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Comparative Evaluation Of Bark, Leaf And Fruit Extracts Of Terminalia Arjuna In Green Synthesis Of Nanoparticles

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Synthesis of Nanoparticles in an Environmental Concern is very good in quality, cost-efficient, and an essential sustainability to the current physical and chemical routes. Terminalia arjuna tree is regularly used medicinally to extract medicinally rich bioactive phytochemicals such as flavonoids, tannins, triterpenoids, phenolic compounds, and glycosides. All those phytochemical communities play the greater role in the reduction and stabilization of nanoparticles at a natural level. The authors review the study on extracts of Terminalia arjuna bark, leaves, and fruits regarding the greener synthesis of nanoparticles. The available evidence suggests that bark extracts produce smaller and more stable nanoparticles, which is mainly due to very high tannin and triterpenoid contents. Leaf extract showed some reduction and stabilization efficiencies and a moderate concentration dispersion mechanism in contrast to other extracts. On the other hand, fruit extraction is rare, and fruit extract antioxidative powers have been found to be high, which will be a very useful substance in many future applications. In this review, compounds from the tree part illustrate their composed structure as antibacterial, antioxidant, anticancer, and biomedical features. This article suggests not only a concept of each part of Terminalia arjuna but also the need to prompt more systematic comparative study to perfect easily biomedical and environmental issues, in addition to creating suitable routes for sustainable production.

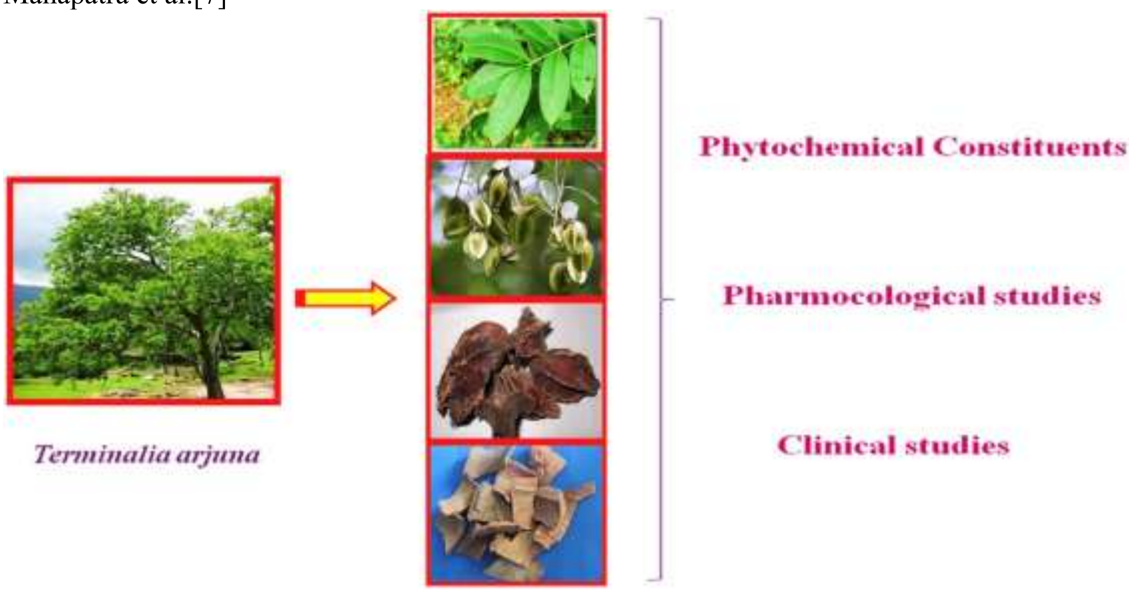
Keywords: Terminalia arjuna, Green synthesis, Nanoparticles, Bark extract, Leaf extract, Fruit extract, Phytochemicals.

