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Determination of the Optimal Temperature for the Green Synthesis of Iron Oxide Nanoparticles

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Abstract. *The synthesis of iron oxide nanoparticles depends on several parameters. These parameters significantly affect their structural, morphological, and magnetic properties. One of these parameters is temperature. Temperature directly influences particle size, phase composition, and magnetic properties. This article systematically analyzes the effect of temperature in various synthesis methods and emphasizes the importance of selecting the optimal temperature.*

Keywords: *iron oxide nanoparticles, rosehip extract, temperature, UV-Vis*

Introduction

Iron oxide (Fe–O) nanoparticles are of great importance in the field of nanomaterials because their magnetic, chemical, and biocompatible properties are widely utilized in medicine, catalysis, sensors, and environmental remediation (Laurent, 2008; Wu, 2014). Particularly, during the synthesis of Fe_3O_4 and γ-Fe_2O_3 phases, control over particle size, crystallinity, and morphology plays a crucial role. One of the main parameters regulating these properties is temperature. Changes in temperature directly affect nucleation and growth kinetics, phase composition, and magnetic behavior (Ahn, 2012).

The structural, morphological, and magnetic properties of iron oxide nanoparticles are strongly dependent on the synthesis temperature (Gnanaprakash, 2007). Temperature variations regulate nucleation and growth kinetics, directly affecting particle size, phase composition, and magnetic parameters (Mahmoudi, 2011). Particles synthesized at low temperatures generally have smaller sizes and poor crystallinity, whereas increasing the temperature enhances crystallinity and leads to the formation of a more homogeneous morphology (Thanh, 2014). High temperatures accelerate diffusion, resulting in increased particle size and stronger aggregation.

Temperature also determines the phase composition of synthesized particles—whether magnetite, maghemite, or other oxide forms. Nanoparticles synthesized at optimal temperatures exhibit high magnetic saturation and stable superparamagnetic behavior. Improper temperature control can lead to increased structural defects and uneven size distribution. This article extensively examines the role of temperature in various synthesis methods and its effects on the properties of the resulting nanoparticles. The results indicate that temperature is a key controlling factor in obtaining iron oxide nanoparticles with parameters suitable for target applications (Gupta & Gupta, 2005).

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In “green synthesis” using plant extracts, temperature plays a special role, as high temperatures can cause the degradation of phytochemical compounds. Moreover, temperature also affects the phase transitions between iron oxide phases; for example, the γ-Fe_2O_3 → α-Fe_2O_3 transformation depends on temperature (Bukhari, 2020). Thus, selecting the optimal temperature during green synthesis is crucial for both the chemical process and the preservation of bioactive compounds in the extract (Hajiahmadi, 2019).

Materials and Methods

In this study, Rosa canina (rosehip) fruit extract was used as a natural reducing and stabilizing agent for green synthesis.

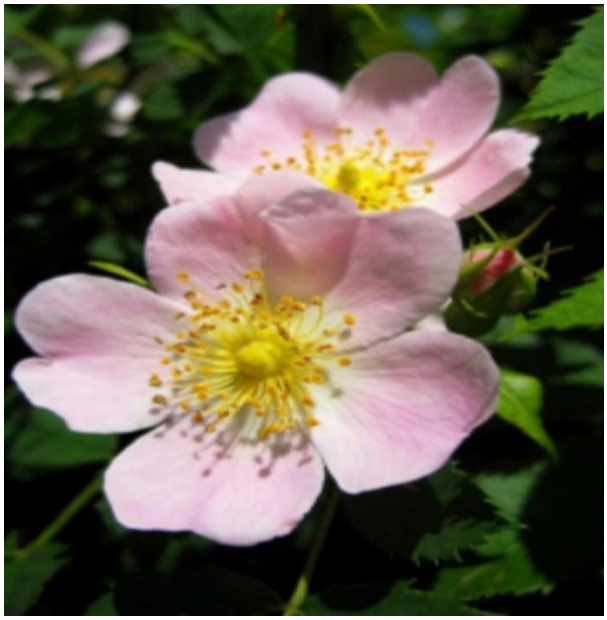

Figure 1. Rosa Canina (Rosehip)

The plant material was collected from local natural areas, dried, and ground into a homogeneous powder. The polyphenols, flavonoids, vitamin C, and organic acids present in Rosa canina fruits play an important role in the Fe^{3+} → Fe^{2+} reduction, making this plant widely used for green synthesis. It is known that phytochemical components degrade at temperatures above 40°C. Therefore, two extraction methods were tested:

- **45°C extract:** Rosa canina powder was kept at this temperature for 48 hours, producing a more stable extract with higher reducing ability (Hajiahmadi, 2019).
- **70°C extract:** At higher temperatures, some phenolic compounds were observed to degrade (Patel, 2021).
- **UV-Vis Spectroscopy:** Measurements performed in the 200–800 nm range showed that in the non-boiled extract, the peaks at 280–330 nm were more pronounced, confirming the stability of the phenolic compounds. In the extract prepared at 70°C, the decrease in peak intensity indicated thermal degradation.

Results and Discussion

The study demonstrated that the most optimal synthesis temperature is 45°C. At this temperature, the bioactive compounds in the extract remain intact, and its reducing capability is preserved.

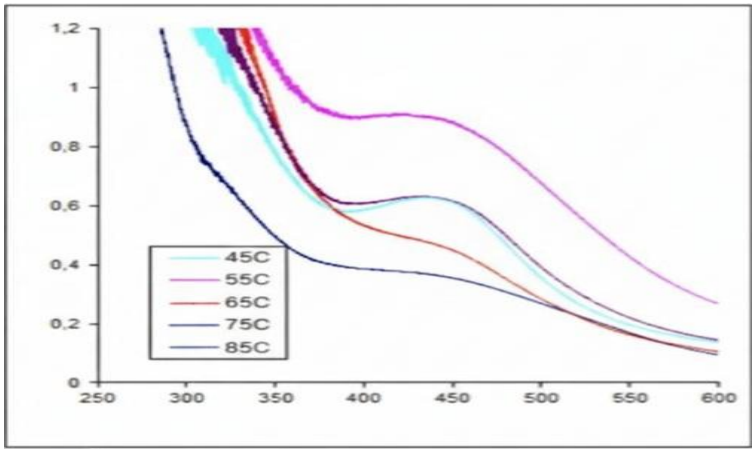

Figure 1. Temperature Dependence

At high temperatures (75°C), phenolic and flavonoid components degrade, weakening the synthesis process. In chemical synthesis methods, increasing the temperature can accelerate diffusion, leading to the formation of larger particles and phase transformations (Teja, 2009). However, in green synthesis, 45°C has been identified as an optimal balance point that ensures both extract stability and appropriate nucleation–growth kinetics.

According to the literature, low-temperature synthesis produces smaller particles, but with poor crystallinity (Cornell & Schwertmann, 2003). Based on our results, 45°C minimizes these negative effects, enabling the formation of high-quality nanoparticles with superparamagnetic properties (Wu, He, & Jiang, 2014).

Conclusion

The results of this study further confirm that temperature is a key controlling factor determining the properties of iron oxide nanoparticles. Preserving the biological activity and chemical stability of Rosa canina extract is crucial in green synthesis. A temperature of 45°C has been selected as optimal for nanoparticle synthesis because it prevents the thermal degradation of bioactive compounds in the extract. High temperatures (75°C and above) significantly reduce the extract's functionality, as confirmed by UV-Vis spectroscopy. With proper temperature control, iron oxide nanoparticles with suitable properties for target applications—high crystallinity, optimal particle size, and stable phase composition—can be efficiently obtained.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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