

Green Synthesis, Characterization, and Antibacterial Potential of Silver Nanoparticles Using *Ficus Racemosa* Stem Bark Extract: A Review

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Abstract:

The green production of silver nanoparticles (AgNPs) utilizing *Ficus racemosa* stem bark extract is the main topic of this paper, which also emphasizes the physicochemical characterisation and antibacterial potential of AgNPs. With its creative solutions for material science, biology, and medicine, nanotechnology has become a promising area of modern science. Green synthesis offers a sustainable, economical, and environmentally responsible alternative to conventional nanoparticle synthesis techniques, which use hazardous chemicals and a lot of energy. In the manufacture of nanoparticles, *Ficus racemosa*, a medicinal plant rich in bioactive phytochemicals such as flavonoids, tannins, alkaloids, and phenolic compounds, functions as a natural reducing and stabilizing agent. Because of their huge surface area and tiny size, the produced AgNPs show strong antibacterial action against a variety of harmful microbes. To verify the creation of nanoparticles and examine their shape and functional groups, a variety of characterisation methods are used, including FTIR, XRD, and UV-visible spectroscopy. The phytochemical makeup and several pharmacological actions of *Ficus racemosa*, such as its antioxidant, antibacterial, anti-inflammatory, and anticancer qualities, are also summarized in this paper. Overall, the study is in favor of using plant-mediated AgNPs in the pharmaceutical and biomedical industries.

Keywords:Green synthesis; Silver nanoparticles (AgNPs); *Ficus racemosa* stem bark; Antimicrobial activity; Phytochemicals; Nanotechnology; Characterization; Antioxidant activity; Medicinal plant.

1. Introduction:

One of the most important technologies of the twenty-first century is nanotechnology [1]. The creation, modification, and application of material at a Scale smaller than 1mm is referred to as nanotechnology [2]. In general, nanoparticles can be divided into three categories: inorganic, carbon-based, organic and composite-based nanomaterial. n nanoparticles are particles that are not composed of carbon and inorganic nanoparticles are typically defined as those based on metal and metal oxide [3]. It is possible to synthesis the nanoparticles of nearly every metal [4]. The potential uses of nanotechnology in a variety of disciplines where scientists, researchers, and small and major businesses are creating nanomaterials or goods using nanomaterials have greatly boosted the growth and development of the world economy [5]. Because of its potential uses in the creation of new technologies the synthesis of metal and semiconductor nanoparticles is an extensive field of study [6]. One of the emerging fields of study in the contemporary realm of material science is nanotechnology. Nanoparticles exhibit entirely new or enhanced characteristics, including their size, distribution and form. Nanoparticles and nanomaterials are finding new uses in a variety of industries [7]. The majorities of chemical processes used to create nanoparticles are too costly and contain harmful, poisonous compounds that pose a number of biological concerns. This strengthens the increasing need to create eco-friendly procedures using green synthesis and other biological methods. Using different plants and their extracts to create nanoparticles can occasionally be preferable to other biological synthesis methods that require the extremely difficult processes of maintaining microbial cultures [8]. Particles with a typical size of less than 100 nm are manipulated in nanotechnology [9]. The development of drugs at the nanoscale (nanomedicine) made possible by nanotechnology has greatly aided in the treatment of cancer worldwide [10].



Figure no. 1 *Ficus racemosa* stem bark

Green synthesis contributes to ecological sustainability by reducing waste production and using renewable resources. Traditional chemical synthesis methods use potentially hazardous materials that could endanger both people and the environment [11]. In order to fulfill the requirement of this study *Ficus racemosa* a traditional natural plant was chosen. Ficus is a member of the Moraceae family and is well known for its wide variety of species, which include over 800 species of trees, shrubs, epiphytes and hemiphytes [12]. Ficus is divided into four species groupings, including *Ficus religiosa*, *Ficus racemosa*, *Ficus benghalensis*, and *Ficus microcarpa* [13]. A notable group of trees found in tropical and subtropical regions, primarily in Asia, America, Australia and Africa, is the genus Ficus. It has several therapeutic qualities and is important in many different treatments [14]. The most well-known of these species is the *Ficus racemosa* plant, which is native to Southeast Asia and is often referred to as the common fig or cluster fig. It has numerous therapeutic uses and is frequently used to treat wounds. The fruit bark and leaves of the plant have all been the subject of pharmacological studies [15]. It lacks aerial roots. The most striking aspect of this tree is the red, stubby figs that grow in small bunch right out of the trunk. The fig is part of a tree with hundreds of flowers, so anyone looking for *Ficus racemosa* flowers should be aware of this. Extremely tiny

wasps that pass through the opening in search of a good place to reproduce fertilize the flowers. Fig trees cannot multiply by seed without these pollinators [16].

