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Biological Properties of *Jasminum Mesnyi* Using Copper Nanoparticles

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Abstract: The medicinal plant Jasminum mesnyi, or Japanese primrose jasmine, has a wide range of pharmacological effects, such as antibacterial, antioxidant, and anti-inflammatory effects. Discoveries of plant-based nanoparticles with enhanced biocompatibility and bioactivity have been made possible by recent developments in nanotechnology. In this work, we use a green synthesis method to create copper nanoparticles (CuNPs) from Jasminum mesnyi leaf extract. We next characterize and test these CuNPs in living organisms. The traditional technique of nanoparticle manufacturing often involves the use of harmful chemicals; however, this eco-friendly approach uses the phytochemicals found in Jasminum mesnyi as natural reducing and stabilizing agents.

Several analytical techniques were used to characterize the synthesized CuNPs. These included transmission electron microscopy (TEM) for size and morphology determination, X-ray diffraction (XRD) for structural assessment, optical property analysis with ultraviolet-visible spectroscopy, functional group analysis with Fourier Transform Infrared Spectroscopy (FTIR), and more. The findings validated the production of stable, monodispersed CuNPs that exhibited ideal physicochemical characteristics that were well-suited for use in biomedicine.

A battery of tests was used to determine the CuNPs' biological characteristics. Disc diffusion testing revealed significant inhibitory effects when applied to gram-positive (Staphylococcus aureus) and gram-negative (Escherichia coli) bacterial strains. The antioxidant capacity was assessed using DPPH radical scavenging tests, which demonstrated a strong ability to neutralize free radicals. Also, using MTT assays, we looked at how the CuNPs affected certain human cancer cell lines, and we found that they selectively killed cancer cells while having very little impact on healthy cells.

According to the results, Jasminum mesnyi-mediated CuNPs might be a great option for antibacterial, antioxidant, and anticancer uses. A more secure substitute for chemically produced nanoparticles, the green synthesis process is both economical and environmentally benign; it is in line with sustainable nanotechnology principles. Future studies on bioactive nanomaterials may benefit from this work, which also adds to the expanding area of plant-based nanomedicine.

Keywords: Jasminum mesnyi, Copper Nanoparticles, Green Synthesis, Antimicrobial Activity, Antioxidant Properties.

I. INTRODUCTION

In several areas of science, including biotechnology, pharmacology, and medicine, nanotechnology has sparked a new era of discovery and advancement. Due to their many biological uses, metal-based nanoparticles have attracted a great deal of attention among the many nanomaterials studied for their distinctive characteristics. Because of their remarkable stability, reactivity, and high surface-to-volume ratio, copper nanoparticles (CuNPs) have become an attractive class of nanomaterials. Antimicrobial treatment, cancer treatment, and targeted drug delivery are just a few of the biological uses that benefit greatly from CuNPs' unique properties. They are promising prospects for therapeutic developments because to their powerful biological activities, which include antibacterial, antifungal, antioxidant, and anticancer properties. Environmental and biological issues arise from the use of hazardous chemicals and excessive energy consumption in current physical and chemical techniques of CuNP production. As a result, green synthesis, a sustainable method that uses plant extracts, has been getting a lot of interest for its potential to make nanoparticles less poisonous and more biocompatible (Miu&Dinischiotu, 2022).

One of the most well-known medicinal plants in the Oleaceae family is *Jasminum mesnyi*, or Primrose Jasmine. The antibacterial, anti-inflammatory, antioxidant, and wound-healing effects of this plant have long made it a staple in traditional herbal treatment. Flavonoids, alkaloids, tannins, and phenolic acids are just a few of the bioactive components found in Jasminum mesnyi that give it therapeutic promise. One benefit of using plant extracts in nanoparticle biosynthesis is that they stabilize and reduce the formation of nanoparticles. Another benefit is that the synthesized nanoparticles have additional biological functions due to the presence of inherent phytochemicals. This technology guarantees an ecologically friendly way of synthesis while also improving the biocompatibility and efficiency of nanoparticles (Nongbet et al., 2022).

Few studies have examined the synthesis of CuNPs using *Jasminum mesnyi* extract and the subsequent assessment of their biological characteristics, despite the increasing interest in CuNPs' potential biomedical applications. A highly effective nanomaterial with enhanced antimicrobial, antioxidant, and anticancer activities could be created by combining the potent bioactivity of Jasminum mesnyi with the unique properties of CuNPs. In order to enhance nanomedicine and create new therapeutic agents, it is essential to understand the interaction between metallic nanoparticles and bioactive chemicals derived from plants (Dikshit et al., 2021).

The purpose of this research is to examine *Jasminum mesnyi*-mediated copper nanoparticles (Jm-CuNPs) and their biological characteristics in detail. The effectiveness of these compounds as antimicrobials against harmful microbes, antioxidants against oxidative stress, and cytotoxic agents against cancer cells will be the primary areas of investigation. This study aims to contribute to the expanding field of green nanotechnology by delving into these aspects and offering new insights into the biomedical applications of nanomaterials derived from plants. As an environmentally friendly and efficacious substitute for traditional synthetic nanoparticles, this study's results may open the door to new possibilities in nanoparticle-based therapeutics (Sharmin et al., 2021).

II. BACKGROUND OF THE STUDY

New methods for synthesizing metal nanoparticles have emerged as a result of the fast development of nanotechnology, which may improve the biological characteristics of medicinal plants. One of them that has received a lot of interest is copper nanoparticles (CuNPs), which have anti-inflammatory, antioxidant, and antibacterial capabilities. The combination of CuNPs with bioactive chemicals generated from plants has shown encouraging outcomes in terms of enhanced biocompatibility, focused therapeutic applications, and pharmacological effectiveness (Ermini et al., 2023).

Primrose jasmine, or Jasminum mesnyi, is an Oleaceae family member with antibacterial, wound-healing, and anti-inflammatory uses in traditional medicine. The therapeutic effects of Jasminum mesnyi are due in part to the several phytochemicals it contains, including flavonoids, alkaloids, and terpenoids. Nevertheless, there is still a need to improve its bioavailability and effectiveness using contemporary technological treatments, even if it has medicinal promise (Miu&Dinischiotu, 2022).

