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Review Article

Potential Applications of Green Synthesized Nanoparticles from *Moringa oleifera*

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Abstract

Now a days, the major reason behind the spreading of highly contagious diseases is the increasing resistance of the pathogens to commercial antibiotics. The remedy to overcoming antibiotic resistance is the use of nature-based products. Many medicinal plants are rich in phytoconstituent which have antimicrobial properties. Among these *Moringa oleifera* is the phenomenal one. It has numerous applications as antimicrobial, antiparasitic, antiviral, anticancer, antioxidant, coagulation-flocculation, and adsorption activities. All parts of *M. oleifera* extracts exhibit strong antimicrobial activity against common antibiotic-resistant pathogens. The application of nanotechnology can enhance the antimicrobial properties of phytoconstituent. It deals with the creation of nanoparticles of small size within 0.1-100 nm which have numerous applications in various fields. Green synthesis of nanoparticles is advantageous over the chemical and physical methods as it is cheap, sustainable, cost-effective, non- toxic, and simple. By using green synthesis methodology synergistic effect may be possible as nanoparticles have different properties than the original one. Here, the review summarizes the use of various parts of *M. oleifera* and its utilization for the synthesis of diverse nanoparticles possessing antimicrobial activity. The green synthesized nanoparticles from *Moringa oleifera* can lead to the finest therapy spearheaded to combat antibiotic resistance amongst pathogens.

Keywords: Phytoconstituent; Medicinal Plants; *Moringa oleifera*; Nanoparticle; Antimicrobial

Introduction

The flora of earth is the richest source of different phytochemicals having immense application in various fields for sustaining human life. From ancient times to the modern age, humans directly or indirectly depend on plants for fulfilling their basic needs such as food, shelter, clothes, and most importantly medicine. Plants are important for survival and maintaining human life on earth. The population with low income in under developing countries and in rural areas do not get access to health care services. Medicinal plant offers basic remedies for treating ailments and maintaining health to them. Many medicinal plants have disease-curing and preventing properties that are routinely used by people from rural areas. Medicinal plants not only provide medicine but also generate employment and income [1]. Among the medicinal plants, *Moringa oleifera* a "Miracle tree" of Indian native belongs to the *Moringaceae* family having numerous applications in different sectors. *M. oleifera* is popularly known as "Drumstick Tree" or "Horseradish tree" and in India, it is popular by the name "Sahjana". It is commonly grown in tropical and subtropical regions of the world mostly Asia and Africa. In Ayurveda, it is commonly named Haritashaaka, Raktaka, and Akshiva, and in the Unani system of medicine as Sahajana [2]. It is cultivated all over world for its nutrient-rich leaves and fruits which have common applications in cooking. The pharmacological properties of *Moringa oleifera* make it useful for treating different diseases such as malaria, parasitic diseases, skin diseases, hypertension, and diabetes. All parts of the *Moringa oleifera* tree are utilized in the formation of traditional medicine and home remedies. The research studies have shown that *Moringa oleifera* extract exhibited biologically important activities such as antimicrobial, antiparasitic, antiviral, anticancer, antioxidant, coagulation-flocculation, adsorption, etc. [3]. Now a days, increasing resistance of pathogens to commercial antibiotics is the major issue of disease progression. It is leading to the spread of highly contagious diseases. The remedy for overcoming the antibiotic resistance of pathogens is the use of nature-based products. Many medicinal plants have phytoconstituent which have antimicrobial property, a possible source of new, cheap, and sustainable antimicrobial agents. *M. oleifera* is nature's gift for the current situation. All parts of *M. oleifera* extract are found to exhibit strong antimicrobial activity against common antibiotic- resistant pathogens.

From ancient times medicinal plants have been used to treat diseases. However, its applications are limited due to its instability, poor solubility, and seasonal availability. Green synthesized nanoparticles overcome the drawback of herbal medication.

Nanotechnology is a branch of science and engineering that offers numerous applications in different sectors. It deals with designing materials in the nanoscale range with at least one dimension less than 100nm. At the nanoscale, the properties of nanomaterials substantially differ from those of bulk materials due to the increased surface area-to-volume ratio. Nanoparticle is the key product of nanotechnology. It can be produced in a physical way, chemical synthesis, and biological way by either using microorganisms or by green synthesis using plant material. Physical and chemical ways of nanoparticle synthesis are costly, harmful, and nonbiodegradable as they involve the use of harmful chemicals. The biological way offers an advantage over the physical and chemical way as it is eco- friendly, sustainable, cost-effective, and biodegradable. However, the green route of nanoparticle synthesis offers advantages over microbe-mediated nanoparticle synthesis as it minimizes the risk of handling pathogens, isolation, culturing, and production [4].

The current review aims to summarize the use of *M. oleifera* plant in various disciplines and potential applications of green synthesized nanoparticles from *Moringa oleifera.*

Usage of *M. oleifera*

The various parts of *Moringa oleifera* have been studied for antimicrobial, antioxidant, and antidiabetic activities. The plant parts used are:

- Leaves
- Seeds
- Fruits/Pods
- Flowers
- Roots
- Stem

Leaves of *M. oleifera*

Leaves of *M. oleifera* contain high levels of Vitamin A (9 times more vitamin A than carrots), vitamin B(folic acid, pyridoxine, and nicotinic acid), vitamin C (12 times more vitamin C than oranges), Vitamin D and vitamin E, as well as it is the rich source of minerals such as potassium (15 times more potassium than banana), iron (25 times more iron than spinach), zinc, calcium (17 times more calcium than milk) and other essential minerals. It is abundant with β Carotene, xanthin, unsaturated fatty acids (alpha- linoleic acid), and essential amino acids. Also, leaves contain different functional groups including Alkaloids, Tannins, Flavonoids, Steroids, Saponins, Polyphenols, Glycosides, Carbohydrates, Proteins, and Amino acids which are responsible for different activities such as antioxidant, antimicrobial, antiviral, and antidiabetic [5].

Antimicrobial activity of leaves

The antimicrobial potential of *M. oleifera* leaves is associated with the presence of different functional groups. Ethanolic, as well as aqueous extract of leaves, shows antibacterial activity against both the pathogenic Gram positive and Gram-negative bacteria such as *Staphylococcus aureus, Escherichia coli, Salmonella typhi, Enterobacter aerogenes, Salmonella typhimurium, Shigella spp*., and *Pseudomonas aeruginosa*. As well as it shows antifungal activity against the *Mucor spp*. and *Rhizopus spp.* Alcoholic and water extract shows strong antifungal activity against the common infectious fungal pathogens such as *Saccharomyces cerevisiae*, *Candida tropicalis*, *Candida albicans*, *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus fumigatus* and *Cryptococcus neoformans* [6,7].

Antiviral activity of leaves

Previous research study showed that alcoholic leaf extract of *M. oleifera* was effective remedy against Foot and mouth diseases caused by Picornavirus. It was also found that aqueous extract of leaf shows effective antiviral activity against Herpes simplex virus type 1 and type 2 [8]. The active ingredients found in the leaf show effective inhibitory action against infectious disease-causing viruses such as HIV (causative agent for acquired immune deficiency syndrome), Epstein Barr virus, and Hepatitis B virus The active compound Niaziminin (thiocarbamate) extracted from the leaf inhibits the tumor promoter- induced Epstein Barr virus activation [9].

