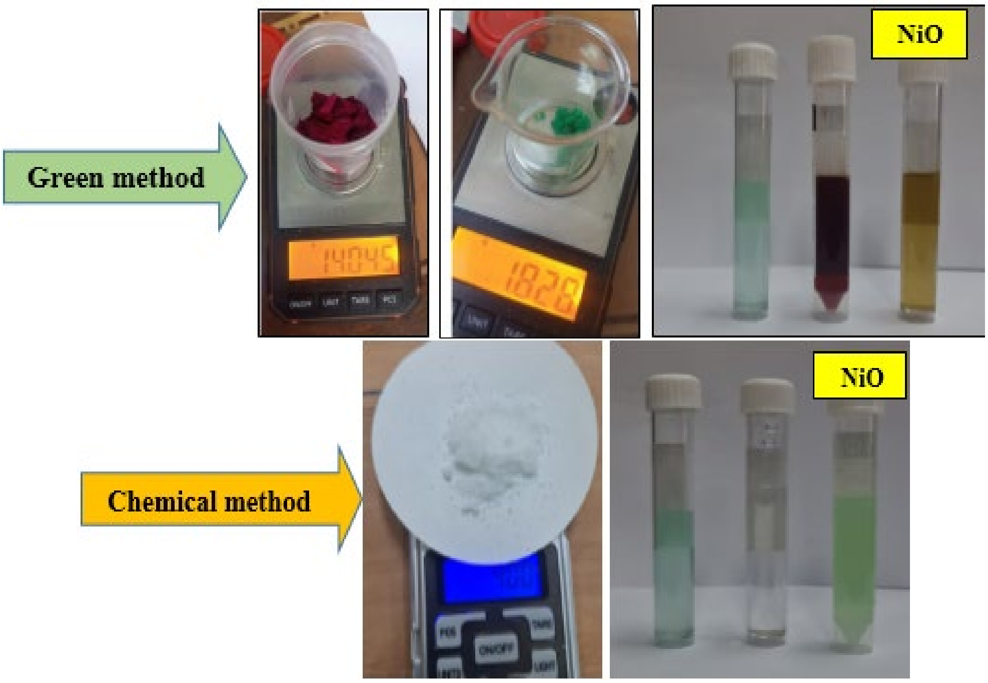

Fig. 1. Preparation of NiO by green synthesis and simple chemical method.

3. Antimicrobial activity

That tested the antibacterial effects of NiO nanoparticles made in different ways (chemical and green) against different types of bacteria and on strain of fungi (Candida albicans). A 100 µg/ml dose of NiO-NPs was added to the wells after the wells were made on the 6 mm agar plate. Incubation took place at 37 °C for 24 hours and determined of zone of inhibition (ZOI) by millimeter.

4. Results and discussion

In the, range of 20° to 90°, as shown in Fig. 2, the NiO films' X-ray diffraction pattern was found with different methods (chemical and green). The films in question had a pure cubic structure. The planes peaks (111), (200), and (220) in XRD diffraction results are in good agreement with (JCPDS-files-NO.711179). There was a peak at 2¸= o 44.66 and 51.9, which was caused by nickel (111) and (200). When NiO film was made using a simple chemical method, the XRD peaks were clearer. This meant that the crystal size was bigger than when NiO was made using green synthesis [12,13]. The average size of NiO (green method) was about 16.80 nm and that of NiO (simple chemistry method) was about 29.61 nm. Table1display results of XRD of NiO film.

$$D= (0.9 * \lambda) /(\beta * \cos\theta) \qquad (1)$$

β: is the full Width at half maximum and θ: is a degree of the diffraction.

