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ECO-FRIENDLY SYNTHESIS OF NICKEL NANOPARTICLES USING ALOE VERA LEAF EXTRACT AND EVALUATION OF THEIR ANTIOXIDANT ACTIVITY

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ABSTRACT

In this study, researcher analyse the antioxidant properties and physicochemical characterisation of nickel nanoparticles (NiNPs) synthesised using Aloe vera leaf extract in an environmentally friendly manner. Plant-mediated green synthesis is an excellent alternative to standard chemical methods that address the growing need for environmentally friendly and non-hazardous synthesis methods. Aloe vera bioactive compounds such phenolics, flavonoids, and polysaccharides stabilise and decrease nanoparticle production. These properties are necessary for nanoparticle growth.

The reaction mixture changed colour, indicating that nickel ions (Ni2+) were reduced into nanoparticles. This experiment was performed using an aqueous aloe vera leaf extract. Many analytical approaches were utilised to characterise the synthesised NiNPs. UV-Visible spectroscopy was utilised to study nanoparticle absorption to validate their formation. Raman spectroscopy illuminated structural and molecular connections. To understand nickel nanoparticle electrical properties and polarisation, dielectric experiments were performed. X-ray diffraction (XRD) was also used to confirm the nanoparticles' crystalline nature and cleanliness. The antioxidant activity of the NiNPs was tested in vitro using standard procedures. The DPPH radical scavenging and FRAP assays were used. Adding phytochemicals from aloe vera to nanoparticles improves their free radical-scavenging ability. The findings show that nanoparticles have high nanoscale antioxidant potential. This study shows that generating nickel nanoparticles using aloe vera leaf extract is simple, cost-effective, and environmentally friendly. Synthesised NiNPs may be used in nanotechnology, biology, and medicines. NiNPs are well-characterised and have high antioxidant action.

KEYWORDS: *Nickel nanoparticles (NiNPs), Aloe vera leaf extract, Antioxidant activity, Eco-friendly method, Antioxidant activity*

INTRODUCTION

Aloe vera is a well-known medicinal plant that has a lot of medications in it that are active in the body. Nanotechnology is a science that is growing quickly because nanoparticles have unique characteristics and may be used in many different ways. Researchers have discovered that nickel nanoparticles (NiNPs) are very useful in the fields of biomedicine, electronics, and catalysis. They have been employed in these three areas. On the other hand, traditional synthesis processes sometimes employ chemicals that might be hazardous and are not good for the environment. People are interested in green synthesis, which uses plant extracts, since it is safe and good for the environment. This is because it uses plant extracts to get around the problems that have been there. *Aloe vera* might work as a natural reducing and stabilising agent while making nanoparticles. This is because it contains a lot of bioactive chemicals in it. This work aims to assess the antioxidant properties of these nanoparticles for possible biomedical applications and to investigate the eco-friendly production of nickel nanoparticles using *aloe vera* leaf extract. This study will be undertaken to achieve both of these research aims (Islam et a,2024).

BACKGROUND

Nanotechnology has gotten a lot of interest in the last few years because of the unique properties of metal nanoparticles and the wide range of uses for these particles. Nickel nanoparticles may be highly useful in many areas, such as biology, electronics, and catalysis, to name a few. On the other hand, traditional synthesis methods typically involve chemicals that might be harmful to the environment and are harmful to the ecosystem. A approach that is both ecologically benign and long-lasting has come to light as a potential solution to this problem. This method is called "green synthesis," and it uses extracts from particular plants. *Aloe vera* is utilised a lot in the process of making nanoparticles since it has both reducing and stabilising characteristics, as well as its natural ability to fight free radicals. This is due to the high levels of bioactive compounds in *aloe vera*. Each of these traits has a role in making nanoparticles (Mansur et al.,2025).