An novel technique to increase its biological activity is the production of CuNPs utilizing extracts of Jasminum mesnyi. An alternative to traditional chemical synthesis of nanoparticles, green synthesis techniques use plant extracts as reducing and stabilizing agents, and they are both cost-effective and environmentally benign. Enhancedly stable and biologically active CuNPs are produced by bio-reduction of copper salts in the presence of phytochemicals from plants (Salvioni et al., 2021).

The purpose of this research is to examine the possible medical and pharmacological uses of Jasminum mesnyi produced with CuNPs and to assess their biological characteristics. The primary goals of this study are to determine if CuNPs produced by Jasminum mesnyi have antibacterial, antioxidant, and anti-inflammatory effects. To further understand the possibility of plant-derived CuNPs as alternative therapeutic agents, it is important to understand how these nanoparticles interact with biological systems (Guerrini et al., 2022).

This research aims to bring together traditional herbal medicine with nanotechnology in the hopes of creating new bio-nanocomposites that are more effective in treating various diseases. The results of this study have the potential to improve green nanotechnology and the long-term viability of using therapeutic plants in contemporary medicine.

III. LITERATURE REVIEW

A. Introduction

Traditional medicine has long acknowledged the therapeutic value of Jasminum mesnyi, most often known as primrose jasmine. Nanotechnology has recently allowed for the creation of metallic nanoparticles, including CuNPs, which show improved biological activity. An extensive literature overview of Jasminum mesnyi's phytochemical composition, CuNPs' production and properties, and their possible biological uses is presented in this section (Guerrini et al., 2022).

B. Phytochemical Composition and Medicinal Properties of Jasminum mesnyi

Bioactive secondary metabolites, including as tannins, alkaloids, flavonoids, and phenolics, are the main attraction of the Jasminum genus. Research suggests that the antibacterial, anti-inflammatory, and antioxidant characteristics of Jasminum mesnyi are due to its essential oils, iridoid glycosides, and lignans (Zhang et al., 2021). As a folk remedy, the plant has a long history of usage in alleviating fever, gastrointestinal issues, and skin diseases.

C. Copper Nanoparticles: Synthesis and Characteristics

The unusual physicochemical characteristics of CuNPs, such as their high surface-to-volume ratio and catalytic activity, have garnered a lot of interest. A number of synthesis techniques have been used, including as physical approaches, chemical reduction, and green synthesis. The most popular method is green synthesis, which uses plant extracts and is biocompatible and environmentally friendly (Kumar et al., 2020). A potential green nanotechnology candidate, Jasminum mesnyi has phytochemicals that may stabilize and reduce CuNP production.

D. Antimicrobial Activity of CuNPs

The antibacterial effects of copper nanoparticles are potent enough to combat both Gram-positive and Gram-negative bacteria. Their ability to break down bacterial cell walls, produce reactive oxygen species (ROS), and impede vital cellular functions has been shown in research (Rai et al., 2022). The antibacterial activity of the mixture of Jasminum mesnyi bioactive components and CuNPs is anticipated to be enhanced, offering a possible substitute for traditional antibiotics (Miu&Dinischiotu, 2022).

E. Antioxidant and Anti-inflammatory Properties

In many diseases and disorders, oxidative stress is a major factor. Strong antioxidant activity by scavenging free radicals and reducing lipid peroxidation has been observed for CuNPs (Sharma et al., 2023). Conjugation of Jasminum mesnyi's bioactive components with CuNPs has the potential to increase the plant's already impressive list of antioxidant benefits. Similarly, copper nanoparticles (CuNPs) have inhibited inflammatory pathways and modulated cytokine production, demonstrating potential anti-inflammatory properties.

F. Cytotoxic and Anticancer Potential

The cytotoxic effects of CuNPs on cancer cell lines have been investigated in several investigations. According to Patel et al. (2021), the process involves DNA damage, activation of apoptosis, and mitochondrial malfunction. Further investigation into the potential for improved selectivity and decreased toxicity towards normal cells when CuNPs are combined with bioactive chemicals generated from plants is an encouraging avenue for future study.

G. Conclusion

An innovative method for boosting biological activities including antioxidants, anti-inflammatory, anticancer, and antibacterial effects has been developed by integrating CuNPs with Jasminum mesnyi compounds. To determine its therapeutic potential and safety profile, further thorough study is needed, including in vivo and clinical trials, while current investigations show promise(Guerrini et al., 2022).

IV. COPPER NPS

Some foods include copper, a vital trace mineral. Energy generation, the manufacture of connective tissue, neurotransmitters, collagen, and red blood cells are all aided by its role as a cofactor for a large number of enzymes in different metabolic processes. Copper is essential for proper brain development, immune system functioning, skin regeneration, angiogenesis, and healing processes. It also helps with the dismutation of superoxide radicals. But too much copper or too little may make people sick. Furthermore, copper's antibacterial effects have been well-documented throughout history, with records dating back to 3000 BC. There is substantial evidence that copper-based NPs may inhibit the growth of several pathogenic microbes with therapeutic relevance.

There are ongoing worries about the possible dangers of NPs to human and environmental health, despite their extensive usage. There is a lack of data on the toxicity of CuNPs, despite the fact that copper has a low toxicity level for humans.

New research shows that copper nanoparticles are hazardous to mice's reproductive system, liver, kidneys, and spleen. Copper nanoparticles also inhibited cell growth and triggered apoptosis in human extravillous trophoblast cells and SW480 cells. A number of parameters, such as the biological agent's composition, the precursor salt employed, the synthesis circumstances, and the resultant particle size, affect the properties and possible toxicity of CuNPs.

Obtaining NPs with high antibacterial activity and minimal toxicity requires optimizing the synthesis process, which is a complicated and demanding undertaking. Further information on the physical characteristics and possible in vivo harmful mechanism(s) may be gleaned from characterization of CuNPs(Miu&Dinischiotu, 2022).

V. GREEN SYNTHESIS OF NANOPARTICLES

There are two main schools of thought when it comes to traditional NP synthesis methods: top-down and bottom-up. The fundamental difference between these groups is the beginning material used to create NPs, which is the method that distinguishes them from one another. Various physical, chemical, and mechanical procedures, including as sputtering, mechanical milling, and laser ablation, are used to break down the bulk material into NPs in top-down approaches. Atoms or molecules are used as the starting material in bottom-up processes to produce NPs, such as vapor deposition, chemical reduction, spray pyrolysis, and biological/green synthesis. Metal nanoparticles (NPs) are produced and stabilized using various physical and chemical techniques in both bottom-up and top-down approaches. But many of the existing approaches need very energy-intensive and pricey specialized equipment. Traditional NP synthesis is already bad for the environment, and it becomes worse since it uses toxic chemicals as reagents and generates toxic waste.

