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Effortless green synthesis of zero-valent copper nanoparticles

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Abstract:

We present a direct, environmentally friendly approach for synthesizing porous zero-valent copper nanoparticles utilizing green tea as both a reducing and stabilizing agent. The synthesis procedure was efficient, economical, and eco-friendly. The impact of the reactants' mixing ratio was examined. Optimal yield, around 70%, was attained at 158°F with stirring for 2 hours at 1000 revolutions per minute. The resulting pellet was rinsed three times with distilled water and ethanol. The nanoparticles were dehydrated in a hot air oven at 122 °F. Nanoparticle formation was confirmed via visible color change, UV-visible spectroscopy (UV-Vis), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), zeta potential measurement, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), and transmission electron microscopy (TEM). The XRD analysis revealed that the particles exhibited an average crystallite size of around 25 nm. SEM scans validate its oval morphology.

Key Words: Green Tea; Copper; Zero-valent; Nanoparticles.

1. Introduction

Nanotechnology is a science that relies mainly on the fabrication of nanoparticles between 1 and 100 nm in size[1]. The utilization of small-size and significant ratios of surface to interior volume contributes to modifications in their physical and chemical properties that differ from those of their respective bulk states. These nanoparticles raised surface energy and further enhanced their biological effects. Numerous varieties of nanoparticles serve in a wide range of applications, involving water purification, electronics, catalytic activity, solar energy, optics, delivering drugs, diagnostics, electronics, textiles, and the packaging of food [2,3].There are numerous techniques for generating nanoparticles, including biological, chemical, and physical processes[4,5]. While used for generating nanoparticles result in less stable nanoparticles and use a variety of harmful substances. Despite the prospect of known reliable pure by conventional methods are typically costly, time-consuming, and potentially hazardous to our surroundings. We can lessen our influence on the environment and produce novel materials with distinctive features by synthesizing nanoparticles using environmentally friendly techniques[6–8]. The utilization of biological biomass, botanical extracts, and microbes can thus be a significant alternative to the conventional methods that address the environmental concerns of nanoparticle fabrication[9]. Researchers are consequently interested in developing a variety of nanomaterials through this biosynthetic process, including metal, metal oxide, and composite nanoparticles[10–13]. Based on earlier research, biomolecules in botanical extracts could act as capping and reducing agents throughout the plant-based synthesis of nanoparticles that are enriched in bioactive substances like Proteins, Alkaloids, Flavonoids, phenolic and Tannins. Consequently, in the present investigation, leaf extracts of green tea were used to produce copper nanoparticles[14,15]. Copper plays a variety of roles in humans, including as a co-factor in the regulation of many enzymes of the cell signaling pathway and the function of immune cells[16]. Plants require copper for various metabolic and chemical processes. Copper is one of the most important trace elements for plant growth[17]. Copper nanoparticles have become particularly interesting in recent years because their properties are different from those of bulk metals[18]. Nano-zerovalent copper (CuNP) has attracted much attention because of its, electrical, catalytic, mechanical, antibacterial, and antibacterial properties[19]. It is used in various fields, such as agriculture, industry, engineering, and technology[20].Nowadays, nanoscale zero-valent iron has received considerable attention owing to its high specific surface area, small particle size, and high reactivity[21–24]. It has been shown that the antibacterial properties of iron nanoparticles (Fe NPs) depend on the high surface area and high volume of nanoparticles, allowing for professional bacterial disinfection[25,26].Recently, researchers have focused on the selective preparation of new bimetallic nanoparticles in various forms based on the synergistic properties of two different metals, which show more interesting characteristics compared to the corresponding monometallic nanoparticles[27,28]. various studies, bimetallic nanoparticles have been shown to be more efficient than monometallic NPs[29]. These strategies result in materials combining two disparate metals that have reinforced and modified properties in comparison to the single metal system[30].Water is undoubtedly an important resource for all living organisms[31,32]. An overriding theme is the necessity to treat various organic and inorganic pollutants, which is one of the world's greatest challenges[33,34]. Because of these organic pollutants' harmful impacts, getting rid of them has been a top priority recently[35,36]. Various methods have been proposed to mitigate pollution and numerous strategies have been investigated[37]. yearly, thousands of tons of dye effluents are released by various manufacturing processes that rely on dye compounds, including the food, textile, cosmetic, and paper sectors[38,39].