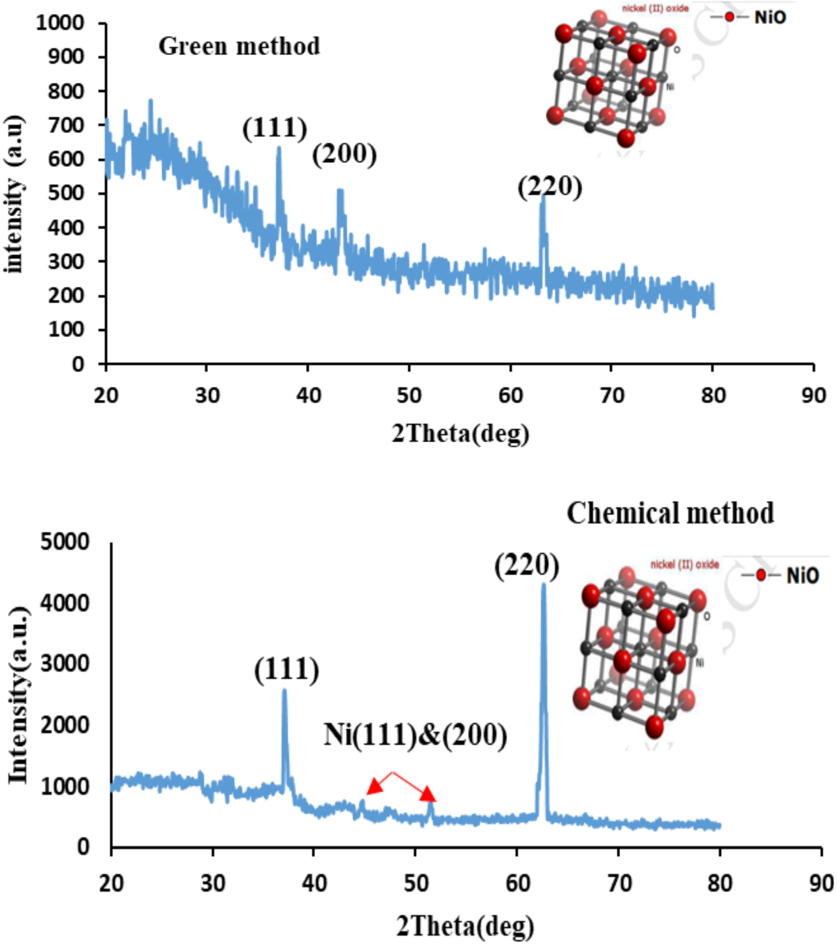

Fig. 2. XRD analysis of NiO films.

Table 1. Result of XRD of samples.

Method	2Theta(deg)	B(deg)	Cryslline size(nm)
Green synthesis	37.14	0.50	16.80
	43.34	0.60	14.27
	63.09	0.30	31.12
Simple chemical	37.09	0.31	27.09
	44.74	0.10	86.09
	51.64	0.20	44.21
	62.69	0.30	31.05

AFM was used to look at the surface morphology of the films in order to learn more about the surface topography. The AFM scans for NiO (green method) and NiO (simple chemistry method) were taken on a scale of 2 × 2 µm2. These are shown in Figure 3(a,b). According to the data, the different methods had a real effect on the surface shape of the films. The NiO film made with the green method is denser and has smaller grains than the NiO film made with the chemical method. There are grains in both films, which look like domes of different colours. White domes are formed when small particles stick together and grow at different heights and away from the substrate. The highest point of NiO-green was 50.60 nm, and the highest point of NiO-chemical was 89.68 nm. All of the surfaces were analysed and found to be uneven on a nm scale and not smooth. The average roughness of NiO (green method) and NiO (simple chemical method) was 3.91 nm and 5.35 nm, respectively. We have also used AFM to find out how the particle sizes in NiO samples are distributed. The average size of the grains was between 139 and 239 nm for NiO (green method) and NiO (simple chemistry method).

