

A Comprehensive Review on Exploring the Potential of *Moringa oleifera* in Green Nanotechnology for Metal Oxide Synthesis

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Abstract: The growing emphasis on sustainable and environmentally benign technologies has led to increased interest in biosynthesis methods for metal oxide nanoparticles. Nanoparticles, in particular, have attracted attention due to their significant role in environmental remediation. This review explores the green synthesis of metal oxide nanoparticles using plant-derived extracts, especially *Moringa oleifera*, which acts as both a reducing and stabilizing agent because of its rich content of bioactive compounds like polyphenols, flavonoids, and proteins. *Moringa oleifera*, also known as the "tree of life" or "miracle tree," is classified as an important herbal plant due to its medicinal benefits. Traditionally, the plant is used to cure wounds, pain, ulcers, liver disease, heart disease, cancer, and inflammation. The review outlines different synthesis approaches and summarizes important characterization techniques used to determine particle size, shape, crystal structure, and surface properties involved in nanoparticle formation facilitated by *Moringa oleifera* extract. Existing challenges, such as issues related to large-scale production, consistency, and long-term stability, are also highlighted. Overall, this review demonstrates the potential of *Moringa oleifera*-based FeO, CuO and ZnO NPs as an eco-friendly and efficient solution for environmental applications.

Key Words: Biosynthesis, Eco-friendly, *Moringa oleifera*, Metal Oxide nanoparticle, Environmental application.

1. Introduction

The nanotechnology sector has proven to be one of the most active research fields [1]. Nanotechnology is a multidisciplinary, promising area of research that offers numerous prospects in industries like agriculture, electronics, pharmaceuticals, and medicine. Nanoscience has inspired material science researchers for exploring innovative methods and develops new ways to engineer novel structures with significant properties and environmental impact [2]. Nanoparticles have a wide range of applications in areas such as cosmetics, food and feed, health care, environmental health, mechanics, biomedical science, chemical industries, drugs, gene delivery, energy science, catalysis, single electron transistor, light emitter, nonlinear optical devices and photochemical application. Nowadays, there is need to develop eco-friendly processes, that do not have use of toxic chemicals in the synthesis protocol while use of non toxic (eco- friendly) reducing and stabilizing agent are the most important issues that must be considered in green synthesis of nanoparticles. Many different methods, such as physical, chemical and green (biological) techniques, have been used to synthesize nanoparticles [3-5]. Metal and metal oxide nanoparticles have high surface to volume ratio which is responsible for their fascinating properties such as antimicrobial, magnetic, electronic and catalytic activity. Researchers have drawn attention towards biological methods due to the success of nanoparticle synthesis using natural reduction, capping and stabilizing agents, and avoiding harmful chemicals and high energy consumption [6-8]. Green synthesis employs a clean, safe, cost effective and environmentally friendly process of constructing nanomaterials. Microorganisms such as bacteria, yeast, fungi, algal species and certain plants act as substrates for the green synthesis of nanomaterials. Traditionally metal oxide nanoparticles were synthesized by various physical and chemical methods. Some commonly used synthetic methods are non-sputtering, Solvothermal, reduction, sol-gel technique and electrochemical technique. But these methods are costly, toxic, high pressure, high energy requirement and potentially hazardous [9]. Hence

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developing of reliable biosynthetic and environment friendly approach has added much importance because of its eco-friendly

products, biocompatibility and economic viability in the long run and also to avoid adverse effects during their application especially in medical field. Biosynthesis of nanoparticles is a bottom up approach where the main reaction occurring is reduction/oxidation. The plant phytochemicals with antioxidant or reducing properties are usually responsible for the preparation of metal and metal oxide nanoparticles [10].