Introduction:

Nanotechnology is an interdisciplinary study of sciences dealing with working at tiny scales - it's typically measured to be figured at 1 - 100 nanometers in dimension, and smaller.[1] Nanoparticles' uniqueness lies in having special physicochemical properties such as high surface area, enhancing the reactants to a total degree, having very unique optical activity, interacting with light, and progressing biological behavior altogether different from their bulk counterpart. The unique property has the potential to show very broad applications in the fields of medicine, pharmaceuticals, agriculture, environment and materials science.[2]

Traditional techniques for nanoparticle synthesis have been based on physical and chemical methods that are not environment-friendly and cost more.[3] From the viewpoint of security, high energy input, high toxicity of chemicals, as well as hazardous waste generation, conventional methods represent the most common issues with the nanoparticles' preparation. Traditional constraints showing a way towards a healthy and ecologically friendly nanotechnology-based approach include the production of nanoparticles through biological systems of plants and microorganisms and biomolecules, often referred to as the emerging third generation technique or green synthesis.[4] It is much cheaper than other methods and others do not require the use of harmful reducing and stabilizing agents.[5]

There are other types of precursors that are controlled ones and support the beneficial synthesis of silver nanoparticles, including silver nitrate and silver chloride.[6] This green synthesis route has a considerable future in nanoparticles fabrication.[7] There are many trees that have different bioactive properties, and from these, leaves, bark, and roots have been used as controlled precursors in the synthesis of nanoparticles. The numerous trees include Terminalia arjuna, Azadirachta indica, Piper nigrum, Syzygium cumini, Ficus benghalensis, Morinda citrifolia, Aegle marmelos, Pongamia pinnata, Nelumbo nucifera, Artocarpus altilis, Carica papaya, and Mangifera indica. It can be seen that with the nanotechnology expansion rate, there is a sudden increase in studies that compare plants as controlled precursors put to many uses, especially the medicinal ones for nanoparticle synthesis. Dimocarpus longan comes as one of the possible candidates for greener synthesis because it may prove to be a precursor rich in nutrition. Researcher also examined medicinal plants Elaeocarpus ganitrus, Terminalia arjuna, Garcinia indica, and Psidium for comparative studies with the work of by Mahapatra et al.[7]



Source: Amalraj, A., & Gopi, S. (2016). Medicinal properties of Terminalia arjuna (Roxb.) Wight & Arn.: A review. Journal of Traditional and Complementary Medicine, 7(1), 65-78.

Objectives of Study:

1) To recap and summarize contemporary work published on the green synthesis of nanoparticles from bark, leaf and fruit extracts of Terminalia arjuna.
2) To uncover differences related to the phytochemical composition in bark, leaf and fruit extracts which impact nanoparticle formation, stabilization and overall synthesis efficiency.
3) The review aims to look into the various green synthesis approaches that use different parts of Terminalia arjuna as a source of bioactive compounds, and highlight the similarities and differences between them.
4) This information will allow us to compare the physiochemical characteristics of nanoparticle formation when derived from the extracts of the bark, leaves and fruit and the contrasting characteristics.
5) The review will determine the gaps and suggest the key areas for future research to standardize and broaden the applications of Terminalia arjuna in green nanochemistry.

Comparative Evaluation of Bark, Leaf and Fruit Extracts of Terminalia arjuna in Green Synthesis of Nanoparticles:

Botanical and Phytochemical Profile of Terminalia Arjuna:
Terminalia arjuna Wight & Arn.,[8] belonging to family Combretaceae [9] displays a heavy deciduous tree found in the vast geographical areas of the Indian subcontinent. It grows mostly near river banks, streams and in moister regions; this fact makes it very reachable and cheap as a traditional medicinal plant from the ancient times. Widely grown and environmentally adaptable with good ethnomedicinal use, the tree can be used for all types of medicinal purposes including the healing of wounds.[10] It has been highly investigated in respect of its pharmacological and phytochemical potential to know their medicinal worth in ethnomedicinal ethnosystem.