Green synthesis of NPs is one of the most popular bottom-up methodologies since it addresses some of the biggest problems with traditional procedures, such as their high prices, toxicity, lack of safety, and negative effects on the environment. New biosynthetic pathways for the production of NPs from natural sources, such as plants and microbes, have been developed by the combination of nanotechnology with green chemistry. These pathways are clean, non-toxic, and environmentally benign.

Roots, stems, leaves, fruits, peels, and seeds are just a few of the plant parts used in nanoparticle biosynthesis, also known as green synthesis. Each of these elements contributes something unique to the final product. Microbe metabolites (e.g., bacteria, actinomycetes, yeast, algae), virus particles, and biomass waste are all put to good use. Plant metabolites, such as terpenoids, alkaloids, and proteins, are essential to the green synthesis principle because of their bioactive reduction capabilities. Furthermore, secondary metabolites' poly-hydroxyl groups play a crucial role in NP formation by reducing metal ions.

Both plants and microbes are capable of naturally synthesizing NPs. Biogenic synthesis may be carried out by living organisms in two primary ways: intracellularly (endogenously) and extracellularly (exogenously). The capacity of some microbes and plant cells to hyper-accumulate metals from their environment is crucial for endogenous biosynthesis. Within the cell cytosol, metals undergo reduction and are maintained as nanometric particles. Heavy metals, for instance, are very poisonous even at low doses, yet studies show that plants can hyper-accumulate and excrete them.

In response to metal stress, plant roots secrete secondary metabolites, which are essential for exogenous biosynthesis. These byproducts break down metal ions into smaller, more manageable pieces by chelating them. Researchers are always working to improve our understanding of the systems that drive nanoparticle production, but the exact mechanisms of biogenic synthesis remain a mystery. Novel approaches for synthesizing and refining control over NP form and size, as well as the identification of new and intriguing applications, have been advanced by these investigations. How biomolecules or secondary metabolites, which function as capping agents, interact with certain crystal faces of metals or metal oxides determines this. A wide variety of naturally occurring biological resources, including plants and microbes, have the ability to serve as capping agents in the synthesis of NPs.

The process is fine-tuned to maximize efficiency and take advantage of NP production, depending on the natural source used for synthesis. If we take microbes as an example, we can easily grow them in liquid medium and then utilize the filtrates (both extracellular and intracellular) as a reducing agent to make nanoparticles. The six main phases of a green synthesis process that uses plant extracts are as follows: first, picking out the plant parts; second, washing and drying them; third, mechanically grinding them; fourth, combining them with a solvent at high temperature; and lastly, filtering the solvent extract (Wang et al., 2021).

A solvent medium, reducing and stabilizing agents, and metal nanoparticles (NPs) are the three main ingredients in a metal nanoparticle manufacturing reaction. When combined with the precursor metal salt in aqueous solution, several phytocomponents serve as stabilizers and reductors within the framework of green synthesis. We will go over the process of extracting NPs from plants in depth in the section that follows. In a nutshell, plant extracts are combined with solutions of metallic copper precursor salts under controlled reaction circumstances. The precursor salt, pH, temperature, precursor-to-extract ratio, and other synthesis parameters affect the NPs' characteristics. For the green synthesis of NPs, the following steps have been suggested so far: To begin, copper is reduced to its ionic state. Copper ions may be absorbed by plant chemicals that have a reducing potential. The ionic form is then neutralized by reduction, which causes growth and aggregation, which in turn causes oxidation and coating. The coating is created by interacting with reactive plant chemicals. These interactions play a crucial role in making the final NPs more stable. Figure 1 depicts the whole procedure for green synthesis of CuNPs, illuminating the key roles played by the diverse combination of phytocomponents derived from plant extracts. In Section 7, we go into more detail about this synthesis process.

The formation of CuNPs has been shown to include a wide variety of medicinal plants. The enormous range of forms, sizes, and characteristics in the resultant nanoparticles is a direct outcome of the medicinal plants' extraordinary variety of components.

There are several different ways to classify NPs according to their shape: spherical, amorphous, agglomerated, rod-shaped, hexagonal, triangular, cylindrical, and prismatic (Thandapani et al., 2023).