2. Taxonomic Classification of *Ficus racemosa*:

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Rosales

Family: Moraceae

Genus: Ficus

Species: racemosa

Synonyms: Ficus glomerata

3. Habit and Habitat:

In addition to being grown wild in many woods and hill regions, it is farmed across India. It can be artificially cultivated and is typically seen near bodies of water like ponds or riverbanks. Reaching a height of 12 meters, the tree is tall and moderate. Enough shade is provided by the lovely green foliage of *Ficus racemosa*. The bark seems cracked and is reddish-grey in color [17].

4. Morphological Characteristics:

Ficus racemosa is a deciduous tree with a bole buttressed; bark uniform thickness, surface layer reddish-brown or yellowish-brown glossy, coarsely flaking, fibrous; blaze milky pink; latex milky; younger shoots and branches finely white fuzzy. Seeds are small, numerous, and grain-like. The bark's outer surface contains detachable transparent flakes that range in colour from grey to rusty brown. Stipules are 12–18 mm long, lanceolate, linear-lanceolate, pubescent and often persistent on young shoots. Petiole is 10–50 mm long, slender, grooved above, brown scurfy; ovate, obovate, elliptic-oblong, elliptic-lanceolate, elliptic-ovate, or oblong-ovate lamina, 6–15 × 3.5–6 cm [18]. Fruit receptacles on the main stem or large tree branches are pyriform, with a diameter of 2 to 5 cm, and are found in large clusters. The fruit of *Ficus racemosa* is round and ranges in length from $\frac{3}{4}$ to 2 inches. Flowers are found in two to three rings close to the entrance of receptacles; they are sessile, heavily compressed, dentate-lacerate with lobes joined below and have glabrous, crimson stamens [19]. The roots of *Ficus racemosa* are lengthy and have a brownish hue. It tastes a little bitter and has a distinct smell. The form of roots is asymmetrical [20].

5. Macroscopical characteristics:

There are numerous woodlands and hillside locations where *Ficus racemosa* first appeared. This plant can be artificially produced in rural settlements for shade and tasty fruits, but it can also grow naturally in forests or on hillsides close to a good water source, such a pond or river. Green, oval or elliptic and growing in big clusters from the main trunk, the leaves are 7.5–10 cm long. When uncooked, the fruits are green; as they develop, they become orange, dull reddish, or dark crimson. There are twenty-three of these rather small, abundant, grain-like seeds. The roots are fairly lengthy and have a brownish hue. It tastes a little bitter and has a distinct smell [21]. The bark is 0.51–1.80 cm thick, greyish-green and has a fragile, uneven and often fractured surface. The inner surface is light brown, with a fibrous fracture and a mucilaginous flavor; when rubbed, white papery flakes appear from the outer surface [22].

5.1 Traditional Uses:

Every part of this plant has been utilized medicinally from ancient times. Its antidiuretic action is the main reason for its use. While the bark has several functions the roots are commonly employed in the ayurvedic medical system to alleviate hydrophobia. It helps with gynecological issues and is used as a galactagogue [23]. *Ficus racemosa* has also been extensively used to treat a variety of illnesses in traditional medicine. Its bark, fruits, leaves, roots, latex and seeds are all used medicinally, frequently in combination with