The potentiality of the traditional value of Terminalia arjuna as an ayurvedic formula for curing heart illnesses has been well established in a traditional ayurvedic text. Dwivedi (2007) emphasized that, according to Indian classical physicians, hritshool and other diseases of heart can be best treated with the powder of the stem bark of T. arjuna.[11] Proven assertions supporting the earlier are through recent clinical experiments, which depicts its valuable role in combating conditions like the coronary artery diseases, ischemic heart diseases, hypertension, and heart failures.[12,26] In patients suffering severe refractory congestive heart failure it is noticed that they become much better after adding T. arjuna bark extract to their standard treatment by decreasing symptoms of the disease and functional capacity according to the New York Heart Association (NYHA).[13] Patients clinically feel subjectively relieved symptomatic-wise and makes the heart performance more because add-on therapy with T. arjuna bark extract is beneficial in ischemic mitral regurgitation after acute myocardial infarction condition, thus leading to regurgitation intensity and less anginal episodes.[14]

Rich in phytoconstituents principally possessing greatest pharmacological effects, the stem bark stood out among the extracts with the most potent radical scavenging. Thus, tannins represent the most potent free-radical scavengers of all, according to Dwivedi's evaluation.[11] It early established that flavonoids were known anti-oxidants, anti-inflammatory agents, and lipid-reducing agents, and therefore, should very beneficially decrease infarct size and improve coronarography after supplementation, says Dwivedi. Luteolin law also relates to a crucial gateway to the anticancer effects of ground extracts. Terminalia arjuna comprised triterpenoid saponins, the only source of medicinally useful triterpene glycosides, sources of endogenous Antioxidants in cardiac tissue lutein, according to Manna et al. (2008).[15] Terminalia arjuna, according to Manna et al.'s 2008 research, stayed uniquely renowned because various potent triterpenoids, such as the oleanane type, had still remained third to other triterpenoids for interacting with ROS-related pathways (Pawar and Bhutani 2005).[16] These phenolic characters, gallic acid, and other antioxidative properties are supposed to be anticancer.[17,25] Among the possible synergism of its minuscule role, alkaloids have indeed a good chance to contribute more effectively in working toward a better cardio-protection and efficacy of any phytochemicals with therapeutic properties of Terminalia arjuna. [11]

Green Synthesis of Nanoparticles Using Plant Extracts:

It is in such an environment friendly manner that the green synthesis of nanoparticles is possible with the help of biological systems, utilizing plant extracts to act as healthier alternatives to conventional physical and chemical synthesis processes. A study, which reads something like Kumar and Yadav (2009), has been produced by the pair, the title being "Extracellular Biosynthetic Strategy for Silver Nanoparticle Synthesis in Some Economically Important Plants."[18] Predicting that nanoparticle biogenesis through plants takes place extracellularly, the use of plant extracts emerges as a reducing agent or stabilizing agent relative to water.[19] The approach does significant savings in chemicals and energy required to maintain cell cultures, avoiding the use of harmful chemicals.

The main principle of green synthesis is transformation of metal ions, say, Ag^+ and Au^{3+}, into metal ion-reductions after adsorbing electrons from some ‘plant pure’ product, as was written by the authors Ankamwar et al.[20] In the context of quickly converting metal salts into metal nanoparticles, plant extracts may have treated metal salt solutions into a way reducing metal salts, as postulated by the authors. Factors of such as pH, temperature, and concentrations of metal ions in the reaction, would greatly influence the size, form, and stability of the nanoparticles produced.

Plant extractions are largely extracted with several phytochemicals like flavonoids, phenolic compounds, tannins, and triterpenoids. These compounds would give reducing and capping agents at the same time. They are founded as the central to nanoparticle formation and stabilization in a classical way.[18] There is a proof that Emblica officinalis fruit extract successfully synthesized silver or gold nanoparticles without any external chemical stabilizers, supporting such a mechanism.[20] Green nanoparticle synthesis activity is found to be very high with a molecule like arjunolic acid of triterpenoids, and it is the most potent antioxidant and metal chelating compound deriving from Terminalia arjuna.[15]

The most reported, Green Synthesized Nanoparticles are those of silver. Ankamwar et al. have shown us how small biosynthesized silver nanoparticles are currently developing from different fungi. Silver nanoparticles with a size of about 10–20 nm have been developed by Ankamwar et al. Along with this, Kathiresan et al. have vividly denounced a reasonable rapid biosynthesis phenomenon from living fungal filtrates.[21] Typically, plant extracts are largely used to make nano-gold particles of 15–25 nm, but the term first sets out the stipulations with regard to stepwise procedures in using nanoparticles, and the results after

Ankamwar et al. [20] and Kumar and Yadav [18]. Experimentally, competent benefits must have been indicated as a tangible demand and the scarcity of experimental examination with Terminalia arjuna as the elemental sources for synthesis of zinc and iron oxide nanoparticles. With the measurements dependent on these estimates performance of replication of syntheses for protocol, exploration of the mechanism or translation applications on a large scale, however, remains sparse, thus demonstrating a significant gap in research.

