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AN ECO-FRIENDLY APPROACH ON THE GREEN SYNTHESIS OF ZNO NANOPARTICLES USING MUSA PARADISIACA SPATHE EXTRACT AND THEIR CHARACTERIZATION

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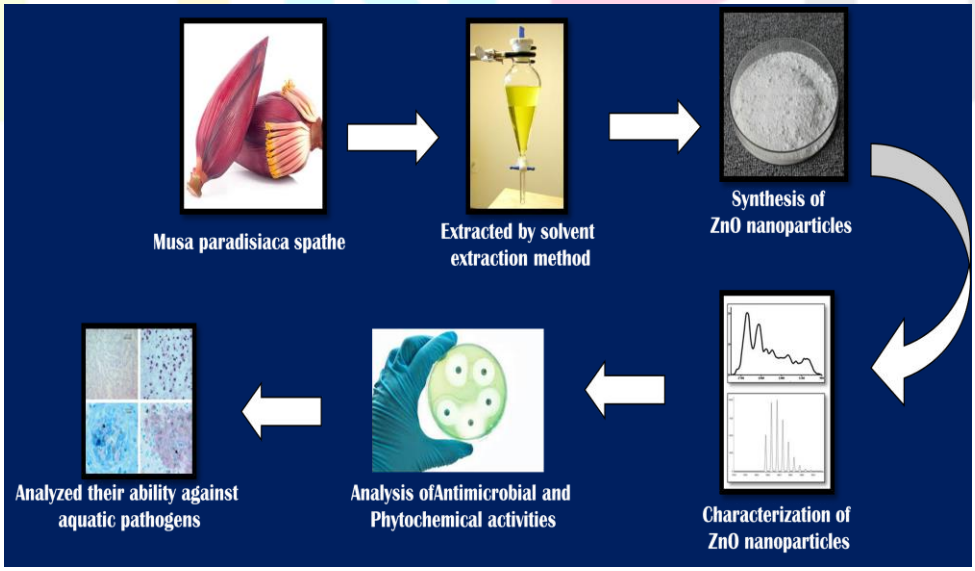
Abstract: **-** Nanotechnology is a flourishing subject of study in modern science. Nanoparticles with a one-dimensional size of 1-100 nm are utilized extensively in medicinal chemistry, atomic physics, and all other domains. Nanoparticles are widely employed because of their small size, orientation, and physical characteristics. Different chemical, physical, and biological processes may readily produce these particles. However, the biological technique is the most popular way of preparation since it is simpler, more environmentally friendly, takes less time is one of the most developing and an eco-friendly approach. The semiconductor ZnO has piqued the interest of scientists due to its high excition binding energy, high scattering activity and recombination even at ambient temperature. The aqueous solution of *Musa paradisiaca* spathe extracts and zinc acetate was used in the green synthesis. The color shift was noticed when a set ratio of plant extract to metal ion was created, proving the creation of nanoparticles. UV-visible Spectrophotometer, FTIR, DLS, Zeta Analysis, XRD, and SEM were used to characterize the nanoparticles. The various applications of ZnO nanoparticles synthesized from *Musa paradisiaca* are also analyzed.

Keywords: - Nanotechnology, *Musa paradisiaca*, ZnO Nanoparticles, Eco-friendly, spathe

GRAPHICAL ABSTRACT



INTRODUCTION

Nanotechnology is a relatively new scientific breakthrough. The discipline was founded in 1959, when Richard P. Feynman, an American physicist at Caltech, said in one of his seminars, "There is plenty of room down the bottom". He proposed that the key to future technology and development was scaling down to the nanoscale [1]. Nanotechnology research has gained interest in recent years by offering basic and practical research opportunities at the nanoscale in a variety of domains, including medicine, materials science, astronomy, and geology [2]. Nanoparticles (NPs) are materials having a diameter smaller than 100 nanometers. They are smaller than their bigger counterparts and have high volume ratios that rise as their size decreases [3]. As particle size shrinks, a huge number of constituent atoms accumulate on the particle surface, leading in highly reactive particles with distinct physical, optical, chemical, and electrical capabilities [4].

1.1 Applications of nanotechnology

Nanoparticle is a tiny entity that, in terms of transport and characteristics, behaves like a full unit in nanotechnology. Nanosystems science and engineering technology is one of the most demanding and rapidly increasing domains of nanotechnology [5]. They are very tiny particles with improved catalytic reactivity, thermal conductivity, non-linear optical performance, and chemical stability due to their enormous surface area to volume ratio [6]. Because of their antibacterial properties, NPs are also being referred to as nano antibiotics [7]. Nanoparticles are now widely used in the industrial, health, food, feed, space, chemical, and cosmetics industries, necessitating a green and environmentally friendly approach to their production [8].

1.2 Types of nanoparticles

Various forms of nanoparticles have been described, including metal oxide nanoparticles, polymer nanoparticles, and metal nanoparticles [9]. Due to their varied characteristics and functions, metal oxide nanoparticles such as Al2O3, MgO, ZrO2, CeO2, TiO2, ZnO, Fe2O3, and SnO are the most versatile materials [10]. Zinc oxide (ZnO), also known as zincite, has received a lot of interest from the scientific community as a "future material" and hence a significant n-type semiconducting metal oxide [11].