Antioxidant activity of leaves

M. oleifera leaves show strong antioxidant activity due to the presence of naturally occurring glycosides containing isothiocyanates, malonates, and flavonoids. In particular, quercetin and kaempferol glycosides are responsible for natural antioxidants such as flavonoids, quercetin, and kaempferol due to broken down to respective aglycones [10].

Medicinal application

With research investigation, it was found that leaf extract has numerous medicinal applications. It can beused in curing eye (catarrh), ear infections, and scurvy. It is also useful in piles, fever, sore throat, and bronchitis. Leaves of *M. oleifera* show anecdotal hypertensive activity which relates to the compound carbamates and thiocarbamates isolated from the leaves. It has also been observed that leaf extract can regulate thyroid and cholesterol levels when studies on rats. It also induces apoptosis and reduces the proliferation and invasion of lung cancer cells. The nutrient richness of *M. oleifera* leaves makes it the best agent to fight against malnutrition, especially in infants and nursing mothers. It can be used in herbal medicine as a hypocholesterolaemic agent in obese patients. Leaf powder has antidiabetic potential (type 2 diabetes and type 1 diabetes). It shows a decrease in blood glucose levels when tested on rats [1,11]. It is also beneficial in improving spatial memory and decreasing neurodegeneration and therefore it is a potential medicinal food for dementia patients. *M. oleifera* dried leaf ethyl acetate extract (10% extracts) in the form of ointment showed significant wound healing activity when tested in rats. It was due to the presence of phytosterols, glycosides, tannins, and amino acids that promote wound healing activity [12]. *M. oleifera* methanolic leaf extract also shows antileishmanial activity which was associated with the compound niazinin, a thiocarbamate glycoside [13].

Use as a Protease inhibitor and Preservative

Leaves of *M. oleifera* are a rich source of naturally occurring protease inhibitor which has high activity against bacterial proteases and therefore, it has immense application for developing sustainable drugs against the proteases such as thrombin, elastase, chymotrypsin, trypsin, cathepsin, and papain. As a protease inhibitor, it is a suitable agent for preserving seafood [14].

Use as a food fortificant for human consumption and Fodder for animal

Plenty of nutrients make leaves a source of vegetables in cooking. leaves are a rich nutritional source of tocopherols, provitamins, ascorbic acid, and carotenoids. Tender leaves are utilized as vegetables. Dryor fresh leaves are also used in soups, noodles, rice, etc. Leaf powder can be used as a flavoring agent. Leaves powder is also added to the chocolate, ice-cream, halawa tahinia, moringa paneer, herbal biscuit, in bread (5% addition increases nutritional value), cakes, yogurts, khakhra, Chin-chin (Nigerian snack), moringa muffin (12% addition of *M. oleifera* powder) [15]. It was found that the addition of leaf powderin products is acceptable for human consumption and the product resulted high in protein, and minerals. Sometimes leaves are also used as fodder for maintaining healthy livestock by maintaining the microbialstatus in the bovine rumen. Nowadays, *M. oleifera* powder can also be used as a fish food in aquacultural systems [16].

Seeds of *M. oleiferaa*

The seeds of *M. oleifera* are a rich source of macronutrients, micronutrients, and all essential amino acids. Macronutrients include sodium, potassium, calcium, and magnesium; micronutrients such as iron,copper, and zinc. Also, it is enriched with seven non-polar amino acids which are responsible for the antioxidant properties. It is also a rich source of Vitamin B1, Vitamin B2, Vitamin B3, Vitamin C, and Vitamin E as well as fat, fiber, and carbohydrate [17].

Antimicrobial activity

The seed extract's bactericidal and fungicidal properties are due to the existence of a unique bioactive molecule called 4-(-L-rhamnopyranosyloxy) benzyl isothiocyanate [18]. It was also found that Methyl N-4-(-L-rhamnopyranosyloxy) benzyl carbamate, 4-(-D-glucopyranosyl-1→4--L- rhamnopyranosyloxy)-benzyl thiocarboxamide, and other isolated compounds like strophantidin, N-benzyl thiocarbonates, N-benzyl carbonates, benzyl nitrites, and a benzyl ester were among the peptides found in the seed that inhibited the growth of both Gram-positive and Gram-negative pathogenic bacteria [11]. Ethanolic extract shows strong antibacterial activity against the common Gram-negative pathogenic bacteria such as *Escherichia coli*, and *Shigella flexneri.* Chloroform and ethanolic extract of seed also show inhibition of fungal pathogens such as *Mucor spp*. and *Rhizopus spp. Pasturella multocida*, *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus* are also susceptible to the seed extract [6]. It was found that bacterial strains such as *Bacillus subtilis, Salmonella typhimurium, Enterobacter aerogenes,* and *Pseudomonas aerogonosa* are inhibited by the application of seed oil extracted from *M. oleifera* [19].

Antiviral activity

The *Moringa oleifera* seed also had antiviral applications. The seed extract of *M. oleifera* has the potential to inhibit the Newcastle disease virus, which causes infectious disease in Avian species and can be transmitted to humans through poultry birds [20]. It also shows potent antiviral activity against the *Influenza A* viruses. It was found that the antiviral activity of *M. oleifera* is due to the inhibition of expression and nuclear transfer of the cellular protein transcription factor EB (TFEB) and repress the autophagic activity [21].

Anticancer/Antitumor

The most important application of *M. oleifera* seed is its utilization as an anticancer agent. The active compounds involved in anticancer properties are β-sitosterol, glycerol-1-(9-octadecanoate), 3-O-(6-O- oleoyl-β-D-glucopyranosyl)-β-sitosterol, and β-sitosterol -3-O-glucopyranoside [22].

Antipyretic activity

The nutrient richness of *M. oleifera* seed makes it an excellent antipyretic agent. The antipyretic activity was tested in rats using yeast-induced hyperpyrexia methodology. The seed extract in different solvents such as ethanolic, petroleum ether, solvent ether, and ethyl acetate shows significant antipyretic activity.The antipyretic activity of *M. oleifera* was due to the presence of phytosterols, glycosides, phenolic compounds, carbohydrates, and amino acids [12].

Use in wastewater treatment

M. oleifera seeds (powder), have traditionally used in water purification because of their inherent coagulation and flocculation properties. Studies have indicated that seed extract has exceptional sedimentation capabilities when applied to the treatment of underground and surface water. Its sedimentation rates were 90% and 95%, respectively [11]. Additionally, it is utilized to improve the biosorption of heavy metals and the main treatment of paper mill effluent. It is a less costly heavy metal adsorbent [23]. Seed extract was a promising sustainable and affordable agent for treating coffee fermentation wastewater [24]. Significant anti-cyanobacterial action was also discovered in *M. oleifera*, and it was shown that the bloom-forming cyanobacterium Microcystis aeruginosa dies when exposed to higher dosages of crushed *M. oleifera* seeds (20–160 mg/liter) because of the quick decline in photosystem II efficiency [25].

Use as a food fortificant or by direct consumption

In all countries whole seeds of *M. oleifera* are consumed fresh like peas, or by roasting them. It can be used in the form of steaming in tea and curries [15].

