RESEARCH PAPER

Green Synthesis of Gold Nanoparticles using *Eruca Sativa* Plant Extracts

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ABSTRACT

Nanotechnology is the field that encompasses the design, improvement, and execution of components with dimensions ranging from 10 to 100 nanometers. This study demonstrates that green production of nanoparticles (NPs) is aviable alternative to physical and chemical processes. Biotechnologically produced NPs have been increasingly preferred over different methods or means Nanoparticles synthesised using physico-chemical methods face numerous obstacles, such as the utilisation of toxic materials and the generation of hazardous by-products. The utilisation of plant extracts for metal salt creation clearly illustrates that the plant-based (green) synthesis of nanoparticles is not a detrimental method. Green synthesis denotes the process of generating nanoparticles by the use of natural resources, including plant extracts and microorganisms, employing energy-efficient procedures that are cost-effective, non-toxic, and environmentally sustainable. Gold (Au) is deemed suitable for the creation of stable nanoparticles. The physical properties of inorganic nanoparticles are largely dictated by their size and shape. Owing to their distinctive optical and physical properties, goldnanoparticles (AuNPs) have extensive uses in several disciplines. *Eruca sativa Mil.* (*E. sativa*), commonly referred to as 'Arugula is', often known as 'a rocket flowers', is a healthy salad green from the Brassicaceae genus. The plant has been documented to exhibit several advantageous therapeutic characteristics, such as antibacterial, anti-oxidants, antiacne, anti-diabetic, antigenotoxic, cancer prevention, analgesics antihyperlipidemic, antihyperglycemic, anti-hyperuricemic, and anti-inflammatory activity. So, This Review deals with AuNPs preparation through green methods using plant extract (*Eruca Sativa*), as well as there characterization with different analytical methods.

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INTRODUCTION

Nanotechnology mainly concentrates on semiconductors measuring between 1 and 100 nanometers. This topic has proven significant in both fundamental and applied sciences [1]. The field of nanotechnology integrates engineering, biology, chemistry, and physic, The size, optoelectronic and chemical characteristics, as well as the distinctive structural shape of NPs, have drawn researchers to explore potential medicinal and food-related applications [2].

Richard Feynman initially presented the notion

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of nanotechnology in 1959 during a speech at Caltech. In this talk, he explored the subject of data regarding a microscopic level and the inevitable application of tiny automata and computing devices in the nearest future [3-5]. Subsequently, this field has witnessed major progress. This phenomenon can be ascribed regarding nanotechnologies and nanodevices possess characteristics that were previously unattainable by existing means, and so, have generated revolutionary solutions. [6] The distinguishing feature of NPs is their distinctive structure characterized by a greater concentration of atoms on the surface as compared to the center [7].A classification of NPs can be established according on their size, It is include zero-dimensional nanostructures, nanowires and nanorods encompass one-dimensional nanostructures, while thin films refer to two-dimensional nanostructures. An inherent difficulty that emerges is the production of NPs in substantial quantities with precise control and intentionality. they are produced by solid, liquid, or gas phase synthesis, with the specific process chosen based on the material type (Metallic, ceramic, or polymeric) and the desired configuration, dimensions and allocation in the end product[8]. Two overarching methodologies employed are several methods, both top-down and bottom-up (Fig. 1) [9].A hierarchical approach technique involves employing nanofabrication technologies regulated by extrinsic parameters of experimentation for fabricate nanoscale structures or functional devices with specified forms and attributes, commencing with more significant dimensions and diminishing them to the requisite values. Conversely, bottom-up techniques aim to construct molecule or atom constituents into progressively complex nanoscale structures or guided self-assembly utilizing sophisticated mechanisms and technologies[10].

Metallic NPs are diminutive metallic particles. The manufacture of NPs has effectively utilized Silver (Ag), alumina (Al), ferrous (Fe), gold (Au), silica (Si), cooper (Cu), zinc (Zn), manganese (Mn), cerium. (Ce), the titanium (Ti), platinum (Pt), the thallium (Tl). A range of nanoparticles made of metal has been meticulously designed for disease therapy and diagnosis. Au, Ag, Zn, and Pt are the most significant anti-cancer agents. Nanoparticles display adjustable optoelectronic properties that depend on their dimensions and morphology. [11]. Previous research have shown that the oxide of zinc, gold and silver, and core-shell silver-gold nanoparticles has beneficial diabetic properties[12].