1.3 ZnO nanoparticles

Zinc (Zn) and its oxide are one of the most intriguing and promising metallic nanostructures (ZnO). Zinc is a moderately active element and a powerful reducing agent; it can rapidly oxidize, producing zinc oxide [12], which is particularly useful in the manufacture of zinc oxide nanoparticles. As one of the most significant microelements in human bodies, zinc [13] performs a crucial function. It is present in all bodily tissues, including muscle and bone (which contain 85% of the total zinc content), skin (11%), and all other tissues; it is intracellular, mostly in the nucleus, cytoplasm, and cell membrane [14]. Zinc has been found to be essential for the efficient functioning of a wide range of macromolecules and enzymes, where it plays both catalytic and structural functions. Zinc finger motifs offer a one-of-a-kind framework that allows protein subdomains to interact with DNA or other proteins [15]. Zinc is also necessary for metalloproteins to function properly.

1.4 Characteristics of ZnO nanoparticles

In terms of structure and characteristics, ZnO has the most diversified nanostructures of any known material. Nanobelts [16], nanonails [17], flower-shaped [18], nano-rods [19], nano-combs [20], and nano-bows [21] have all been manufactured in a nano-size controlled way with the goal of specific applications in electrical, photonic, and spintronic devices. Because the behavior of materials is influenced by crystal morphologies, these nanostructures might be used to fabricate functional enhanced Nano electrical devices [22]. Its strong heat conductivity makes it a good ingredient for plastics, rubbers, cement, and ointments. The radiation hardness of ZnO is also relevant for optoelectronic applications at high altitudes or even in space. There are two types of zinc oxide crystals. The wurtzite structure is primarily exploited as a transparent conducting oxide (TCO) in the thin film industry [23], whereas the zinc blende structure may be generated as a metastable phase by epitaxial growth on a substrate having cubic lattice structures [24].

1.5 Biosynthesis of ZnO nanoparticles

Biosynthesis of nanoparticles is a method of producing nanoparticles with biomedical uses utilizing microbes and plants. This method is environmentally friendly, cost-effective, biocompatible, safe, and green [25]. Plants, bacteria, fungus, algae, and other organisms all contribute to green synthesis. They enable large-scale manufacturing of ZnO NPs without the need for further impediments [26]. NPs made using a biomimetic method have higher catalytic activity and need less costly and harmful chemicals. Researchers manufacture nanoparticles within the size range of 100 nm in recent years as a result of advances in science and technology, and this substantial study and concern on nanoparticles is spreading due to their potential application in a wide range of science and technology. ZnO is a kind of metal oxide that has photocatalytic and photo-oxidizing properties against chemical and biological species.

Nature has evolved several techniques for the synthesis of nano and micro length sized inorganic materials, which have contributed to the establishment of a relatively new and mostly unknown area of research centered on nanomaterial biosynthesis. The use of bio-organisms in synthesis is consistent with green chemistry concepts. Environmentally friendly, non-toxic, and safe chemicals are used in "green synthesis" of nanoparticles [27]. There is a need to create cost-effective nanoparticle production methods that do not involve harmful chemicals. Because of their eco-friendly nature and other biomedical applications, "green nano-synthesis" technologies are preferred over chemical and physical methods of synthesis [28]. Various microbes, enzymes and plant extracts are used as reducing agents in the green process approach during synthesis and so hazardous pollutants are kept out of the environment rather than being cleaned up after they havecreated [29].

1.5.1 Plant sources in the Biosynthesis of nanoparticle

Physical, chemical, and environmentally friendly approaches can all be used to make ZnO nanoparticles (NPs). Plants, fungi, and bacteria might biosynthesised metal and metal oxide NPs, which could be a potential strategy to generate biocompatible NPs with favourable antibacterial properties. However, under physiological situations such as infected wounds or septicemia, the uniformity of shape, size, and size distribution of NPs is critical for eliciting substantial antibacterial responses [30].

1.5.1.1 Musa paradisiaca spathe–as a plant source for nanoparticle synthesis

Musa paradisiaca is a well-known Musaceae plant that has been used in traditional medicine for hundreds of years to treat a variety of ailments and health issues. The presence of active constituents in plant materials may be responsible for human health benefits. Tannins, Alkaloids and phenolic compounds are the important bioactive molecules present in plants [31]. *Musa paradisiaca* is found in tropical areas all over the world. *Musa paradisiaca* fruit is a significantly healthy and the most commonly consumed fruit in the world. The different morphological and microscopic properties of the plants are given here. The herb appears to have a wide range of effects on a variety of diseases [32].

Musa paradisiaca have been identified as the most common nutritionally valuable plant in all the season [33]. *Musa paradisiaca* is also called as Kadali in Sanskrit is one of the mostly valued medicinal plants which is used to cure various ailments in the Indian traditional system of medicine [34]. Musa plants, banana and plantain are the large perennial herbs growing in a sympodial rhizome [35].

Each plant develops a single inflorescence resembling drooping spike, with big spathes opening in succession, elliptical, 15-20 cm long, concave, dark red in colour, and somewhat mushy. Fruits are rectangular and fleshy, measuring 5-7cm in length in the wild and longer in cultivated forms. *Musa sapientum* is a perennial herb with a tuberous rhizome and a stiff, long pseudostem that grows 5 to 9 metres tall. The inflorescence, which is large and has a reddish brown spathe, is used to make vegetables. The ripe fruits are sweet, juicy, and seedy, with a thicker peel than other bananas [36].

