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A review on eco-friendly synthesized nanoparticles of *Ficus religiosa* and their applications

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Abstract

Green synthesis via eco-friendly routes has attracted the exotic interest of scientific researchers due to its reliable, resilient, eco-friendly, and non-toxic nature. Since numerous attempts have been made with reflective uses by synthesizing various nanomaterials using metals/ metal oxides, during the last era. The current review intends to report, update, and discover all information pertaining to *Ficus religiosa* L. medicinal plant combined with diverse metal and non-metal nanoparticle production using a greener method. *Ficus religiosa* is a therapeutic plant widely used for synthesizing various nanoparticles due to its abundant secondary metabolites, which may act as bio-reducing and stabilizing agents. Metal/metal oxide precursors like Ag, Au, TiO, ZnO, CuO and SnO_2 were used for the synthesis of nanoparticles by using either part/whole plant, bark and leaf infusions. This study emphasizes the use of various Ficus religiosa plant parts for scientific purposes, which has numerous applications in various fields and may be a good drug candidate for nano-based drug delivery systems.

Key words : *Ficus religiosa* L., metal/metal oxide nanoparticles, silver, copper oxide, nanotechnology.

Nanoparticles are minute particles that range between 1-100 nm in size and are imperceptible to the human eye. They are also referred to as “zero dimension” nanomaterials on the other side one-dimensional nanomaterials larger than nanoscale are referred to as nanowires and nanotubes, whereas two-dimensional nanomaterials are known as self-assembled monolayers. Nanomaterials are having various applications in different fields[11]. In the evolutionary field of nanobiotechnology, there has been an appreciable research intrigue in the key area of drug delivery by utilizing particulate delivery systems as barriers for small and large molecules. The nanoparticles synthesized from organic materials *i.e.,* from plants, bacteria, fungi, algae etc are known as green synthesized, whereas artificial nanoparticles are synthesized by using inorganic materials. Due to their widespread applications in the fields of chemistry, physics, biology, and, medicine research on metal-based nanoparticles is one of the most important areas of nanotechnology. Nanomaterials' most essential and specific properties are having a high surface area-to-volume ratio and exhibiting remarkable antibacterial properties. Silver nanoparticles with noble characteristics may have numerous uses in the fields of photonics, microelectronics, lithography, and photocatalysts. A variety of physicochemical techniques can be used to synthesize nanoparticles. However, these techniques have several limitations, including the handling of dangerous chemicals and the need for high pressure and temperature during the generation of detrimental toxic waste.

Taxonomical classification[12]:

Domain	Eukaryota
Kingdom	Plantae
Subkingdom	Viridaeplantae
Phylum	Tracheophyta
Subphylum	Euphyllopsida
Class	Magnoliopsida
Subclass	Dilleniidae
Order	Urticales
Family	Moraceae
Tribe	Ficeae
Genus	*Ficus*
Specific epithet	religiosa Linnaeus
Botanical name	*Ficus religiosa*

Description:

Ficus religiosa L. commonly called 'peepal' belongs to the Moraceae family and is a variety of figs and a sacred tree native to India. There are 750 species of woody plants in the genus Ficus, and *Ficus religiosa* is one of the more significant species[15]. Numerous amino acids, including asparagine, alanine, tyrosine, valine, and threonine are present in the fruits of this plant. The tree has wide-spread branches, brown bark, and a very massive trunk. The aromatic and medicinal properties of *Ficus religiosa* are well described and discussed by Surendra *et al.*[17].