GOLD NANOPARTICLES

Gold (Au) is deemed suitable for the creation

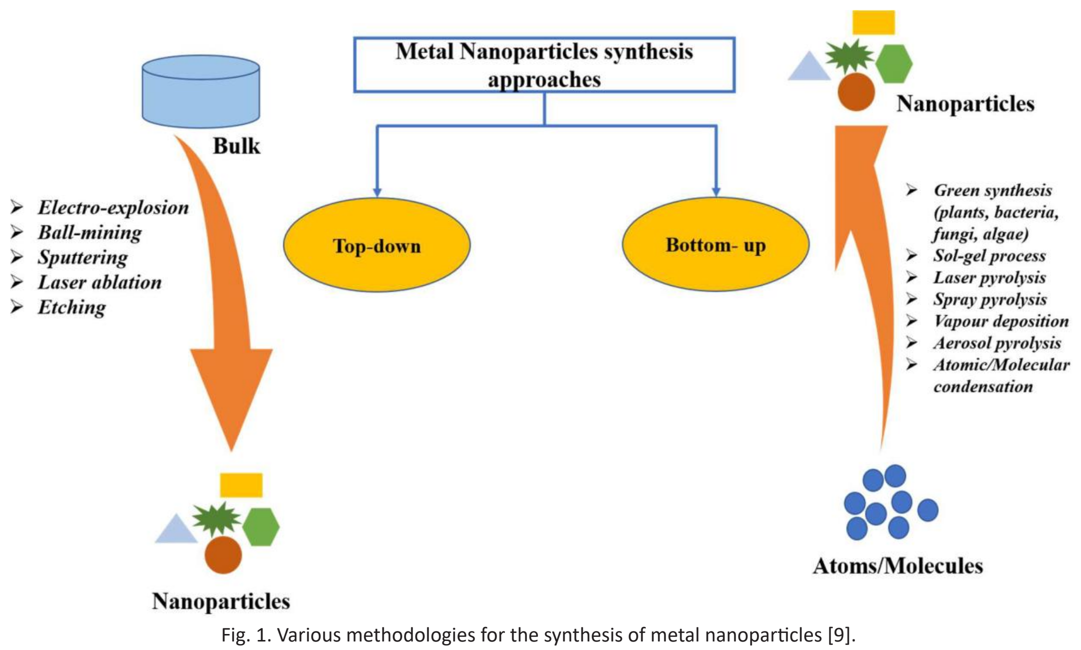

Fig. 1. Various methodologies for the synthesis of metal nanoparticles [9].

of stable nanoparticles. A considerable quantity of the physical attributes of inorganic NPs and physical characteristics, AuNPs have extensive uses in several disciplines. Augmented nanoparticles (AuNPs) exhibit notable characteristics like (a) a diminutive size ranging from between 1 and 100 nm, (b) chemical and physical characteristics affected by dimensions, form, and arrangement, (c) remarkable endurance, (d) including subjective and objective attaching abilities, among others [13].

Form and Dimensions

Various methods are available for the formation of AuNPs with differing shapes and ratios. The dimensions and morphology of AuNPs are essential factors that affect their physical, chemical, and electrocatalytic characteristics. Particles of metal within the size range of one to ten nm exhibit qualities that are depending on their dimensions when compared to bulk substances [14].

A restricted array of methods is available for the synthesis of AuNPs with uniform diameters. Faraday, Michael pioneered the use of a two-phase method to synthesized AuNPs that were through the removal of gold salts using phosphorous in carbon disulfide. Researchers have devised a widely used technique for producing tiny gold AuNPs . These gold salts were reduced using the solution of sodium borohydride in conjunction with the capping substance dodecanethiol [15].

The dimensions of the nanoparticles were confirmed to be between 1 and 3 nm utilizing High-resolution images transmitted electron microscopy (HRTEM). The dimension of particles can be regulated by modifying the thiol content. In agreement with Turkevich's findings, G. Frens concluded that the the reduction of golden chloride salts via a sodium citrate solution is a highly effective approach for producing uniform AuNPs with varying diameters. Variation of reactant ratios enables the attainment of autonomous nucleation and growth of metal NPs with varying diameters [16].