There will be a good number of plants that can make utilizing sustainable green synthesized ways great project approaches into the nanoparticles making sector for being very handy when it comes to the formation of both silver and gold nanoparticles.

Bark Extract of Terminalia arjuna in Nanoparticle Synthesis:

Terminalia arjuna is one of the well-known medicinal plants for having reputation both in Ayurveda and traditional Indian medicine practice. However, very limited experimental and phytochemical studies have been carried out on aqueous, ethanolic or alcoholic extracts of bark mostly. "Thus, according to Dwivedi, it has been traditionally powdered and used in different preparations of Ayurvedic medicine.[11] Furthermore, almost all of the experimental studies on the plant with respect to cardioprotective effect have been done using dried bark powder or alcoholic extracts being administered orally.[21-22] All these systems very well find the compatibility with most of the processes of drug discovery that could be used for searching green synthesis methodologies by involving plant extracts with aqueous or alcoholic solvents in order to bring reduction and soldering.[18]

Baric contains numerous phytochemicals, as it is the most studied part of T. arjuna plants. The most important compound in barks consists of tannins, flavonoids, glycosides, triterpenoids, phenolic compounds, and other major minerals, said Dwivedi.[11] Arjunolic acid, arjunic acid, arjungenin, terminalin acid are some of the compounds identified as major triterpenoids.[16,23] According to Manna et al. and Kumar & Yadav, these compounds are highly reputed for their antioxidant, metal-chelating, and redox-regulating properties, which are important for nanoparticle synthesis in plants.[15-16]

As of now, jawarish-formulated Gedunin-packed silver nanoparticles have yet to be synthesized; pantin capsules, a synthetic dendritic polymer used for the administration of genes, encapsulated phytochemically similar plant extracts, involving reduced silver and gold nanoparticles (Ankamwar et al.).[20] High tannin and triterpenodial content of T. arjuna bark are indicative of considerable potential for the stabilization of nanoparticles. The experimental proofs may still be unavailable and apprehensions about sustainable bark procurement are there, but more work is required using nano-technological modes of an orderly systemic comparison study with renewable vegetative parts.

Leaf Extract of Terminalia arjuna in Nanoparticle Synthesis:

The processes in the generation of Terminalia arjuna leaves bring about a huge variation in the phytochemical fingerprints and biological activities when compared with what is done for manufacturing using nanoscale. This also involves the concentration of active principles from the plant, which are very poorly soluble in the reduced volume of the four organic solvents - ethanolic, butanolic, methanolic, or ether extract. Second to the solvent fractioning, there was further processing through ether fractionation, ethyl acetate fraction, etc.; this gave a description of active principles in a few of the fractions so generated and an idea for the nature of what those may be. Larger majority studies have been focused around ethnopharmacological studies, phytochemistry of the active principles, and evaluation of pharmacological activities from this plant.

Hence, there would be felt for more such phytochemical and pharmacological work on this plant as it were completely different concerning earlier reports. Thus, it is imperative not only to absorb more specificities for the development of the right complementary drugs sourced from these plants.

A chemical study carried out as part of a phytochemical investigation confirmed some redox-active compounds from the leaves of T. arjuna. Many years ago Gallic acid, ethyl gallate, and the flavone luteolin were identified as some of the same constituents present in the leaf extract by the combined team of Pettit et al.[17] Luteolin was identified as powerful antioxidant, anticancer, and anti-inflammatory agents, based on the intrinsic metals within it. Consequently, Terminalia arjuna leaves, rich in phenolic acids and flavonoids, were suitable to reduce metal and stabilize nanoparticles.