2. Material and method

2.1 Green synthesis

A. synthesis of Extract

Copper nanoparticles were synthesized in green tea leaves. Approximately 20 g of leaf was collected, washed thoroughly in distilled water, cut into small pieces, ground, and dried, after which approximately 250 mL of distilled water was added. The mixture was heated in a magnetic stirrer for approximately 120 min at 167 °F. The extract was filtered through Whatman filter paper and stored in a refrigerator until further used again.

B. *Synthesis of copper nanoparticles*

For nanoparticle synthesis, approximately 50 milliliters of leaf extract were added drop by drop to 50 milliliters of 0.1 molar copper sulphate solution in a 250 mL conical flask. The solution was heated at 158 ºF and stirred for 2 h at 1000 round per minutes. The resultant pellet was autoclaved and washed three times with distilled water and ethanol. The nanoparticles were dried in a hot air oven at 122ºF. The process flow chart and the schematic of synthesis is presented in **Figure 1**.

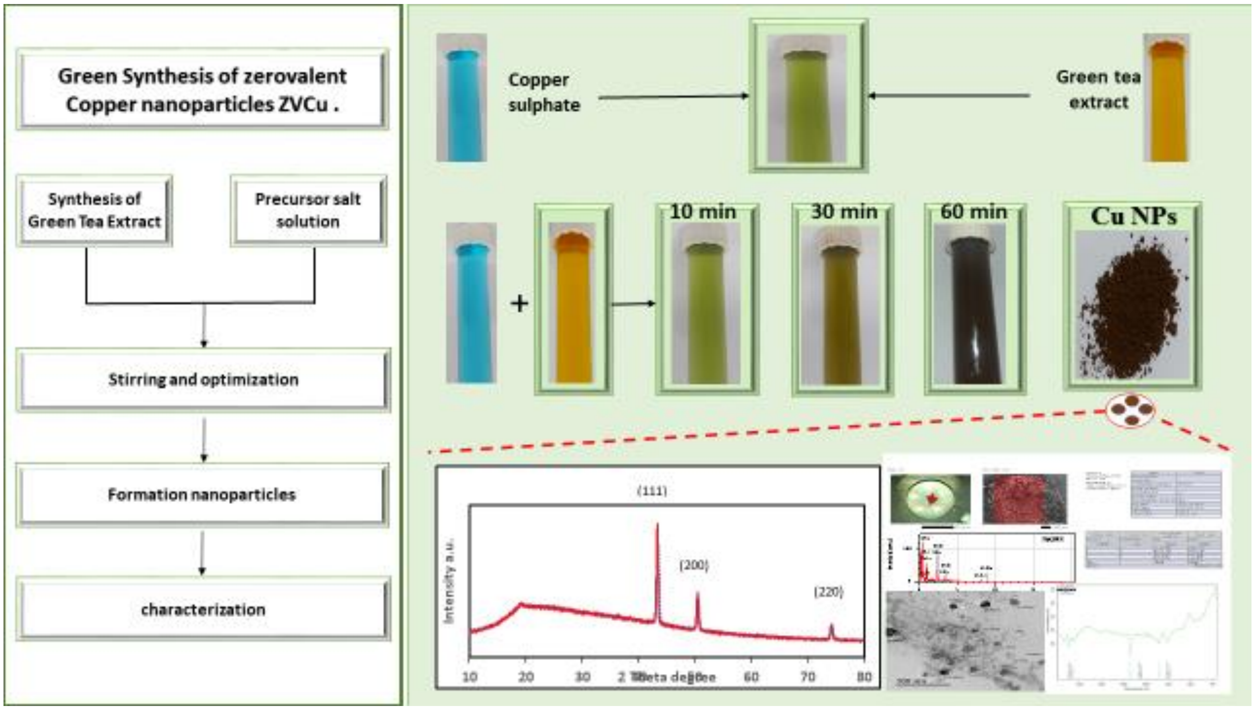


Figure 1: *Schematic of process flow diagram, synthesis of green tea extract solution, and characterization of biosynthesized CuNPs*

3. Result and discussion

1- XRD

Figure 2 shows the XRD pattern of the zerovalent copper nanoparticles prepared by green synthesis using Green tea as reducing agent of copper sulphate. The diffraction peaks can be indexed as a pure phase of the zerovalent copper nanoparticles. the sites and intensity of the diffraction peaks are consistent with the standard pattern for JCPDS card No. (5000216). The XRD pattern of the product, exhibited the formation of copper nanostructure product assigned by the reflection peaks at 43.308, 50.417, and 74.099 which reflected plans (111), (200) and (220) respectively. The average crystallite size of copper product was determined to be about 25 nm using the Debye-Scherrer equation.