Use of seed oil in cooking, cosmetics, and as a machine lubricant

The seeds of *M. oleifera* are rich in lipid content. It ranges from 14% to 46% of dry weight. “Ben oil” (*Moringa* seed oil) is extracted by pressing the seeds of *M. oleifera* and contains a high amount of tocopherol and presence of high monounsaturated to saturated fatty acid ratio. Ben oil has important applications in body spas and as a stimulant for hair growth, manufacturing perfumes, and lubricants in machinery. It has been found that the physical and chemical properties of Moringa seed oil are equivalent to olive oil. Hence, it is the best alternative to the other oil. Therefore, it is not only utilizedas a frying oil but also in a salad. Research investigation on seed oil in cooking found that it reduces the risk of coronary heart diseases [26].

Use as a renewable energy source

As a renewable energy source (biodiesel) seeds of *M. oleifera* can be used as favorable renewable fuels due to their excellent calorific value and easy production technique [27].

Medicinal properties

The seeds of *M. oleifera* are rich in phytoconstituent, which offers curative properties in the medicinal field. Previous research investigations have reported that Ayurvedic practitioners used dried seeds as an antiallergic. It can also be administered nasally in rhinitis disease. Seed extract can activate the hepatic stellate cell activation. Research investigation have reported that seed extract is an effective remedy against the CCl_4-induced hepatic liver damage and fibrosis when tested in rats. It has also been reported that ethanolic seed extract exhibited antiarthritic activity [17].

Fruit/Pod of *M. oleifera*

M. oleifera pod is rich in dietary fiber. In comparison to leaves, it is rich in Vitamin C and also a rich source of Vitamin B1, Vitamin B2, Vitamin B3, Vitamin E and carbohydrate. *M. oleifera* pod is rich in the predominant phenolic compounds such as quercetin, caffeic acid, and kaempferol. It is also rich withmineral constituents, amino acids and phytoconstituent such as isothiocyanate, thiocarbanates, o-ethyl- 4-((α-1-rhamnosyloxy)-benzyl) carbamate, o-(2'-hydroxy-3'- (2''-hepteneyloxy)) propyl undecanoate, nitriles, β- sitosterol and methyl-p-hydroxybenzoate [17].

Antimicrobial activity

Methanolic extract of *M. oleifera* fruit shows excellent broad-spectrum antibacterial and antifungal activity against Gram-positive and Gram-negative bacterial strains such as *Staphylococcus aureus, Bacillus subtilis, Vibrio cholera, Bacillus cereus, Salmonella typhi, Shigella dysenteriae, Pseudomonas aeruginosa, Klebsiella species,* and *Proteus spp.* As well as pathogenic fungi such as *Alternaria spp., Colletotrichum spp., Curvularia spp.,* and *Fusarium spp*. were also susceptible to the methanolic fruit extract [28].

Medicinal properties

M. oleifera fruit also has antihypertensive properties. Studies have indicated that the action was linked to arbamate and isothiocyanate glycosides that were isolated from the fruit of *M. oleifera's* ethanolic extract. Fruit powder lowers fat and cholesterol levels in rabbits in vivo because of its potent antioxidantproperties and stimulation of hepatic enzymes [29].

Wastewater treatment

M. oleifera pod is a naturally available inexpensive raw material employed for absorption of organic compounds such as benzene, toluene, ethylbenzene, and cumene from water sources. Therefore, reducesthe cost of the wastewater treatment process. Research investigation also shows that pods of *M. oleifera* effectively remove heavy metals from wastewater such as copper, nickel, chromium, and zinc ions dueto their biosorption ability [30].

Use as a vegetable for human consumption

Fresh fruit is routinely used as vegetables in cooking as it is nutritionally rich with various macro and micronutrients [15].

Flower of *M. oleifera*

The flowers of *M. oleifera* are rich in flavonoids, phenolic acids, tocopherols, β-carotene, vitamins, important sulfur-containing amino acids such as methionine and cysteine, minerals such as calcium and potassium, and proteins [17].

Antimicrobial activity

The presence of phenolic and flavonoid groups in *M. oleifera* flowers is linked to their antibacterial properties. The antibacterial activity is determined by pterygospermin, a functional active component that was extracted from the flower [31].

Trypanocidal activity

Previous research investigation has shown that *M. oleifera* flower contains β amyrin, β-sitosterol, kaempferol, quercetin, and a proteinaceous protease inhibitor (Trypsin inhibitor) which interferes with the development of *Aedes aegypti* larvae. Flower extract contains high quantities of flavonoids which are responsible for trypanocidal activity against *Trypanosoma cruzi* [32].

Use as a food fortificant

Flowers are also used as a vegetable in cooking because of its nutrient richness. Dry flowers are used as a flavoring agent in tea [17].

Use in wastewater treatment

Research investigation on flower extract shows that it can be used in the bioremediation process. It should be the best alternative to chemical disinfectant. As it shows excellent bactericidal and bacteriostatic activity against both the Gram-positive and Gram-negative bacteria. It was strongly effective against *Escherichia coli* an indicator of water faecal contamination as well as it inhibited the *Bacillus subtilis, Staphylococcus aureus*, *Salmonella enteritidis,* and *Proteus mirabilis.* Precipitated *M. oleifera* protein fraction also shows inhibitory activity against *Bacillus subtilis, Enterococcus faecalis, Salmonella enteritidis, Proteus mirabilis,* and *Escherichia coli* [33].

Roots of *M. oleifera*

Roots of *M. oleifera* are rich with phytoconstituents such as 4-(α-L-rhamnopyranosyloxy) benzylglucosinolate and benzylglucosinolate. Roots are also rich in nutrients like vitamine C, calcium, magnesium, and phosphorous. This nutrient richness of roots offers a variety of applications in different sectors.

Antimicrobial activity

Roots of *M. oleifera* is an excellent antimicrobial agent. Benzyl isothiocyanate is an antifungal and antibacterial compound isolated from the roots of *M. oleifera*. Moranigine and Moringine are functionally active compounds associated with the antibacterial and antifungal activity extracted fromthe root of *M. oleifera* plant [34].

Medicinal properties

The roots of *M. oleifera* are rich with functionally active compounds which contribute to its medicinal application. The root bark contains the alkaloid moringinine, which acts on the sympathetic nervous system to increase cardiac performance. According to earlier investigations, root-bark preparations have been used to treat earaches, tumors, and ulcers. Additionally, it has analgesic qualities and aids in the evacuation of the tuberculous gland from the neck area [1]. Root extract has significant anti- inflammatory properties when tested on rats [35]. Ethanolic extract of roots of *M. oleifera* shows antileishmanial activity due to the presence of active constituent niazinin, a thiocarbamate glycoside [13].

Wastewater treatment

The root of *M. oleifera* is rich in dissolved macronutrients. This richness can be utilized in the water treatment process. Research investigations have shown that limited addition of root powder in contaminated water effectively decreases the *E.coli* count. This research finding has suggested that it offers dual benefits during water purification. It not only kills *E.coli* but also gives health benefits as it increases the dissolved macronutrients in the water [36].

Use as a food

Due to the nutrient richness of *M. oleifera* roots, it can be consumed dry or can be utilized by boiling with other herbs [36].