The dimensions of AuNPs can be modified by modifying Gold as a precursors and decreasing the strength of Reduction agents. Observations suggest that powerful reduction agents such as NaBH4, facilitate the production of smaller AuNPs, whereas less potent reducing agents, such as citrate, lead to the formation of somewhat bigger NPs. Scientists have examined how the concentration of ions of chloride influences the dimensions of AuNPs. by means of Reduction of citrate. The dimensions of AuNPs are influenced

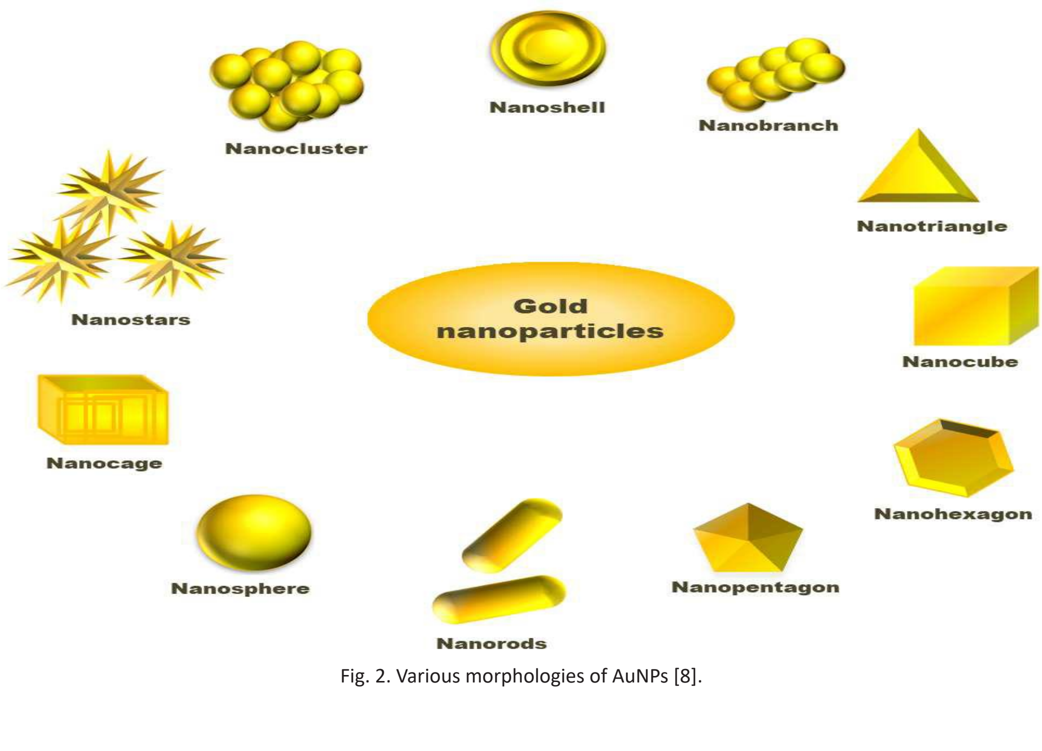

Fig. 2. Various morphologies of AuNPs [8].

by their aggregation, which is triggered by chloride ions. [17].

The choice of solvents in the synthesis of NPs is crucial as it determines the final size and shape by either influencing the interaction between the surface of NPs and the solvent molecule or the fluid and the molecules of ligand [18] .

Investigators have documented the production The manufacture of sphere gold nanoparticles (AuNPs) employing $H[AuCl_4].3H_2O$ as the beginning, vitamin C as the agent that reduces, and citrate of sodium as the stabilizing agent.

Initially, they effectively synthesized nanoparticles measuring 30 nm in size. These tiny particles act as a precursor for the manufacture of AuNPs measuring 69 nm and 118 nm., therefore facilitating future growth.[19].