LITERATURE REVIEW

A new study has shown that this technology is becoming more important by showing how plant extracts can be used to make metal nanoparticles in a way that is better for the environment than the ways that are presently used. Recent studies have also shown that this technology is growing increasingly important. Numerous research has shown the feasibility of efficiently synthesising nickel nanoparticles using a diverse array of plant sources. The results of these investigations lead to this conclusion. Taking all of this into relation, it is quite clear that phytochemicals, which include flavonoids, phenolics, and proteins, are very important for the processes of reduction and stabilisation. *Aloe vera* has undergone several examinations, and the results indicate that it is an effective method for the manufacture of stable nanoparticles. This is because it contains a lot of bioactive parts. Numerous studies have shown that nickel nanoparticles that are mediated by plants have a lot of antioxidant action. The majority of this action may be due to the phytochemicals that are attached to the nanoparticles' surfaces. Characterisation techniques like X-ray diffraction, Fourier transform infrared spectroscopy, Raman spectroscopy, and UV-Visible spectroscopy have been extensively used to validate the synthesis, structure, and properties of nanoparticles. These methods have helped us reach this goal. Nickel nanoparticles synthesised using environmentally safer processes may be used in the fields of biomedicine and pharmaceuticals, according to the existing body of study (Nair et al.,2025).

NICKEL NANOPARTICLES

Nickel nanoparticles, or NiNPs, are nanoscale materials that have different physical, chemical, and magnetic properties than bulk nickel. Nickel nanoparticles have these characteristics as compared to bulk nickel. Because of this, these nanoparticles are very useful for many different purposes because of the properties. Nickel nanoparticles, or NiNPs, are used a lot in the domains of catalysis, electronics, cleaning up the environment, and biological research. This is because they are small and have a lot of surface area, which makes them more reactive and perfect for a wide range of uses. One technique used in ecologically friendly synthesis is the generation of nickel nanoparticles by the use of plant extracts. In the context of these techniques, bioactive substances simultaneously function as reducing agents and stabilising agents throughout the process. The attachment of phytochemicals to the surface of these nanoparticles makes it feasible for them to show biological activity, such the capacity to act as antioxidants. These nanoparticles may have other functions to play in the biological system (Dhanda et al.,2023).

Nickel nanoparticles, or NiNPs, are tiny metallic particles that have unique physical and chemical characteristics. Some of these traits include a strong magnetic behaviour, a higher catalytic activity, and a large surface area. Nickel nanoparticles have a lot of useful properties that make them useful in many fields, both scientific and commercial. Nickel nanoparticles (NiNPs) are made from *aloe vera* leaf extract in a way that is good for the environment. The approach in issue uses phytochemicals that are already in the environment as reducing and stabilising agents. This changes nickel ions into nanoparticles. This kind of synthesis is good for the environment since it makes the nanoparticles better at performing biological activities and reduces the risks they bring to the environment. The bioactive chemicals on the surface of nickel nanoparticles (NiNPs) help to keep these particles stable, but they also have a big effect on how well these particles work as antioxidants. Because of this, NiNPs can neutralise free radicals, which makes them an interesting choice for use in biomedicine and pharmaceuticals (Mary et al.,2022).

CHARACTERISATION TECHNIQUES THE SYNTHESIZED NANOPARTICLES WERE CHARACTERIZED USING THE FOLLOWING TECHNIQUES

Characterisation of the produced Ni NPs was done through a few techniques that ensured the synthesis and functionality of the NPs. The production of the NPs was identified by UV-Vis spectroscopy by virtue of the absorption property of the NPs. FTIR spectroscopy was conducted to determine the functional groups of *Aloe Vera* leaf extract used for the reduction and stability of the NPs. Information regarding the structure and size of the particles was obtained through Raman spectroscopy. The structure and size of the Ni NPs was determined through XRD. SEM was utilized to study the morphology and size of the NPs. Dielectric studies were conducted to investigate the dielectric behavior of the synthesized NPs (Yadav et al.,2025).