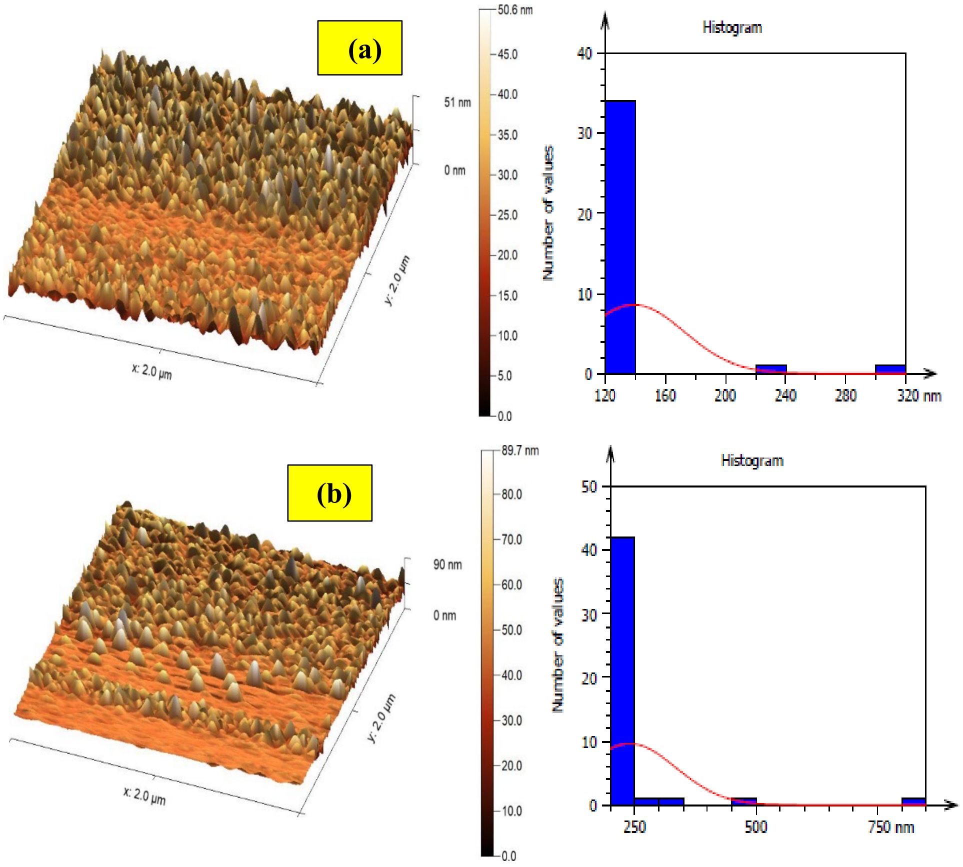

Fig. 3. AFM image of the synthesized NiO films at different method.

Fe-SEM was used to look at the surface morphology of the nanoparticles that were made. The SEM pictures (scaled at 200 nm) for NiO (green method) and NiO (basic chemistry method) can be seen in Figure 4(a,b). Figure 4(a) shows that the particles are very grouped together with size of particles were 29.36 nm in size, which is in the nano-range. Ultrafine NiO nanoparticles have a high surface energy and high surface tension, which makes them clump together. This is likely why there are some bigger nanoparticles present. The SEM picture shows that the nano-ranged size was 38.09 nm using the chemical method, and the shape of the particles shows that they are mostly round and oval, as shown in Figure 4(b).

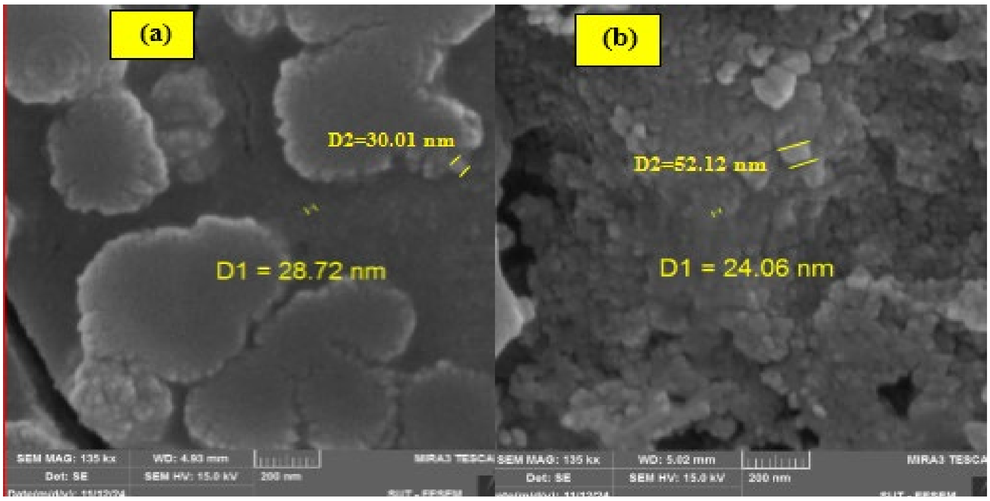

Fig. 4. SEM image of the synthesized NiO-NPs at different method.