Traditional uses of different part of *Ficus racemosa* Figure no. 2

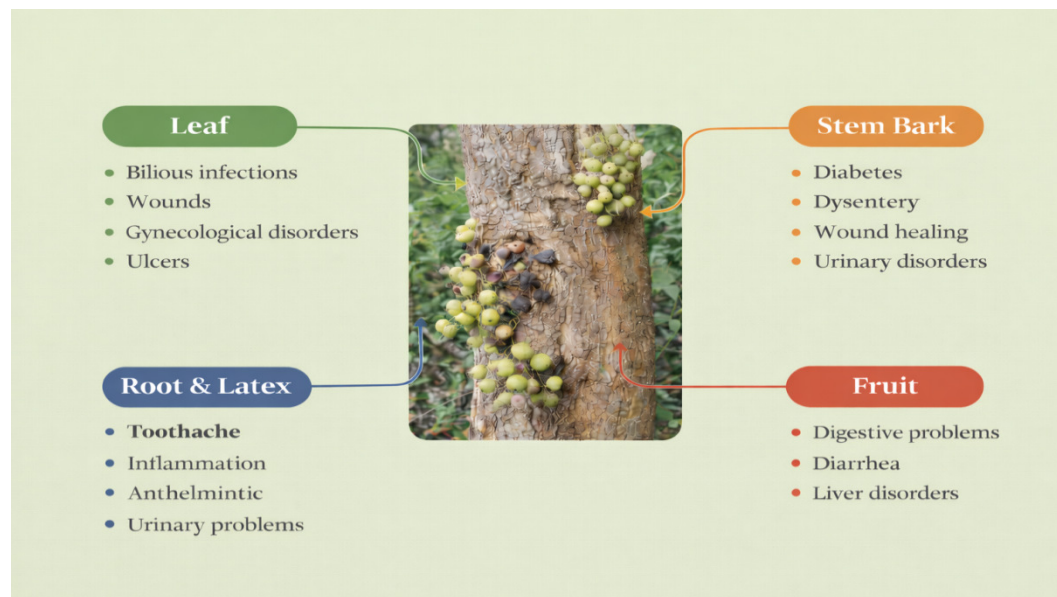


Figure no.2 Traditional use of different part of *Ficus racemosa*

other plants [24]. *Ficus racemosa* (family Moraceae), also referred to as cluster fig or "gular," has been widely utilized to treat a variety of illnesses in traditional medical systems like Ayurveda, Unani and folk medicine [25]. The stem bark of *F. racemosa* has long been used as an astringent and is useful for wound healing, skin problems, diarrhea, dysentery and diabetes [26]. Piles, ulcerative colitis, diarrhea and dysentery are all treated with a decoction of the bark. Additionally, it is used to treat asthma and diabetes. Latex is applied externally to wounds to reduce edema, discomfort and inflammation while accelerating recovery. Additionally, it is taken with sugar to boost male sexual potency and lessen diarrhea and dysentery, particularly in children [27]. These ethnomedicinal uses have been scientifically supported by modern pharmacological studies demonstrating antidiabetic, anti-inflammatory, antimicrobial, hepatoprotective and antioxidant activities, validating its traditional significance [28].

6 Phytochemical Composition:

The leaves, bark, fruits, and roots of *Ficus racemosa* are rich in a variety of bioactive phytoconstituents [29]. The plant's many pharmacological properties are mostly attributed to flavonoids, alkaloids, tannins, phenolic chemicals, glycosides, saponins and terpenoids [30]. In addition to sterols like β -sitosterol, stigmasterol, lupeol and α -amyrin acetate, the stem bark is especially rich in substances like bergenin, kaempferol, coumarins and other glycosides. [31]. Its significant antioxidant capacity is further highlighted by the presence of leucocyanidin derivatives and ellagic acid [32].

7Pharmacological activities:

7.1 Antidiuretic:

At dosages of 250, 500, or 1000 mg/kg body weight, *Ficus racemosa* bark decoction has been shown to have an antidiuretic effect. Additionally, it increased urine osmolarity while decreasing urine Na⁺ levels and the Na⁺/K⁺ ratio, indicating several mechanisms of action [33].

7.2 Antitussive:

Sulfur dioxide gas is used to create a cough in mice in order to study the antitussive properties of a methanolic stem bark extract. Ninety minutes after delivery the extract was most inhibited at a dosage of 200 mg/kg [34].

7.3 Anti-oxidant activity:

The ability of *Ficus racemosa* ethanol and water extracts to scavenge free radicals was evaluated using both steady-state and time-resolved methods. In the steady-state, *Ficus racemosa* ethanol extract had much higher antioxidant activity [35]. AgNPs made from *Ficus racemosa* bark exhibit strong antioxidant activity in addition to antibacterial properties because they include polyphenolic components that scavenge free radicals and lessen oxidative stress [36].

7.4 Antihelmintic:

Adult earthworms were used to investigate the antihelmintic effects of crude extracts of *Ficus racemosa* bark; these extracts caused pin-prick reactions and hindered spontaneous movement. The effect of 3% piperazine citrate was comparable to this [37].

7.5 Antibacterial:

The antibacterial activity of *F. racemosa* stem bark-mediated AgNPs is one of their most notable pharmacological properties [38]. A hydroethanolic preparation of *Ficus racemosa* leaves was effective in treating *Actinomyces viscosus*. It was shown that 0.08 mg/ml was the smallest inhibitory dosage [39]. AgNPs' tiny size and wide surface area allow them to penetrate microbial cell membranes, interfere with cellular processes and induce cell death, all of which contribute to their improved antibacterial effect [40]. Strong inhibitory effects against a variety of Gram-positive and Gram-negative bacteria and fungi are demonstrated by these nanoparticles [41].

7.6 Antipyretic:

At dosages of 100, 200, and 300 mg/kg body weight, methanol extract of *Ficus racemosa* stem bark dramatically decreased both normal body temperature and yeast-induced pyrexia in albino rats up to five hours after drug administration. The antipyretic effect was comparable to that of paracetamol [42].