Previous study demonstrates that Gold nanoparticles of diverse dimensions and morphologies, including elongated nanorods, diminutive nanorods, cubic structures, and spherical forms, may be synthesized by Reversible flocculation induced by surfactant micelle-mediated depleting interactions. Exact regulation of the measurement of the amount of surfactants and the separation of floating particles from the water column are critical processes in the procurement of various types of nanoparticles. Jianhui Zhang and his colleagues have researched the precise size regulation and a variety of geometries in the shape-selective synthesis of gold nanoparticles (AuNPs), including hexagons, belts as well, rods of steel, triangles, octahedrons, and dumbbells. [20].

The impact of temperature on the dimensions of AuNPs has been investigated by researchers through the manufacture of gold nanoparticles (AuNPs) at varying temperatures with the stabilisation of tetraoctylammonium bromide (TOAB). The synthesis at room temperature confirms the existence of AuNPs that are with a median diameter of 5.2 nm, displaying a spherical morphology. Observation of a significant alteration in the morphology of the AuNPs was made where the production of gold nanoparticles (AuNPs) was conducted at a temperature of 100 °C for a duration of 30 minutes. NPs vary in size ranging 5.2 - 6 nm and displaying polygonal configurations such as hexagonal shapes, a pentagon, and squares when observed using HRTEM . The equivalent the shapes with three dimensions are first the cuboctahedron, icosahedron, then cube. Annealing at two hundred degrees Celsius resulted in substantial alterations to the morphology and size of AuNPs. The average size of the nanoparticles shown by the HRTEM is 15 nm, and they show hexagonal shapes, triangles and a pentagon among other configurations. Ananealing at a certain temperature of three hundred degrees Celsius produces these nanoparticles and nanocubes. [21].

Fig. 2 graphical abstract attempts to encompass many shapes of AuNPs.

Optical Properties

The NPs exhibit exceptional optical characteristics independent of those of discrete molecules and macroscopic metals. The remarkable achievements of AuNPs in nanoscience and technology can be attributed, in part, to their optical characteristics especially in relation to plasmon resonance on surfaces (SPR) [22]. Vulnerability to Nps The illumination causes the oscillating electromagnetic field of light to produce group coherence oscillation in the free electrons that are inside the band of conduction of the nanoparticles.

Consequently, the charge separation leads to the generation of an oscillation of a dipole within the electric field of light. This fluctuation attains its maximum amplitude.

Peak of maximum intensity at a specific frequency referred to as SPR. Also magnitude of the assessment of SPR may be conducted using a spectrophotometer with an UV.-visible wavelength using absorbance measurement. of SPR. This NPs exhibit significantly higher strength compared to other metals. In accordance with Mie concept, band intensity, and wavelength of SPR are influenced by variables like metal type, size, and form, displays the structure, content, and the nanoparticles in the medium: dielectric constant [23].The optical absorption characteristics of synthetic AuNPs of various forms and sizes were investigated by means of the photoacoustic method (PA). Seed-mediated growth methods were used to synthesis gold nanorods and nanospheres. The photoacuostic spectrum of AuNPs exhibit two distinct modes: transverse and longitudinal. Notably, gold nanospheres with a diameter of around 20 nm exhibit a robust photoacoustic absorption band centered at around 522 nm. In contrast, nanorods display a two-band absorption band centered at Transverse and longitudinal surface plasmon resonance has approxitudes of 522 and 698 nm. Smaller than 2 nm AuNPs do not show this absorption. [24].

ERUCA SATIVA PLANT

Eruca sativa Miller (E. sativa), also known as 'arugula' or 'rocket wings', is a nutritious salad plant from the family of Brassicaceae (Figure 3). Its aromatic properties make it frequently used in both culinary and medicinal contexts.An ancient application of this plant involves promoting enhancing fertilisation and sperm production, optimising gastrointestinal and the urinary functions, and addressing ocular problems [25]. The Greeks utilised the leaves of E. sativa used to alleviate gastrointestinal disorders, sickness and as a form of diuretic [26].