Phytochemical composition of Ficus religiosa:

Every part of the *Ficus religiosa* tree is used in herbal medicine preparation[12]. This tree is the richest source of phytochemicals, and nutrients and an important component in traditional and ayurvedic medicine. *Ficus religiosa* tree contains phytochemicals like lanosterol, β–sitosterol-D glucoside, sigmasterol, cadinene, bergapten, bergaptol, steroids, flavonoids, alkaloids and phenol content (Fig. 1). Due to the presence of these phytoconstituents, it exhibits various pharmacological properties[1]. The bark of *F. religiosa* is used as an ingredient in food products like arjun tea, *Neotea arasa* and candies. Arjun tea acts as an antioxidant, contains micro nutrient Coenzyme Q10 and effectively lowers cholesterol and cures heart disease[17]. Different metal and metal oxide-based nanoparticles are synthesized by using leaf and bark extracts of the *Ficus religiosa* L plant.

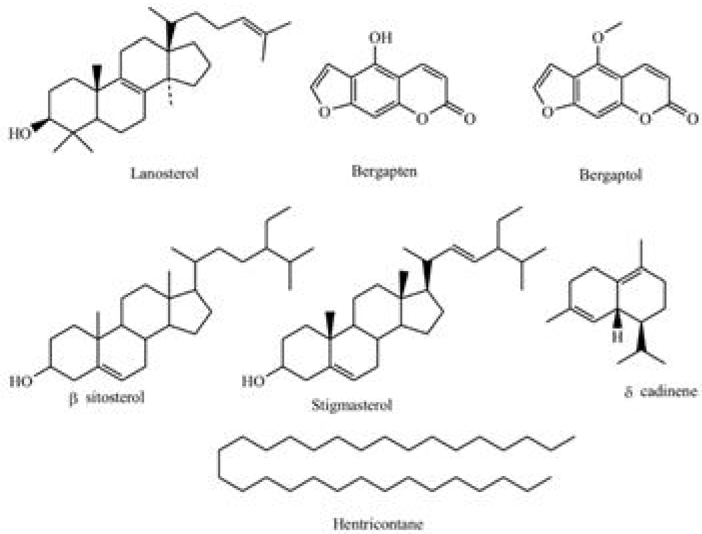

Fig. 1. Phytoconstituents present in *Ficus religiosa* L.

Biogenic synthesis and applications of metal and metal oxide nanoparticles using Ficus religiosa L.

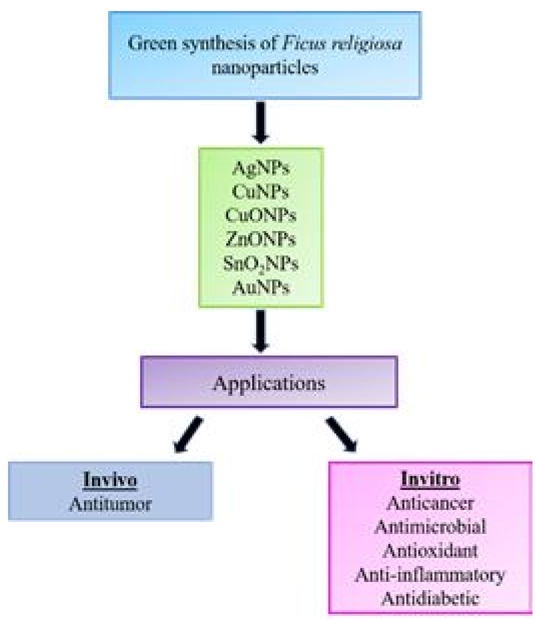

Fig. 2. *Ficus religiosa* nanoparticles and their applications

Silver nanoparticles :