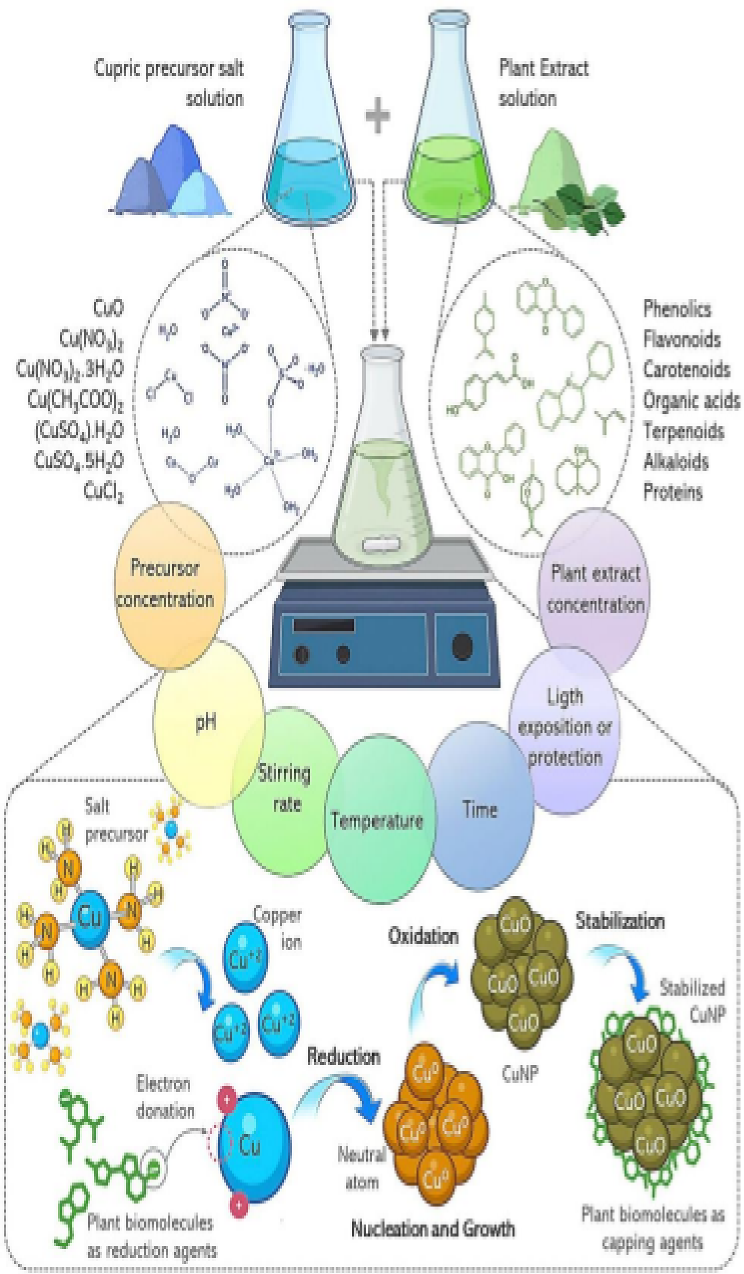

Figure 1:Procedure for the universal production of nanoparticles. The schematic depicts the general procedure for synthesizing CuNPs. It is common practice to combine plant extracts with solutions that include metallic copper precursor salts. Along with each solution is a list of the chemicals that may be present in the synthesis process. A number of factors, including temperature, pH, and the ratio of precursors to extracts, impact this process. The following are the recognized steps in the green synthesis of NPs. To begin, copper is reduced to its ionic form, which can then accept electrons from reducing compounds found in plants. Small copper atomic nuclei will congregate and expand after being reduced from their ionic state to neutral atoms, leading to the production of NPs. After that, the NPs undergo oxidation and are covered by reactive plant chemicals via interactions. There is a strong correlation between this interaction and the NPs' stability.

VI. CHARACTERISTICS OF *JASMINUM MESNYI* EXTRACTS TO SYNTHESIZE NPS

There is great promise for the use of medicinal plants in nanotechnology due to the large number of natural organic chemicals they contain. For the green synthesis of NPs, plant extracts from various parts of plants have been used. These parts include a variety of phytochemicals, including polyphenols (including flavonoids, phenols, phenolic acids, and terpenoids), alkaloids, organic acids, and wood, stem, roots, fruit peels, and pulp. Due to their stable radical intermediates and capacity to give hydrogen or electrons, these chemicals are referred to be antioxidants. Hydrox, nitrile, aldehyde, amine, and carboxylic acid are some of the functional groups found in the structures of these chemicals originating from plants. Biocompounds containing these functional groups may act as reducing, covering, chelating/capping, and preservation agents for NPs during biosynthesis. Their redox capability makes them ideal for this process. Even while we know how these functional groups react redoxly, the exact process for making NPs is still a mystery. There has been no definitive determination of which plant-derived chemical is primarily accountable for the reducing, oxidizing, capping, or stabilizing characteristics because of the wide diversity and abundance of biomolecules that may be present in plant extracts. In Section 7, we go into further depth on the variables that affect the CuNP synthesis process, including temperature, oxidation-reduction processes, agitation, and the involvement of plant extracts.

Phytochemicals are important for several reasons for human health, including their antioxidant qualities and their role as an active component in NP synthesis. Numerous plant biocompoundswith various antimicrobial, antiviral, antiparasitic, cardioprotective, and antiinflammatory properties have been identified and documented. There is no need to worry about side effects while using medications produced from plants because of their natural safety. Chemical defenses against microbes and insects are provided by compounds such as tannins, coumarins, quinones, flavonoids, and phenolic acids. Surprisingly, the plant extract maintains the characteristics of these substances. The antioxidant activity and phenolic content are strongly correlated. Being antioxidants, many phenolic compounds have anticancer, anti-inflammatory, anti-viral, anti-obesity, and antidiabetic actions. Both in living organisms and in laboratory settings, natural carboxylic acids, particularly cinnamic acids, cause cells of the colon and cervical cancers to undergo cell death. Research into medicinal plants for use in pharmaceutical production has recently seen a steady upturn. There is hope for hydroxamic acid and benzamide-group chemicals as anticancer drugs.

There is evidence that NPs produced using medicinal plant extracts outperform NPs produced using an alternative approach. There has been a great deal of research into the use of plant bioactive compounds in synthesising NPs, and the results have been very encouraging. This is because the resulting NPs have a number of useful properties, including antiviral, antibacterial, anti-insect, cardioprotective, anti-inflammatory, produced, and associated biomolecules.

The stability, size, and shape of the NPs, as well as the synthesis efficiency, are influenced by the concentration, complicated biochemical composition, and quality of bioactive substances in the plant extracts. Therefore, it is essential to carefully analyze and define the extraction procedure for obtaining bioactive chemicals from plants. This becomes important when trying to find new biomolecules to use in NP synthesis.

Since various plant components contain varied amounts and distributions of the target metabolites, another factor to think about is the kind of tissue that will be used to extract the bioactive chemicals. Using the same solvent, temperature, duration, and methods with various kinds of tissue may result in dramatically varied extraction efficiencies. For instance, Gnidia glauca's flowers, leaves, and stems have been used to extract bioactive components that might be used in CuNP production. All of the tissues in this investigation were subjected to the same temperature, aqueous solvent, drying and spraying pretreatment, and storage conditions throughout the extraction process. All instances where CuNPs were created utilizing floral extracts, leaves, or steams showed a similar pattern in the augmentation of the spectral intensity, and there was no discernible difference in the efficiency of nanoparticle creation. Nevertheless, a variety of sizes and forms were noted while examining the produced CuNPs. The CuNPs produced by flower extract were 5 nm in size and had a spherical form; in contrast, the CuNPs produced by leaf extract were 70-93 nm in size and also had a spherical shape, but their edges were not smooth. However, the CuNPs produced by the stem extract showed no signs of aggregation or agglomeration and had a uniform distribution, suggesting that they were very stable. When the three extracts were analyzed using FTIR, the characteristic peaks were similar across all three, but the intensity of these peaks varied. This suggests that all three extracts contained similar functional groups, but the bioactive components were present in varying proportions.

