Plant-Mediated Green Synthesis of Metal Nanoparticles : Integrating Metabolomics, Nanoinformatics, and Antimicrobial Evaluation Against Clinically Relevant Human Pathogens

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Abstract: Present investigation was carried out to deliberation the bio-synthesis of antagonistic activity analysis efficacy of silver and zinc nanoparticles against humanpathogens using Wrightia tinctoria plant leaves extract. The silver and zinc nanoparticles were characterized find out several analytical techniques. UV-Visible Spectrometer, FT-IR, X-ray diffraction pattern analysis and SEM-Scanning electron microscope with EDAX-analysis. The bio-synthesis silver and zinc nanoparticles were analyses for their antagonistic activity against humanpathogenic microorganisms. Further investigation of bio-synthesized silver and zinc nanoparticles in Wrightia tinctoria leaves extract. Antagonistic activity of bio-synthesized silver and zinc nanoparticle Wrightia tinctoria in leaves extract. The *E. faecalis* is highest zone of inhibition than that against *E. coli*, *K. pneumoniae* and *S. aureus* in Wrightia tinctoria plant leaves silver extract. The moderate activity of *E. coli*, *K. pneumoniae* and *S. aureus* maximum activity in both samples. Where as in zinc nanoparticles showed antibacterial efficacy against *S. aureus* is higher zone of inhibition than that against *E. coli*, *E, faecalis* and *K. pneumoniae* leaves zinc extract. The maximum activity of *S. aureus* in both samples.

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Key words: Wrightia tinctoria; UV-Visible Spectrometer; EDAX-analysis; E. coli; E. faecalis; Klebsiella pneumoniae.

1. Introduction

In the past, medicinal herbs served as the only source of treatment and made a significant contribution. Ancient civilizations placed a high priority on knowing how to heal various diseases with medicinal plants. Plants played a major part in human medicine up until the middle of the nineteenth century and continue to do so today [1]. Due to its low cost, effectiveness, and frequent inadequacy in providing modern medicine, as well as cultural and religious preferences, about 80 / of people in underdeveloped nations rely on traditional medicine for their primary health care requirements. [2].

Traditional or folk medicine refers to methods used to treat, identify and prevent disease within a society that are not supported by scientific research. It is context specific since it is determined by a cultures' knowledge and values, just like social contractions and risk negotiations are. These methods become "complementary", non-conventional or alternative medicine" when modern civilizations adopt them outside of their historical context. [3]. One of the ten largest angiosperm families, the Apocynaceae includes a number of well-known medicinal plants. The 392 genera and 5140 species that make up this family today are primarily found in tropical and subtropical regions, while some can also be found in arid regions. In India, the family is represented by 60 species over 30 genera, including trees, shrubs and vines. [4]

The vaids or ethnic people used various herb parts in the forms of Kwatha (decoction), Phanta (hot infusion), Hima (cold infusion), Arka (liquid extract), Churna (powders), Guggul (resins and balsams), Taila and Kuzhambus (medicated oil), Bhasma (residue after incineration- calcined preparation), Ghrtam, Leh in India, the plants have significant societal value as ornamental and as offerings in temples. Flowers are produced all year round by Allamanda, Alstonia, Catharanthus, Nerium, plumeria, Thevetia and Tabernaemontana. From the southern tropical rainforest to the temperate woodland of the Himalayan foothills, the plants are present as habit or have been naturalized throughout India. Nearly all members in the family generate milky sap, which is one of its defining characteristics.

Simple, oblique and whorled describe the leaves, Flowers are big and vibrant. Several significant big genera are included in this, including Rauvolfia, Taberemontana, Parsonsia, Anspidoperm, Apocynum, Plumeria, Vinca and Catharanthus. This family has 16 genera and about 25 species with significant ethanobotanical value. Apocynaceae species have also been shown to contain pharmacological activity such as anticancer, diabetic, antiplasmodial,

antiulcer, hypoglycemia and antirheumatic properties, which makes them susceptible to adulteration when employed in traditional medical herbal mixes. [5]

Throughout history, humans have relied on nature to provide their basic needs, such as providing them with food, shelter, medicine, clothes, tastes, fertiliser and transportation [6]. This is especially true in developing nations, where herbal has a long history of use, where medicinal plants continue to play a significant role in the healthcare system for vast segments of the world's population. Both industrialised and developing countries are increasingly developing their understanding of these plants' medicinal properties and economic benefits. [7]

Some contain active elements (also known as bioactive compounds or components) derived from plants. Some of these claims and beliefs of people are irreplaceable despite the recent breakthrough in science and technology, according to recent research that foumd plant-derived medications from the study of curative, therapeutic, traditional treatments and especially the folk knowledge of indigenous people [8]

The introduction and manufacturing of novel, more platforms for the investigation and development of more effective antimicrobial drugs against multidrug-resistant strains are required due to the growing worldwide threat posed by a potential epidemic of antibiotic-resistant bacteria. [9]. O. vulgare leaf extracts were used to create AgNPs, which exhibit broad-spectrum antibacterial action against nine distinct human infections, Escherichia coli (entropathogenic, EP), Aeromonas hydrophila, Salmonella paratyphi, Salmonella sp., Shigella dysenteriae and Shigella sonnei all showed greater than 10-mm zones of inhibition. The common antibiotic chloramphenicol has antibacterial activity on par with this level [11]. The highest growth inhibition activity against Staphylococcus aureus (14.67mM) was seen in AgNPs produced with Skimmia lauerola leaf extract [11].