7.7 Anti-cancer activity:

Lipid peroxidation, xanthine oxidase, glutamyl transpeptidase, topoisomerase-II, hydrogen peroxide (H_2O_2) generation, renal glutathione content and antioxidant enzymes generated by potassium bromate ($KBrO_3$) were all significantly reduced when *Ficus racemosa* extract was administered orally at doses of 200 and 400 mg kg^{-1} . In rats, this nephrotoxic substance causes kidney cancer. Antioxidant enzymes and renal glutathione levels considerably increased. These results imply that *Ficus racemosa* extract is an effective chemopreventive medication that prevents rats' nephrotoxicity caused by $KBrO_3$ [43].

7.8 Wound healing:

F. racemosa powder was used to make the ointment. *F. racemosa* with 15% w/w petroleum jelly. Charles Foster strain rats were used in the investigation and an 8mm full-thickness punch wound model was used. Using the ointment, a very considerable production of tissue DNA, RNA and total protein was seen [44]. *Ficus racemosa* stem bark ethanolic extracts accelerated the healing of excision and incision wounds in rats [45].

7.9 Antidiarrheal activity:

The effectiveness of an ethanolic extract of *Ficus racemosa* stem bark against several experimental forms of diarrhea in rats is investigated. It considerably reduced PGE₂-induced enter pooling and castor oil-induced diarrhea in rats. The results demonstrated its efficacy as an antidiarrheal medication [46].

8. Metallic nanoparticles

Silver (Ag), gold (Au), copper (Cu), zinc (Zn), and iron (Fe) are among the metals that make up metal nanoparticles (MNPs), which are nanoscale materials (1–100 nm). They have become increasingly important in nanotechnology, medicine, agriculture and environmental applications because of their high surface area-to-volume ratio, special optical, catalytic and antibacterial qualities [47]. Physical, chemical, and biological (green synthesis) techniques can be used to create MNPs. Because it is economical, environmentally safe and free of hazardous chemicals, green synthesis employing plant extracts is becoming more and more popular among these [48]. In particular, metal nanoparticles have antimicrobial, antioxidant, anticancer and anti-inflammatory qualities. For instance, because of their broad-spectrum antibacterial activity against bacteria, fungi and viruses, silver nanoparticles (AgNPs) are extensively researched [49].

9. Nanoparticle Characterization:

To verify the creation, stability, size, shape, surface morphology, and functional characteristics of nanoparticles, characterisation is an essential step. A variety of analytical methods are used to thoroughly examine produced nanoparticles [50].

9.1 FTIR:In FTIR analysis, infrared red rays are passed through the sample, some IR rays are engrossed by the sample, and the remaining rays pass through it. The spectrum provides absorption or transmission as a function of wavelength, which characterizes the sample substances [51]. FTIR analysis is an appropriate, economical, straightforward, and non-invasive technique to identify the role of biomolecules in the reduction of nanoparticles (silver nitrate to silver) [52].

9.2 UV-Visible Spectrophotometry:When utilizing UV-Vis absorption spectroscopy to characterize nanoparticles, the size range is 2–100 nm, and the nanoparticle size level varies from many metals. The nanoparticles verified by UV-Vis absorption spectroscopy are typically examined at wavelengths between 300 and 800 nm. Strong absorption of the metallic nanoparticles produced under specific salt conditions results in a point spectrum in the observable region [53].

9.3 X-ray Diffraction:XRD can be used to investigate the atomic structures of materials. This method is useful for determining the materials' qualitative and quantitative levels. The size and structure of crystalline nanoparticles were identified and verified using XRD analysis [54].

10. Conclusion:

In conclusion, a promising, sustainable, and environmentally benign method in the realm of nanobiotechnology is the green synthesis of silver nanoparticles using *Ficus racemosa* stem bark extract. *Ficus racemosa* has a variety of bioactive phytochemicals that are essential for the reduction and stabilization of nanoparticles, hence removing the need for hazardous chemicals employed in traditional synthesis techniques. Because of their small size and huge surface area, which improve their contact with microbial cells the produced silver nanoparticles show strong antibacterial activity against a variety of harmful microbes. Additionally, the successful synthesis and structural characteristics of nanoparticles are confirmed by the use of different characterization techniques as FTIR, XRD, and UV–visible spectroscopy. *Ficus racemosa*'s biomedical significance is further reinforced by its exceptional pharmacological qualities, which include antioxidant, anti-inflammatory, antidiabetic, and anticancer effects, in addition to its ability to synthesize nanoparticles. Prior to clinical and industrial applications, issues like large-scale production, long-term stability and toxicity assessment must be resolved. Standardization, in vivo investigations, and cutting-edge uses like nanomedicine and tailored drug administration should be the main topics of future research. All things considered, *Ficus racemosa*-mediated silver nanoparticles have a lot of promise as a viable and efficient substitute for pharmacological and biological uses.

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