SEM ANAYSIS

A scanning electron microscopy (SEM) research investigated the surface morphology, shape, and dimensions of Nickel nanoparticles synthesised from *Aloe vera* leaf extract. The SEM pictures mostly revealed nanoparticles that were round and the same size. But strong surface energy made some particles stick together. The environmentally friendly process generated Nickel nanoparticles with diameters in the nanometre range, which proved that they could be made. The photos showed a flat surface, which made it seem like the *Aloe vera* extract had bioactive molecules that could wrap around it and keep it stable. The SEM study demonstrated the biosynthesis, shape, and spread of Nickel nanoparticles (Bulla et al.,2024).

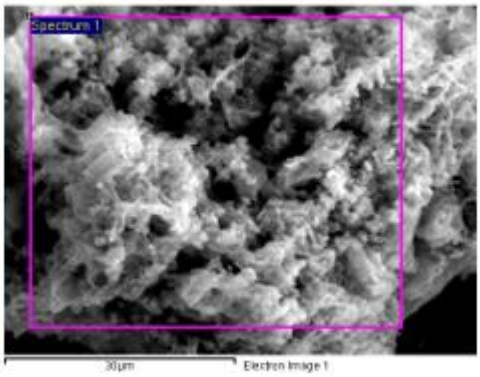


Figure 1: SEM images of Nickle nanoparticles using Aloe vera Extracts

STRUCTURE ANALYSIS USING XRD

Purity and crystalline structure of Nickel nanoparticles synthesised using *Aloe vera* leaf extract were determined using XRD analysis. Distinct diffraction peaks corresponding to the planes (111), (200), (220), and (311) of fcc crystalline structure for Nickle metal appeared on the XRD spectra at the angles 38°, 44°, 64°, and 77°, respectively. The observation of specific peaks gave more assurance that the particles had been successfully synthesised with crystalline structure. It can be observed from the XRD spectra that there were no additional peaks, hence indicating that the particles were highly pure and exhibited good crystallinity. Furthermore, the use of Debye-Scherrer equation to determine crystallite size of nanoparticles proved that the particles were in nanometre dimensions. Therefore, it can be concluded that the XRD findings indicated that the synthesied Nickle nanoparticles had good crystalline structures (Wu, et al.,2024).

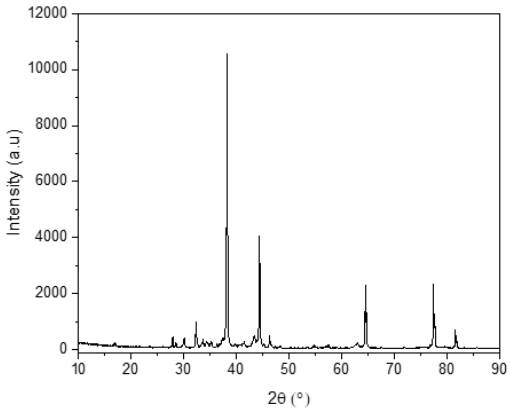


Figure 2: XRD analysis of Nickle nanoparticles using *Aloe vera* Extracts

UV–VISIBLE SPECTRAL ANALYSIS

The use of the leaf extract of *Aloe vera* is one of the subjects that was investigated with the purpose of determining the creation of Nickel nanoparticles. Ultraviolet-visible spectroscopy was the method that was used in the experiment that was carried out. The confirmation that Nickel nanoparticles were formed from Nickel ions was achieved by the observation of the Surface Plasmon Resonance (SPR) peak in the area spanning from 400 to 450 nanometres. As a result of analysing the peak heights and wavelengths, it was possible to get further knowledge on the dimensions and form of the nanoparticles (Athithyan et al.,2024).