In Figure 5, you can see the absorption spectra of the NiO NPs that were made using the chemical and green methods. Between 200 and 1100 nm was the range of wavelengths that the NPs showed at room temperature. It was found that both samples have a high absorption between 200 and 400 nm and a very high transmittance above 400 nm. The solution is exceedingly light and uniform, as shown by its amazing transparency. The unique surface plasmon resonance (SPR) band could be seen in the NiO-NPs that were made using green synthesis between 308 and 395 nm. This matched up with what another study [14] found. NiO did not show surface plasmon resonance when it was chemically made may be because the particles were large. To find the band gap, the standard Tauc's relation (eq. 2) was used.

$$[(ahv)^{1/n} = A(hv\ \ Eg)] \tag{2}$$

hv, A, and n are the energies of the photons that hit the surface, a constant, and Any kind of electronic transition can cause absorption, and the exponent number can be either 1/2 or 2. This is because direct and indirect transitions are different. The optical band gap for the absorption peak can be found by extending the straight line part of $(\alpha hv)^2$ versus hv to zero, as shown in figure 6 [14,15]. The E_g for NiO nanoparticles was found to be 3.75 eV for a plant extract and 3.5 eV for a chemical method. The energy gap is linked to the particle size measurements, as we can see. The energy gap gets bigger as the particle size goes down.

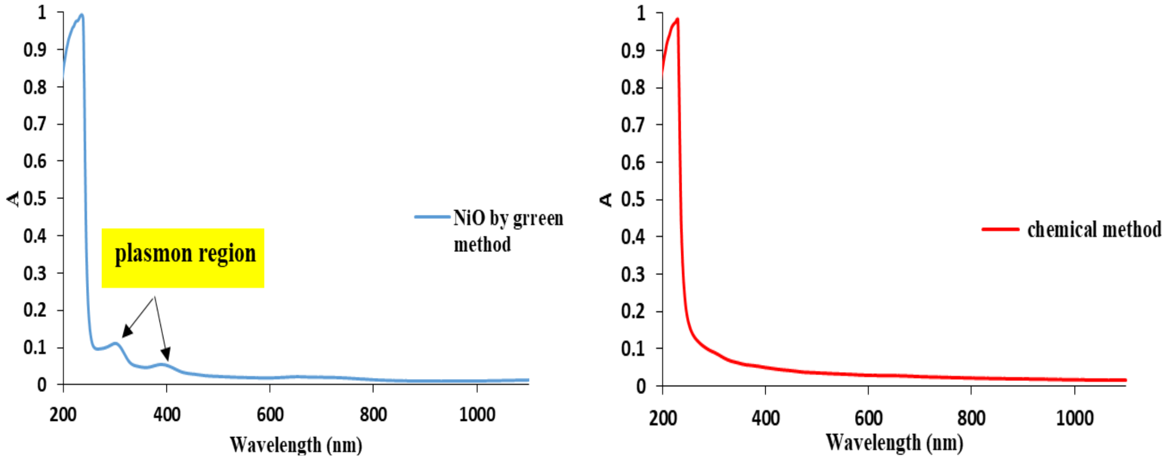

Fig. 5. Absorption spectrum of NiO by different method.

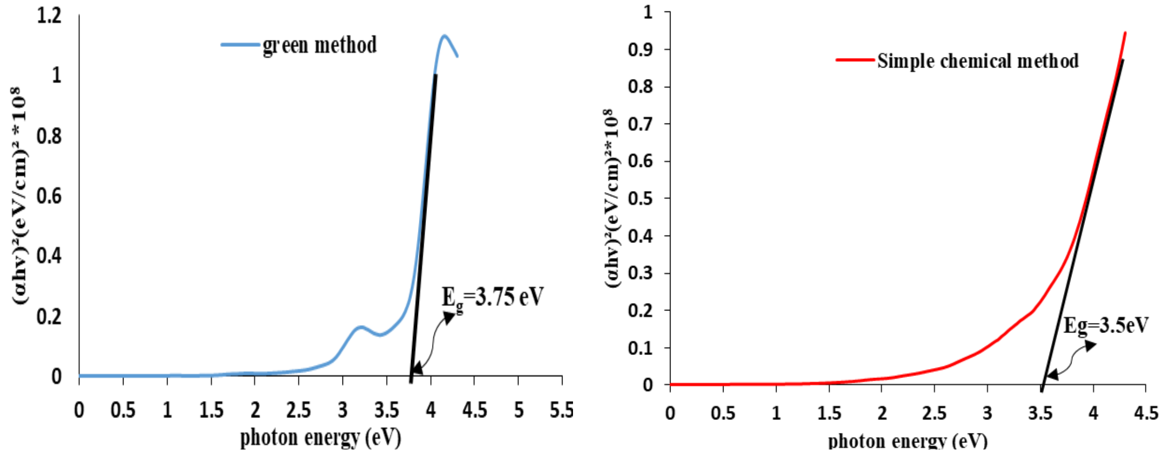

Fig. 6. Tauc's relation to determined energy band gap of NiO nano-particles at different method.