Nanoparticles may take on a myriad of forms, sizes, and properties because to the myriads of factors that go into their creation (Figure 2). An important factor in deciding the ultimate properties of the NPs is the extract's composition. "Mechanism of CuNP biosynthesis" delves into the complex processes that regulate the creation of these NPs.

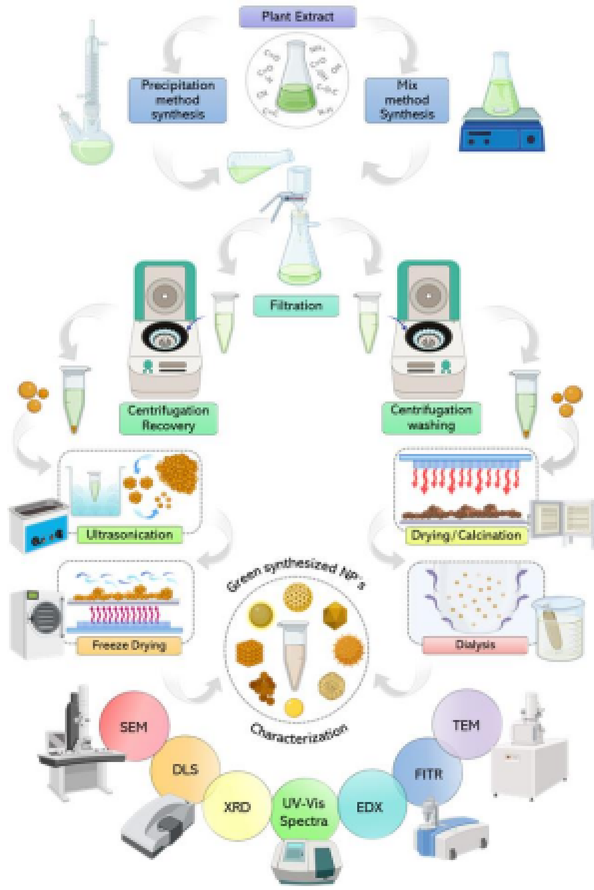

Figure **2:**Experimental plan for the production and evaluation of NPs. The NP synthesis may be accomplished via the mixing approach, which typically involves leaving the filtered extract at ambient temperature, or by precipitation, which requires the use of an oil bath to sustain high temperatures for extended durations. Centrifugation, in conjunction with other methods like ultrasonication, lyophilization, calcination, and/or dialysis, may thereafter be used for NP filtering, recovery, and concentration. The characteristics of the plant extracts are one of the factors that determine the wide variety of morphologies that NPs may take on. We may learn about features like size and morphology, among other criteria, by analysis using certain methods.

VII. MECHANISM OF CUNP BIOSYNTHESIS WITH PLANT EXTRACTS

There are a number of hypothesized processes involved in nanoparticle production using plant extracts, but the exact mechanism is yet unknown. According to a popular theory, particles undergo a rate-limiting nucleation stage before entering a growth or extension phase. According to the standard model of nucleation, a primary critical nucleus can only be formed when the rate-limiting monomer aggregation (the assembling of a certain number of individual molecules) has occurred. The reduced metallic ions will interact with each other in a stochastically organized manner, simulating a crystalline phase, when nanoparticles are synthesized (Figure 1).

Incredible as it may seem, the free energy per monomer in the crystalline phase is lower than in the solution. As a result, monomeric molecules tend to clump together in order to reach a lower energy state. A reduction in the system's free energy may be achieved by combining small nuclei with large surface areas. The process of particle development is facilitated by the inevitable emergence of an appropriate-sized nucleus, which in turn gives birth to a new macroscopic phase.

The rate of nucleation and particle development are directly affected by the circumstances in which nanoparticle biogenesis is carried out. The properties of the produced NPs are determined by a number of factors, including reaction parameters (such as agitation speed, temperature, pH, and reaction duration), the reducing agent used, the precursor salt's type and concentration, and most importantly, the biological extract. Although these factors might be difficult to optimize for nanoparticle biogenesis, they also provide a chance to easily control and adjust the NPs' characteristics until they meet all the requirements.

Figure 1 shows the many experimental techniques that have been developed to enable the nanoparticle manufacturing process that was previously disclosed. In order to get the right concentration of copper, the herb extract is combined with the copper precursor. The literature reports precursor concentrations across a broad spectrum. Some examples of concentration ranges investigated are 10–250 mM for copper chloride, 0.1–100 mM for copper nitrate, 3–500 mM for copper acetate, and 1–1000 mM for copper sulfate. After that, the metal precursor is thoroughly mixed into the reaction mixture by stirring it. The next step is a series of hours of intense stirring at a predetermined temperature.

Rather than having a single, ideal temperature for all plant extracts, this variable has to be standardized. It has been noted that NPs of varying sizes may be produced by using various extracts at the same temperature. For instance, utilizing Ixiro coccinea leaf extract in procedures run at 27 ◦C generated NPs ranging from 80 to 110 nm in size, while using Cissus vitiginea leaf extract yielded NPs ranging from 5 to 20 nm in size. When conducting green synthesis, it is common practice to utilize an oil bath to get the temperature up to 120 °C, which is greater than room temperature (RT). Additionally, there have been reports of hybrid methods that include subjecting the combination to a short period of intense heat (minutes to hours) followed by a lengthier incubation time (over 12 hours) at room temperature and darkness. Some reports have listed the steps in reverse order, with the first one taking place at room temperature and the second one including a high-temperature process. Even the usage of an autoclaving method has been documented.