2. Material and Methods

2.1. Plant Material

The Wrightia tinctoria plant also kown as Paalai in Tamil, is a member of the Apocynaceae family and was found in Mallikundham, a village in the Mecheri Block of the salem District of Tamil Nadu State, India. At the Herbarium of the PG and Research Department of Botany, Arignar Anna College (Arts and Science), Polupalli, Kirushnagiri District- 635 115 Tamilnadu, India. Herbarium specimens were prepared and the taxonomic identification of the plant was confirmed. For future use, a vocher specimen of plant was add to the herbarium.

2.2. Scientific classification

Kingdom	:	Plantae
Division	:	Tracheophytes
Class	:	Angiosperms
Order	:	Gentianales
Family	:	Apocynaceae
Genus	:	Wrightia
Species	:	W. tinctoria

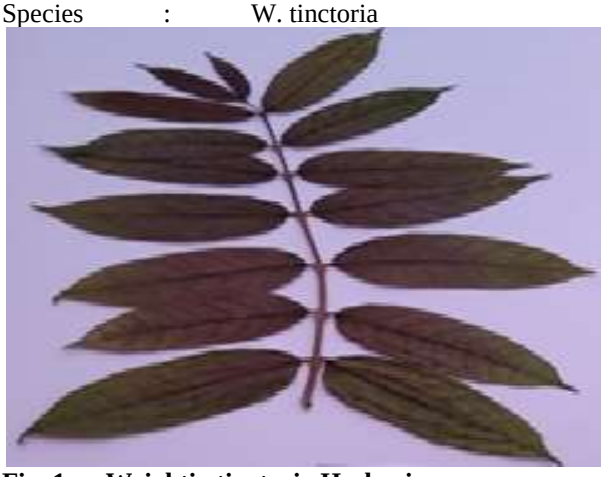




Fig. 1 Wrightia tinctoria Herbarium **Wrightia tinctoria Habitat**

2.3. Chemical

Sigma-Aldrich Chemical Ltd. (St Louis, MO, USA) and another company sold chemicals such as Silver nitrate (AgNO3), Zinc sulphate (ZnO NPs) and AR grade Hi Media, Mumbai, India.

2.4. The process of making plant extracts

Aqueous solvent was used to extract plant parts such as (100g) leaves individually in a soxhlet system. The extract was concentrated using a rotary evaporator at 40 to 50 C and lowered pressure to obtain 4.80 g of yield from the aqueous fractions, after being filtered through cotton and whatman filter paper No.1. The extracts were stored at 4 C until further usage in sealed containers. The extracts were examined for antibacterial activity, UV, FTIR, EDA and SEM.

UV-Visible spectrum study of an extract from plant used to make Silver and Zinc sulphate by periodically sampling aliquots (0.2ml) of the suspension and diluting the samples with 2ml of de-ionized water, the bio reduction of silver and zinc sulphate in aqueous solution was observed.

After which the resulting diluents UV- Visible spectra are measured. On a Thermo Heyios 2 model spectrometer operating between 190 and 1100 nm, UV-Visible spectroscopic examinations of the generated for bioreduction at room temperature.

2.6. FT-IR study of Silver and Zinc plant extract biosynthesis

A pellet for infrared (IR) analysis was made by thoroughly mixing 200 mg of dry potassium bromide with 2 mg of the Silver and Zinc Bio-synthesis plant extract in a mortar for 30 minutes while it was exposed to an IR lamp. Using a Perkin- Elmer spectrum GX, the IR spectra of plant extract containing silver and zinc nanoparticles was measured from 400 to 4000 cm1.

2.7. Analysis of X-RAY diffractiong

XRD was used to determine the size and kind of silver, zinc sulphate nanoparticles. Using a Shimadu XRD-6000 / 6100 model with 30 kv, 30 mA and Cuk radians at a 2 angle, this was done, A quick analytical method that can reveal the dimensions of unit cells is X-ray power diffraction, which is primarily used to determine the phase of crystalline materials. After being pulverized, the substance under analysis is eventually identified by its bulk composition. Using Debye Sherrer's equation, the particle or grain size of the particles on the silver and zinc sulphate nanoparticles was measured. $D = 0.94 \lambda / B \cos \theta$.

2.8. Analysis of silver and zinc sulphate nanoparticle using an EDAX spectrometer

A high-energy electron beam is used to scan a sample with a SEM, which produces images of the sample image using raster scan patterns. Following the creation of nanoparticles utilising plants in this experiments, lyophilization was carried out using a VIRTIS BENCHTOP machine. Using a JEOL-MODEL 6390 machine, SEM and EDAX analysis were performed. A very little amount of a sample was used to create a thin film on a copper grid that has been coated with carbon. Any excess solution was then blotted away and the films on the SEM grid were then allowed to dry for five minutes under a mercury lamp.

2.9. Silver and Zinc nanoparticles using underwent SEM examination

In a Hitachi S-3500 N, scanning electron microscopy was carried out. Silver and Zinc sulphate nanoparticles were produced by drop coating and applied to pure titanium for high-resolution scanning electron microscopy examination, the extract solution was cleaned from the film on the SEM grid using a blotting paper and the grid was then allowed to dry before the measurement. 20.000 x magnification and a working distance of 15 mm are the setting used for SEM measurements on a Hitachi S-3500 N. The instrument was run at a 25 KV accelerating voltage with a #3 objective aperture and a 50 strength condenser lens.