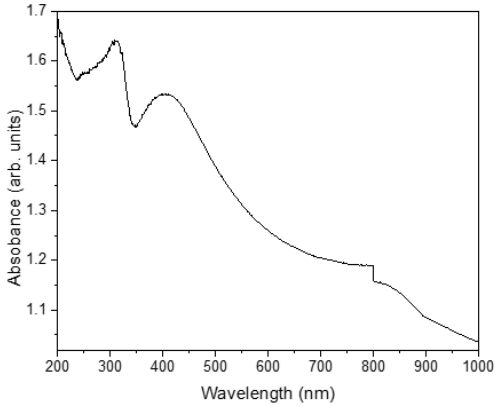


Figure 3: UV–visible spectral analysis of Nickel nanoparticles using Aloe vera Extracts

DIELECTRIC ANALYSIS

An investigation of the electrical properties and polarisation behaviour of Nickel nanoparticles that were synthesised from *Aloe vera* leaf extract was carried out by the researcher via the use of dielectric analysis. Dielectric analysis was the method that was used to effectively carry out this inquiry. Additionally, the findings demonstrated that the dielectric constant decreased as the frequency increased and vice versa. The discovery was made since the polarisation of space charge is lower at higher frequencies. Taking this into consideration, one may conclude that the typical dielectric dispersion takes place. This behaviour not only demonstrated that nanoparticles could be used in electrical and sensing devices, but it also demonstrated that the shape of the nanoparticles and the manner in which their charges were distributed had an effect on how they behaved (Roshid et al.,2025).

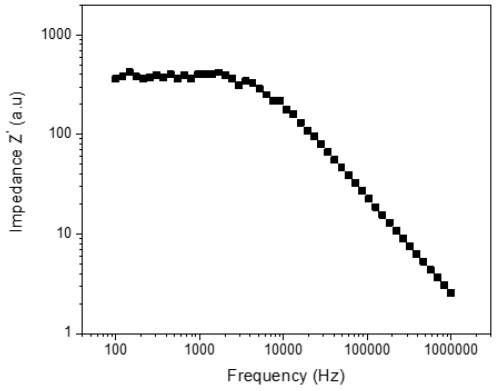


Figure 4: Dielectric analysis of nickel nanoparticles using Aloe vera Extracts

RAMAN SPECTROSCOPY

Raman spectroscopy was utilised to look at the molecular interactions and vibrational properties of the nickel nanoparticles that were made with the help of *Aloe vera* extract. This was done to meet the goal of the study. There were clear peaks in the Raman spectra that matched the functional groups of the biomolecules in the *Aloe vera* extract. The Raman spectra showed these peaks. These peaks showed what these biomolecules did to help the nanoparticles become smaller and stay stable. The study also concluded that Nickel nanoparticles and phytochemicals interact, hence facilitating the effective synthesis of ecologically favourable molecules (Girotra et al.,2024).

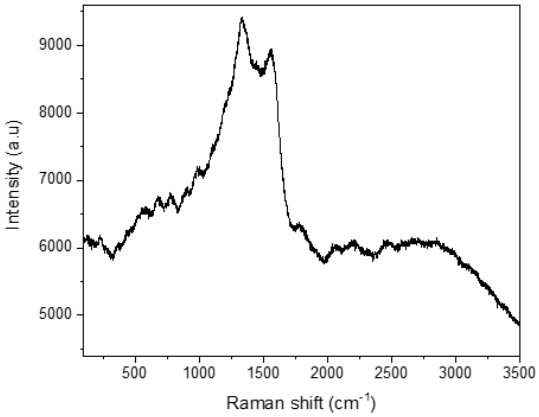


Figure 5: Raman spectroscopy of Nickel nanoparticles using Aloe vera Extracts

IR SPECTRA

Nickel nanoparticles synthesised from *Aloe vera* leaf extract include several functional groups that aid reduction and stabilisation in their FTIR spectra. Functional groupings are thought to reduce and stabilise. Unique peaks corresponding to stretching vibrations of the O–H, C=O, and C–O groups demonstrate that *Aloe vera* contains phenolics, flavonoids, and other beneficial chemicals. Some peaks indicate bioactive chemicals. These functional groups cap and reduce nickel nanoparticles, making them simpler to manufacture and stabilise. The little peak location changes after nanoparticles are created may indicate nickel ion-plant protein interaction. These changes indicate interaction (Islam et al.,2024).