1.5.1.2 Beneficiary aspects of Musa paradisiaca spathe extract

Alkaloids, saponins, tannins, flavonoids, terpenoids, coumarins, cyclogylcosides, total phenols, and steroids were found in the early qualitative examination of phytochemicals. Alkaloids and glycosides were found in the petroleum ether extract, but phytochemical elements were not found in the chloroform extract. Alkaloids, saponins, flavonoids, terpenoids, coumarins, glycosides, phenols, and steroids were found in the ethanol extract of spathe. Only coumarins and phenol were found in an aqueous extract. Other phyto components such as quinones, steroids were not present in any of the extracts [37]. Banana spathes are rich in carbohydrates, proteins, minerals, and fibres [38]. Furthermore, the utilisation of an agricultural leftover (banana spathes) as an affordable livestock feed might help to ensure the economic viability of cattle. *Musa paradisiaca* l spathe extract has a high mineral concentration. Sodium, calcium, phosphorus, and potassium were all abundant, while iron and magnesium were low. Calcium, phosphorus, and iron were abundant in the trash. The flour made from the plantain spathe had greater salt and phosphorus levels, which might be related to changes in soil conditions (soil type and mineral content) as well as variable ambient circumstances [39][40].

The expected outcome of the study is the synthesis of ZnO Nanoparticles and its characterization. The bioactive extract may be potential agent, eco-friendly and cost effective alternative sourcein various fields. Still there are options to investigate the unexplored potential of the plant based on its uses. Furthermore, bioactive constituents needs to be isolated and should be considered for further *in vivo* studies to confirm the claims and to explore the potential of development of leads that may contribute in drug development.

MATERIALS AND METHODS

2.1 Sample collection

The *Musa paradisiaca* flower was obtained at a nearby market in Theni, and its spathe was utilized as the study sample. The collected samples were brought to the Microbiology laboratory of Nadar Saraswathi college of Arts and Science, Theni for further analysis.

2.2 Extraction of *Musa paradisiaca* spathe

The spathes were peeled off and the flowers are separated. Spathes were identified in dark purple and pale white colour. The dark purple spathes were collected and the remaining spathes were discarded. They were cleaned to remove the white deposits and washed thoroughly with double distilled water. Then the spathe was cut into small pieces. The spathe was weighed similarly for extraction. The spathe with distilled waterwas heated in the microwave oven to obtain an extract. Similar processes were done to obtain the extract by continuous heating. It was stored in the room temperature to cool down.

2.3 Synthesis of zno nanoparticles from *Musa paradisiaca* spathe extract

Some volume of the extract was mixed with a required amount of hydrated Zinc acetate and consequently the mixture is added with sodium hydroxide at desired temperature. Some perform optimization at this point using different temperature, pH, extract concentration and time. Incubation period results in a change of color of the mixture to yellow which was a visual confirmation of the synthesized NPs.

2.4 Phytochemical screening of *Musa paradisiaca* spathe extract

The section discusses the examination of *Musa paradisiaca* spathe extract in various solvents, which were carried out according to standard protocols with slight changes. Standard procedures were used to check for the presence of bioactive components in the extract.

2.4.1 Test for alkaloids (Mayer`s test)

1 ml of extract is treated with few drops of Mayer's reagent. The creamy layer formation is the confirmation of presence of alkaloids

2.4.2 Test for carbohydrates (Fehling`s test)

0.5ml of Fehling's A reagent and 0.5ml of Fehling's reagent B is mixed and added to the few drops of extract and heated in boiling water bath. Formation of red color precipitate indicates the presence of carbohydrate.

2.4.3 Test for sterol and steroids (Salkowski test)

To 5 ml of extract few ml of chloroform and equal volume of conc. Sulphuric acid were added. Appearance of red color in chloroform layer and green fluorescence in acidic layer shows the presence of cholesterol.

2.4.4 Test for amino acid and protein (Biuret test, Ninhydrin test)

5 ml of extract and equal volume of 50% sodium hydroxide and then 2 drops of 1% copper sulphate were added. The formation of violet color shows the presence of amino acid and protein. 1ml of extract is treated with 5 drops of 0.2% Ninhydrin in acetone. The formation of color indicates the presence of amino acid and proteins.

2.4.5 Test for cellulose

1ml of extract is treated with few drops of iodine solution followed by few drops of sulphuric acid. Dark brown red color shows the presence of cellulose.

2.4.6 Test for phenols (Ferric chloride test)

2ml of ferric chloride solution is added to 1 ml of the extract. The formation of deep bluish green solution shows the presence of phenol.

2.4.7 Test for anthocyanin

1ml of sodium hydroxide was added to 2ml of extract and boiled for 5minutes. The formation of green color is the confirmation of the presence of anthocyanin.

2.4.8 Test for starch

Few drops of iodine is added to the extract. The formation of blue-black color shows the presence of carbohydrates.