2.10. Assemblage of microorganisms

The bacteria strains used in the biological experiments were from the Microbial Type Culture Collection (MTCC) at the Institution of Microbial Technology (MTECH), Chandigarh, India. Klebsiella pneumoniae (MTCC 3040), Escherichia coli (MTCC 119), Entrobacter facalis and Salmonella aureus (MTCC 734).

2.11. Synthetic nanoparticles' hostile behaviour

By using the well diffusion method, the antagonistic activity of produced silver and zinc nanoparticles against the bacterial strains Klebsiella pneumoniae (MTCC 3040), Escherichia coli (MTCC 119), Entrobacter facalis and Salmonella aureus (MTCC 734) was examined. The pathogenic cultures were grown in broth in order to test for bacteria. On a Muller Hinton Agar plate, a well about 8 mm in diameter was formed using gel puncture. On test media, the cultures were swabbed. On nutritional agar, four agar wells were created and after adding 1mM of AgNPs solution and ZnoNPs within concentration, each well was inoculated, the plates were incubated at 37 C for 24 hours and the zone of inhibition was then discernible.

3. Result

3.1. Wrightia tinctoria leaf extract contains nanoparticles made via green biosynthesis of silver and Zinc sulhate

3.2. Analysis of UV- Visible spectrum

The reduction of the aqueous silver and zinc ions after exposure of Wrightia tinctoria extract to microve radiation results in the creation of silver and zinc sulphate nanoparticles. Which may be easily observed by UV- Vis spectroscopy. When zinc ions were reduced into particles during exposure to plant extract from leaves, the colour of the extract changed from yellow to pale yellow. When silver ions were reduced into silver particles during exposure to plant extract, the colour of the extract changed from yellow to dark brown. The action of surface lasmon vibrations in silver nanoparticles causes them to appear yellowish to dark brown in aqueous solution, as is widely known. As soon as the plant extract was added to the aqueous solution of the silver ions complex, the colour began to shift from yellowish to brown as a result of the reduction of the silver ion and zinc ion, which may be a sign that silver nanoparticles were being formed. The Wrightia tinctoria leaves lant extract synthesised silver and zinc nanoparticles reaction is reported, along with the UV-Vis spectra that were obtained. A great peak value of 276 nm in the UV analysis reveals the presence of silver nitrate solutions and a higher beak value of 425 for zinc. In contrast, as shown in Fig 4, silver and zinc nanoparticles displayed the highest peak values (276 nm and 425 nm respectively).

3.3. FTIR analysis using a spectrometer

Wrightia tinctoria leaves extract following bio reduction of silver and zinc nanoparticle extract were studied for this FTIR absorption spectra. It is ossible to evaluate the suggested information regarding the chemical change in bio reduction. Infrared spectra are helpful for identifying samples because they frequently exhibit distinct features that are distinctive of particular grouping of molecules vibrations. Vibration in carbohydrates, lipids and proteins was seen in the band between 650 and 1750 cm-1. The biggest category is proteins and the peptide groups, which is a structural repeat unit in proteins, produced up to 9 distinctive bands. The protein infrared spectrum has two important bands called amide I and II. The strongest absorption band in proteins is amid I.



Plant extract Silver extract Zinc extract

Fig 2 Wrightia tinctoria leaves extract, silver extract and zinc extract



Synthesis of silver extract



Synthesis of zinc extract

Fig 3 Synthesis of silver and zinc Wrightia tinctoria leaves plant extract

Table 1. FTIR Functional group of Wrightia tinctoria before and after silver and zinc synthesized extract.

S.No	Groups	Silver (nm)	Zinc (nm)
1	Chloroalkanes		658
2	CH_2	704	
3	Aromatic ether		
4	C-O-H Arylalyl asymmetrical		1385
5	CO	1639	1638
6	Methylene		
7	C-H	2075	2113
8	Alkynes		
9	Phosphines		
10	OH or N-H group	3418	3342