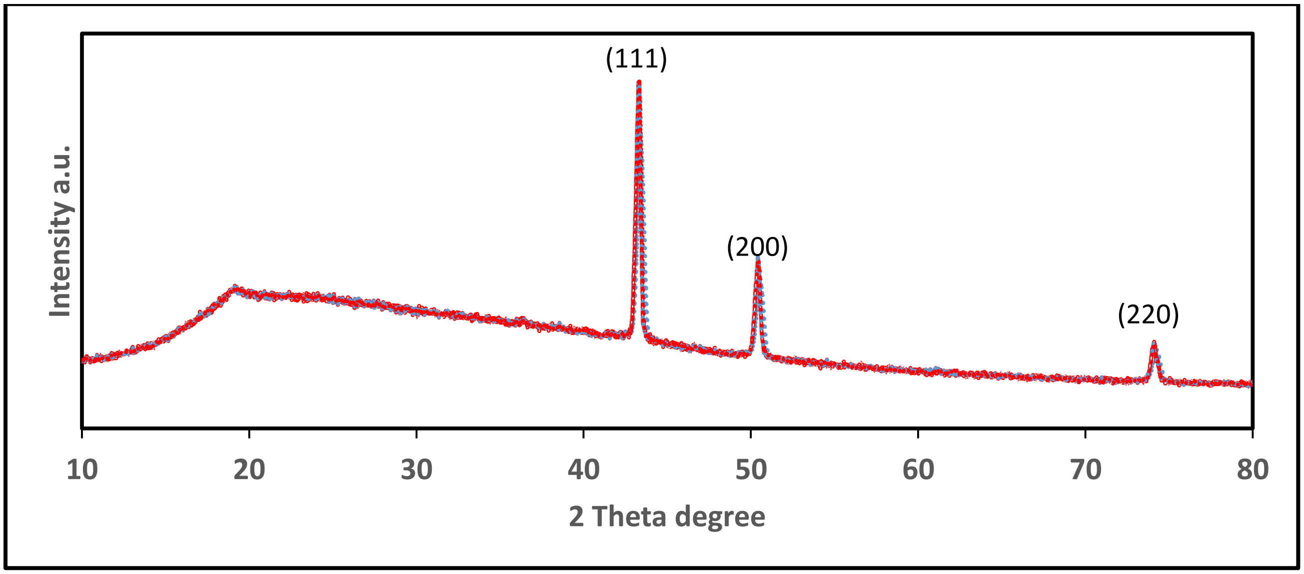


Figure 2: *XRD pattern of the zerovalent copper nanoparticles*

2- TEM

the sizes of the synthesized copper nanoparticles were investigated using transmission electron microscopy (TEM). The TEM micrographs of the as-synthesized copper nanoparticles are shown in Figure 3.TEM micrographs confirmed the formation of Cu spherical nanoparticles with monodispersing. It was found that the size of the as-synthesized nanoparticles ranges from14-25 nm and that the average grain size was 25 nm.