Stem of *M. oleifera*

The stem of *M. oleifera* is rich with phytoconstituent such as β-sitosterone, β-sitosterol 4- hydroxymellein, 4-hydroxymellein, β-sitosterol, and 4-(α-L-rhamnopyranosyloxy)- benzylglucosinolate,triterpenoids, flavonoids, and anthraquinones [18].

Antimicrobial activity

M. oleifera stem shows antimicrobial activity. Research investigation has shown that the stem extract contains β-sitosterone, β-sitosterol 4-hydroxymellein, and Vallin which exhibit antibacterial and antifungal activity [37].

Antioxidant activity

The stem of *M. oleifera* shows strong antioxidant activity comparable to the standard ascorbic acid. The antioxidant activity was due to the presence of tannins, flavonoids, steroids, and alkaloids [35].

Green synthesis of nanoparticle:

The bioactive constituent of *M. oleifera* can reduce the metal or metal oxide to its nanoparticle which shows a synergistic effect with *M. oleifera*, compared to the original material. Nanotechnology is a growing scientific field that has received increasing attention for developing new creations ranging fromapproximately 1nm to 100nm.

Green synthesis of nanoparticles using plant-based products involves the extraction of active constituents in suitable solvents with appropriate conditions of temperature, pH, and time followed by mixing with suitable metal for the formation of nanoparticles [36].

Leaf extract nanoparticle

Leaves of *M. oleifera* have high nutritional and medicinal value. They were excellent sources for thesynthesis of various nanoparticles.

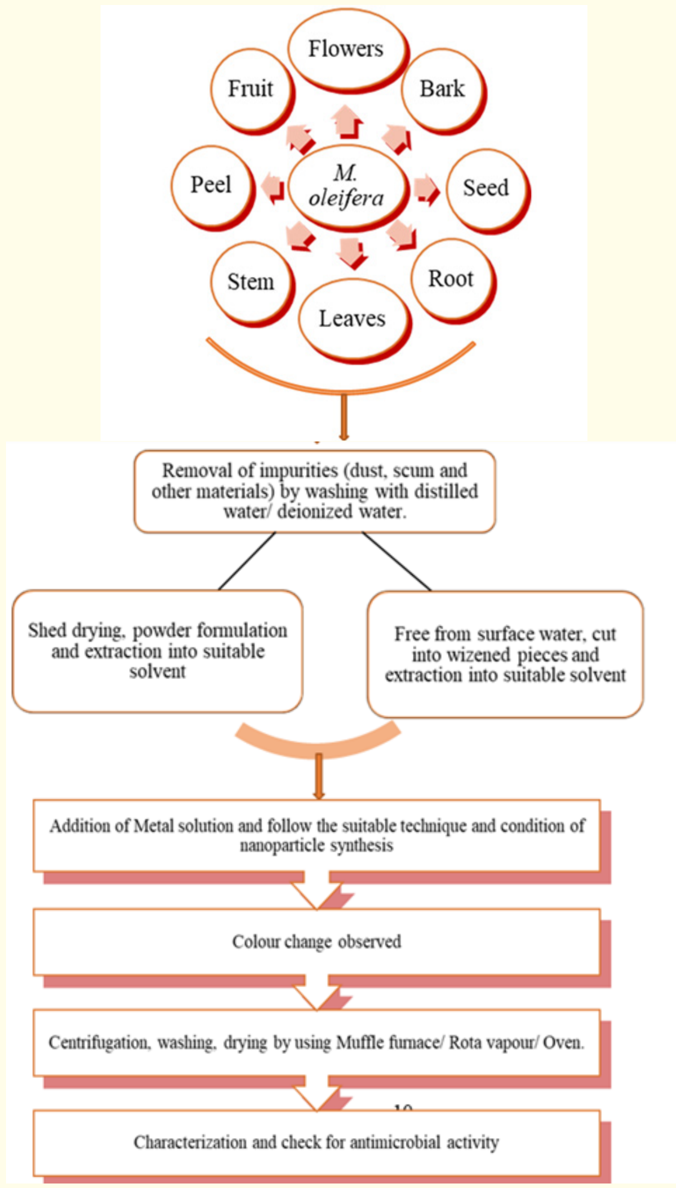

Figure 1: Flow diagram for green synthesis of nanoparticle.

Vanadium nanoparticle

Vanadium nanoparticles (NPs) are one of the metal nanoparticles that receive more attention due to the presence of special optical and electrical characteristics. It can be synthesized by the green synthesis method. Fresh leaves aqueous extract (5 gram %) was used for the synthesis of vanadium nanoparticles. 10 ml extract was allowed to react with 190 ml aqueous solution of vanadium chloride (1 mM) for 2 hrs on a magnetic stirrer. The phytoconstituent of *M. oleifera* was responsible for the reduction of vanadiumto its nanoparticle (V^{2+} into V^0). Vanadium nanoparticle inhibits the growth of *Escherichia coli* and *Salmonella typhi* but unable to inhibit *Candida albicans* and *Candida tropicalis.* This finding was beneficial implication in the medicinal field as a bactericidal agent [38].

Silver nanoparticle

Silver nanoparticles are among the most studied nanoparticles among metal nanoparticles due to their wide range of applications in various fields. Synthesis of small-sized silver nanoparticles also has immense application as an antibiotic against resistant bacteria. Silver nanoparticles were synthesized by using a hot aqueous extract of *M. oleifera* leaves (10 gm % dry leaf powder in deionized water). 1mM aqueous silver nitrate solution is used for nanoparticle synthesis (1:9, extract: solution). Synthesized silver nanoparticles (spherical, 57nm sized) show considerable antimicrobial activity as compared to standard antibiotics. It shows the maximum zone of inhibition against *E. coli, Staphylococcus aureus,* and *Candida tropicalis* as compared to *Klebsiella pneumoniae, Candida krusei,* and *Bacillus cereus* [39]. Silver nanoparticles were also effective against the *Pseudomonas aeruginosa* in comparison with standard antibiotics streptomycin, when the nanoparticle synthesis was done in hot aqueous extract of *M. oleifera* leaves (5 gm % fresh leaves in distilled water.) This research finding indicates that the silver nanoparticle of *M. oleifera* leaf can be used in the medicinal field as a strong promising candidate as an antimicrobial agent [40]. Millipore water is also used for the synthesis of silver nanoparticles. 5 ml extract (10 g % dry leaf powder and fresh leaf powder in Millipore water respectively) allow to react with 50 ml of aqueous AgNo3 (1mM) solution by exposing to direct sunlight. Synthesized nanoparticle shows promising antibacterial and antifungal activity against *Staphylococcus aureus* (43300), *Enterococcus faecalis* (5129), *Escherichia coli* (35218), *Pseudomonas aeruginosa* (27853) *Klebsiella pneumoniae* (700603) *Candida albicans* (ATCC 90028), *Candida krusei* (ATCC 6258) and *Candida parapsilosis* (ATCC 22019). Neomycin-resistant bacteria such as *E. faecalis, P. aeruginosa,* and *S. aureus strains* are inhibited at a concentration of 25 µg ml^{-1}. while only 12.5 µg ml^{-1} was sufficient to inhibit the growth of *E. coli* and *E. faecalis*. Whereas, only 6.25 µg ml^{-1} concentration of AgNPs was sufficient to inhibit the growth of all tested fungal strains. This finding suggests that silver nanoparticles were not only effective at low concentrations but also indicated a broader susceptible bacterial spectrum range as compared to the commercial Neomycin MIC range [41].