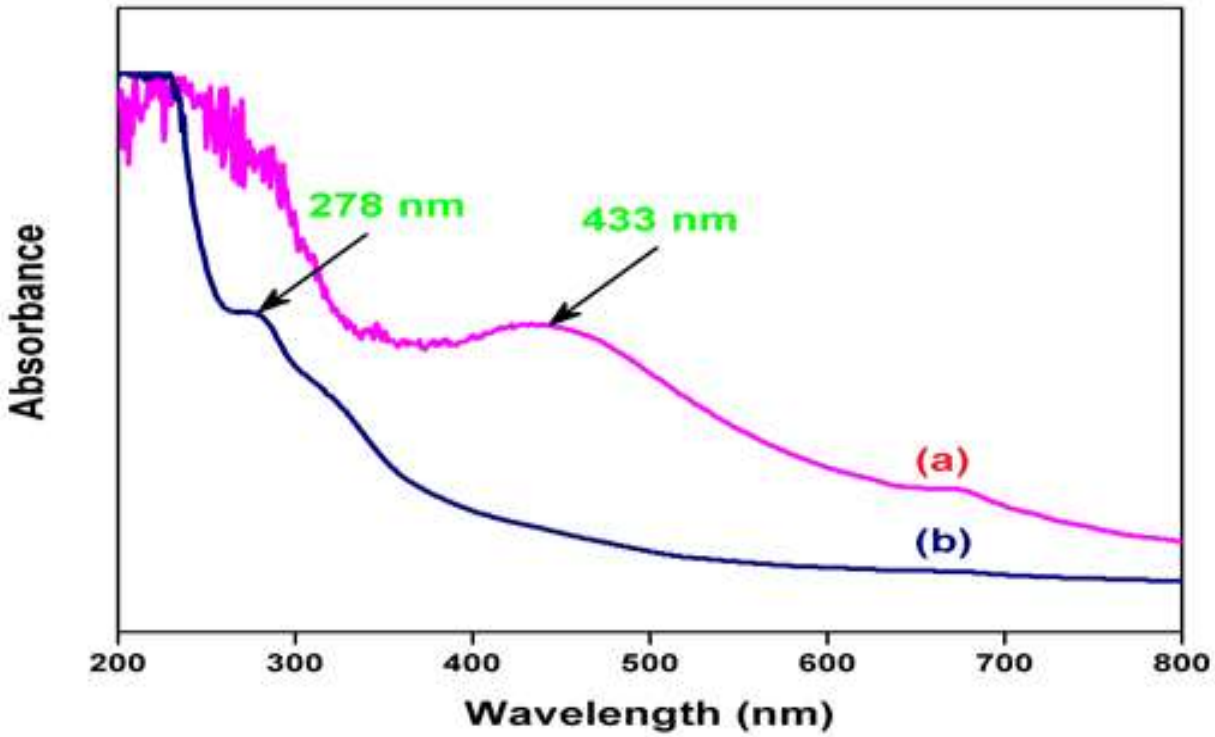


Fig 4 UV-Vis absorption spectra of aqueous Silver nitrate (AgNPs- a) and Zinc sulphate (ZnO NPs- b) with Wrightia tinctoria leaves extract time intervals.

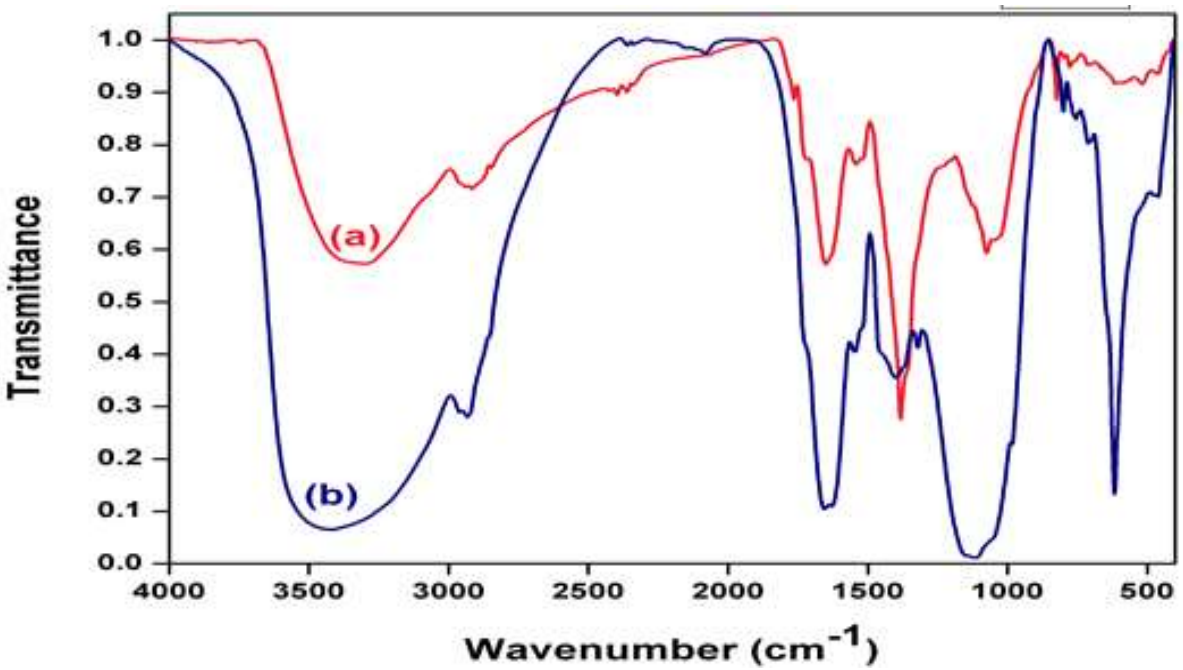


Fig 5 FT-IR Spectroscopy analysis of Wrightia tinctoria synthesis Silver and Zinc leaves extract

Stretching vibrations of the C = O (70-85 /) and C-N (10-20 /) group have a major role in controlling it. It occurs between the frequencies of 1600 and 1700 cm-1. The backbone shape and hydrogen bonding arrangement define the precise band position. Amide II is more complicated than amide I and is located between 1510 and 1580 cm -1 .

Amide II is mostly produced through in-plane N-H bending. Which accountd for 40 to 60 percent of the potential energy. The remaining potential energy is produced by stretching vibrations of the C-N (18-40 /) and C-C (10 /) pairs.