2.4.9 Test for quinones / anthroquinones (Chloroform ammonia test)

Added few ml of conc. sulphuric acid and 5 ml of chloroform to 5 ml of hot extract and kept in boiling water bath. Heated extract of 2 ml was added with 1ml of 10% ammonia and shaken well. The appearance of pink red in the ammoniacal layer indicates the presence of anthracene derivative.

2.4.10 Test for flavonoids (Ammonia test, Lead acetate test)

Dip the filter paper in the extract and expose to ammonia vapors. The yellow colour change indicates the presence of flavonoids.

2.4.11 Test for tannin (braemer's test)

To 5 ml of extract few drops of 10% ferric chloride was added. The appearance of dark green color indicates the presence of tannin.

2.4.12 Test for hydrolysable tannin

4 ml of 10% ammonia was added to 4 ml of extract. The formation of emulsion on shaking indicates the presence of hydrolysable tannin.

2.4.13 Test for volatile oil

0.1ml of diluted sodium hydroxide and few drops of diluted hydrochloric acid were added to 2ml of extract. The formation of white precipitate shows the presence of volatile oil.

2.4.14 Test for lignin

The filter paper was dipped in the extract and a drop of phloroglucinol reagent was added. The appearance of red or purple color indicates the presence of lignin.

2.4.15 Test for terpenoids

To 5 ml of extract 2ml of chloroform was added and 5ml of conc. sulphuric acid was added along the side of the test tube. Appearance of reddish brown at the interphase indicates the presence of terpenoids.

2.5 Characterization of Zno nanoparticles

Structural and optical properties of the ZnO nanoparticles were determined by using Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), Fourier Transform Infra-Red spectroscopy (FTIR), Dynamic light Scattering (DLS), Zeta potential.

2.6 Determination of Antimicrobial activity against the aquatic pathogens

The antibacterial activity of *Musa paradisiaca* spathe extract was tested on four different species of aquatic bacteria independently. The zone of inhibition was determined using the well diffusion method of antibacterial testing.

RESULTS AND DISCUSSION

For this study the samples were collected from the local market, Theni. The present study elucidates the Green synthesis of ZnO Nanoparticles by using the Spathe of *Musa paradisiaca* and the analysis of its characterization.

3.1 Isolation and extraction of Musa paradisiaca spathe

30 gm of sterilized *Musa paradisiaca* spathe was mixed with 300 ml of distilled water in the ratio of 1:10. The spathe was allowed to boil in a microwave oven. The boiling water with sapthe was observed for every two minutes to determine the colour change. Approximately in 10 mins the extract was obtained with the color change. *Musa paradisiaca* spathe extract was obtained in a dark purple colour and it is placed in the room temperature to cool down.

3.2 Analysis of phytochemical activities

The extract obtained from the *Musa paradisiaca* spathe is analysed for various phytochemical analysis. This is mainly to analyze the presence of alkaloids, carbohydrates, flavonoids, amino acids, proteins, phenols, sterols, steroids, tannins, anthocyanins, volatile oils, quinones, ligins and terpenoids. The results obtained were tabulated in the Table 1 and were also compared with similar phytochemical analysis of various plant sources and the interpretations were discussed.

Several phytochemical surveys have been published, including one that used a random selection technique and included plant accessions from all around the world. The alkaloids and steroidal sapogenins were the main chemical compounds of interest in these studies, but additional naturally occurring phytocomponents such as flavonoids, tannins, unsaturated sterols, triterpenoids, essential oils, and others have also been reported [41]. Reference [42] interpreted that Plantain flower spathe is utilized as a diabetic diet as well as a medication since the phytochemicals found in the bract supply some valuable pharmaceuticals. It contains phytochemicals such as polysaccharides, sterols and steroids, quinones and anthraquinones, alkaloids, leucoanthocyanidins, tannins, anthocyanins, and terpenoids, which may protect against free radicals. Similarly based on the results analysed by Reference [42] the phytochemical analysis were determined for the *Musa paradisiaca* spathe extract which showed significantly positive results.

The identification of phytoconstituents in plant material aids in predicting the plant's potential pharmacological activity [43]. Since, phytochemical analysis is mainly to determine the medicinally active substances found in the plants, the results proved that *Musa paradisiaca* is a medically active substance and it can be used in the various fields of application.

3.3 UV-visible spectroscopic analysis results

The sample was subjected to the analysis of UV-Visible spectroscopic analysis to examine the quantitative analysis, dispersion of the analytes, color analysis and the biological compounds in it.

The UV–visible spectrophotometer measurement of synthesised nanoparticles confirmed the production of particles in the early stages. Scan UV-Spectrophotometer in the range of 200–400 nm was used to examine solid white coloured samples of ZnONPs manufactured utilising both sheep and goat faecal matter. Several peaks were found in the UV area, indicating the production of zinc oxide nanoparticles [44].