We can see from the X-ray diffraction, SEM, and AFM of NiO made by green synthesis that the crystals are smaller than those made by chemical method. The high-energy gap and surface plasmon show that the particles made by the plant method are very small. In medical uses, it preferable to use small particles because they can get through the cell wall of microbes more easily. The preliminary data suggest that the green synthesis can activity better. In the FTIR spectra of NiONPs that were collected in two different ways (chemical and green) (Fig. 7), a clear band at 524,672 cm^{-1} was seen in the 400–4400 cm^{-1} range. This sharp band is caused by the stretching of Ni–O, according to [31]. The peak at 3404, 3440, 1633, and 1644 cm^{-1} showed that the hydroxyl group of alcohols or phenols was present. The absorption peak at 2927 and 2961 cm^{-1} may be caused by the -CH stretching vibrations of the -CH2 and -CH3 groups. Another peak at 2429, 1125, and 1385 cm$_{-1}$ showed the C=O, C-O bending, and N-O groups [16–19]. In the green method, the spectrum of nickel oxide by Beta vulgaris extract is stronger at the peak that goes back to OH , this proves that there are a lot of phenols, which raises the production of free oxygen radicals and hydroxyl radicals that kill cells. Also, the green way has a bigger vibration peak that shows the presence of nickel oxide. This is because the particles are smaller, which speeds up the absorption process.

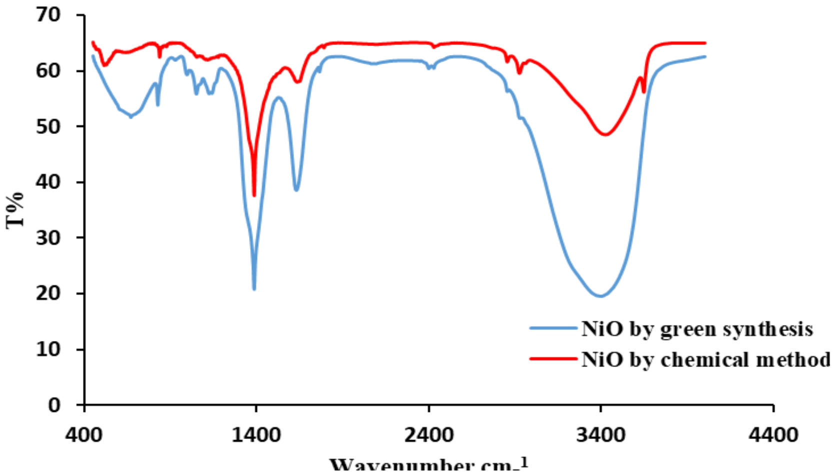

Fig. 7. FT-IR spectra of NiO nano-particles at different method.

The growth of microbes was tested using the agar well diffusion assay in culture media that had the same amount of NiO-green technique and NiO-simple chemical method nanoparticles, as shown in fig8. There was a range of antimicrobial effects different, because different oxidation and reduction agents were used in the process. The results shown in Table 2 show that NiO NPs (green method) were better at killing bacteria than NiO-NPs (simple chemical approach). The effect rate is different for G+ve and G-Ve bacteria because their cell walls are built in different ways. Some it thinks that NiO-NPs are harmful by two way they speed up or slow down cellular processes in host cells. When microbial strains and nanoscale materials come into touch with each other electrically, reactive oxygen species are made. It is thought that reactive oxygen species kill microbes. nanomaterials and microbial types could work together in two ways. In the first potential reaction, Ni $^{2+}$ ions and the negatively charged parts of the bacterial cells interact strongly, breaking down the cells. In the second potential reaction, O_2 goes through another electric reaction that makes O^{-2} radicals. This makes H_2O_2. The reaction between H^+ and water makes $^{\bullet}OH$. These new species ($O^{-2\bullet}$ and •OH) are very important for breaking down lipid or protein molecules on the outside of cells [36, 37]. Therefore, the antibacterial effects of nanoparticles come from Ni 2+ ions that come from NiO nanoparticles. Ions are released to help with oxidative stress, which makes the barrier more permeable. Because of this reactive stress, the cells die [20–24].