Recognised from ancient times, the plant was recorded in the Greek herbal known as Material Medical. With heights of up to one metre, this biennial plant stands out for dark green leaf usually less than twenty centimetres in length. Characterised by elongated, terminal lobes that may be coarsely serrated or lobed, Rocket is a group of plants producing distinctly flavoured rosettes of vivid green, dissected leaves [27]. Eruca sitiva leaves include salt, calcium, magnesium, and carbohydrates fibres. Packed with vitamins like carotenes, tocopherols, vitamin C, and folic acid are Eruca Sativa leaves. The whole E. Sativa offers nutrients such as vitamins A., C., and K.; thiamine; riboflavin; niacin; the B6 vitamin (pyridoxine); and pantothenic acid[28].The plant has lately garnered considerable attention due to its abundant phytoactive chemicals and its remarkable biological importance in diverse biological processes. Numerous phytochemicals, such as glucosinolates, are found in different regions of the plant. Chemical compounds such as tannin, phenol compounds, flavonoids, essential oils, and saponins [29]. The plant has been recorded to demonstrate many advantageous therapeutic characteristics, such as antibacterial, anti-oxidants, anti-acne, anti-diabetic, antigenotoxic, cancer prevention, an analgesic antihyperlipidemic, anti-hyperglycemic, antihyperuricemic, and anti-inflammatory properties activity [30–32].

GREEN SYNTHESIS OF AUNPS FROM PLANT

A diverse range of pharmaceutical treatments derived from natural substances, extensively employed for the purpose of targeting and treating different dermatological disorders. Extraction of complex chemical compounds derived from flora, animals, microbes, and minerals is a frequent natural practice using various extraction methods. These chemicals serve as precursors for development of subsequent larger molecules. Gold is chemically and biologically inert and widely acknowledged as biocompatible. Until now, it was solely referred regarding as the surface of the metal. Within the field of nanotechnology, the development of nanoparticles and research on the physico-chemical properties of golden have positioned it as a model material for developments in many other fields [33,34].

Several Physical and chemical synthesis approaches are widely acknowledged for the biosynthesis of gold nanoparticles (AuNPs). Nevertheless, the majority of those procedures faced limited acceptance mostly because of the presence of hazardous chemicals and high temperatures during the synthesis procedure.

Fig. 3. Eruca sativa leaf.

Their potential to cause harm to both humans and the environment has been documented [35,36]. The predominant biosynthetic technique is the extracellular NP synthesis method [37]. The manufacture of AuNPs using plant tissues, bacteria, fungus, actinomycetes, and other sources has been documented in the literature (Fig. 4) [38].

Nevertheless, the environmentally benign method of synthesizing AuNPs from the plant is laudable the production of AuNPs from the plant utilizes numerous plant components, such as branches, tree bark, stems, and roots as sources. The components are meticulously chopped and then boiled in distilled water to produce the extract. Refinement of the extract can be achieved by the filtration process and centrifuged. In solutions of metal salts, such as $HAuCl_4$ is often combined with plant extract at ambient temperature [39]. Bioactive extracts from plants include a range of metabolites and organic substances such as alkaline compounds, flavonoids, polysaccharides, proteins, cellulose, and phenolic substances. These chemicals, together with secondary metabolites, are used in the formulation of nanoparticles. These processes can include the aerobic Reducing of metallic ions leads to nanoparticles and serve as stabilizing substances. [40]. The reduction process of AuNPs can be actively facilitated by the presence of functionalized amino groups ($–NH_2$) in proteins found in plant extracts, Phytochemicals, including the flavones alkaloid compounds, phenols, and anthracenes possess specific groups (including –C=O–,–C=C–, –C–O–,and –C–O–C–) that facilitate their production of AuNPs [41]. This process does not require the use of external stabilizing or capping