Zinc nanoparticle

M. oleifera Leaf extract is also utilized in the synthesis of zinc nanoparticles. Precipitation method is used in which 10 ml aqueous extract (5gm%) was mixed with 50 ml of 20 % NaOH solution. This prepared solution was used for nanoparticle synthesis by diluting it with distilled water (1:10, solution). zinc acetate (2.1%) and ammonium carbonate (0.96%) solution were added dropwise with continuous stirring. The antibacterial activity of synthesized nanoparticles shows that *E. coli* and *Bacillus subtilis* are highly susceptible. This finding suggests that zinc nanoparticle is a novel antibacterial drug against Gram-positive and Gram-negative bacteria [42].

Copper nanoparticle

M. oleifera extract was also used to create copper nanoparticles. *M. oleifera* (10 gm%) was extracted in 80 ml of water-ethanol (1:1) and allowed to react with 20 ml of copper sulfate pentahydrate (1 gm in 20 ml of deionized water) for three hours at 600C in order to create nanoparticles. In comparison to *Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, Enterococcus faecalis, Aspergillus niger, Aspergillus flavus, Candida albicans,* and Candida glabrata. The produced nanoparticle exhibits high antibacterial and antifungal action. The results of the study indicate that it was a more promising antifungal agent than an antibacterial one [43]. For the creation of nanoparticles, fresh leaf aqueous extract (5 gm%) was also utilized. Copper acetate monohydrate solution (0.01M in deionized water) wasallowed to react with extract in a 1:1 ratio at 250 rpm for 25 minutes in order to create nanoparticles. When tested against fungal strains like *Candida albicans* MTCC 227, *Aspergillus niger* MTCC 282, *Aspergillus clavatus* MTCC 1323, Trichophyton mentographytes MTCC 8476, and *Epidermophyton floccosum* MTCC 7880, the synthesized copper nanoparticle exhibits strong antifungal activity using thereference standard Griseofulvin. This discovery implies that *M. oleifera* leaf copper nanoparticles may be employed as an antifungal treatment to treat fungal infections [44]. Research investigations have found that copper microsphere was a promising bactericidal agent against both the Gram-positive and Gram-negative bacterial strains. The copper microsphere was prepared by allowing 1 gram of Cu (NO3)2to react with 30 ml filtered aqueous extract (5gm in 150ml) at 80^{0}C. It shows strong bactericidal activity against *S. aureus* followed by *Klebsiella pneumoniae* and *E. coli*. The least bactericidal activity was found in case of *Bacillus cereus* [45].

Titanium nanoparticle

In view of the clinical aspect, wound infection by pathogenic bacteria has been the major problem of recent era. Which was associated with the increased resistance of pathogens to commercial antibiotics. Research investigations have found that titanium nanoparticles exhibited wound-healing properties. Titanium nanoparticles of 100nm size and spherical synthesized using *M. oleifera* leaf extract was the miracle for overcoming the problem of wound infection. The nanoparticle was synthesized by allowing 10 ml aqueous extract (10gm% leaf powder in deionized water) to react with 90 ml of 5mM titanium dioxide solution of pH 1.5 with continuous stirring for 5 hrs at 50^0 C. The Invitro research study on albino rats shows that titanium nanoparticles of *M. oleifera* leaves have excellent wound healing efficacy compared to conventional standardized treatment. This wound-healing activity was due to the antimicrobial properties of titanium nanoparticles. This finding opens up a new path of medical research. It is the best eco-friendly, cost-effective, time-saving alternative in the medical field [46].

Nickel oxide nanoparticle

Recently, nickel oxide nanoparticles also had drawn a lot of interest because of their chemical stability, electron transfer capability, electrocatalysis, and super conductance. The nickel oxide nanoparticle was synthesized using hydroalcoholic extract of fresh *M. oleifera* leaves. The 20 ml filtered infusion (20gm % water-ethanol solution (1:1) for 24 hrs) was used for nanoparticle synthesis by mixing it with a dropwise addition of 80 ml of 0.1 mM aqueous Ni $(NO_3)_2$ solution with continuous stirring at 90^0C for 20 min. The resultant synthesized nanoparticle shows cytotoxic as well as antibacterial effects against *Escherichia hermannii, Escherichia coli, Streptococcus pnemoniae,* and *Staphylococcus aureus* [47].

Dry leaf powder was also used for the synthesis of nickel nanoparticles. Deionized water is used for extract preparation (1 gm% at 50^0C for 30 min on a magnetic stirrer). Nanoparticles were synthesized by allowing the 0.1M of nickel nitrate to react with 100ml of extract with constant stirring for 24 hrs. The synthesized nanoparticle shows promising antibacterial activity against Gram-negative *Escherichia coli* (ATCC 9677) and Gram-positive *Staphylococcus aureus* (ATCC 6538 P) [48].

Magnesium Oxide nanoparticle

Magnesium oxide nanoparticles were also synthesized by using an aqueous extract of dry leaves (4gm % at 60^0C for 20 min). The reaction medium involves the 10 ml of 1mM $MgCl_2$ solution allowed to react with 10 ml of extract (600 rpm) at 90°C with dropwise addition of 2M NaOH into the solution (3 hrs). The resultant green synthesized MgO nanoparticle has potent antibacterial activity against Gram- positive *Staphylococcus aureus* and Gram-negative *Escherichia coli* [49].

Iron nanoparticles

Another important alternative to commercial antibiotics is the green synthesis of iron nanoparticles (FeNPs) using *M. oleifera* leaf extract. It is a good alternative to chemically synthesized nanoparticles. The nanoparticle was synthesized by mixing the dried leaf powder extract (4gm % at 60^0 C for 20 min) with 0.1 M $FeCl_3$ in different volume concentration ratios such as 1:1, 1:2, 1:3, and 1:4 with continuous stirring for 30 minutes. The resultant nanoparticle inhibited the growth of Gram-negative *Escherichia coli* O157 [50].

Cerium oxide nanoparticles

Not only metal but also rarest earth metal from the lanthanide series has received tremendous attentionas a future material for diagnostic and therapeutic application in the biomedical field. Cerium oxide nanoparticles were applicable in various fields because of their unique chemical and thermal stability, high conductivity, reliable oxygen storage, and catalytic activity. Green synthesized Cerium oxide nanoparticles are environment-friendly and safe as compared to chemically synthesized nanoparticles. It was synthesized using an aqueous extract of *M. oleifera* leaf (20gm % in double distilled water at 65^0C for 30 min). 3.72 grams of cerium nitrate hexahydrate allowed to react with 50 ml filtered extract on a magnetic stirrer for 2 hrs at 80^0C. The resultant calcinated cerium oxide nanoparticle shows antibacterialand antifungal activity against bacterial strains such as *S. aureus, P. aeruginosa,* and *E. coli* and antifungal activity against the fungal isolates *C. albicans* and *A. fumigatus*. Gram-positive bacteria were found more susceptible to cerium oxide *M. oleifera* nanoparticles as compared to Gram-negative [51].