The complexity of the Amide III band depends on the specific of the force field. Hydrogen bonding and side chain characteristics. Therefore, the extraction of structural information from this band is only marginally useful. Pure lipid molecules have more complicated FTIR spectra. There are three different absorption bands visible, the most recognizable for lipids being the CH3 and CH2 (3.025-2.954 cm-1) and the C= O ester (1.746 cm-1, 654 cm-1). It is evident from these separate lipid separate lipid spectra that the FTIR spectrum contains recognisable and distinct fingerprints for triglycerides and phospholipids. Strong bands in the spectrum with wavelength of 1024, 1080 and 1150cm-1 are indicative of the C-O stretching vibrations of carbohydrates. A prominent peak for the phosphate group in nucleic acids may be seen at 1084 and 1225 cm-1. The various functional groups among the exopolysaccharide are revealed by the FTIR analysis of exopolymeric substances. Table 1 and Fig 5. Show the resence of various exopolysaccharide groups that were found using FTIR.

Wrightia tinctoria leaf extract nanoparticles made of silver and zinc revealed broad, intense absorption bands at 621 and 694 cm-1, which indicated the existence of chloroalkanes and a sharp, intense band at 709 and 717 cm-1, which clearly suggested the presence of methylene (CH2) vibrations. Wrightia tinctoria leaves extract silver and zinc produced nanoparticles, respectively, were discovered to include secondary alcohols, phenols and aromatic ethers with distinctive bands at 1232 cm-1. For all exopolysaccharides, the C signal band H vibrations were seen at 1371 to 1385 cm-1. 1411 cm-1 of OH bending in primary alcohol were seen. At 3398 to 3435 cm-1, the molecular OH sharp bands were observed. All of the Wrightia tinctoria leaves extract produced silver and zinc nanoparticles were found to include alkynes, which can be distinguished by their unique band appearance at 2113 cm-1. Wrightia tinctoria leaves extract produced silver and zinc nanoparticles showed variance in both form and absorbance intensity across all spectra, demonstrating the presence of carbohydrates, proteins, DNA and lipids in varying composition and amount.

3.4. XRD determine research

The XRD in Figure 3 demonstrated the presence of silver colloids in the 20.8, 30.8 and 70.7. At 2 = 20.8, 30.8 and 70.7 in the XRD pattern, braggs reflections were seen. Given that the may be classified as a face-centered-cubic (FCC) structure of silver, these bragg reflections amply demonstrated the existence of sets of lattice planes. While the XRD patterns 20, 20.8 and 30 showed braggs reflections. These bragg reflections amply demonstrated the presence of sets of lattice planes and further supported the identification of these structures as zinc's face-centered cubic structure. Silver and zinc nanoparticles produced in this current synthesis are therefore crystalline, as shown by their XRD patterns. Additional as-yet-unassigned peaks were seen in addition to the bragg peaks inactive of FCC silver and zinc nanoparticles, including that the bioorganic phase crystallised on the surface of the nanoparticles.

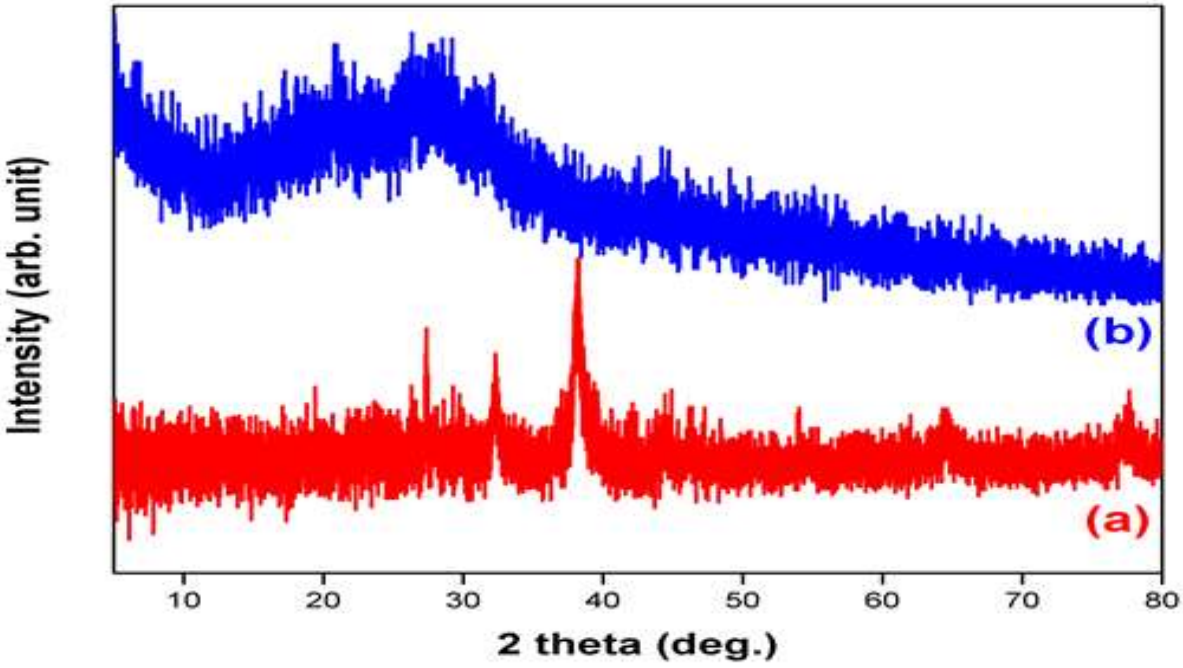


Fig 6 Phase matched XRD pattern of silver (a) and zinc (b) nanoparticles.