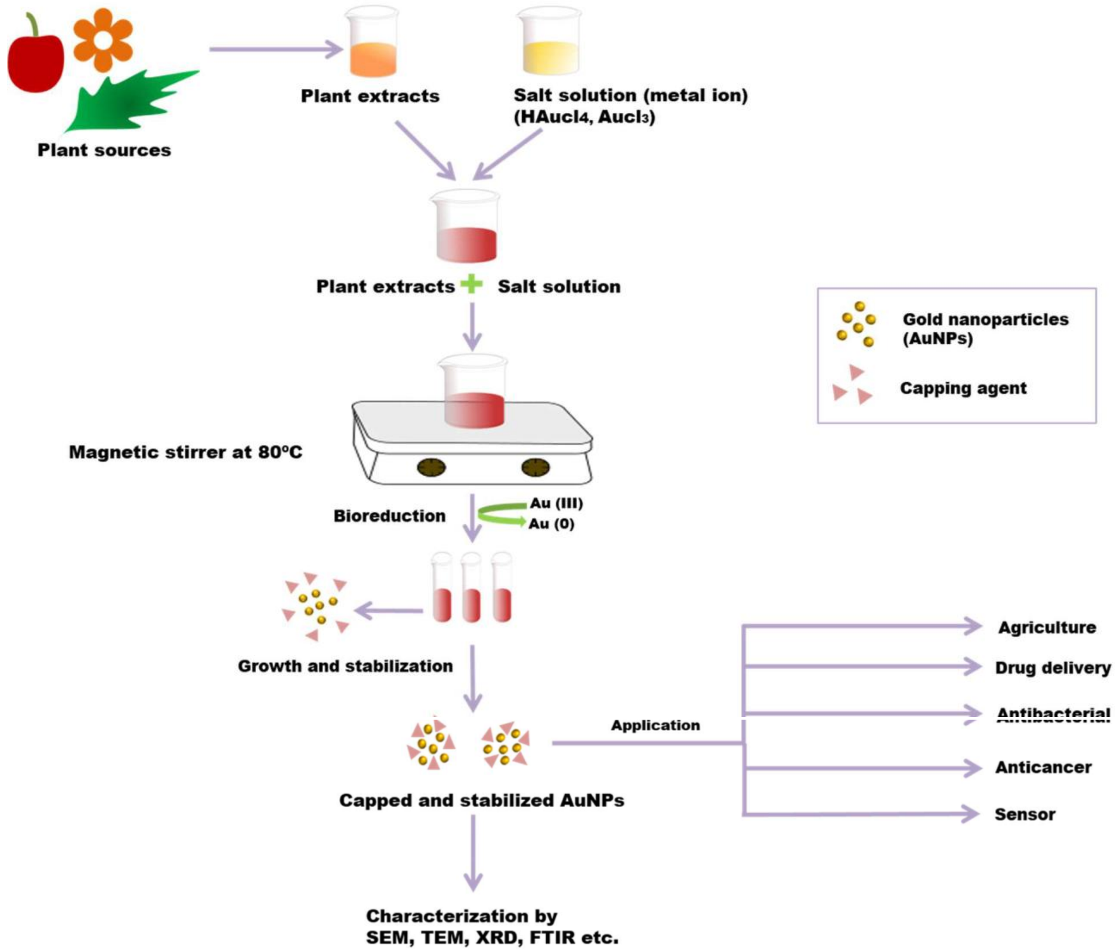

Fig. 4. Eco-friendly synthesis of AuNPs using a plant [38].

agents. Instead, several phytochemicals function as agents for the reduction and stabilization/capping of extracellularly produced AuNP. This substitution eliminates the toxicity associated with compounds like NaBH4 [42]. The biological reduction process is the conversion of Ions of metal shift from monovalent or bivalent states of oxidation to a zero-valent state configuration. Subsequently, the nucleation process involves the emergence of reduced metal atoms [43]. The metallic salt solution containing the extract is ultimately reduced from Au^{3+} to Au^0, resulting in the creation of Au nanoparticles occurs rapidly within minutes to hours employing one-step, one-pot, and environmentally suitable technique [44]. Due to the variety of phytochemicals present in plant extracts, no unique mechanism for this manufacturing process has been established. The variations in the type and amount of reducing substances in plant extracts dictate the differing sizes seen.The discussion relates to morphological NP synthesis [45]. Research has shown that altering the synthesis factors, such as the pH level, metal salt water, heat, and reaction time, may affect the size and shape of nanoparticles [46].

Different Eco-friendly synthesis of NPs by using

Table 1. Green Synthesis of Different NPs From Eruca Sativa plant.