Bismuth nanoparticle

Commercial standard antibiotic preparation was generally used in controlling the growth of pathogens but this preparation does not have a wide range of activity against the pathogenic strain. The best alternative is the use of bismuth nanoparticle which has a wide range of applications in different sectors. It was found that the synergistic effect of green synthesized bismuth nanoparticles could be possible. It was synthesized using the hydroalcoholic extract of *M. oleifera* leaves (10gm% in water-ethanol solution 1:1). The 80 ml filtered extract was allowed to react with 20 ml of bismuth nitrate pentahydrate (1 gram bismuth nitrate pentahydrate in 20 ml of demineralized water) for 3 hrs on a magnetic stirrer at 60^{0}C. Bismuth nanoparticles show good antibacterial activity against bacterial strains including *Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus,* and *Enterococcus faecalis*. Bismuth nanoparticles also show antifungal activity against the fungal isolates including *Aspergillus Niger, Aspergillus flavus, Candida albicans,* and *Candida glabrata.* This finding should possible employment of synthesized nanoparticles against candidiasis and various microbial infections [52].

Calcium oxide nanoparticles

Alkaline earth metal also exhibited the property of nanoparticle synthesis by green methodology. Calcium oxide commonly known as "burnt lime" or "quick lime" finds application in various industries.Calcium oxide was inexpensive and plenty in nature. It possesses unique catalytical and biological properties. Green synthesis of calcium oxide nanoparticles was done by reacting the 20 ml of aqueous extract of *M. oleifera* leaves (2-gram leaf powder in 100 ml deionized water at 60^{0}C for 25 min). with 2 grams of calcium nitrate ($Ca(NO_3)_2 H_2O$) added into the extract once the temperature reached 50^{0}C- 60^{0}C, and the basic nature is maintained by the addition of a few drops of sodium hydroxide (2M NaOH). The synthesized calcium oxide nanoparticle exhibits bactericidal activity against gram-positive and gram-negative bacteria. Gram-positive *Staphylococcus aureus* was more susceptible than gram-negative *E. coli* [53].

Flower extract nanoparticle

M. oleifera flower is an excellent source of medicinally important Nutrients. The abundant content of flavonoids, β-carotene, tocopherols, phenolic acids, vitamins, cysteine, methionine, calcium, potassium, and proteins make it utilizable in the medicinal field. The abundant nutrient richness of flowers makes them an excellent source for nanoparticle synthesis.

Silver nanoparticle

The aqueous extract of the *M oleifera* flower is used for the synthesis of silver nanoparticles. It was synthesized using silver nitrate ($AgNo_3$) and allowed to react with 2 ml extract (20 gm % at 100^{0}C) for 30 min. Similarly, different concentration was formed using 4ml, 6ml, and 8ml extract. The formationof a reddish-brown color indicates the synthesis of nanoparticles in the solution. The synthesized nanoparticles show excellent antimicrobial activity against Gram-positive bacteria such as *Staphylococcus aureus* instead of Gram-negative *Klebsiella pneumonia.* The Gram-positive bacteria lack the outer membrane resulting in more interaction of silver nanoparticles with the Gram-positive cellwall than the Gram-negative cell wall. This property of silver nanoparticles makes them an excellent antibacterial agent in the medical field [54].

Palladium nanoparticles

Palladium (Pd) has numerous applications in various catalytic reactions. Green synthesis of palladium nanoparticles was prepared by allowing 1 mM palladium acetate solution to react with *M. oleifera* flower powder extract prepared in double distilled water (10 gm %, boiling for 20 min). Palladium nanoparticles showed excellent antimicrobial activity against the bacterial strain *Enterococcus faecalis* compared to the commercial antibiotic ciprofloxacin. No inhibitory zone is observed for *Bacillus cereus,Staphylococcus aureus, Escherichia coli,* as well as yeast strains such as *Candida albicans,* and *Candidautilis.* The outcome of this research study was that it can be used as a drug against the *Enterococcus faecalis* [55].

Hydroxyapatite nanoparticles

Like metals, mineral constituents were also used in the synthesis of nanoparticles. Among them, calcium was more commonly utilized in the formation of nanoparticles. Calcium is the main constituent of bone and teeth. The best source of calcium is hydroxyapatite which contains calcium and phosphorous in a ratio of 1:67 which becomes an excellent source of drug delivery in the form of nanorods. Hydroxyapatite nanorods can be prepared using the microwave-assisted *M. oleifera* flower extract. 1M calcium hydroxide ($Ca(OH)_2$) solution (250 ml) was used for nanoparticle synthesis. For nanoparticle synthesis, 0.6 M of orthophosphoric acid [H_3PO_4] solution was mixed with calcium hydroxide solution. pH value adjusted by slow addition of 0.8 M NaOH. After that preparation, it was allowed to react with *M. oleifera* flower extract (50-gram flower powder boiled in 250 ml of deionized water). The reaction medium was stirred for 1 hr and kept for 24 hrs at room temperature for the formation of a gelatinous precipitate. The synthesized nanoparticle was collected by drying in an oven (350 W) for 10 min and calcinated in a muffle furnace for 1 hr at 100^0C. The synthesized nanorod shows excellent antimicrobial activity compared to the crude flower extract and standard antibiotics. It shows superior antibacterial activity against gram-positive bacteria compared to gram-negative bacteria. *Monococcus luteus* shows maximum zone of inhibition as compared to *Bacillus subtilis* and *Staphylococcus aureus*. Also, the gram-negative bacteria *Salmonella paratyphi* shows maximum inhibition compared to *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. Antifungal studies of hydroxyapatite nanorods were also given excellent results against the tested strain of fungus. *Candida albicans* shows maximum inhibition compared to *Aspergillus fumigatus* and *Aspergillus niger* [56].

Bark extract nanoparticle

M. oleifera bark is rich with the content of alkaloids, phenolic acids, terpenoids, and flavonoids. The nutrient richness of *M. oleifera* bark makes it useful in the medical field. Metal nanoparticles are also synthesized by using the bark extract.

Magnesium oxide nanoparticle

Magnesium oxide nanoparticles have a wide range of applications in different fields. The magnesium oxide nanoparticle was prepared by allowing bark extract (soaking 4-gram bark powder in 100 ml of distilled water at 60^0C for 10 min) to react with a 50 ml (1 mM) solution of $MgCl_2 \cdot 6H_2O$. The preparation was allowed to react for 3 hours at 90^0C with stirring at 600 rpm and dropwise addition of 1 M NaOH solution. The Nutrient richness of bark was responsible for the reduction of metal ions during nanoparticle synthesis. The synthesized nanoparticles show excellent antibacterial activity against gram-positive bacteria such as *S. aureus* and *E. faecalis* and gram-negative bacteria which include *E. coli* and *S. dysenteriae* [57].

Stem extract nanoparticle

Stem is also rich in phenolic and flavonoid content, making it a suitable agent for the reduction of metal during nanoparticle synthesis. Previous studies reported that stem extract shows antimicrobial activity.

The Additive effect could be possible when it combines with suitable metal and results in the formation of nanoparticles.