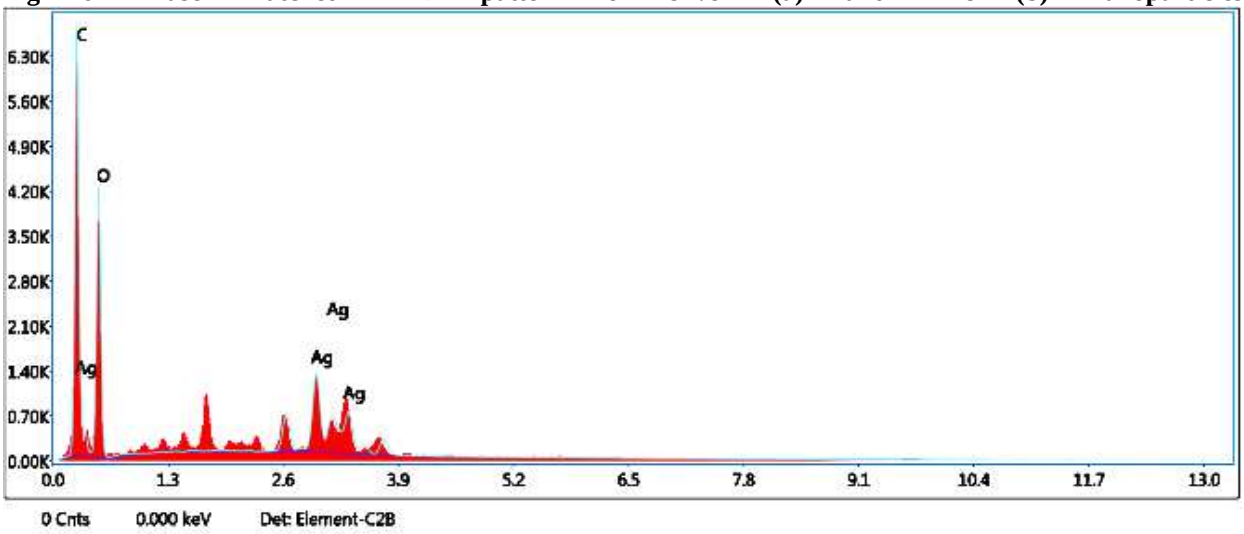


Fig 7 EDAX spectra recorded from a film after formation of silver nanoparticles X-ray emission peaks labelled.

Table: 2 Synthesis of silver nanoparticle element weight, atomic and error analysis.

Elements	Weight %	Atomic %	Error %
CK	37.16 %	50.81 %	4.89 %
OK	45.53 %	46.53 %	9.38 %
Ag	17.51 %	2.67 %	32 %

