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# Green copper nanoparticles obtained using plant extract from *Tetsukabuto* hybrid pumpkin peel

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**Abstract**

The concern with environmentally responsible processes is increasing, so studies involving process with non-toxic reagents have grown worldwide. This work produced copper nanomaterials using pumpkin peel through a green route. Green synthesis of nanomaterials is noteworthy for its use of non-toxic, biodegradable reagents that do not harm the environment. The proposed synthesis is simple, easy, quick, and economical. The peels of the *Tetsukabuto* hybrid pumpkin were used to produce the extract by the green route. The synthesis was followed by characterization with various analyses including XRD, Raman Spectroscopy, Scanning and Transmission Electron Microscopy (SEM/TEM), Selected Area Electron Diffraction (SAED), Fourier Transform Infrared Spectroscopy (FTIR), surface area determination (BET), and elemental composition. The copper nanoparticles were thermally stable, with a surface area of 18.69 $m^2\ g^{-1}$, spherical with sizes ranging from 3.5 to 5.8 nm. This work is relevant in the field of nanotechnology and green synthesis. The nanoparticles can be applied in adsorption processes for water and wastewater treatment.

*Keywords:* Green synthesis; Copper nanoparticles; *Tetsukabuto* pumpkin;

## 1. Introduction

The synthesis of nanoparticles using plant extracts, knowns as green synthesis, has emerged as a sustainable and eco-friendly approach in nanotechnology. This method leverages the natural reducing and stabilizing agents found in plants to produce nanoparticles, avoiding the use of hazardous chemicals [1]. Pumpkin, particularly the *Tetsukabuto* hybrid, have shown great potential in this field. The peels of this hybrid pumpkin can be used to extract bioactive compounds that facilitate the formation of nanoparticles [2].

In the case of *Tetsukabuto* hybrid pumpkin peels, their rich composition of phytochemicals such as polyphenols, flavonoids, and antioxidants plays a fundamental role in nanoparticle formation. These compounds act as reducing agents, converting metal ions into nanoparticles and stabilizing their structure [3]. This dual functionality not only ensures the uniform size and shape of nanoparticles but also enhances their stability and biocompatibility for various environmental applications. This study aimed to synthesize and characterize copper nanoparticles using pumpkin peel extract as the solvent.

## 2. Materials and Methods

The green synthesis was conducted using 20 grams of pumpkin (*Tetsukabuto*) peels heated in 100 ml of distilled water for 60 minutes. 20 grams of copper sulfate pentahydrate ($CuSO_4.5H_2O$) was dissolved in 40 ml of the extract. The pH of the solution was adjusted to 8 with a NaOH solution. The resulting sample was a precipitate that was dried in a forced air circulation oven for 390 min at 70°C [2].

## 3. Characterization of copper nanoparticles

The characterization equipment used were: Quantachrome Touchwin (BET analysis), Transmission Electron Microscopy (TEM. JOEL, JEM12200 EX-II), Scanning Electron Microscopy (SEM HV: 15.0 kV, VEGA 3 TESCAN), and Energy Dispersive X-ray Spectroscopy (Oxford, model X-Max 80), and Witec, alpha 300R (21ºC) for Raman spectroscopy.

## 4. Results and Discussion

Images of CuNp obtained from TEM analyses are shown in Figure 1a. The size of CuNp in this work (3.5 - 5.8 nm) was comparable to that obtained in a previous study [4], where copper nanoparticles were synthesized using *Hyptis Suaveolens* (L.). The SAED analysis indicates crystallinity for CuNp nanoparticles. The pattern shown in Figure 1b displays well-defined spots, which is a characteristic of crystalline materials that preserve the periodicity of their crystal structure during diffraction [5].

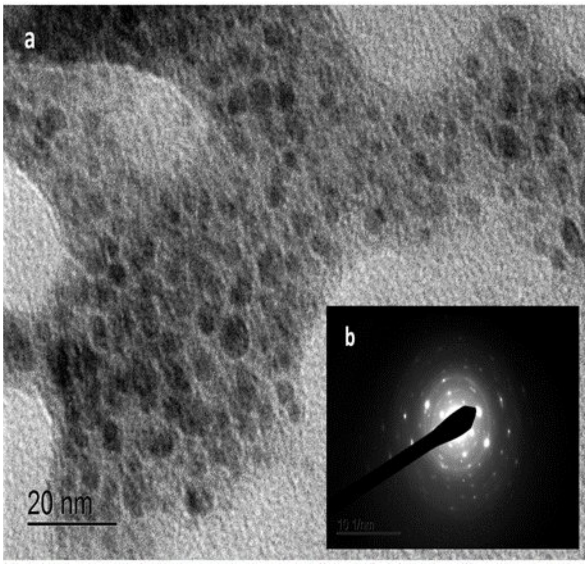


Fig. 1. TEM (a) and SAED (b) of CuNp.