Silver nanoparticles

Silver nanoparticles have gained increasing attention due to their promising antibacterial activity. Silver nanoparticles were synthesized using the secondary metabolites of endophytic bacteria and fungi in stemextract. The stem extract (10gm in 1000 ml distilled water at 60^0C for 20 min) was kept at room temperature to allow the growth of endophytic bacteria and fungus. Specifically, *Nigrospora sp*. fungus was the endophyte and produces secondary metabolites such as griseofulvin, dechlorogriseofulvin, 8- dihydroamulosin, and mullein during 10 days of incubation which allows the bioreduction of Ag^+ ions. The supernatant with metabolites was used for nanoparticle synthesis. Different ratios of fermented extract were added to 1mM silver nitrate solution (1:1, 1:5, and 1:10) and allowed to react for 10 min. The produced nanoparticles not only exhibit outstanding antibacterial activity against the pathogenic strains of *Escherichia coli* (ATCC-25922), *Klebsiella cloacae* (ATCC-23355), and *Staphylococcus epidermidis* (ATCC-12228), but their zone of inhibition was comparable to that of a typical antibiotic. This research finding leads to the development of new routes of nanoparticle synthesis by using secondary metabolites. This finding was the best alternative for commercial antibiotics [58].

Fruit (Pod) extract nanoparticle

Like leaves and flowers of *M. oleifera*, fruits are also a rich source of nutrients. Its nutrient richness makes it suitable for the synthesis of nanoparticles. Nutrient availability of fruits reduces the metal ion and converts it to suitable-size nanoparticles. Which have applications as an antimicrobial agent.

Bimetallic silver and copper nanoparticles

M. oleifera fruit pulp aqueous extract made in Milli-Q water was used to create bimetallic silver and copper nanoparticles. 40 mg of copper acetate and silver nitrate were added to the filtered filtrate, and the mixture was allowed to react for 24 hours at 70^0C to create the nanoparticles. Following synthesis, the antibacterial activity of the nanoparticle was examined. The produced nanoparticles exhibit outstanding antibacterial efficacy againt both Gram-positive and Gram-negative bacterial species, including *Bacillus subtilis, Staphylococcus aureus, Pseudomonas putida, Escherichia coli*, and *Klebsiella pneumoniae*. The outcome of this research finding shows that it has the potential to become an excellent antibacterial drug [59].

Seed extract nanoparticle

The phytochemical constituent of *M. oleifera* seed makes it a suitable agent for nanoparticle synthesis. The presence of bioactive component 4- (α-l-rhamno pyranosyloxy), benzyl isothiocyanate is responsible for the antibacterial power of the seed [11].

Ag-doped zinc oxide nanoparticles

Green synthesis of nanoparticles by using the seed extract of *M. oleifera* has become a novel investigation as an antimicrobial agent. Ag-doped zinc oxide nanoparticles were created by utilizing *M. oleifera* seed aqueous extract. To create the nanoparticle, 100 milliliters of 0.5 M zinc acetate and 10 milliliters of AgNo3 solution (0.01M) were reacted for 30 minutes at room temperature while being constantly stirred. The aforementioned reaction media was then mixed with 40 ml of aqueous MO seed extract and left for 20 minutes. After 20 minutes, white precipitated nanoparticles formed when 2 M sodium hydroxide aqueous solution was gradually added until the pH reached 12. The synthesized nanoparticle shows excellent antimicrobial activity against all the tested bacterial strains including *Staphylococcus aureus* (MTCC-96), *Salmonella typhi* (MTCC-734), *Pseudomonas aeruginosa* (MTCC- 2453), *Klebsiella pneumonia* (MTCC-39), *Escherichia coli* (MTCC-82), *MRSA* (Methicillin-resistant *Staphylococcus aureus* Standard strain CA 05 SCCmec Type IV) and *Candida albicans* (ATCC-90028).Maximum susceptibility was observed against the *Candida albicans* (ATCC-90028) and *Staphylococcusaureus* (MTCC-96) over the other tested strains. It also shows good antifungal activity against the tested fungal isolates including *Fusarium spp., Rosellinia necatrix,* and *Sclerotinia sclerotiorum.* This finding opens the path for the use of nanoparticles as a drug not only in pharmaceuticals but also in the agricultural field for controlling diseases [60].

Magnetite nanoparticles

Functionalized magnetite nanoparticles (Fe_3O_4) were synthesized using *M. oleifera* seed extract. The nanoparticle was prepared by using the saline(1M) extract of *M. oleifera* seed (1 gm %) The filtered extract (0.45µ membrane filter after 30 min) was allowed to react with a solution of 2.8 g of $FeSO_4$ and 1.1 g of Fe $(NO_3)_3.9H_2O$ in 10 mL of distilled water on a magnetic stirrer. Then, 1.2 g of sodium hydroxide (NaOH) was added at room temperature. The black coprecipitate was then functionalized with saline extract. 20 ml saline extract was then sonicated with different concentrations of nanoparticles for forming functionalized magnetite nanoparticles. The synthesized nanoparticles effectively remove the *Staphylococcus aureus* from the surface and sludge up to 99%. This research finding provides a low-cost and easy method of water disinfection over the costly UV light, nanocomposite film, and X zeolite [61].

Silver nanoparticles

Among all nanoparticles silver nanoparticles show high photocatalytic, electromagnetic, and antimicrobial activity. Overcoming the antibiotic resistance of pathogens can be possible using the green synthesized silver nanoparticles. For the synthesis of nanoparticles, the extract was prepared by refluxing 30 kg *M. oleifera* seed with ethanol for 2 hours and concentrating with reduced pressure. It resulted in the formation of ethanol extract which was then separated by solid extraction in petroleum ether and alcohol. The alcohol portion was then filtered and freeze-dried using a rotary evaporator and utilized for nanoparticle synthesis. Silver nanoparticles were synthesized by adding 10ml (10mg freeze-dried powder in 10ml distilled water) aqueous extract of seed into 90 ml of 0.5mM silver nitrate solutionat 60^0C and stirring with a magnetic stirrer at 300rpm for 2 hr. The resultant nanoparticles show strong antibacterial activity against the Gram-positive bacteria *Staphylococcus aureus* (ATCC-29213) and the Gram-negative bacteria *Escherichia coli* (ATCC-25922), *Pseudomonas aeruginosa* (ATCC-27853), and *Salmonella enterica* serotype *typhimurium* (ATCC-14028). The highest antibacterial activity was observed against Gram-negative bacteria, specifically against *Escherichia coli* compared to others. This difference in susceptibility was associated with the cell wall composition of the tested bacterial strain [62].

Peel extract nanoparticles

All the parts of *M. oleifera* were useful in the medicinal field because of its nutrient richness. Peel of the *M. oleifera* plant was also rich with functionally active compounds which have immense application innanoparticle synthesis.

Palladium nanoparticles

The green synthesis of palladium nanoparticles also employed peel extract, which produced asynergistic impact in contrast to the original. Peel was extracted methanolically using the Response surface approach. Various factors, including temperature (60, 65, and 70^0C), methanol concentration (20,25, and 30 ml/g), extraction time (1, 2, and 3 minutes), and microwave power (300, 400, and 500W), were employed to get a good yield. Palladium nanoparticles were synthesized using the microwave irradiation technique. Pd $(OAc)_2$ (1 mM, 80 mL) solution was added to the resulting 20 ml RSM optimized extract. After that, maintain the reaction mixture at 300 W for five minutes. Gram-positive and gram-negative bacteria are both effectively inhibited by the produced nanoparticle. Gram-positive bacteria *Staphylococcus aureus* shows more susceptibility compared to Gram-negative bacteria *Escherichia coli.* Pathogen susceptibility to palladium nanoparticles has been linked to the nanoparticles' interaction with the protein in the cell membrane, which damages the cytoplasm and ultimately causes cell death. This novel method of nanoparticle synthesis and its application as an antimicrobial agent opens a new opportunity in the pharmaceutical industry [63].