Even though there is no experimental verification according to Kumar and Yadav,[18] plant extracts rich in flavonoids and phenolic compounds are typically utilized as potent agents for the green synthesis of metal nanoparticles. Phytochemical studies that were performed on the leaves of T. auriculata are promising, pointing to this plant as a potential source of nanoparticles. Phytochemical analysis and apoptosis experiments reveal that the leaves are a putatively anticancer and anti-microbial agent candidate for nanoparticles usefulness which is very promising and satisfactory.

With their state of extraction realism, leaf extractables are said not to be sustainable because it can deprive a plant of its leaves only for the time being, not a permanent loss. Most sustainable advantage by interlayer is the fact that each leaf component can be carved off. But there is not much on scientific evaluations towards nanotechnology and therefore deserves a broad experimental study, which equals getting the fullest possible picture of the possible role in nanoparticle synthesis of T. arjuna so that we can be better assured about its potential economic benefits.

Fruit Extract of Terminalia arjuna in Nanoparticle Synthesis

One difference from the barks and leaves of Terminalia arjuna is that empirical studies on the fruit part of this plant are very few. The ethnomedicinal records indicate that fruits were traditionally used in conjunction with barks and leaves for the therapeutic purposes (Dwivedi).[11] But mainly the scientifical work is mostly aimed at bark preparation in pharmacological and experimental studies. The arjuna fruit itself, however, has not been taken much into account in the preparation of extracts, which are using proper standardization as far as pharmacological and may be falling under nanotechnological operations are concerned.

Though Dwivedi has acknowledged all parts of the plant to be generally medicinally useful, no limited chemical profiling exists for T. arjuna fruit. This indeed indicates the presence of bioactive constituents in plants.[11] Certain phenolic compounds and antioxidants have been observed in other fruit of medicinal plants, which are necessary ingredients for green synthesis processes.[18] There exist wordless yet extraordinary nature of new phytochemical abundance as yet lack of phytochemical richness yet are promising for respective site of discoveries.

A proof, in fact, does not exist on the efficacy of nanoparticle synthesis from the fruit extract of Terminalia arjuna. However, fruit extracts of almost all medicinal plants have been successfully carried out in the successful green synthesis. Among these are the most impressive of those reported by Ankamwar et al. that explains how the fruit extract of Emblica officinalis was used very efficiently to induce extracellular synthesis of silver and gold nanoparticles through the residence of anti-oxidants from fruits which assist in metal ions reduction.[20]

The reported anticancer activity of an ethyl acetate extract was evaluated experimentally; therefore, the T. arjuna plant exhibits preferential anticancer potential in comparison to the leaf. Essentially, T. arjuna shows anthelmintic activity against earthworms with causing permanent paralysis, characterized as the conventional way of evaluating anthelmintic potential of any extracted molecule. The observations derived from the experiments regarding 100% mortality of P. posthuma earthworms stimulated us to study in-depth the medicinal efficacy of the plant, adding medically potent aspect to its list of properties.

Comparative Evaluation of Bark, Leaf, and Fruit Extracts:

Bark makes up the majority of the parts of the tree from which most of the available information is obtained and which is rich in phytochemistry. As stated by Dwivedi, the bark had more tannins, flavonoids, triterpenoids, glycosides, and important minerals when compared with other parts of the plant.[11] All together, these constituents establish the material with significant antioxidants and cardioprotective properties-moreso than the heart, the antioxidants are concentrated in the bark. Many bioactive terpenoids have been isolated and characterized structurally as comprising a number of tri-terpenoids including arjunolic acid, arjunic acid, arjungenin, and terminic acid from the bark.[16,23] These metabolites have also engaged themselves in chelating metal and redox properties, which might be relevant in green nanoparticle synthesis, too.

The leaf extracts of this plant are also said to be endowed with phenolic acids and flavonoids like gallate, ethyl gallate, luteolin, etc. They are not only antioxidant activities but also have potent cytotoxic properties. However, the quantity and number of these compounds are less than T. arjuna. This is the least studied of all parts of this species Countryman notes that aboriginal people use it for noxious purposes, but no detailed studies have been forthcoming to date.