Moringa oleifera the “miracle tree”, flourish globally in almost all tropical and subtropical regions, but it is believed to be native to Afghanistan, Bangladesh, India, and Pakistan [11]. It belongs to the genus *Moringa* and the family Moringaceae [12], and is highly sought after for its tender pods, flowers and leaves, all of which are safe for human consumption [13]. Studies have shown that *M. oleifera* is among the cheapest and most reliable alternatives for good nutrition [14]. Nearly all parts of the tree are used for their essential nutrients. *M. oleifera* leaves have a high content of beta-carotene, minerals, calcium, and potassium [15]. The leaves, in particular, are recognised for their natural healing properties and are popularly consumed in a variety of ways [12, 16]. Its diverse medicinal applications continue to expand, drawing significant scientific interest[17]. The botanical classification of *Moringa oleifera* Leaf is shown in table 1. The biological activity of leaf extracts is contingent on the solvent used, which selectively isolates specific bioactive compounds. This variability leads to distinct pharmacological properties. Thus, solvent choice plays a crucial role in determining the therapeutic potential of the extract[18].

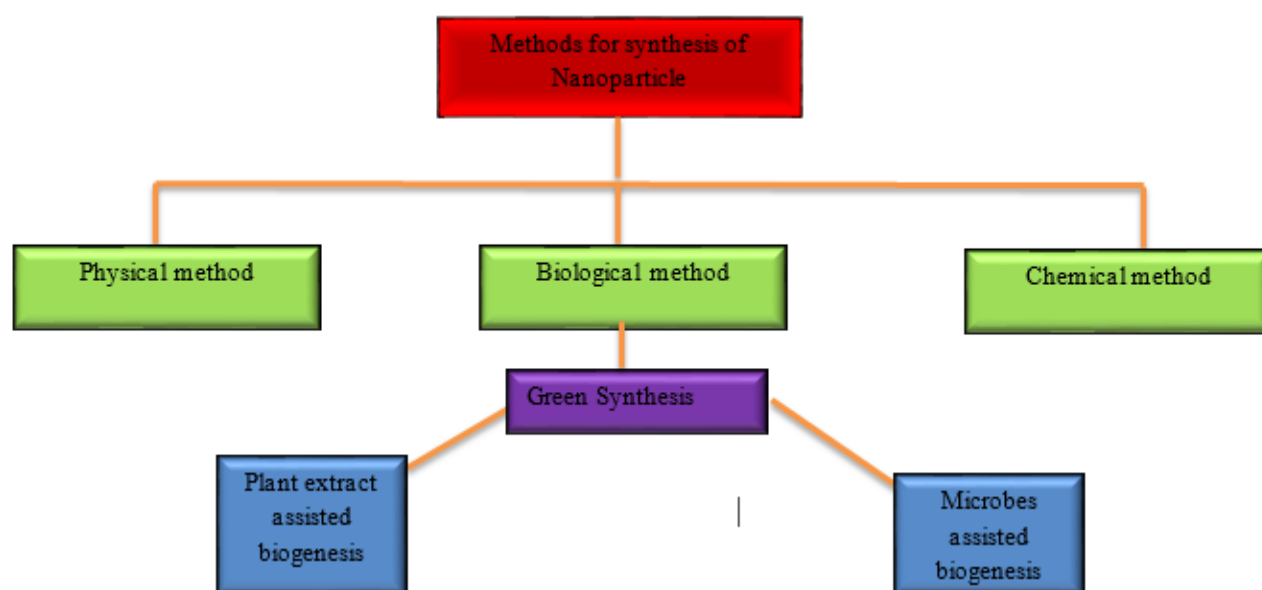


Figure 1: Different Methods of nanoparticle synthesis.

It is a valuable source of antioxidants, including quercetin and chlorogenic acids, along with flavonoids, phenolics, astragalin, anthocyanins, cinnamates, and carotenoids. In addition, it is rich in carotene, iron (Fe), potassium (K), calcium (Ca), terpenes, quinines, saponins, alkaloids, proteins, tannins, and vitamin C.[19, 20]. Recent studies reviewed here highlight the use of *Moringa oleifera* leaf extracts in the biosynthesis of FeO, CuO, ZnO nanoparticles, owing to their environmentally friendly and sustainable nature. Researchers and scientists are increasingly interested in this approach for synthesizing metal oxide nanoparticles (MO NPs) because the leaf extract is readily available, safe to use, and rich in a wide variety of bioactive metabolites.