Plant	Salt Solution	Nano Particles	Size	Reference
Eruca Sativa	$AgNO_3$	AgNPs	1.45 – 5.08 nm	[47].
Eruca Sativa	$Zn(NO_3)_2.6H_2O$	ZnO NPs	71.07 nm	[48].
Eruca Sativa	$AgNO_3$	AgNPs	8.11- 15 nm	[49].
Eruca Sativa	$AgNO_3$	AgNPs	4.97 – 14.4 nm	[50].
Eruca Sativa	Na_2SeO_3	Se-NPs	39.4 -124.6 nm	[51].
Eruca Sativa	$Zn(NO3)_2.6H_2O$	ZnO NPs	53.12 nm	[52].
Eruca Sativa	Fe_3O_4	Fe_3O_4 NPs	25 nm	[53].
Eruca sativa	$AgNO_3$	AgNPs	4.97-14.4 nm	[54].
Eruca Sativa	Na_2SeO_3	Se-NPs	39.4 nm	[55].
Eruca Sativa	SiO_2	SiO_2NPs	28.79 nm	[56].
Eruca Sativa	$Pb(CH_3COO)_2.3H_2O$	Pb-NPs	16.74 nm	[57].
Eruca Sativa	$AgNO_3$	AgNPs	50 nm	[58].
Eruca Sativa	$AgNO_3$	AgNPs	5-17.5 nm	[59].
Eruca Sativa	$CuCl_2$	CuNPs	15 nm	[60].
Eruca Sativa	$AgNO_3$	AgNPs	18 nm	[60].
Eruca Sativa	$HAuCl_4$	AuNPs	20 nm	[60].
Eruca Sativa	$AgNO_3$	AgNPs	90 nm	[61].
Eruca Sativa	$HAuCl_4$	AuNPs	80 nm	[62].

Table 2. Employed Techniques to Characterization of AuNPs .

Techniques	Uses	Reference
Ultraviolet–visible (UV.–VIS)	Optical characteristics of AuNP is significant, wavelength spectrum of 200 to 1100 nm.	[48].
Fourier-transform infrared. spectroscopy (FTIR)	Determine the functional groups in AuNPs, wave number range of 400-4000 cm^{-1}.	[48].
X-ray diffraction (XRD)	The crystal-phase structure and crystallite size of the AuNPs were determined utilizing the Scherrer equation.	[64].
Field emission scanning electron microscopy (FESEM)	Morphology of AuNPs, determined using energy-dispersive X-ray (EDX).	[48].
Atomic force microscopy (AFM)	Investigation of the surface topography and roughness of nanostructures.	[65].
Zeta Potential	Quantify the surface charge of NPs, greater than (±) 30 mV have demonstrated stability in suspension due to the surface charge inhibiting particle aggregation.	[66].
Inductively coupled plasma-mass spectrometry (ICP-MS)	Offer exceptional sensitivity and robustness, making them very powerful instruments for elemental analysis. Concentrations of analysts at the sub-parts-per-trillion level.	[67].

Eruca sativa Plant are listed in Table 1.

CHARACTERIZATION OF GOLD NANOPARTICLES

AuNPs were analyzed utilizing a range of advanced characterization techniques. Multiple photos- and physicochemical characteristics, including size, shape, surface charge, and color, were examined to optimize the synthesis process of AuNPs [63]. For the characterization of AuNPs Many techniques were used for these purpose like ; UV-Vis, FT-IR, XRD, FESEM , AFM, Zeta potential and ICP mass. As Presented in Table 2.

CONCLUSION

Gold nanoparticles (AuNPs) are considered a very promising opportunity for researchers and scientists, especially in the field of medical science. This Review presents an eco-friendly, straightforward, cost-effective, non-toxic, physiologically active, and innovative approach for the biosynthesis of AuNPs using Eruca Sativa leaf extract. The bioactive constituents included in Eruca sativa leaves have significant antioxidant, antibacterial, anti-acne, anti-cancer, and anti-inflammatory properties. The phytochemicals in the extract of leaves function as biological stabilizers and reducing agents in the formation of AuNPs. The presence of AuNPs may be confirmed using UV-visible spectroscopy, FTIR, XRD, FESEM, AFM, Zeta potential analysis, ICP-MS, and more methodologies. This review article will augment our understanding of the appropriateness and significance of the plant, which contains a varied range of known bioactive chemicals for the synthesis of AuNPs.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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