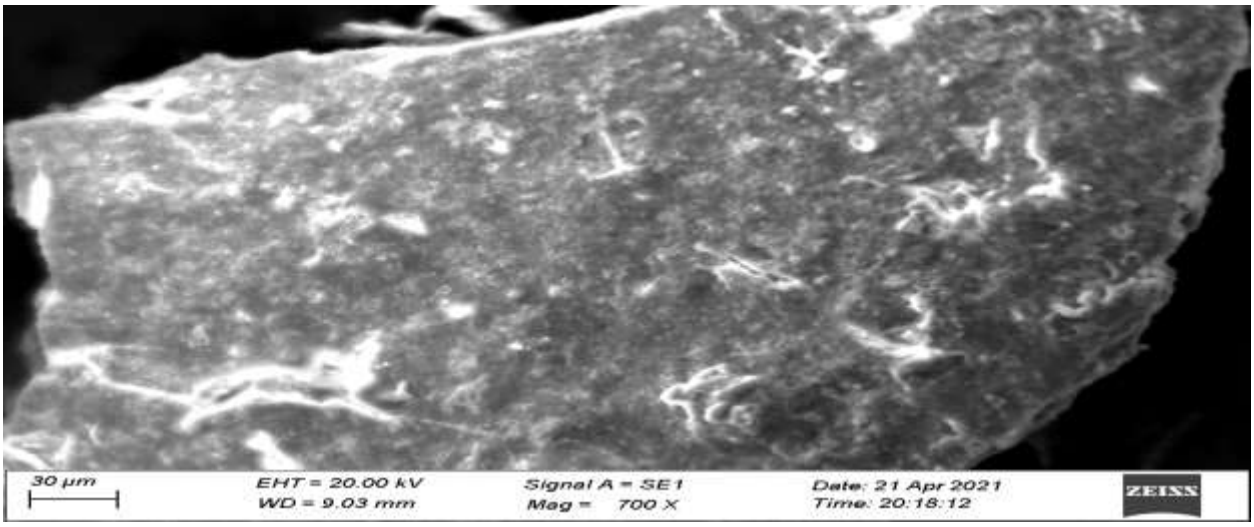


Fig 8 SEM image of silver nanoparticles formed Wrightia tinctoria

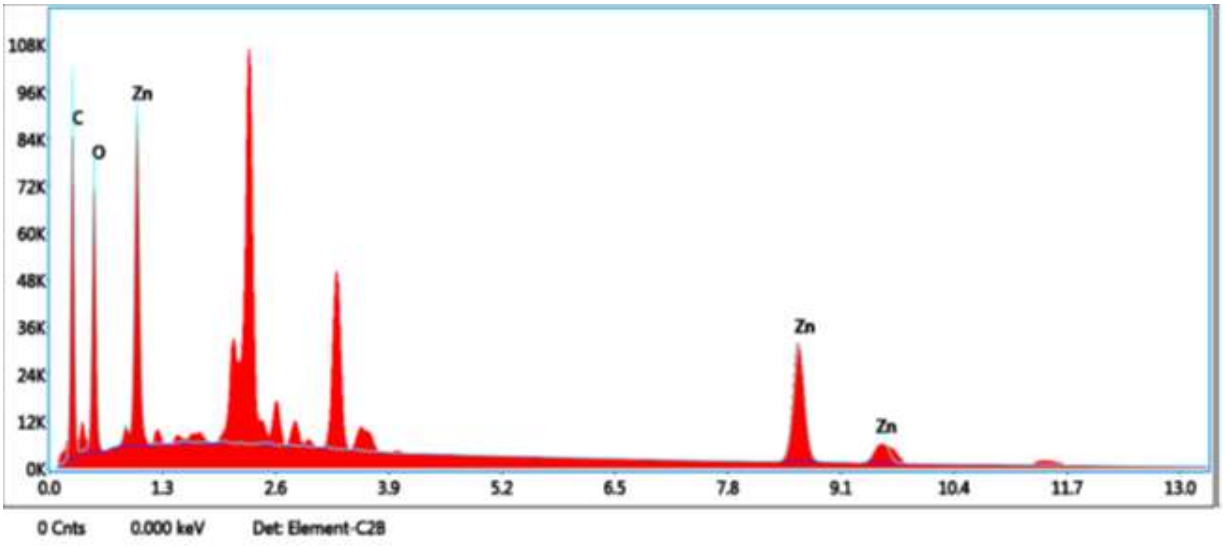


Fig 9 EDAX spectra recorded from a film after formation of zinc nanoparticles X-ray emission peaks labelled.

Table: 3 Synthesis of zinc nanoparticle element weight, atomic and error analysis.

Elements	Weight	Atomic	Error
CK	24.33	41.36	8.52
OK	36.33	46.36	7.62
Ag	39.35	12.29	2.06

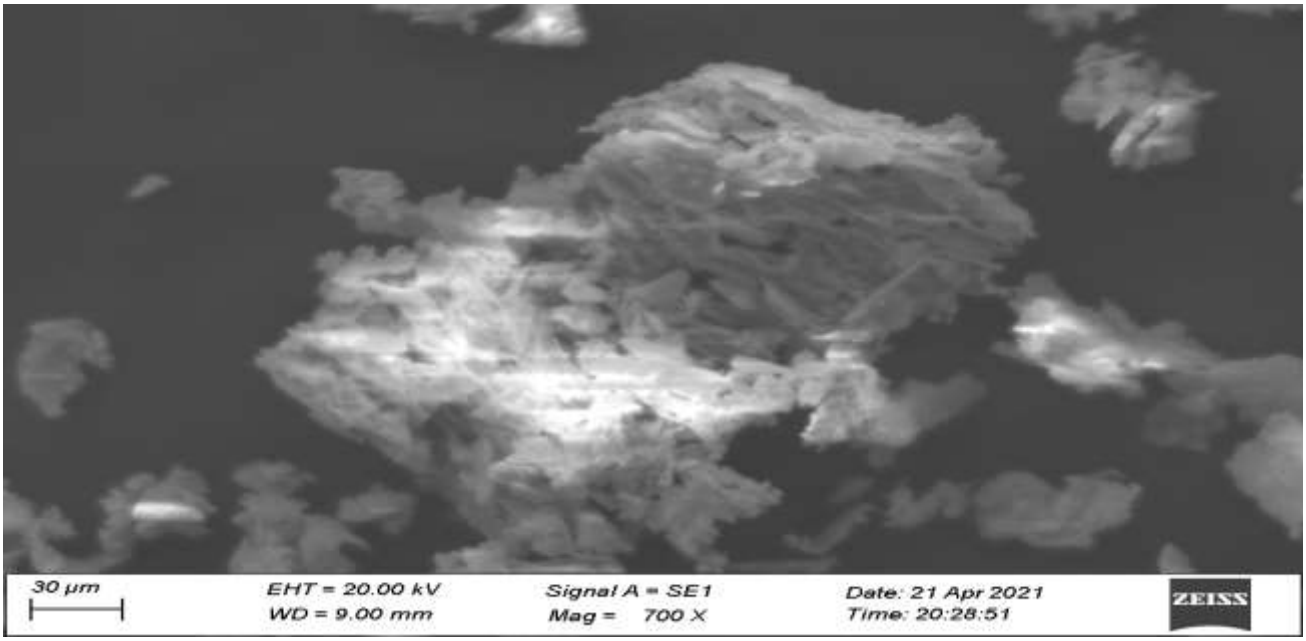


Fig 10 SEM image of zinc nanoparticles formed Wrightia tinctoria

3.5. The picture displayed EDAX spectra from silver nanoparticles

It is evident from 5 EDAX spectra that the weight percentage of silver in the silver nanoparticles decreased by Wrightia tinctoria is 17.51. While zinc nanoparticles decreased have a weight of 43.53, according to EDAX spectra.