Utilization of the bark for the preparation of nanoparticles will further be supported by its beneficial antioxidant arjunolic acid by Manna et al.[15] Probably leaf extract reactions may give medium efficiency, while fruit extracts seem to be more speculative due to unavailability of sufficient data. Environmentally, sustainable comparison of alternatives should be arrived at when considering the use of leaf and fruit that has not been herewith studied entirely as extraction of the stem bark.[11] This, consequently, demands further culture of studies on the mentioned scores.

Comparative Table:

Plant Part	Major Phytochemicals	NP Type (Reported/ Expected)	Size Range (nm)	Bioactivity	Advantages
Bark	Tannins, flavonoids, triterpenoids (arjunolic acid), glycosides	Ag, Au (expected)	10–25*	Strong antioxidant, cardioprotective	High reduction efficiency, strong stabilization
Leaf	Flavonoids (luteolin), gallic acid, phenolics	Ag, Au (expected)	15–30*	Anticancer, antimicrobial	Renewable, moderate phytochemical content
Fruit	Not well characterized	Ag, Au (potential)	10–25**	Ethnomedicinal relevance	Sustainable, underexplored research scope

*Estimated based on plant-mediated nanoparticle synthesis studies.[18,20]
**Based on analogous fruit-extract synthesis systems.[20]

A comparative investigation was indicative to reveal the fact that the bark extracts from Terminalia arjuna contained phytochemicals in maximum concentration form and were characterized well theoretically for some of the highest efficiency quotients towards synthesis of nanoparticles as reported earlier.[14-15] These aspects still keep the potential of any prolonged uses of extracts from leaves and fruits under unexplored conditions. A large research gap right now is when nanomaterials could be synthesized by direct experimentation with materials which are present in the plant of T. arjuna. It's really important to investigate things as it's the basis of scientific reason to compare different plant parts systematically with an aim to identify the best sources of phytochemicals for the efficient and sustainably green synthesis of nanoparticles.

Characterization Techniques Used in Reviewed Studies:

It is important, in fact core defining clues of identifying nanoparticles which are observed and analyzed to show evidence of their occurrence and some of the signs of their physicochemical attributes, which evaluate the stability and ultimately perform behavior tests concerning the biological properties.[27] There may be an easy but insufficient still reliable approach to accessing the mechanism concerning all these analyses and investigations simply by making reviews or something else really with the names referred to as green nanotechnology phytosynthesis.[28] Occurred with most of other methods this few is going to be definitely under the category called "tools as tools, except they have been not employed in this current experiment".

The most popular technique to detect these first metallic nanoparticles synthesized, almost universally, is UV-Visible spectrophotometry because of the SPR peaks that usually confirm their synthesis.[29] As example, Ankamwar et al. claimed that UV-visible spectrophotometry technique was used for monitoring of the synthesis of silver and gold nanoparticles in Emblica officinalis fruit extract based on distinct peak absorbances which should see in UV-Visible spectrum while a series of bands revealed the presence of waves proved highly indicative of silver and other metal nanoparticles.[20] Following that, Kathiresan et al. research two bands of the application of a biofilm of Silver nanoparticle with marine fungus according to UV Regions at 430 nm.[24] Most commonly, the researchers used UV-visible spectroscopy for synthesis of nanoparticles within four hours with simple, reproducible, and non-invasive devices for the rapid detection and screening thereby ensuring for production stability studies of the nanosystems where greenness is maintained through the synthesis processes..

A process for identifying a functional group involves applying FTIR,[30] but not very often, that is, taking up and reducing metal ions and stabilization of nanoparticle-conjugate. FTIR was found to be a missing experimental aspect in all reports in Ankamwar et al. [20] and Kathiresan et al. [24] but was an important part of the work done by Kumar and Yadav [18], hence used as the basis to confirm the phytochemical involvement through synthesis against the phenolics, flavonoids, proteins, tannins, and capping agents.

Both were well-known among the scientific community as they pioneered Green Nanoscience which had been forgotten for a long time. However, there were noticeable differences between both authors. Wet-chemical methods sound pretty traditional; you will hardly find people naming it with a different title. It seems so because both these researchers, like some others, had applied the wet-chemical method in their research. Yet FTIR was not decipherably expressed in the experimental investigation conducted by Ankamwar et al. [20] and Kathiresan et al. [24], but surely, Kumar and Yadav [18]. Labeling the FTIR spectra will reveal the authenticity of the nanoparticles obtained and ensure that the proposed technique does discourage the application of hard work for further measurement of size and crystallinity analysis techniques.