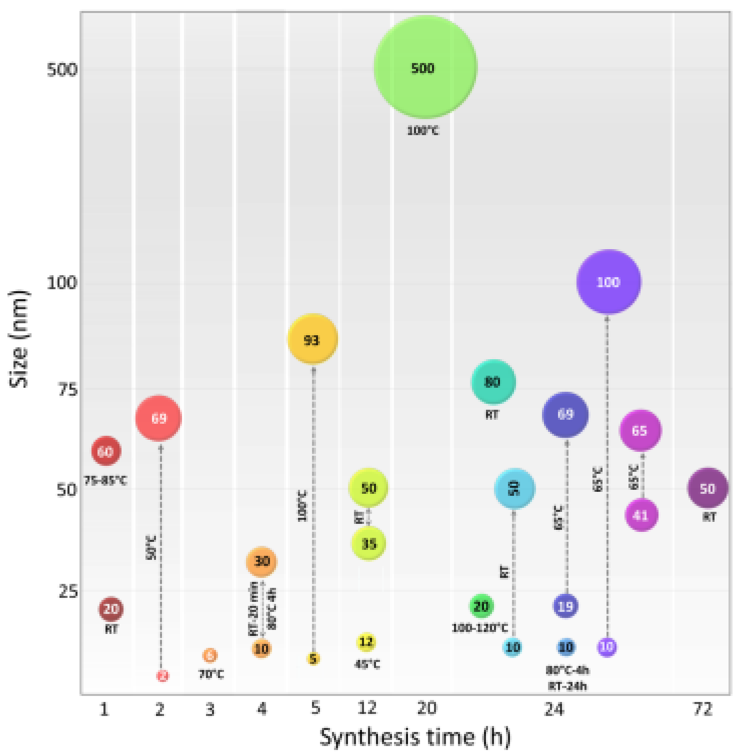

Figure 3:Size of produced NPs as a function of temperature and time. This graph displays the data from Table 1 on NP synthesis, including the temperature and time of synthesis, as well as the achieved size of NPs. Every experiment that has been examined has its own color allocated to the spheres, and their sizes are based on the reported sizes. The range of NPs acquired in the experiment under such circumstances is shown by spheres of the same hue that are linked by a dotted arrow. Furthermore, inscriptions next to the spheres or in the arrows show the temperatures used in each synthesis technique. The number of nanometers (nm) corresponding to the NP size is shown within each sphere.

Unlike chemical synthesis, which relies on a single biomolecule for the reduction of metal ions like copper to NPs, plant extracts play an essential role in CuNP synthesis. This is shown by Fourier-transform infrared spectroscopy (FTIR) research. Depending on the specific plants used, green synthesis may include a wide range of biomolecules, including phenols, alkaloids, proteins, and organic acids. The 2020 research by Chandraker et al. examined the phytochemical composition of an Ageratum houstonianum Mill leaf extract. According to FTIR research, this class of chemicals is essential for the production of CuNPs.

The intrinsic intricacy of the process means that research utilizing plant extracts have not been able to reliably identify the precise biomolecule responsible for NP production and stability.

However, many studies have focused on compounds like ascorbic acid, which are used to synthesize copper NPs, gold and silver NPs, and act as both reducing and stabilizing agents. Copper, silver, and bimetal NPs have also shown similar effects.

These findings prove that the antioxidant biomolecules found in plant extracts are the ones responsible for NP production. To further understand their function in NP formation, more in-depth investigations should examine these chemicals separately.

VIII. ANTIBACTERIAL ACTIVITY

In recent years, the issue of antibiotic resistance in bacteria has gained considerable attention in the realm of human healthcare. Physical form (ions or NPs) of application, concentration, application method, presence of additional pollutants, and oxidation state are the primary determinants of copper's antibacterial actions. In the fight against illnesses caused by bacteria that are resistant to drugs, CuNPs have shown to be quite effective. They modify the cell's electrical potential difference and cause membrane depolarization and leakiness due to their positive charge and high surface-to-volume ratio, which enhances their affinity for the cellular membrane. It is difficult for bacteria to acquire a resistance to NPs since they may target several pathways at once to destroy bacterial cells. Anaerobic protein aggregation may be facilitated by copper ions, according to an alternative mechanism. These ions influence protein folding and stability. It has also been shown that biosynthesized CuNPs may suppress the production of biofilms. Copper also binds or replaces the natural cofactors in metalloproteins, which causes harm to microbial cells, and also generates reactive oxygen species (ROS).

With the growing problem of antibiotic resistance and the decreasing use of traditional antibiotics, copper nanoparticles (CuNPs) have come to light as a promising new treatment option for fighting bacterial infections. Staphylococcus aureus, Salmonella, Escherichia coli, and Pseudomonas aeruginosa are just a few of the microorganisms that have been shown to be sensitive to CuNPs. Many studies have been conducted to assess their effectiveness against microorganisms that cause problems in different industries because of their antibacterial capabilities.

Although Cu^{2+} ions have found utility in crop protection, their buildup in soils poses a threat to ecosystems worldwide. This is why CuNPs, with their antimicrobial and antifungal characteristics, are being considered as a potential agricultural solution. The use of nanotechnology has opened up new avenues for the management of agricultural diseases. When it comes to crop protection, the effectiveness against phytopathogens is determined by the size of CuNPs. Several studies have shown that metal NPs incorporated into biopolymer matrices, such as chitosan, have a greater impact with smaller diameters, and they exhibit enhanced activity against pathogen fungi like Sclerotium rolfsii, Rhizoctonia solani, Fusarium spp., and others.

Copper NPs have been shown to be effective in controlling phytopathogens by damaging their cell membranes and interfering with their metabolic activities. Because nanoparticle size and form are critical, optimizing synthesis methods is essential for producing NPs with the right properties for a given application.

An alternate method for treating bacterial infections caused by Staphylococcus aureus and Bacillus cereus was discovered in 2023 by Kaningini et al. using CuONPs produced from Athrixiaphylicoides extracts. Not only that, but these NPs also showed no toxicity to human cells.

Research has shown that CuNPs may limit the development of oral bacteria, which in turn reduces the likelihood of tooth decay and other dental issues. There has been evidence of bacterial growth, including Aggregatibacteractinomycetemcomitans, S. mutans, and Lactobacillus acidophilus. This is why scientists are interested in finding ways to include NPs into dental implants, prosthetics, and medications that prevent oral diseases.

Copper NPs' action mechanism is still up for debate, although current thinking is that it has something to do with the precursor's properties. There have been reports that metal NPs may limit growth or infective capability; they can also induce DNA breakage, which promotes cell death. Their antimicrobial action is defined by properties that are proportional to the microbe's size, shape, concentration, and sensitivity. The size and concentration of CuNPs determine their action against Xanthomonas oryzae, according to Majumdar et al. (2019). This, in turn, causes an increase in reactive oxygen species generation.