PHYTOCHEMICALS	TESTS	RESULTS
Alkaloids	Mayer`s	+
Carbohydrates	Fehling`s	+
	Cellulose	+
	Starch	-
Amino acids & proteins	Biuret	-
	Ninhydrin	-
Phenols	Ferric chloride	-
	Phospomolybdic	-
Sterols & steroids	Salkowski	+
Quinones\ Anthroquinones	Chloroform-Ammonia	+
Flavanoids	Ammonia	-
	Lead acetate	-
Tanin	Braemar`s	+
Anthocyanin	Anthocyanin	+
Volatile oils	Volatile oils	-
Lignin	Lignin	-
Terpenoids	Terpenoids	+

Table 1 Phytochemical analysis of *Musa paradisiaca* spathe extract

The UV-Vis spectrum is used to monitor the conversion of zinc acetate to zinc oxide. The band, which was identified as "surface Plasmon resonance band" and is attributed to excitation of valence electrons of ZnO organised in nanoparticles (nanocrystal/ nanosphere), was observed between 360 and 450 nm. The symmetrical structure of the band suggests consistent scattering of spherical nanoparticles [45].

The absorption peak of the fitted ZnO nanoparticles' immersion spectrum is nearly 360 nm. Because of their large excitation binding energy at ambient temperature, it demonstrates the exposition, excitation, and absorption (at 360 nm) of ZnO nanoparticles [46]. The most frequent technique for analysing plasmon resonance excitation of ZnO nanoparticles with absorption peak ranges of 370 nm is UV-Vis spectroscopy. The most frequent technique for analysing surface chemistry, optic characteristics, shape and size, and accumulation status of produced nanoparticles is UV-Vis spectroscopy [47].

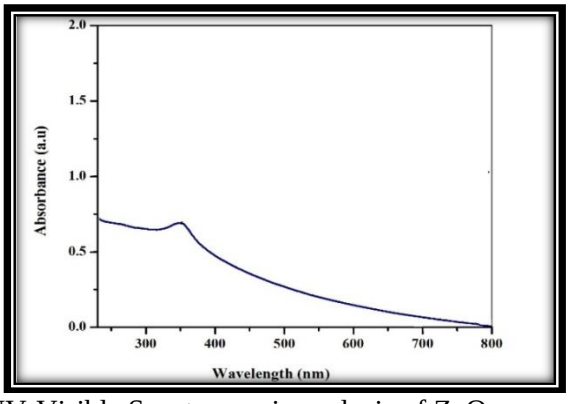


Fig 1 UV-Visible Spectroscopic analysis of ZnO nanoparticles

According to the informations interpreted by Reference [44] the peak inferred at the 360 nm Figure No.1 in the UV-Visible spectroscopic analysis indicates the production of ZnO nanoparticles. Based on the reference [45] suggested the consient scattering of spherical nanoparticles. Reference [45] interpreted the results that peak exhibited at 360nm demonstrates that the ZnO nanoparticles have large excitation binding energy even at ambient temperature. The band inferred at 360 nm indicates the conversion of zinc acetate to zinc oxideand it explains the consient dispersion of ZnO nanoparticles.The interpreted results shows that the ZnO nanoparticles synthesized by *Musa paradisiaca* spathe exhibits optimistic results for UV-Vis spectroscopic analysis.

3.4 SEM analysis results

Samples were subjected to the SEM analysis to determine the structural imaging, morphological structures and the various the range of materials.

One of the most extensively used tools for characterization of nanomaterials and nanostructures is the scanning electron microscope (SEM). The signals generated by electron-sample interactions disclose information about the sample's surface shape (texture), as well as its chemical composition [48]. SEM was used to examine the shape and structure of the ZnO NPs for further characterization. The recent study discovered that ZnO NPs are agglomerates of nanocrystallites and are spherical in form. This was clearly analyzed in the reference [45]. Nanoparticles were visualized in spherical and hexagonal quartzite shape through SEM analysis of about 59.57 nm.

It was easy to spot oval-shaped particles and flower-shaped structured irregularly produced particles. Nanoparticles have a smaller particle size, with ZnONPs (GFM) measuring nearly 40–120 nm and ZnONPs measuring 60–130 nm (SFM). A homogenous distribution of particles can give us better knowledge on a morphological study and approximate particles size [44]. At working distances of 8.0 and 8.5, scanning electron microscopy (SEM) pictures were taken. The porosity of the material, as evidenced by the existence of multiple cavities and a working distance of 8.5 mm, verifies the chemical analysis results by indicating the presence of silica (white particles) [49].

Our study examined that the SEM analysis projected the average size of nanoparticles to be Individual zinc nanoparticles clump together in the SEM picture in accordance with the reference [45]. Closer examination reveals the existence of multiple nanoparticle aggregates in the agglomerated mass with the reference [49] working distance of about 8.00 mm which refers to the Despite the fact that these particles overlap, the overall dispersion effect is good. According to reference [44] the nanoparticles observed in SEM analysis have a maximum size of 60 nm with oval shape with app. particle size of ZnO nanopartices Fig 2.

It was shown that using natural particles as reducing agents might cause particle agglomeration, giving the appearance of larger particles, similar to ZnO nanoparticles produced through biological synthesis. [50] With the further analysis of our study relates the agglomeration of the ZnO nanoparticles Fig 3.