The technique has been proven to be very useful now in the development of modern nanoparticle characterization. This could be 10-20 nm for silver nanoparticle; 15 to 25 nm for gold nanoparticle, as was done by Ankamwar et al. [20] in TEM studies; it is be 1-5 nm for some cases, as illustrated by Kathiresan et al. [24] in the evaluation-the smallest isolated, or nanometer-sized, may be a prejitali with silver nanoparticles of Penicillium fellutanum and transmittal electron microscopy.

The equipment related details for Dynamic Light Scattering and measurements of zeta potential were given slim examples in the work of Balaji et al. (2009). But by Kumar and Yadav [18], these were exemplified as necessary techniques for interpreting the particle size distribution and therefore studying aggregation behavior, surface charge, and colloidal stability. Thus, statistical extension has been made in physicochemical and functional characterization vera from the newly known data into a comprehensive physicochemical evaluation to be specified for understanding the biological function analyzed in the entire analysis of the nanoparticle synthesis catalyzed by Terminalia arjuna.

Challenges and Research Gaps:

To date, food-bound green nanotechnology has been projected as the most rapidly growing among plant sources. Although it happens that there are several research opportunities in pharmacologically-targeted studies conducted on Terminalia arjuna. Major issues and research gaps stand in the way of reliable and sustainable use in therapeutic applications. This requirement is tackled in order to facilitate the translation of the laboratory findings into useful devices for practical real-world biomedical- as well as environmental applications.

The major problem of mainstream so far in plant extract preparation is just the fact that all systems can't be standardized in nanoparticle synthesis. Extraction conditions are very much likely to lead to the difference in shape, size, and yield and even stability. The other reasons include variability on the certain plant part that is used, the type of solvent system, and reaction parameters. The methods of extraction done in the case of the extract of Terminalia arjuna extracted for pharmacological assessment are wasteful or using poor procedural green nano-material synthesis processing so less green nanoparticle can be produced by using them. It varies, so the effects cannot be reproducible from experiment to experiment, and, discourages direct comparison of the consequents from study to study.

Another research gap is significant to note as the previous studies were not in any systematic comparison of the bark, leaves, and fruit of T. arjuna for nanoparticle effectiveness or a bioresponse. Although the bark has been studied extensively, the study of leaves and fruits are much more minimal. This obstructs the discovery of green, efficient innovative alternative research.

Toxicity and safety are also concentrated in the among most neglected areas of research. The extracts probably show a good safety average in phytotherapy doses for the T. arjuna tree, but against bioavailability and a totally different biological mechanism, long-lasting efforts were supposed to be onto a comprehensive toxicological study, but not by nonspecific foods to prohibit the drug from clearing the intracellular actions into the body.

Entering the industrial scale of green synthesis involves the hindrance of process control, thus citing this as among the challenges concerned with scale-probability and control during laboratory production. Probably the greatest eco problem around it is the very difficult bark extraction that would characterize an entirely new means of making plant parts renewable-again, fitting quite well into the standardization aspects of these methods directed towards the viability of Terminalia arjuna-in comparison with other green nanotechnology growth paths.

Conclusion:

In reference to the role of phytoconstituents in the applicability and significance of C. arjuna bark, leaf, and fruit extracts in green nanoparticle synthesis, the greatest phytochemical richness was obtained by extracting methanol from bark and is used for wide pharmacological and ethnomedicinal attributes, radical scavenging capacitating, cardioprotective, metal chelating abilities required in reducing, and stabilizing nanoparticles. In their extraction, most importantly, the extract showed a good quantity of phenolics and flavonoids, namely, luteolin and gallic acid, thus having redox potential rich enough to add few nanoparticle studies to it. The potential is worth the most by a lot-His sec. arjun root extract has least pharmacognistic and nanotechnological evidence made on. T. Arjuna possesses very bright prospects for sustainable green nanotechnology.

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