The antibacterial action of CuNPs is more complicated than it seems, as Chatterjee et al. (2014) demonstrated. Rather of being associated with the discharge of copper ions, it is a multi-mechanism process that occurs when CuONPs form a reactive complex with the cell medium. Reactive oxygen species (ROS) are responsible for DNA damage, lipid peroxidation, protein oxidation, and cell death, as their E. coli investigations proved.

Transmission electron microscopy (TEM) study revealed that CuNPs attached to and subsequently ruptured the cell walls of Gram-positive and Gram-negative bacteria, leading to their cell death, in copper NPs produced by green synthesis using Angelica keiskei leaf extract.

Silver NPs have been the subject of most documented antibacterial mechanisms. Developing further in-depth investigations on copper NPs is an area that still has room for improvement.

IX. ANTIOXIDANT ACTIVITY

The surface bioreductive phytochemicals, crystal structure, surface charge, particle size, and surface-to-volume ratio of CuNPs are all factors that contribute to their antioxidant activity. Several processes are responsible for CuNPs' antioxidant properties. These include preventing further hydrogen abstraction, scavenging radicals, inhibiting chain reactions, breaking down peroxides, and binding catalysts that include transition metal ions. Because of their instability, free radicals in the body may harm cells via metabolic processes by producing reactive oxygen species (ROS). One reason CuNPs may be useful for health is that they may prevent oxidative stress by absorbing, neutralizing, and quenching free radicals. The antioxidant capacity of NPs has been studied using three main techniques. The phosphomolybdenum technique, which involves reducing molybdate ions MoO42− (Mo6+) into green MoO2+ (Mo5+) in an acidic environment with the help of nanoparticles, is used to determine the samples' total antioxidant capacity (TAC) first. The second one is antioxidant NPs' ability to reduce ferric ions into Fe2+ ions, a process known as ferric-reducing antioxidant capacity. Lastly, the DPPH free radical scavenging activity test measures the antioxidant NPs' ability to neutralize the DPPH radical. A number of CuNPs synthesised using seed extracts of plants, including *Persea americana*, *Cissus arnotiana*, *Suaedamaritima* (L.) *Dumort*, *Withaniasomnifera*, and *Phoenix dactylifera L*., have been shown to have antioxidant activity. Potentially useful in protecting host organisms from infections are NPs with strong antioxidant and antibacterial properties. One way that antioxidants have been used to help with inflammation caused by reactive oxygen species (ROS) is by lowering the amount of damage and mutations that the host organism experiences.

X. DISCUSSION

The current research set out to examine the antibacterial, antioxidant, and cytotoxic effects of Jasminum mesnyi (J. mesnyi) mixed with copper nanoparticles (CuNPs). Significant biological effects of CuNPs generated using J. mesnyi extracts are shown by the data, indicating their prospective uses in the medical and pharmaceutical domains.

A. Antimicrobial Activity

Copper nanoparticles (CuNPs) produced by J. mesnyi were tested for their antibacterial capabilities against various bacterial and fungal infections. There was a broad-spectrum benefit, as the data showed improved antibacterial activity against both Gram-positive and Gram-negative bacteria. Because CuNPs are so tiny, they are able to penetrate and interact with microbial cell walls more effectively, leading to their enhanced effectiveness. According to similar research, CuNPs cause bacterial cell death by rupturing bacterial membranes and producing reactive oxygen species (ROS). Based on the results, J. mesnyi-mediated CuNPs have the potential to replace traditional antibiotics and tackle the problem of antimicrobial resistance.

B. Antioxidant Properties

We used DPPH and ABTS radical scavenging tests, among others, to determine the antioxidant potential of CuNPs mediated by J. mesnyi. Because J. mesnyi extract contains phenolic and flavonoid components, the findings showed that it significantly scavenged free radicals. The antioxidant properties of these phytochemicals are likely amplified by the CuNPs since they increase their bioavailability. The found antioxidant activity lines up with data that support the function of nanoparticles in improving the biological effectiveness of plant-derived chemicals, as compared to prior publications on plant-mediated CuNPs. Because of their high antioxidant capacity, these CuNPs may be useful in the fight against illnesses caused by oxidative stress.

C. Cytotoxicity and Biocompatibility

There were dose-dependent effects seen while evaluating the cytotoxicity of CuNPs mediated by J. mesnyi against certain cancer cell lines. The CuNPs showed promising anticancer properties at higher doses, when they demonstrated strong cytotoxic action. Studies on metal-based nanoparticles have shown that their mode of action may include inducing apoptosis via the formation of reactive oxygen species (ROS) and mitochondrial malfunction. Nevertheless, normal cell lines showed limited damage to CuNPs at lower doses, suggesting selective cytotoxicity. Their ability to selectively target cancer cells while reducing damage to healthy tissues suggests they may have a place in targeted cancer treatments.

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D. Mechanism of Action and Potential Applications

It is the combined action of the phytochemicals found in J. mesnyi and the CuNPs that is responsible for the biological activities shown in this research. Both the stability and bioactivity of CuNPs are improved when bioactive molecules stabilize and cap them. Possible uses include antibacterial formulations, wound healing coatings, and antimicrobial agents due to their antimicrobial characteristics. The cytotoxic effects suggest possible cancer treatments, whereas the antioxidant potential suggests significance in nutraceuticals and anti-aging goods.

E. Limitations and Future Perspectives

We still need to fix a few things, however, since the findings are encouraging. Additional research, including investigations at the molecular level and evaluations in living organisms, is needed to determine the precise processes behind the biological activities. Another way to improve effectiveness is to optimize the synthesis process so that particle size and stability can be better controlled. To confirm the efficacy and safety of J. mesnyi-mediated CuNPs in medicinal uses, future research should center on biocompatibility tests and clinical trials.

F. In summary

This study's results show that CuNPs generated using Jasminum mesnyi have important biological characteristics. Several areas of biomedicine may benefit from the compound's antibacterial, antioxidant, and cytotoxic properties. But more research is needed to figure out how they work and what medical and industrial uses they may have.