Ficus religiosa plant leaf silver nanoparticles (AgNPs) were synthesized and characterized and found that the nanoparticles were in spherical shape[9]. AgNPs were synthesized using *Ficus religiosa* leaf extract by a simple, cost-effective and eco-friendly process. The nanoparticles were about 5-23 nm in size. Fourier transform infrared (FT-IR), Transmission electron microscopy (TEM), zeta potential analyses and X-ray diffraction (XRD) were used to characterize the produced nanoparticles. *F. religiosa* AgNPs exhibited efficient free radical scavenging properties and were used to treat Dalton's ascites lymphoma in mice model[8]. The *Ficus religiosa* silver nanoparticles (FRAgNPs) showed good antibacterial activity and also cytotoxic effects in different cell lines. The size of the nanoparticles was about 21 nm. Apoptotic changes were induced in A549 and Hep2 cancer cells through the involvement of intrinsic and extrinsic apoptotic pathways by FRAgNPs[7]. Chauhan *et al.*[3] reported silver nanoparticles synthesis and characterization from leaves of the *F. religiosa* plant with 67 nm size. The metal salt solution after phyto treatment has shown the maximum absorbance peak at approx 410 nm. Synthesized AgNPs exhibited potential antimicrobial activity against *Staphylococcus aureus* and *Bacillus subtilis*. *Ficus religiosa* leaf extract stable silver nanoparticles synthesis mechanism was reported by Saware and Venkataraman[14]. Silver nanoparticles prepared from bark of *Ficus religiosa* were applied for the removal of chromium from wastewater[10].

Copper oxide nanoparticles :

Synthesis of copper oxide nanoparticles using *Ficus religiosa* leaf extract as a reducing and protecting agent was reported by Sankar *et al.*[13] and Kalaiarasi *et al*[5]. The characterization of copper oxide nanoparticles was analyzed with FE-SEM, FT-IR, dynamic light scattering (DLS) and XRD. The size of the produced copper oxide nanoparticles was approximately 577 nm, and their absorbance peak was at 285 nm, as validated by a UV-vis spectrophotometer. The total HDAC level and the expression of class I, II, and IV HDAC mRNA in A549 cells were both markedly decreased by the greenly generated CuO NPs. Both intrinsic and extrinsic caspase cascade pathways were triggered by CuO NPs against A549 cells[13]. They may also have the potential to control the mRNA and protein expression of tumour suppressor and oncogene genes. Therefore, CuO NPs nanoparticles can be implemented as a chemotherapy agent.

Zinc oxide nanoparticles :

The zinc oxide nanoparticles (ZnO NPs) were synthesized using the aqueous leaf extract of *Ficus religiosa* (Fig. 3). The ZnO NPs were characterized by UV-visible spectroscopy, XRD, TEM and SEM-EDX. The synthesized ZnO NPs were tested as a larvicidal agent against the larvae of *Anopheles stephensi* and as an antibacterial agent against the *Escherichia coli* (gram-negative) and *Staphylococcus aureus* (gram-positive) bacteria. The larvae of *An. stephensi* were found highly susceptible to the ZnO NPs[16]. The fourth instar of *An. stephensi* had 100% mortality, and the maximum mortality was seen in synthesised ZnO NPs against the first through third instars (LC50 50, 75, and 5 ppm). The highest mortality was observed in synthesized

Table-2. Nanoparticles synthesized from leaf and bark extracts of the *Ficus religiosa* plant

S.No	Plant part	Nanoparticles	Morphology	Application	Reference
1	Leaves	Silver	21 nm and spherical	Antibacterial and anticancer activity	2
2	Leaves	Zinc oxide and titanium oxide	NA	Larvicidal and antibacterial activity	5
3	Leaves	SnO_2	~15 nm	Fabrication of OFETs for Glucose monitoring	8
4	Leaves	Copper oxide	577 nm	Induced anticancer activity in A549 lung cancer cells	13
5	Leaves	Silver	67 nm	Antibacterial activity	7
6	Leaves	Silver	5-35 nm	In vivo anti-tumour activity	9
7	leaves	Silver	Spherical 5-50 nm	NA	3
8	Bark	Gold	Spherical	Antibacterial	6
9	Bark	Silver	NA	Wastewater treatment	14
10	Leaves	Mg-doped ZnO NPs	NA	Antioxidant, anti-inflammatory and antidiabetic activity	16
11	Leaves	ZnO NPs	70-80 nm	NA	4