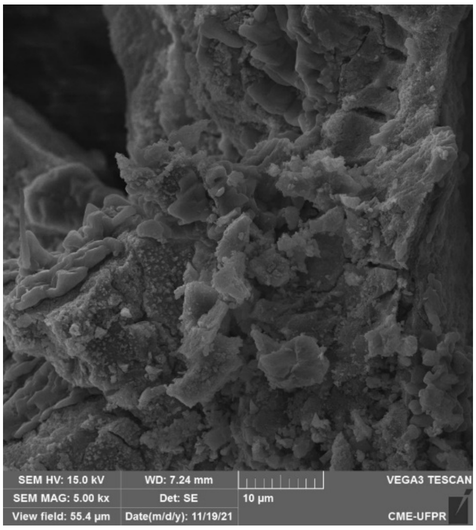


Fig. 2. SEM of CuNp.

SEM micrographs (Fig. 2.) revealed irregular morphological surfaces for CuNp. Sathiyavimai *et al.* (2021) [6] synthesized copper oxide nanoparticles using *Psidium guajava* leaf extract and obtained a platelet-like surface morphology. This can be attributed to the fact that different extracts have distinct capping agents, which can interfere with the morphology of the material.

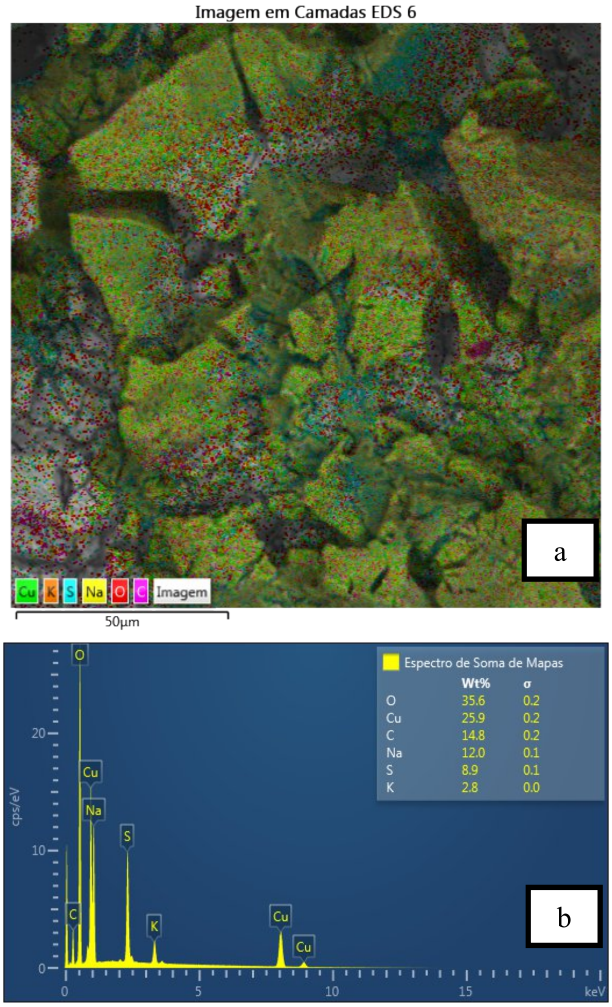


Fig. 3. Energy Dispersive Spectroscopy (EDS) (a) and Sum of Maps Spectrum (SME) (b) results of CuNp; Energy Dispersive Spectroscopy (EDS).

Figure 3 shows spectra obtained from (a) Energy-Dispersive Spectroscopy (EDS) and (b) Sum of Maps Spectrum (SME) analyses of CuNp. The SME analysis (Fig. 3.) reveals high contents of copper and oxygen, with percentages of 25.9 and 35.6, respectively, indicating the formation of CuO. Moreover, an optical absorption peak of copper at approximately 1 keV was detected by SME analysis, in agreement with previous studies [6]. Additionally, the identification of other elements, such as sodium, potassium, and sulfur, suggests the presence of compounds from pumpkin peel extract (sodium and potassium) and impurities from the copper salt precursor.