3.6. SEM features of nanoparticle morphology

The silver nanoparticles size and form, as well as their morphological dimension, were visualised using the SEM technique. The results showed that the average size of silver nanoparticles was 5 mm, whereas the average size of zinc nanoparticles was 30 nm.

3.7. The effectiveness of silver and zinc nanoparticles in opposition

Wrightia tinctoria green silver and zinc nanoparticle antagonistic action in leaf extract. In Wrightia tinctoria plant leaves silver extract, the E. faecalis is the highest zone of inhibition

Table: 4 Antagonistic activity of silver nanoparticles against human bacterial pathogens.

Ag NPs	E. coli	E. faecalis	S. aureus	K. pneumonia
5 ml	5mm	10mm	4mm	4.5mm
10ml	5mm	12.5mm	5mm	5mm
PE	4mm	-	5mm	5mm
AB	10mm	10mm	12mm	12.5mm



Entrobacter faecalis Escherichia coli Salmonella aureus Klebsiella pneumonia

Fig 11 Antagonistic efficacy of synthesis silver nanoparticles on Wrightia tinctoria leaves extract against human pathogen



Klebsiella pneumonia Escherichia coli Entrobacter faecalis Salmonella aureus

Fig 12 Antagonistic efficacy of synthesis zinc nanoparticles on Wrightia tinctoria leaves extract against human pathogen.

Table: 5 Antagonistic efficacy of synthesis zinc nanoparticles on Wrightia tinctoria leaves extract against human pathogen.

Zno Nps	E.coli	E. faecalis	S. aureus	K. pneumonia
5	5mm	7.5mm	7.5mm	5mm
10	7.5mm	7mm	10mm	7mm
PE	6mm	5mm	-	-
AB	-	-	5mm	-

compared to that against E. coli, K. pneumoniae and S. aureus all had moderate to high activity levels in both samples. In contrast, zinc nanoparticles demonstrated greater zone of inhibition against S. aureus than they did against E. coli, E. faecalis and K. pneumoniae leaves zinc extract. S. aureus highest level of activity in both samples. Table 4, 5.

4. Discussion

Nanotechnology, which has made significant advancements, is one of the concepts in science and technology that has recently experienced rapid development. The potential to create new systems, structures, technologies and nanoplatforms with looming bids in a wide range of disciplines exists in the nanomaterial that possesses specific physicochemical features. Nanomaterials are tiny particles with a large surface area to volume ratio that have advantages over larger particles in terms of thermal conductivity, catalytic reactivity, nonlinear optical performance and chemical stability. This property has inspired a lot of researchers to look for cutting-edge synthesis methods. Though traditional processes (physical and chemical) take less time to create large quantities of nanoparticles, they require hazardous substances, such as stabilisers, to keep them stable, which causes toxicity in the environment. Due to the cost benefits and availability of natural capping agents in the form of proteins provided by plant extract-mediated biogenesis of nanoparticles, green technology utilizing plants is emerging as an eco-friendly, nontoxic and secure alternative. The biological synthesis of different metal oxide and metal nanoparticles through plant extraction is used to control chemical toxicity in the environment. This is a marginal technique for controlling chemical synthesis and it allows for a distinct shape and size of nanoparticles with a meticulous synthesis.

The development of biodegradable, functionalized and biocompatible nanoparticles continues to be a very active research topic for biomedical applications. Up until now, among many other biomedical uses. This article's goal is give an analysis of historical, pharmacological and nanotechnology research done on this plant.

5. Acknowledgment

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6. Reference

1. Camejo-Rodrigues J., Ascensao L., Bonet M.À., Valles J. 2003. An ethnobotanical study of medicinal and aromatic plants in the Natural Park of Serra de Sao Mamede (Portugal) J Ethnopharmacol. 89:199–209.

2. Shanley P., Luz L. 2003. The impacts of forest degradation on medicinal plant use and implications for health care in Eastern Amazonia. Bioscience.53 (6):573–584.
3. Crellin, J.K., 2001. Social validation: an historian's look at complementary/ alternative medicine. Pharm. Hist. (Lond). 31: 43-51.
4. Endress ME, Bruyns PV. 2000. A revised classification of the Apocynaceae. Bot Rev : 66:1-56.
5. Endress ME. 1997. Key characters at the interface of the apocynacs and the asclepiads. Am J Bot: 84:189.
6. Schulz V, Hänsel R. Tyler VE. 2001. Rational Phytotherapy. A Physician's Guide to Herbal Medicine. 4th Berlin: Springer-Verlag: 306.
7. Regulatory situation of herbal medicines. 1998. Geneva, Switzerland. A worldwide review: 1-5.
8. Ahn, K. 2017. The world trend of using botanical drugs and strategies for developing global drugs. BMB Reports. 50 (3): 111-116.
9. Kapil A 2005. The challenge of antibiotic resistance: need to contemplate. Ind J Med Res. 121:83–91.
10. Sankar R, Karthik A, Prabu A, Karthik S, Shivashangari KS, Ravikumar V. 2013. Origanum vulgare mediated biosynthesis of silver nanoparticles for its antibacterial and anticancer activity. Coll Surf B Biointer 108:80–84.
11. Ahmed KBA, Subramanian S, Sivasubramanian A, Veerappan G, Veerappan A.2014. Preparation of gold nanoparticles using Salicornia brachiata plant extract and evaluation of catalytic and antibacterial activity. Spectrochimica Acta Part A Molecul Biomol Spectros 130:54–58.