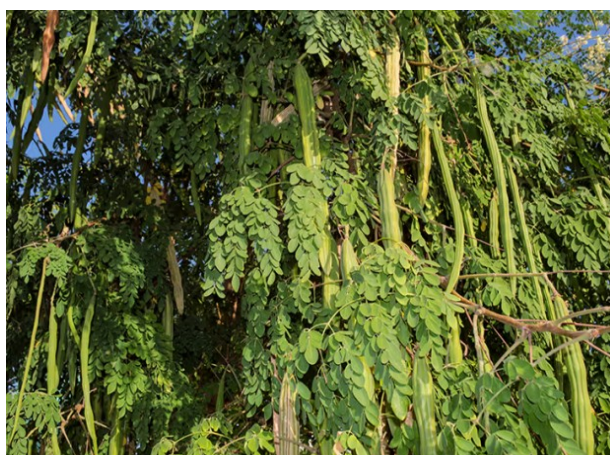


Figure 2. The *Moringa oleifera* plant

Kingdom	Plantae
Subkingdom	Tracheobionta (Vascular plants)
Superdivision	Spermatophyta
Division	Magnoliophyta (Flowering plants)
Class	Magnoliopsida (Dicotyledons)
Order	Brassicales
Family	Moringaceae
Genus	<i>Moringa</i>
Species	<i>Oleifera</i>

Table 1. Classification of *Moringa oleifera*

2. Nanoparticle Synthesis Methods

Nanoparticles can be synthesized through two main approaches: **bottom-up** and **top-down** methods [21]. In the bottom-up approach, nanoparticle formation mainly occurs through **oxidation–reduction (redox) reactions**. Today, nanoparticle synthesis is a rapidly growing research area, with increasing emphasis on developing **environmentally friendly and sustainable methods** [22].

According to the principles of green chemistry, three key factors should be considered during nanoparticle production:

1. The type of **solvent** used in the synthesis process.
2. The use of an **eco-friendly reducing agent**.
3. The selection of **non-toxic stabilizing or capping materials**.

Most conventional chemical and physical synthesis techniques rely heavily on **organic solvents**, largely because many commonly used capping agents are hydrophobic [23]. In contrast, the use of **biological organisms and biomaterials** for nanoparticle synthesis aligns well with green chemistry principles, as it employs environmentally safe reducing and stabilizing agents while minimizing harmful effects on the environment [24]. The biological synthesis of **metal oxide nanoparticles** has attracted significant interest because these nanoparticles exhibit unique and valuable properties, including enhanced **optical, electronic, and chemical characteristics**, making them suitable for a wide range of applications.

3. Synthesis of Nanoparticles

Biosynthesis of nanoparticles is an approach of synthesizing nanoparticles using microorganisms and plants having biomedical applications. This approach is an environment-friendly, cost-effective, biocompatible, safe, green approach[25]. The *Moringa oleifera* plant synthesized metal oxide NPs in many processes. The method consists of three steps: primary mechanism, biosynthesis, and characterization of nanomaterials. *Moringa oleifera* plant extract was utilized as a reducing/oxidizing, capping, and stabilizing agent for the production of metal oxide NPs.