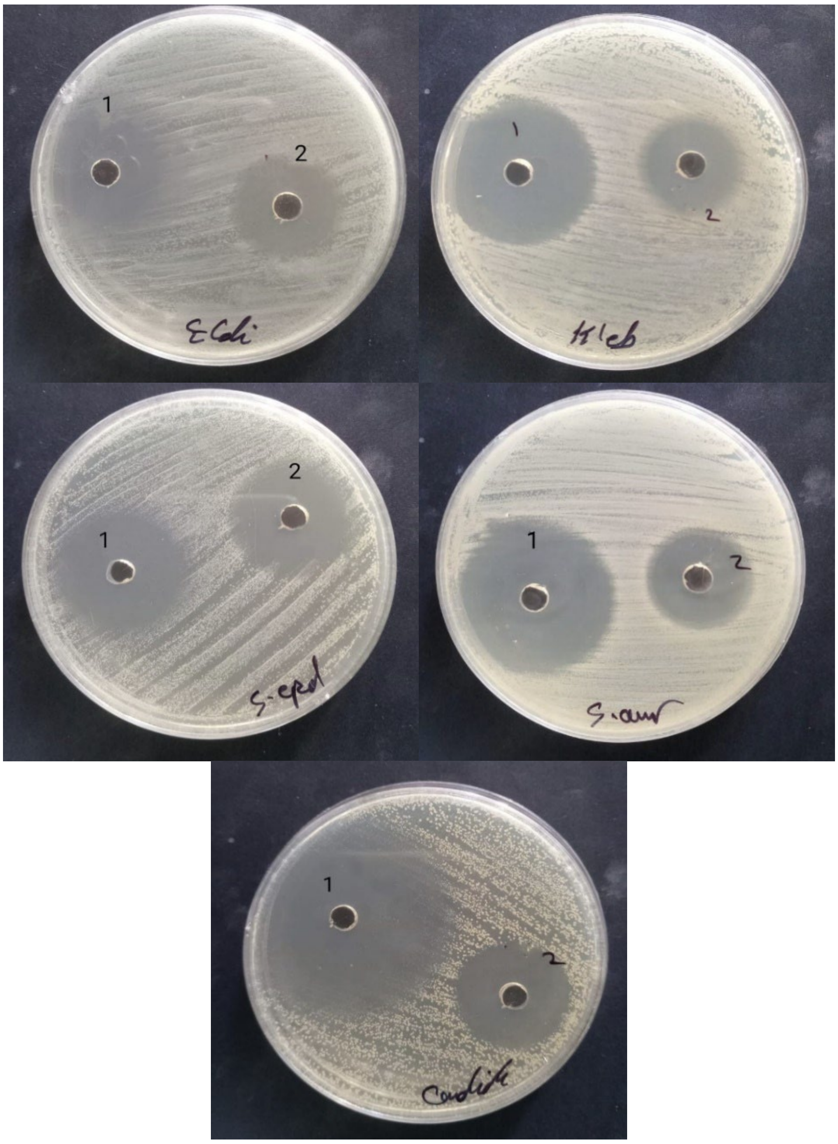

Fig. 8. Antimicrobial activity of NiONPs at different method.

Table 2. Results of NiO against microbial.

Method	*E-Coli*	*Kleb.*	*S.epd.*	*S.aur*	*Candida*
Green synthesis(1)	26 mm	36 mm	29 mm	40 mm	49 mm
Simple chemical(2)	25 mm	21 mm	30 mm	25 mm	27mm

5. Conclusions

NiO nanoparticles were made using Beta vulgaris extract as a reducing and stabilising agent in a new, simple, efficient, and eco-friendly green synthesis process. In addition, we explained an experiment that was used to make NiO nanoparticles using a simple chemistry method by NaOH as a stabilising and reducing agent. In all scientific experiments, we look for three main things: low cost, environmental safety and efficiency. Through the results, it was proven that the green method achieved these basic conditions. The chemical method wasn't good for the environment and had to be washed more than four times to get rid of the salts that were made during preparation.

From the X-ray diffraction, SEM, and AFM of NiO made by green synthesis, we can see that the crystals are smaller than those made by chemical method are. The surface plasmon and high-energy gap also show how small the particles made by the plant method are. Nickel nitrate salt is changed into small nickel oxide nanoparticles with the help of biomolecules in the extract. Both ways have their own benefits, and the one used depends on the nanoparticles' qualities that are wanted and the purpose of the experiment. In this study, the antibiotic effects were very good.

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