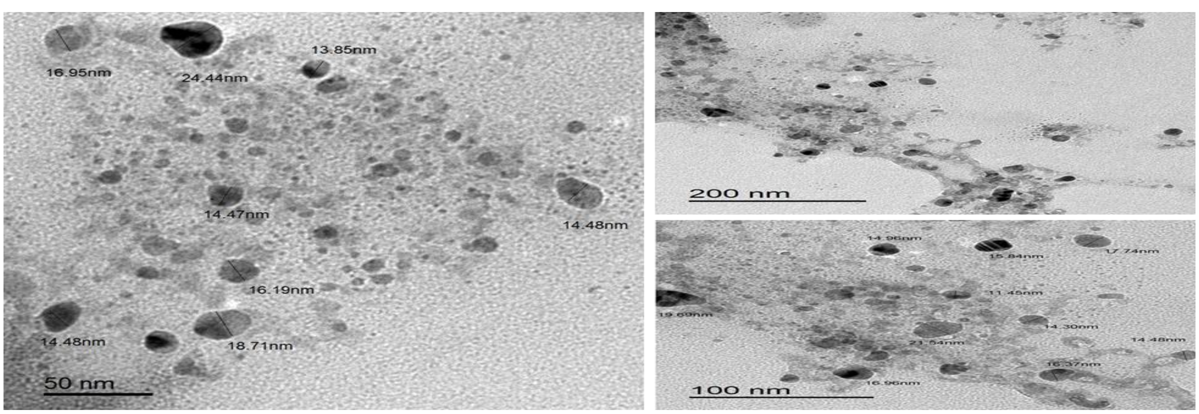
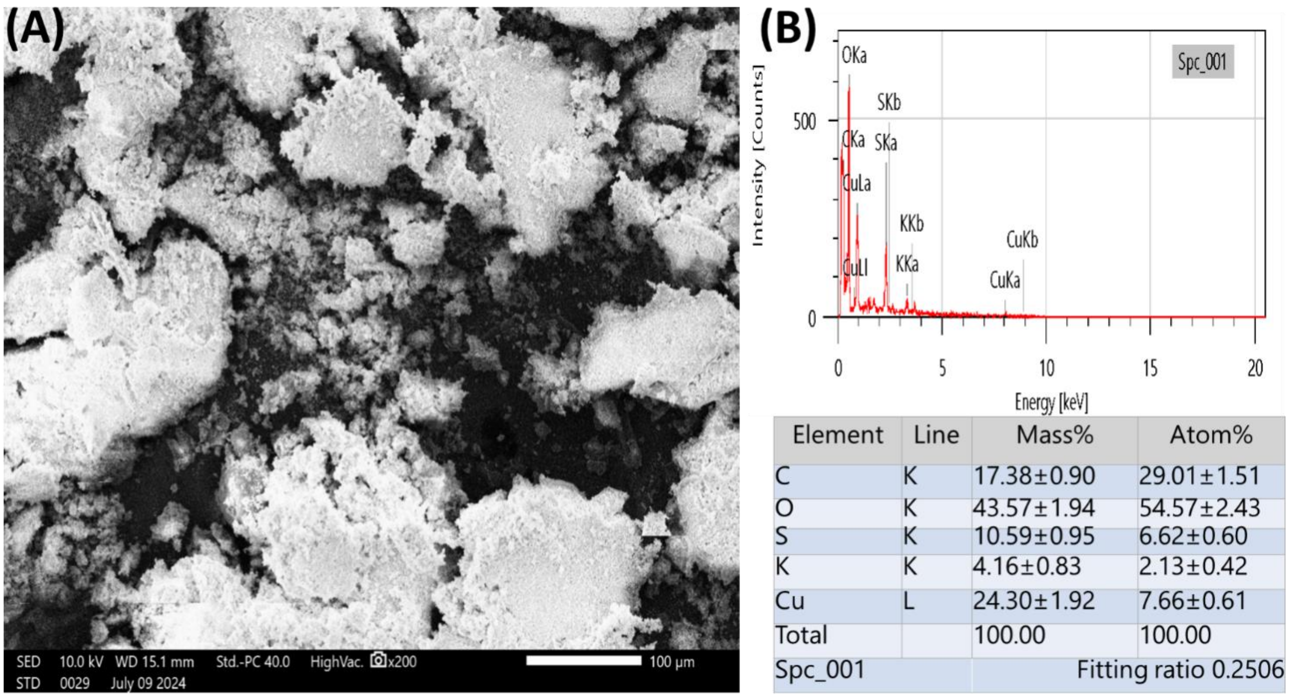


Figure 3: *TEM image of the zerovalent copper nanoparticles*

3- SEM + EDX

Figure 4A shows The Morphology of the copper nanoparticles was examined by scanning electron microscopy (SEMs). It has an oval shape. Energy dispersion X-ray analysis (EDX) was used to study the elements of the green synthetic copper nanoparticles. Figure 4B shows the Cu metal's EDX spectrum, showing a significant percentage composition and element peak of 1–8 keV. Biomolecules used to cover the copper nanoparticles also appeared as small peaks.