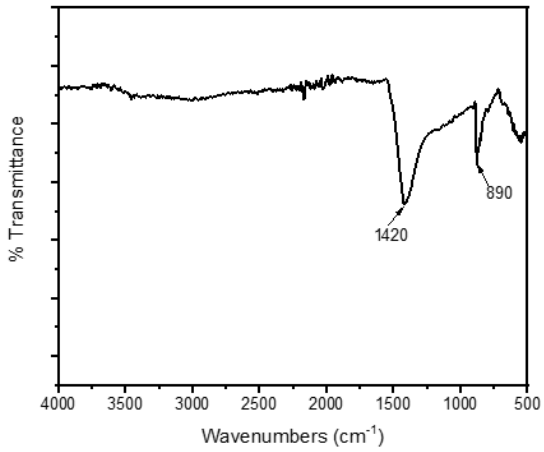


Figure 6: IR Spectra of Nickel nanoparticles using Aloe vera Extracts

RESEARCH OBJECTIVES

- To synthesise nickel nanoparticles using *Aloe vera* leaf extract through an eco-friendly (green) method.
- To characterise the synthesised nickel nanoparticles using suitable analytical techniques.
- To evaluate the antioxidant activity of the synthesised nickel nanoparticles.
- To investigate the relationship between green-synthesised nickel nanoparticles and their antioxidant potential.

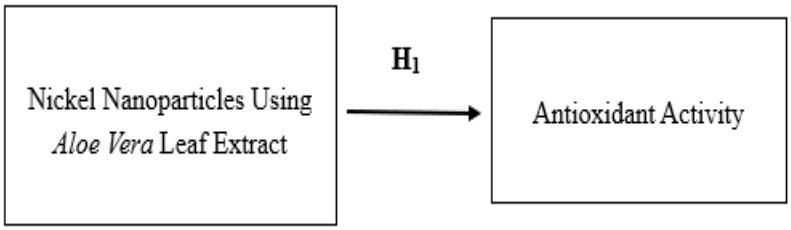
SIGNIFICANCE OF THE STUDY

This work suggests the use of *Aloe vera* leaf extract for the synthesis of nickel nanoparticles in a sustainable and eco-friendly manner. This process does away with the necessity for harmful chemicals, which makes them less harmful. This makes it clear how phytochemicals in plants make and keep nanoparticles stable. Phytochemicals are found in plants. The antioxidant properties of green-synthesized nanoparticles have potential for biomedical and pharmacological applications, especially in alleviating oxidative stress and related illnesses.

RESEARCH QUESTIONS

- How can nickel nanoparticles be synthesised using *Aloe vera* leaf extract through an eco-friendly method?
- What are the physicochemical characteristics of the synthesised nickel nanoparticles?
- What is the level of antioxidant activity exhibited by the synthesised nickel nanoparticles?
- Is there a significant relationship between the green-synthesised nickel nanoparticles and their antioxidant activity?

METHODOLOGY
CONCEPTUAL FRAMEWORK



HYPOTHESIS

Nickel nanoparticles made from *Aloe vera* leaf extract have a lot of antioxidant activity. Plant phytochemicals are the main thing that makes this high level of antioxidant activity possible. Phytochemicals derived from plants exhibit properties of both reducing and stabilising agents throughout the whole synthesis process. They also stay connected to the surface of the nanoparticles during the entire process. These bioactive chemicals make the nanoparticles work better as antioxidants, which in turn makes them more effective overall. This is done by making the nanoparticles better at picking up free radicals and at the same time making them more effective as antioxidants (Mansur et al.,2025).

On basis of the above discussion the researcher formulated the following hypothesis, which will investigate the relationship between the nickel nanoparticles using *Aloe vera* leaf extract and Antioxidant activity.

H_{01}: There is no significant relationship between nickel nanoparticles using *Aloe vera* leaf extract and Antioxidant activity.