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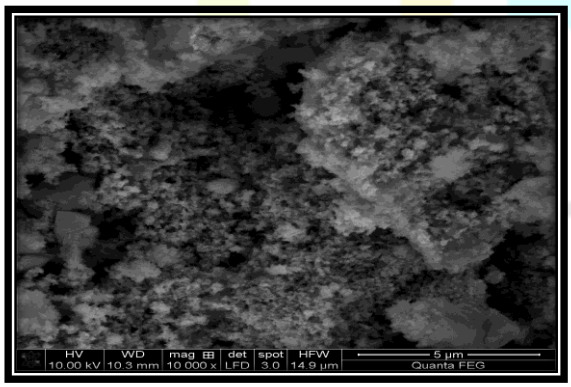

Fig 2 SEM analysis of ZnO nanoparticle

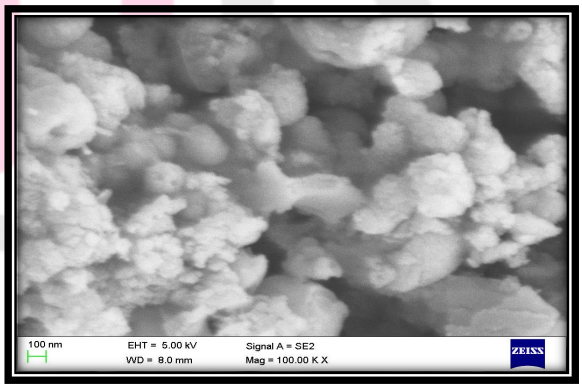

Fig 3 SEM analysis of *Musa paradisiaca* synthesized ZnO nanoparticles

3.5 FT-IR analysis results

The sample is subjected to the FT-IR analysis for the identification andcharacterization of the molecule, which is examined for the absorption patterns of all other compounds.

Based on the reference [44], proteins and metabolites such as terpenoids, flavonoids, aldehydes, and ketones are the surrounding of the synthesised ZnONPs as functional groups. The carbonyl groups from amino acid residues and proteins have a better potential to bind metal, indicating that proteins can inhibit agglomeration, according to FTIR study. The intense peaks at 2334.10 cm−1, 2361.74 cm−1, and 2340.96 cm−1 indicate the creation of CO2 molecules,

which could absorb during the synthesis [51][52]. The C=C stretch in the aromatic ring corresponds to the peak at 1630.06 cm−1. The stretching of C–O in the amino acid is indicated by bands at 1099.15 cm−1 and 937.71 cm−1. It was discovered that specific bond vibration peaks occurring at defined wavenumbers are responsible for the reduction of ZnO and the capping agent of bioreduced ZnO NPs [45]. These findings revealed that the zinc oxide particles were well-configured, as shown by the x-ray diffraction data. The FTIR results based on the results concluded by [53][54][55]. The fundamental mode of vibration of alcohol, carboxylic acid, ether, and ester was confirmed at 3458.04, which corresponds to the O-H stretching vibration, 1625.35, which corresponds to the N-H bend, and 1418.86, which corresponds to the C-C stretching vibration. C-N symmetric stretching vibration is represented by 1148.10 [56].

The fundamental mode of vibration is 3276.16, which corresponds to the carboxylic acid group's O-H stretch, peak 2122.43, which corresponds to alkynes, 1635.55, and 510.93, which corresponds to aromatic in general. The fundamental mode of vibration is 3276.16, which corresponds to the carboxylic acid group's O-H stretch. The FTIR analysis of *Ocimum Tenuiflorum* leaves extract reveals the significant of the synthesis of Zinc Oxide nanoparticles [57].

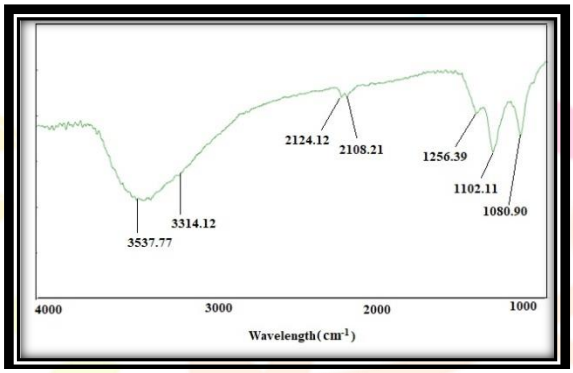

Fig 4 FT-IR analysis of ZnO nanoparticles

Based on the results obtained Fig 4 as 3537.77, 3314.12 exhibits the alcohol, carboxylic acids, ether and ester it corresponds to O-H stretching vibration inferred from reference [56], 1102.11, 1080.90 indicates the C-O bands, 1256.39 refers to the O-H bonds which indicates the presence of ZnO nanoparticles. 2124.12, 2108.21 corresponds to the alkyne groups with reference [57]. Thus from the results inferred FT-IR analysis exhibited the functional group in the particular sample which is responsible for the synthesis of Zno nanoparticles.

3.6 DLS analysis result

Musa paradisiaca spathe extract undergoes the analysis of Dynamic light scattering effect to emphasize the dispersion of the particles and its nature of stability in various physiological conditions.

DLS result revealed that particles were polydispersed, implying that diverse sizes of particles were created, e.g., the population of particle size 500nm was larger than the population of particle size 90nm [45]. It is used to study stability of the particles. It also show whether the particles aggregate over time by seeing whether the hydrodynamic radius of the particle increases. If particles aggregate, there will be a larger population of particles with a larger radius. The suspension of ZnO nanoparticles green synthesised from *Rosa indica* leaf extract was used in dynamic light scattering. The DLS particle size distribution suggests that green produced nanoparticles are around 10nm in size. The green ZnO nanoparticles that were produced are not agglomerated [58].