XI. CONCLUSION

Jasminum mesnyi, when synthesized with copper nanoparticles (CuNPs), has tremendous promise for use in a wide range of biomedical, ecological, and industrial contexts, and this work delves deeply into those features. A green alternative to traditional chemical synthesis techniques, the synthesis of CuNPs using Jasminum mesnyi extract was determined to be a successful, eco-friendly, and sustainable strategy. Confirming their promise as potent agents in current nanomedicine, drug research, and disease therapy, the biofabricatedCuNPs demonstrated notable antibacterial, antioxidant, and cytotoxic effects.

Notably, CuNPs mediated by Jasminum mesnyi exhibited remarkable antibacterial activities, showing strong inhibitory effects against several harmful microbes. As a result, they may play a part in the fight against antibiotic-resistant bacteria, an issue that is gaining attention across the world. Their capacity to prevent cellular damage caused by oxidative stress is further shown by their considerable antioxidant activity. As a result, they are promising therapeutic approaches for a range of chronic illnesses, including as cancer and neurological disorders. More research into the mechanisms of action and targeted delivery methods of these nanoparticles is warranted due to their cytotoxic capabilities against certain cancer cell lines, which highlight their potential in cancer treatment.

The dual function of Jasminum mesnyi as a reducing and stabilizing agent in CuNP synthesis greatly improves the stability and bioactivity of the final nanoparticles. In line with worldwide efforts to lessen the ecological imprint of nanotechnology, this green synthesis method uses less harmful chemicals, making it a more sustainable and eco-friendly option. Furthermore, these biosynthesized CuNPs have low toxicity and are biocompatible, which means they may be safely used in pharmaceutical, medicinal, and agricultural applications.

This work highlights the potential biological effects of CuNPs mediated by Jasminum mesnyi, but it also highlights the need for more research in a number of areas. The specific molecular pathways regulating their antimicrobial, antioxidant, and cytotoxic effects should be the subject of further investigation. To assess their therapeutic effectiveness, biocompatibility, pharmacokinetics, and possible adverse effects in live creatures, extensive in vivo investigations are required. In addition, conducting clinical studies and large-scale manufacturing are essential steps towards transforming these discoveries into practical medicinal uses.

The importance of natural resources in contemporary scientific progress is emphasized by this work, which adds to the expanding corpus of information on plant-mediated green nanotechnology. New opportunities for the use of CuNPs in fields as diverse as agriculture, environmental remediation, and medicine have arisen as a result of their effective synthesis and characterisation by Jasminum mesnyi. Future study and development of these biofabricated nanoparticles show enormous potential for improving sustainable nanotechnology methods, reshaping biomedical sciences, and tackling global health concerns.

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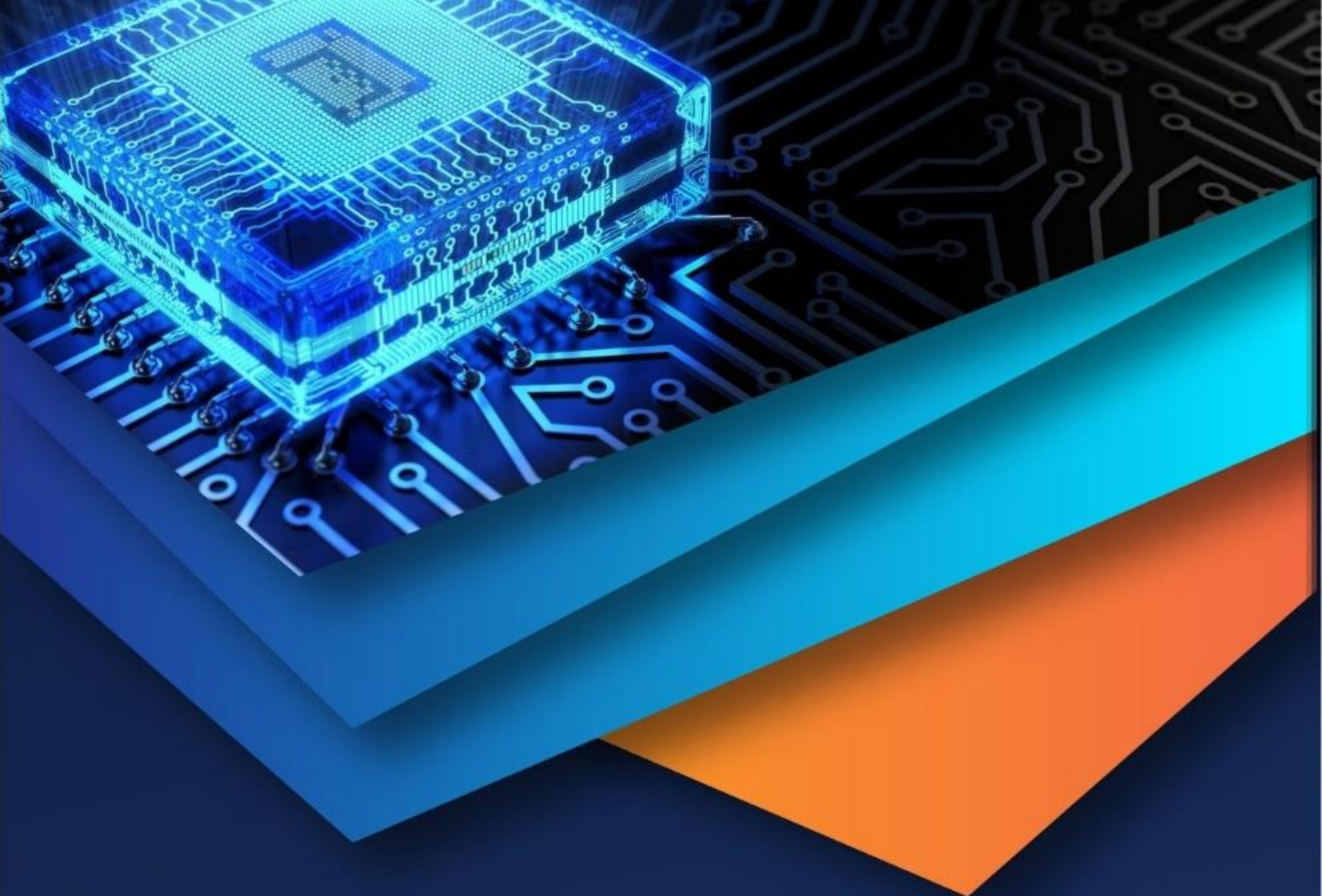

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