H_1: There is a significant relationship between nickel nanoparticles using *Aloe vera* leaf extract and Antioxidant activity.

RESEARCH DESIGN
COLLECTION

The fresh leaves of *Aloe vera* were sourced from a local farm. It fell on the shoulders of the Department of Pharmacognosy and Natural Medicine at the University to verify the identity of the plant. Extracts obtained from the leaves of the *aloe vera* plant served as the chemicals for the experiment.

Figure 7: Fresh Aloe vera leaf plant

EXTRACT PREPARATION OF ALOE VERA

As soon as the fresh leaves of *Aloe vera* were collected, they were cleaned with distilled water to get rid of any dust or other impurities that could have been there. After washing, the leaves were let to air-dry at room temperature to get rid of any moisture that may have been on the surface. After the leaves were dry, they were either broken into tiny bits or chopped into smaller pieces with care. To get the bioactive chemicals out of the plant material, it was necessary to boil a given amount of it in distilled water for a certain amount of time (usually between ten and twenty minutes). This was done to get the chemicals out. It was then filtered using Whatman filter paper once it had cooled down to achieve a clear leaf extract. This was done to get the effect that was wanted. Researcher collected the filtrate and kept it at four degrees Celsius so that it would be available to use later to make Nickel nanoparticles.

Figure 8: Extract Preparation of aloe vera

PHYTOCHEMICAL ANALYSIS OF PLANT EXTRACT

After being harvested, *Aloe vera* leaves were cleaned with distilled water to remove dirt and other impurities. The leaves were dried in the open at ambient temperature to remove any surface moisture after washing. After drying, leaves were broken or carefully chopped into little pieces. To extract bioactive chemicals from plant material, boil it in distilled water for 10–20 minutes. This removed chemicals. A clean leaf extract was obtained by filtering it with Whatman paper after cooling. To get the intended impact. The filtrate was kept at 4°C for eventual use in Nickel nanoparticle production.

A Soxhlet apparatus continually extracts bioactive components from dried *Aloe vera* leaves for phytochemical studies. To accomplish the research aim. This ensures seamless operations. A solvent like ethanol or methanol is always used for extraction. After depositing plant matter in the Soxhlet chamber, the solvent heats, evaporates, and condenses. This continues until all plant material is gone. This ensures the best extraction feasible given the conditions. After that, environmental material is quality-tested. Flavonoids, alkaloids, phenols, tannins, saponins, and terpenoids are present. This category includes flavonoids. Correct extraction is required before these tests. Phytochemicals create and stabilise Nickel nanoparticles.

Figure 9: Soxhlet Apparatus

TESTS FOR FLAVONOIDS

Flavonoids, which are found in the extract of *Aloe vera* leaves, play a significant role in making nickel nanoparticles in a way that doesn't harm the environment and in keeping these particles stable. Standard qualitative phytochemical testing is done to make sure these compounds are there. During the alkaline reagent test, adding sodium hydroxide solution to the extract makes it become a bright yellow colour. The colour, on the other hand, goes away when diluted acid is added to the extract. This means that flavonoids are really in the extract. The lead acetate test may show if flavonoids are present by showing that a yellow precipitate forms when a solution containing lead acetate is added to the solution. Also, people utilise the Shinoda test a lot. When magnesium turnings and strong hydrochloric acid are mixed together, they become pink or scarlet, which is further evidence that flavonoids are present. The purpose of this test is to see whether flavonoids are there. The experiments showed that flavonoids were present in the *Aloe vera* extract, which is what the studies found. Flavonoids are responsible for lowering the amount of nickel ions and raising the antioxidant activity of the nanoparticles that were made (Mary et al.,2022).