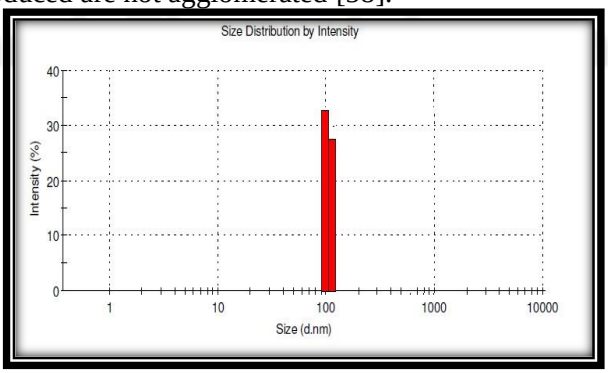

Fig 5 DLS (Dynamic Light Scattering) of ZnO nanoparticles

According to the results of reference [45], our studies in the DLS resulted that particles were polydispersed which implies that diverse sizes of particles were synthesized and it also exhibits the stability of the particles, for example, the population of particle size 100nm was more than 30nm particles which can have the stability at various physiological potential Fig 5.

3.7 Zeta potential results

Sample is subjected to the analysis of zeta potential to determine the colloidal stability of the charged particles and to determine it.

Zeta potential it is the potential difference between the dispersion medium and the stationary layer of fluid attached to the dispersed particle. A value of 25 mV (positive or negative) can be taken as the arbitrary value that separates low-charged surfaces from highly-charged surfaces. The significance of zeta potential is that, its value can be related to the stability of colloidal dispersions [45].

Zeta potential [mV]	Stability behavior of the colloid
From 0 to ±5	Rapid coagulation or flocculation
From ±10 to ±30	Incipient instability
From ±30 to ±40	Moderate stability
From ±40 to ±60	Good stability
More than ±61	Excellent stability

Table No.2 Zeta potential stability range of ZnO nanoparticles [45]

The magnitude of the zeta potential (-30 mV to +30 mV) indicates the colloidal system's potential stability. The nanoparticles generated have a Zeta potential of -15.3 mV, indicating that they are moderately stable [59] The zeta potential is a common measurement of a particle's surface charge and defines colloidal stability. Suspensions with a voltage of 15 mV are referred to as stable colloids [60]. Zeta potential also known as Surface potential has direct relationship with the stability of a structure as mentioned in Table 2. For molecules and particles that are small enough, a high zeta potential will confer stability, i.e., the solution or dispersion will resist aggregation. When the potential is low, attraction exceeds repulsion and the dispersion will break and flocculate. Our studies related that the result of zeta potential showed that surface potential of NPs was found to be -12 mV i.e., incipient [45].

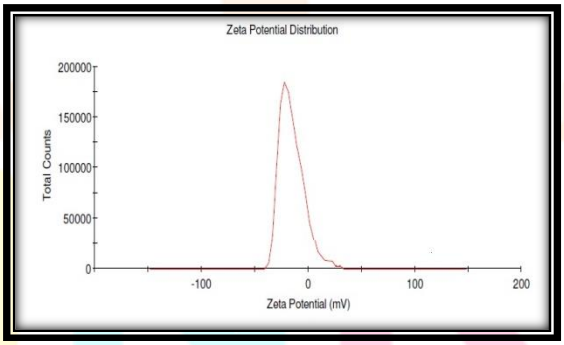

Figure No. 6 Zeta potential analysis of ZnO nanoparticles

3.8 *XRD (x-ray diffraction)*

The sample is analyzed for XRD analysis. X-ray Diffraction study is mainly to obtain the crystalline and average particle size of synthesized nanoparticles and it shows the dispersion of a particular material.

The surface morphology of scanning electron microscope characterization was further regulated using X-ray diffraction outputs. A scanning electron microscope image clearly shows the form, crystal size, and surface morphology of the ZnO nanoparticle [46]. Comprehensive structural investigations show that the outputs are cubic in shape and crystallised in a pleasing pattern. The sizes measured were around 40 nm.

At 27.39° and 40.64°, two large diffraction peaks were found, with crystal planes of (100) and (002), respectively. Only two broad peaks can be seen in the onion-extracted nanoparticles. In addition, with the exception of onion, 47.31°, 53.60°, 72.63°, and 73.75° were observed in all extracted samples having (101), (102), (200), and (112) of crystal planes, respectively [61]. The XRD pattern of the synthesised Zinc oxide nanopowder at 2 = 36.19°, the observed diffraction peaks of ZnO correspond to the lattice plane (101).

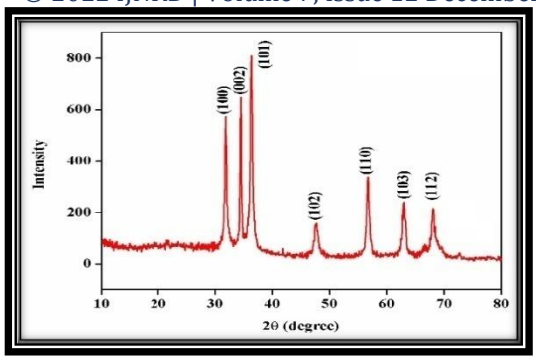

Figure No.7 X-Ray Diffraction analysis of ZnO nanoparticles

Diffraction occurs as waves interact with a regular structure whose repeat distance is about the same as the wavelength Diffraction peaks around 32, 35, 37, 48, 57, 63, 68 degree were seen in the XRD spectrum, which are near the (100), (002), (101), (102), (110), (103), and (112) of the wurtzite crystal structure of ZnO corresponded to lattice plane. A lattice plane (100), (002), (101) represents the presence of pure form of nanoparicles.