Figure 4 shows the nitrogen sorption isotherm at -195.8°C for CuNp. Based on the BET classification [7], a type III isotherm with hysteresis was observed. As shown in Table 1, CuNp presented micropores, and the surface area of CuNp is 18.68 m² g⁻¹ Elzoghby *et al.* (2021) [8] synthesized copper-polyamide nanostructures for uranium sorption and obtained a value (16.89 $m^2$ $g^{-1}$) close to that found in this study. Ramos et al. [2] synthesized iron nanoparticles using the same method as in this study and found a surface area of 18.87 $m^2$ $g^{-1}$. The iron nanoparticles synthesized by the authors were highly effective in the photodegradation of a recalcitrant antibiotic molecule.

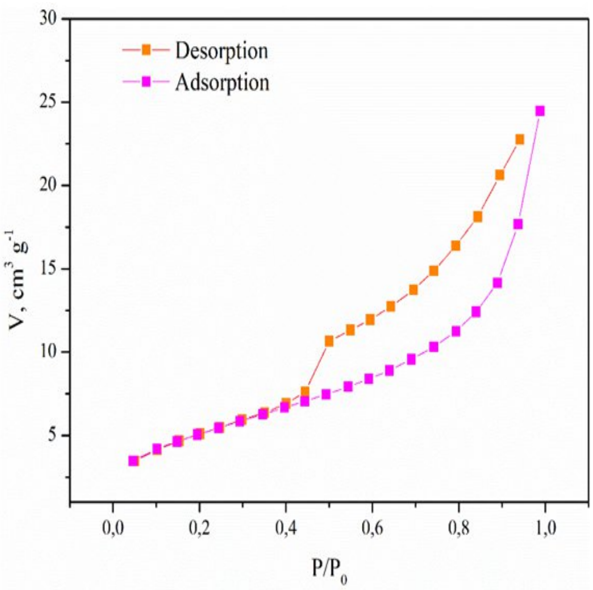


Fig. 4. Nitrogen sorption isotherm at -195.8 °C on CuNp.

Table 1. Textural characterization of nanoparticles.

| Properties | CuNp |
|---|---|
| Surface area BET, $m^2$ $g^{-1}$ | 18.68 |
| Total pore volume, $cm^3$ $g^{-1}$ | 3.70 x $10^{-2}$ |
| External surface area, $m^2$ $g^{-1}$ | 18.18 |
| Micropore volume, $cm^3$ $g^{-1}$ | 1.46 x $10^{-6}$ |
| Micropore area, $m^2$ $g^{-1}$ | 0.50 |
| Mean pore radius, nm | 80.68 |

Figure 5 shows the Raman spectroscopy of CuNp samples, revealing vibrational peaks from 0 to 1250 $cm^{-1}$. Vibrational peaks below 1000 $cm^{-1}$ can be attributed to bonds derived from copper oxide (Cu-O). Shubhashree *et al*. (2022) [4] synthesized copper nanoparticles using *Hyptis Suaveolens* extract and observed a peak at 614 $cm^{-1}$ attributed to this bond. The peaks found between 1000 and 1250 $cm^{-1}$ can be related to phenolic compounds present in the pumpkin shell extract.

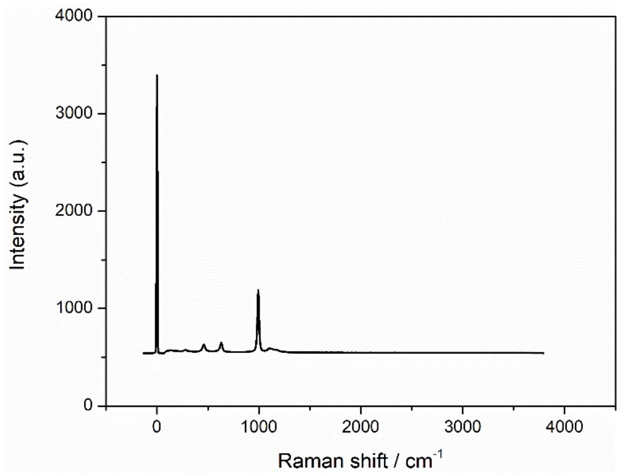


Fig. 5. Raman spectroscopy of CuNp.

## 4. Conclusion

The production of green copper nanoparticles using a solvent derived from hybrid pumpkin peel extract was successfully achieved. The nanoparticles exhibited characteristics suitable for applications in advanced oxidative processes and adsorption processes, attributed to their crystallinity and surface area of 18.68 m² g⁻¹. Furthermore, the copper nanoparticles are spherical in shape, facilitating their application in the microbiological field.

## Acknowledgements

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