Table 1: Data showing the extractive value of whole plant of Aloe vera Extract

Solvent	Weight of Plant Powder (g)	Weight of Extract Obtained (g)	Extractive Value (%)
Methanol	50 g	6.8 g	13.6%
Ethanol	50 g	5.2 g	10.4%
Aqueous (Water)	50 g	3.1 g	6.2%
Chloroform	50 g	1.4 g	2.8%

ANTIOXIDANT ACTIVITY

The DPPH free radical scavenging technique was used to validate the antioxidant activity of the *Aloe vera* methanolic extract. Dissolving 3.94 milligrammes of DPPH in 100 mL of methanol produced the DPPH solution with a concentration of 0.1 mM. To make a quercetin stock solution, 1 milligramme of quercetin was dissolved in 1 millilitre of methanol. The final concentrations obtained by diluting the 1 mg/mL stock solution were twenty, ten, five, 2.5, 1.25, and 0.625 µg/mL. The 50 mg/mL stock solution was prepared by first dissolving 50 mg of extracts in 1 mL of DMSO using a vortex machine. A 50% DMSO solution was used to make the extracts at doses of 1000, 500, 250, 125, and 62.5 µg/mL.

An adaptation of the colorimetric technique was used to evaluate the antioxidant activity of the plant extract using a 96-well plate assay. Our positive control for the DPPH test was 20 µg/mL of quercetin, and negative control was 50% DMSO. Triplicative amounts of 300 εL plant samples, 100 µL quercetin (positive control), and 100 µL DMSO (negative control) were separately deposited on 96-well plates. Next, DPPH reagent, 100 µL per well, was applied. The next stage was to incubate it in a dark place for half an hour. This was followed by the measurement of absorbance at 517 nm using a micro-plate reader. The proportion of DPPH free radicals was determined using the following formula.

$$\% \text{ Inhibition} = \left(\frac{A_{control} - A_{Sample}}{A_{Control}}\right) \times 100$$

Where, $A_{control}$ = Absorbance for the DPPH

A_{sample}= Absorbance of the DPPH + Sample

An effective concentration of the sample is required to scavenge 50% of the DPPH free radicals; this is known as the IC50 (50% inhibitory concentration). The IC50 values were obtained by plotting the extract concentration against the scavenging action on an inhibition curve.

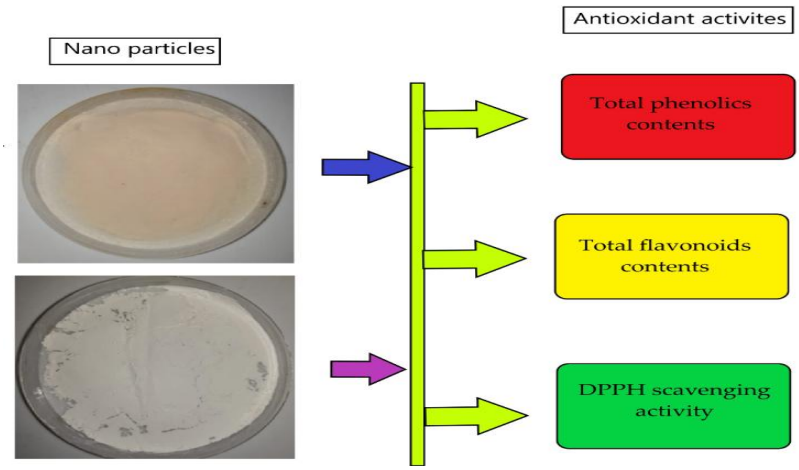


Figure 10: "Antioxidant activity of Aloe vera methanolic s extract"

RESULTS

PHYTOCHEMICAL SCREENING

A phytochemical study found that the leaf extract of *Aloe vera* has a variety of important bioactive chemicals. Flavonoids, alkaloids, phenols, tannins, saponins, and terpenoids are all examples of compounds that fall under this group. These phytochemicals not only help the extract fight germs, but they also help reduce and stabilise Nickel nanoparticles.