Iron Oxide (FeO) Nanoparticles

Samson O. Aisida et al. [26] studied the synthesis of biocompatible and eco-friendly single route method for the subjugation of ferric chloride solution using a natural extract from *Moringa oleifera* (MO) as an implied capping agent. They compared the significant effect of the sundry (SD) and room temperature (RT) on the biochemical properties of the MO as a capping agent. In 100 ml of DW as a precursor salt of pH 5.7, 0.15 M ferric chloride hexahydrate (FeCl₃ 6H₂O) was dissolved. These solutions were added separately to the RT-MO, and SD-MO extract in a 1:1 vol ratio. By the reduction process, FeO-NPs were gradually obtained as the solution of FeCl₃ was added to RT-MO and SD-MO solution from brown to dark black. In SEM observed that the RT-MO induced are slightly agglomerated in while SD-MO induced particles are highly aggregated. The formation of FeO-NPs was further confirmed by energy dispersive X-ray spectroscopy (EDX). UV-spectrophotometer verified the surface plasmon resonance peaks at 668 nm indicate the formation of FeONPs for the RT-MO induced sample while the SD-MO sample shows no peak alongside with the extract. , XRD analysis indicated the RT-MO induced particles have prominent and better diffraction peaks than the SD-MO induced particles as observed. The functional bioactivities present in the MO extract observed via FTIR were involved in the bio-reduction and stabilization of FeO-NPs and are reasonably higher with RT-MO particles than with SD-MO. In VSM(Vibrating sample magnetometer), the saturation magnetization (Ms) value for the RT-MONPs (2.07 emu/g) is higher than the SDMONPs (1.17 emu/g) samples. Thus the preparation from RT is preferable to SD due to the increase in the saturation magnetization.

Tovar et al. [27] reported work similar to earlier studies, where *Moringa oleifera* leaf extract and iron(III) chloride hexahydrate were utilized for the green synthesis of FeO nanoparticles. In this method, the *Moringa* extract functioned as a capping agent. The synthesized FeO NPs, enriched with nitrogen (N), phosphorus (P), and potassium (K), were evaluated for their effects on corn seed germination and growth. Furthermore, MO-derived FeO nanoparticles exhibited desirable structural and superparamagnetic characteristics, along with particle sizes suitable for biomedical applications.

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Aisida et al. [28] developed a green and ecofriendly method for synthesizing nanoparticles using an aqueous extract of *Moringa oleifera* as both a reducing and stabilizing (capping) agent. In this process, MO leaf powder extract was combined with an FeCl_3 solution to produce dark-brown-capped MO-FeO nanoparticles. UV-Visible spectroscopy verified the formation of FeO NPs through an observable color transition from orange to dark brown. SEM and TEM analyses further revealed that the nanoparticles possessed rod-shaped morphologies with an average particle size of approximately 15 nm. Biosynthesized FeO NPs inhibited growth more effectively than chemical FeO NPs against antimicrobial. Smaller nanoparticles possess a larger surface area and enhanced bioactivity, which make them highly effective as antimicrobial agents against pathogenic microorganisms. *Moringa oleifera* leaves were dried under room temperature (RT) and sunlight (SL) conditions before nanoparticle synthesis. The *Moringa* extract again served as a capping agent, and upon the gradual addition of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ solution, the reaction mixture changed from brown to dark black, indicating FeO NP formation. SEM characterization revealed particle sizes ranging from 16–18 nm for RT FeO NPs and 18–20 nm for SL FeO NPs. XRD analysis indicated that RT-derived nanoparticles possessed a body-centered cubic (BCC) lattice structure, whereas SL-derived nanoparticles displayed a quasicrystalline structure.

Henry F. Kiwumulo et al., [29] following a protocol from Aisida et al. [28], Iron oxide nanoparticles (Fe_3O_4 -NPs) was synthesized through an economical and completely green biosynthetic method. The structural characteristics of the Fe_3O_4 nanoparticles (Fe_3O_4 -NPs) were analyzed using ultraviolet–visible (UV–Vis) spectroscopy, X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDX), and scanning electron microscopy (SEM). UV–Vis analysis revealed absorption peaks at 225 nm for the sixth dilution and 228 nm for the fifth dilution, suggesting that the nanoparticles possess photosensitive properties. SEM observations further verified their predominantly spherical morphology. Following the drying of moringa leaves, the entire synthesis process required about 5 hours, producing nanoparticles with an average diameter of approximately 16 nm. Owing to their favorable characteristics, these biosynthesized nanoparticles show promise for applications in drug delivery systems, particularly in low- and middle-income countries (LMICs).