NA- Not available

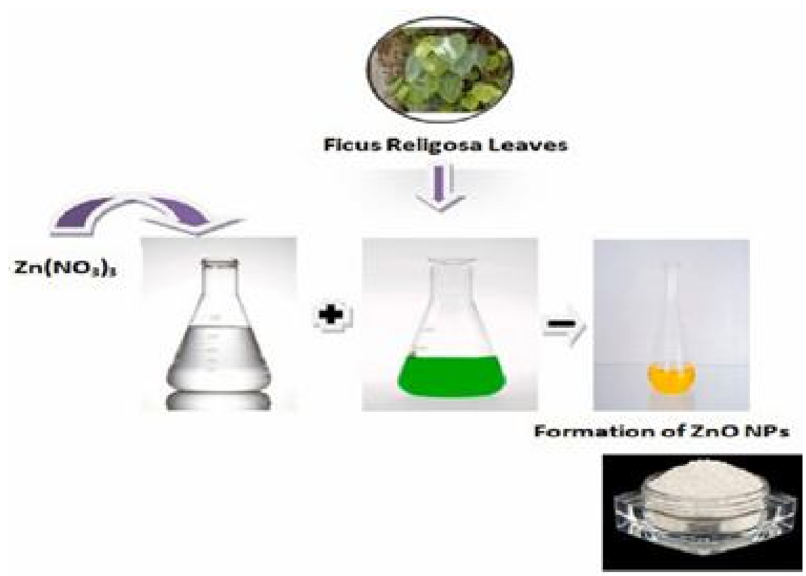

Fig. 3. Synthesis of Zinc oxide nanoparticles from *Ficus religiosa* leaf extract[16]

ZnO NPs against first to third instars of (LC_{50} 50, 75, and 5 ppm) and 100% mortality in fourth instars of *An. stephensi*. ZnO NPs are more effective as larvicides than TiO NPs. ZnO Nps exhibited 8 ± 0.612 mm in *E. coli* and 6 ± 0.563 mm zone of inhibition in *S. aureus*[14]. Mg doped ZnO NPs prepared by leaf extract of *Ficus religiosa* exhibited antioxidant, anti-inflammatory and anti-diabetic activity[6].

Titanium oxide nanoparticles :

Aqueous *Ficus religiosa* leaf extract was used to produce the titanium oxide nanoparticles (TiO NPs). The TiO NPs were characterized by UV-visible spectroscopy, XRD, SEM-EDX and TEM. The synthesized TiO NPs were tested as a larvicidal agent against the larvae of *Anopheles stephensi*, and as antibacterial agents against the *Staphylococcus aureus* (gram-positive) and *Escherichia coli* (gram-negative) bacteria[5].

Gold Nanoparticles :

Gold nanoparticles synthesized from the bark extract of *F. religiosa* and the physical and biological characterization were done. The synthesized *Ficus religiosa* AuNPs were stable with uniform capping. AuNPs were characterized with different techniques like UV-Vis spectroscopy, FTIR, XRD and TEM. These nanoparticles were nontoxic to HEK 293 cells. These eco-friendly nanoparticles may be the alternatives to chemicals that are toxic to human health[18].

This review's main goal is to explain, educate, and provide examples of different metallic nanoparticles that can be made from source materials (*Ficus religiosa* L.) in a more efficient and cost-effective manner. Additionally, these biologically produced nanoparticles have been demonstrated to have significant benefits in a variety of scientific fields, including anti-microbial efficacy against harmful bacterial and fungal strains, anticancer, anti-inflammatory, antidiabetic, larvicidal and catalytic activity. Ficus, therefore, has tremendous importance in the field of nanoscience, which might serve as the fundamental framework for a drug delivery system and as a replacement therapy for the treatment of a variety of ailments. Hence Ficus bids immense value in the nanoscience domain which may form the elementary platform to drug delivery systems and also treat diverse diseases as a substitute therapy.

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