Root Extract nanoparticles

The root of *M. oleifera* is rich with phytoconstituent which has high potential as an antimicrobial agent. The nutrient richness makes it suitable for nanoparticle synthesis.

Zinc oxide nanoparticles

Green synthesis of zinc oxide nanoparticles was done by using root extract of *M. oleifera* plant. Nanoparticle synthesis was done by adding 5 ml root extract (20-gm %in double distilled water for 1 hr at 60^0C) into 50 ml of Zn $(NO_3)_2$ solution (0.1 M) and allow to react at 60-90^0C for 2 hours. *Bacillus subtilis* and *Escherichia coli* exhibit a high susceptibility to these nanoparticles, suggesting that they could be used as an antibacterial medication against both gram-positive and gram-negative bacteria [64].

Silver nanoparticles

Silver nanoparticles were synthesized using the fresh aqueous root extract of *M. oleifera* (15 gm% in sterile distilled water at 100^{0}C for 30 min). Nanoparticle synthesis was done by mixing 10 ml root extract in 100 ml of $AgNO_3$ solution (1:10 V/V) with continuous stirring on a magnetic stirrer at 80^{0}Cfor 30 min. The synthesized nanoparticle shows excellent antibacterial activity against gram-negative bacteria compared to gram-positive. *Salmonella typhi* was highly susceptible while *Bacillus subtilis* shows less susceptibility [65].

Partsused	Formulation	Nanoparticle	Extract preparation	References
Leaves	Fresh leaf extract +1mM aqueous vanadium chloride solution	Vanadium nanoparticle	Distilled water	[38]
	Fresh leaf extract + 1 mM aqueous silver nitrate solution	Silver nanoparticle	Millipore water	[39]
	Dry leaf powder extract + 1mM aqueous silver nitrate solution	Silver nanoparticle	Deionized water	[40]
	Fresh leaf extract + 1 mM aqueous silver nitrate solution	Silver nanoparticle	Distilled water	[39]
	Freeze dried leaf extract + 1 mM aqueous silver nitrate solution	Silver nanoparticle	Millipore water	[41]
	Fresh leaf extract +20 % NaOH solution + zinc acetate (2.1%) andammonium carbonate (0.96%) solution	Zinc nanoparticle	Distilled water	[42]
	Dry leaf powder extract + Copper sulphate pentahydrate	Copper nanoparticle	Water-ethanol (1:1)	[43]
	Fresh leaf extract + copperacetate monohydrate (0.01M) solution	Copper nanoparticle	Deionizedwater	[44]
	Fresh leaf extract + Cu $(NO_3)_2 \cdot 3H_2O$	Copper Microsphere	Distilled water	[45]
	Dry leaf powder extract + 5M Titanium dioxide solution of pH1.5.	Titanium nanoparticle	Deionizedwater	[46]
	Fresh leaf extract + 0.1mM Ni $(NO_3)_2$ solution	Nickel oxide nanoparticle	Water Ethanol	[47]
	Dry leaf powder extract + 0.1M Nickel nitrate	Nickel oxide nanoparticle	Deionized water	[48]
	Dry leaf powder extract + 1mM $MgCl_2$ solution	Magnesium oxide nanoparticle	Distilled water	[49]
	Dry leaf powder extract + 0.1 M $FeCl_3$	Iron oxide nanoparticle	Distilled water	[50]
	Dry leaf powder extract + Cerium nitrate hexahydrate	Cerium oxide nanoparticle	Double distilled water	[51]
	Dry leaf powder extract +Bismuth nitrate pentahydrate	Bismuth nanoparticle	Water-Ethanol solution (1:1)	[52]
	Dry leaf powder extract + Calcium nitrate (Ca $(NO_3)_2$ H_2O)	Calcium oxide	Deionized water	[53]
	Fresh flowers extract + 1mM silver nitrate ($AgNO_3$)	Silver nanoparticle	Distilled water	[54]
II. Flower	Dry flowers extract + 1 mM palladium acetate solution	Palladium nanoparticles	Double distilled water	[55]
	Dry flowers extract + 1M calciumhydroxide (Ca $(OH)_2$) solution+ 0.6 M of orthophosphoric acid [H_3PO_4] solution + slow additionof 0.8 M NaOH.	Hydroxyapatite nanorods	Deionizedwater	[56]

	Dry power extract + 1 mM solution of $MgCl_2.6H_2O$ + 1 MNaOH solution.	Magnesium oxide nanoparticles	Distilled water	[57]
III. Bark	Fermented extract (stem extract+fungal growth) + 1mM Silver nitrate solution	Silver nanoparticles	Distilled water	[58]
IV. Stem	fruit pulp extract + silver nitrateand copper acetate	Bimetallic silver and coppernanoparticles	Milli-Q water	[59]
V. Fruit (Pod)	Seed extract + 0.5 M Zinc acetate + $AgNO_3$ solution (0.01M) + 2 MSodium Hydroxide solution.	Ag doped zinc oxide nanoparticles	Distilled water	[60]
VI. Seed	Seed extract + $FeSO_4$ and Fe $(NO_3)_3.9H_2O$ + sodium hydroxide(NaOH)	Functionalizedmagnetite nanoparticles	Saline water(1M)	[61]
	Seed extract + 0.5mM silver nitrate	Silver nanoparticles	Freeze dried ethanol extractfurther dissolved in distilled water	[62]
	RSM optimized peel extract +1mM Pd $(OAc)_2$	Palladium nanoparticle	Methanol	[63]
VII. Peel	Dry powder root extract + of $Zn(NO_3)_2$ solution (0.1 M)	Zinc oxide nanoparticle	Double distilled water	[64]
VIII. Root	Fresh chopped root extract+$AgNO_3$ solution (1:10 V/V)	Silver nanoparticle	Sterile distilledwater	[65]

Table 1

Conclusion

This review summarizes the uses and applications of *M. oleifera* plant parts and the utilization of extracts in green nanotechnology for the synthesis of various metal and metal oxide nanoparticles. Based on the past scientific research reports, *M. oleifera* is an important medicinal plant that has immense application in various areas. *M. oleifera* is rich in phytonutrient which has antimicrobial properties. With the help of nanotechnology, various nanoparticles were synthesized using the extracts of *M. oleifera* parts. This innovation overcomes the drawback of antibiotic resistance of pathogens to commercial antibiotics. The medicinal plant *M. oleifera* has several uses in the medical area when combined with nanotechnology because it is rich in various chemical components. Based on this research finding it can be used as an antimicrobial drug in the pharmaceutical field. Thus, the use of non-toxic, renewable sources for nanoparticle synthesis is an important novel strategy for maintaining a sustainable environment.

Conflict of Interest Statement

We declare that we have no conflict of interest.

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