3.9 *Antimicrobial activity of ZnO nanoparticles*

Zinc oxide nanoparticles demonstrated antibacterial action against microorganisms (bacteria and microbes), as well as excellent photodegradation properties, while on the other hand, they showed promise in drug administration and anticancer treatment. Nanoparticles are often regarded as the finest antibiotic replacements [62]. These nanoparticles have antibacterial characteristics due to their tiny size and huge surface area, which includes electrostatic contact between nanoparticles and microbial cell surfaces. Zinc oxide nanoparticles cytotoxic activity causes holes to form on the microbial cell's surface, allowing cytoplasmic contents to seep out and the cell to die [63]. They can interact directly with the microbial cell membrane, causing the membrane to break down [64].

Several investigations are being conducted to investigate the usage of various unknown plant extracts in the production of zinc oxide nanoparticles. They have been successfully produced from a number of plant species and components, including stems, roots, leaves, bark, and plant enzymes, for use as antimicrobials in a wide range of applications. Zinc oxide nanoparticles have the potential to be an ideal antibiotic alternative by providing a robust resistance against multidrug-resistant microorganisms [65]. The antibacterial activity of nanoparticles is shown to be highly dependent on their size. The bactericidal activity of nanoparticles with a lower size was shown to be greater in this investigation [66]. The existence of an inhibitory zone in the well diffusion experiment demonstrates that ZnO has a biocidal effect by breaking the cell membrane. The surface activity of ZnO in contact with the bacterial membrane surface may cause bacterial cell wall rupture [67][68].

These nanoparticles particularly manufactured CuO, ZnO, and Ag, exhibit strong antibacterial activity and might be used as an antibiotic alternative in aquaculture [69]. Zinc oxide nanoparticles exhibit potent antimicrobial activities [70]. Zinc oxide nanoparticles inhibited the growth of *A. hydrophila* and *A. salmonicida* [69]. Likewise the ZnO Nanoparticles synthesized by *Musa paradisiaca* also showed a significant zone of inhibition for the aquatic pathogens *Vibrio alginolyticus*, *Vibrio harveyi*, *Vibrio haemolyticus* and *Aeromonas hydrophila* Table No.3. So, there is some antimicrobial activity for the ZnO nanoparticles synthesized by *Musa paradisiaca* spathe and it may be undergone for further aquaculture practices.

Name of the species	Zone of inhibition (in mm)	
	Concentration (75 mg)	Concentration (100mg)
Aeromonas hydrophila	3.2	6.5
Vibrio harveyi	4.7	8.2
Vibrio haemolyticus	2.5	5.4
Vibrio alginolyticus	0.9	2.4

Table No. 3 Antimicrobial activity of the ZnO nanoparticle against aquatic pathogens

CONCLUSION

Nanotechnologies are now widely regarded as having the potential to improve a wide range of fields, including drug discovery, manufacturing industries and research and development. Nanoparticles can have a wide range of physical and chemical properties compared to their larger counterparts. Nanoparticles can be synthesized mainly by physical, chemical and biological processes recently biological synthesis of nanoparticles is gaining importance because of its cost efficiency, easy availability and an alternative for harmful chemicals. The plant extract functions

as a reducing and stabilising agent for the bio-reduction reaction to create unique metallic nanoparticles since it contains diverse secondary metabolites. Therefore, Green synthesis of nanoparticles using biological systems, particularly plant extracts, is a growing subject in nanotechnology and it has a wide range of possible uses in the environmental and biomedical domains. Green synthesis strives to reduce the use of harmful chemicals in particular. There are various types of nanoparticles synthesized by the green synthesis of nanoparticles within Zno nanoparticles have a greater advantage recently mainly because of its stability.

Our studies relates to the green synthesis of Zno nanoparticles from *Musa paradisiaca* spathe extract. Positive results were obtained in the synthesis of ZnO nanoparticles from *Musa paradisiaca* spathe extract. The phytochemical analysis was undergone which showed the presence of alkaloids, steroids, sterols, phenols, anthocyanins, quinines, anthraquinones, lignins and terpenoids. Similarly the characterization of ZnO nanoparticles was also analyzed to determine the stability, functional groups, particle size, structural analysis and its various properties. Mainly, UV-Visible spectroscopic analysis, XRD, DLS, SEM, FT-IR, and Zeta potential has been analyzed which showed satisfactory results for the *Musa paradisiaca* synthesized ZnO nanoparticles. Our overall studies exhibited that the green synthesized ZnO nanoparticles has a satisfactory results for the analysis of phytochemicals in it and their characterization showed that there is a sufficient stability and the dispersion of particles for the process of a pharmaceutical research and development. Our studies finally concluded with the results that it has some antimicrobial activity against the aquatic pathogens. So, further studies can be developed in the field of aquaculture and its several implications.

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