Table 2: "Preliminary phytochemical analysis of different extract of aloe vera"

S.N.	Phytochemicals	Methanolic extract
1.	Reducing Sugar	- -
2.	Polyphenols	++
3.	Alkaloids	++
4.	Glycosides	++
5.	Quinones	- -
6.	Flavonoids	++
7.	Saponins	- -
8.	Cumarins	++
9.	Terpenoids	++

Note: "++"presence, "- -" absence

As part of an antimicrobial susceptibility test, a 6-millimeter-diameter-well was created using the agar well diffusion technique. To accomplish the negative inhibition, 50% DMSO was used. Click here to see Table, which displays the length of the inhibitory zone for the methanolic extract.

Table 3: "Aloe vera analysis showing Diameter of Zone of inhibition (nm)"

	Neomycin*	Sample (methanolic extract)
E. coli	16	-
S. aureus	22.5	19
K. pneumoniae	15	20
S. typhi	12	-

ANTIOXIDANT ACTIVITY

The IC50 value of ascorbic acid and *Aloe vera* is presented in Figure. The IC50 of standard ascorbic acid was obtained to be 25.75 ± 0.90 μg/mL and different concentration of the crude methanolic extract of *Aloe vera* was recorded as 91.63 ± 6.54 μg/mL.

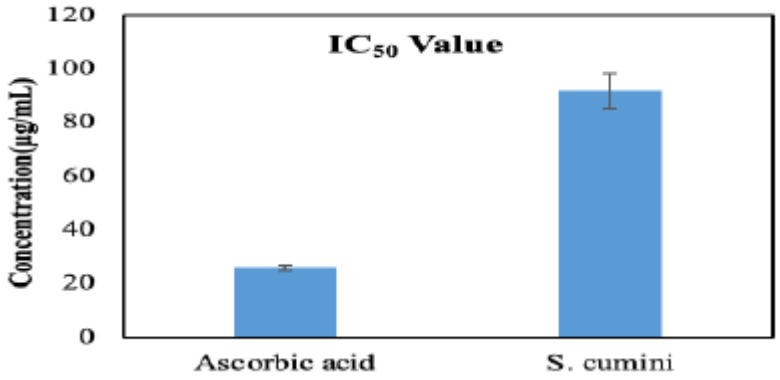


Figure 11: Antioxidant activity

Figure, displays the results showing that the methanol extract outperformed ascorbic acid in terms of IC50 value. This data proves that it is an effective antioxidant. Previous studies using different fractions of ethanol extracts demonstrated that the plant's leaves had potent antioxidant capabilities in the DPPH and FRAP experiments. At 1154 ± 67.37 µmol trolox equivalent/g, the ethyl acetate fraction had the highest capacity, while the n-butyl alcohol fraction came in second at 1178.27 ± 21.26 µmol trolox equivalent/g. Based on their respective IC50 values of 15.7 ± 2.4 and 23.5 ± 2.7 µg/mL, the fractions in question showed the best performance in the DPPH approach.

DISCUSSION

Based on what has been said, it is clear that using *Aloe vera* leaf extract to make nickel nanoparticles in a green way is a good idea for the environment. Several characterisation techniques that illustrate the evolution and properties of nanoparticles indicate that phytochemicals in the extract have a significant role in reducing and stabilising the nanoparticles. Several study methodologies corroborate this assertion. A significant array of methodologies substantiates the viewpoint presented. Because the nanoparticles had a relatively high level of antioxidant activity, which was seen in the nanoparticles that were made, it is very likely that the bioactive molecules that are bound to the surface of the nanoparticles and help them scavenge free radicals are what caused this to happen. The findings suggests that *aloe vera*-mediated nickel nanoparticles have considerable potential for applications in biomedicine and pharmacology. This is because the results are based on taking everything into account.

In conclusion, the production of nickel nanoparticles in an environmentally friendly manner using *Aloe vera* leaf extract offers a simple, economical, and ecologically sound method. The nanoparticles that were made may have extremely strong antioxidant activity since they include phytochemicals that come from plants. Because of this, they might be useful in biology and medicine.

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