Element	Line	Mass%	Atom%
C	K	17.38±0.90	29.01±1.51
O	K	43.57±1.94	54.57±2.43
S	K	10.59±0.95	6.62±0.60
K	K	4.16±0.83	2.13±0.42
Cu	L	24.30±1.92	7.66±0.61
Total		100.00	100.00
Spc_001		Fitting ratio 0.2506	

Figure 4: *(A)SEM image of copper nanoparticles . (B) Energy dispersion X-ray analysis copper nanoparticles.*

4- FTIR

Figure 5 shows FTIR analysis was carried out to determine the biomolecules that may be involved in the production of green tea extracts and the functional groups or organic compounds that are responsible for the formation0 of copper nanoparticles. This indicates that the functional groups play an important role in the synthesis of copper nanoparticles because they provide reduction groups that contribute to the synthesis of nanoparticles.

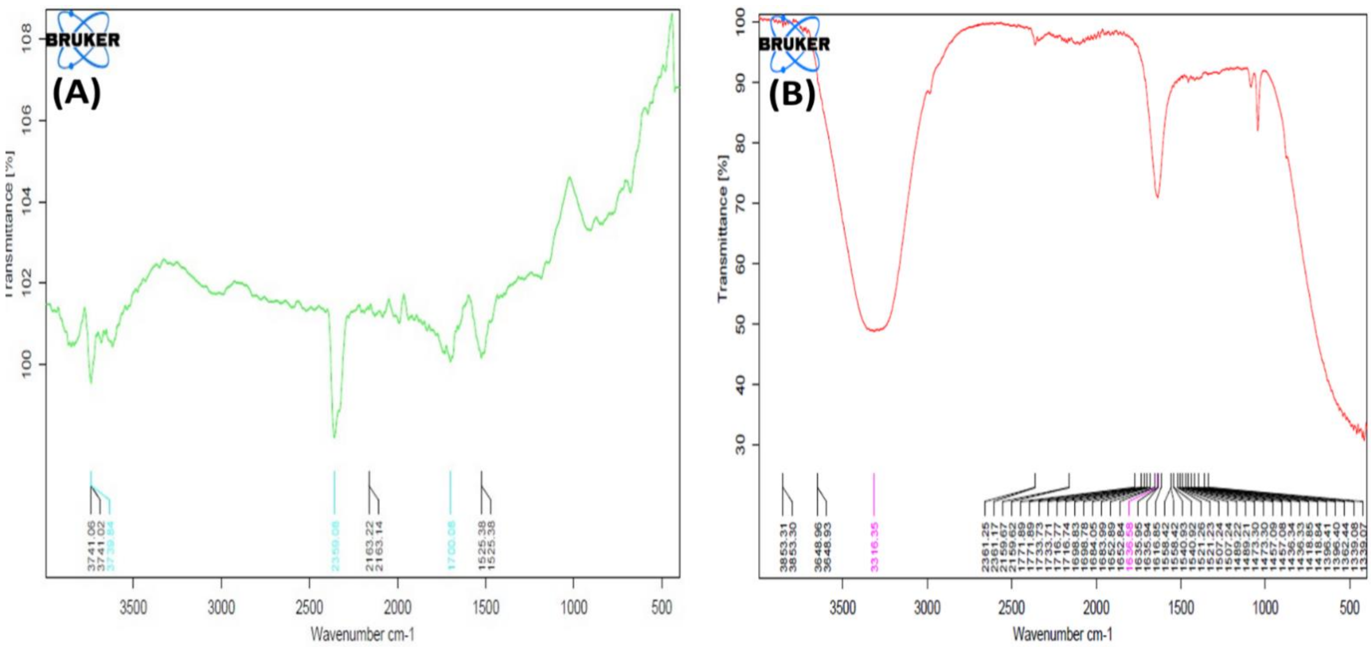


Figure 5: *FTIR (A) Copper (B) Extract*

4. Conclusion

The current study aimed to synthesize CuNPs by leaf injection using a simple, non-toxic process. We present a convenient and green-based method for synthesizing Cu NPs using green bean powder and its extracts as reducing and stabilizing agents. No harmful reduction or stabilizing agents were used during the synthesis of Cu NPs. The analysis revealed that Cu NPs were successfully synthesized with uniform particle sizes of 15–25 nm.

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