Copper Oxide (CuO) Nanoparticles

Imosobomeh L. Ikhioya et al., [30] described the eco-friendly synthesis of copper oxide (CuO) and its subsequent characterization for use in supercapacitors. Using extracts from dried, finely ground *Moringa oleifera* leaf as the reducing/capping agent. The synthesized copper oxide nanoparticles (CuO NPs) were characterized using X-ray diffraction (XRD), ultraviolet-visible (UV-Vis) spectroscopy, energy-dispersive spectroscopy (EDS), and scanning electron microscopy (SEM). Their electrochemical performance was further evaluated through cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS).

The characterization results confirmed the successful green synthesis of CuO NPs and revealed their promising supercapacitive properties. The UV-Vis analysis showed that the absorbance of the nanoparticles increased linearly with concentration. Among all samples, the 0.6 mol CuO NP sample exhibited the highest absorbance value of 0.35 at a wavelength of 398 nm. Reflectance measurements indicated low reflectance in the medium ultraviolet region, while the reflectance gradually increased toward the visible region, reaching a maximum value of approximately 16% in the short ultraviolet range.

XRD analysis was used to estimate the crystallite sizes of the synthesized nanoparticles. The crystallite sizes for the 0.2, 0.3, 0.4, 0.5, and 0.6 mol CuO NP samples were found to be 43.14 nm, 43.68 nm, 24.23 nm, 5.70 nm, and 12.87 nm, respectively, with an overall average crystallite size of 25.93 nm. SEM observations revealed distinct morphological features of the CuO nanoparticles. In particular, the 0.2 mol CuO NP sample displayed well-defined cubic grains with nanorod-like structures and tube-shaped pores, indicating a clearly distinguishable nanoparticle morphology.

G. Kalaiyan, et al [31] studied about hierarchical copper oxide (CuO) microspheres were successfully synthesized through a plant mediated synthesis approach using *Moringa oleifera* leaf extract as a reducing and stabilizing agent. The structural, chemical, and morphological characteristics of the synthesized CuO microspheres were systematically characterized using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and energy-dispersive X-ray analysis (EDAX). The XRD diffraction pattern verified the successful synthesis of monoclinic CuO, with a calculated crystallite size of 19.6 nm. SEM observations showed the presence of pompon-like CuO microspheres characterized by a highly porous sponge-like structure. CuO displayed significant bactericidal effectiveness against the selected bacterial species.

K. Pagar, et al., [32] employed *Moringa oleifera* leaf extract as a capping agent along with a copper acetate solution for the green synthesis of nanocrystalline CuO powder, which appeared as a fine dark-black material. This ecofriendly synthesis approach produced CuO nanoparticles that were subsequently characterized using XRD, FE-SEM, EDX, FT-IR, UV-DRS, and photoluminescence (PL) analyses. The synthesized CuO nanoparticles demonstrated significant antifungal activity. Similarly, another study [33] utilized *Moringa oleifera* leaf extract for the preparation of CuO microspheres through a green synthesis method. The color of the solution changed from bluish to dark green during stirring, indicating that the biological components included in the MO leaf extract converted $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ to Cu^{2+} ions. The XRD analysis confirmed the formation of CuO nanoparticles with a monoclinic crystal structure, indicating that the phytochemicals present in the *Moringa oleifera* leaf extract facilitated the conversion of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ into Cu^{2+} ions. SEM micrographs revealed clustered morphologies resembling hierarchical CuO microspheres. Additionally, FTIR spectra displayed asymmetric stretching and deformation vibration bands associated with Cu–O bonds, further supporting the formation of monoclinic crystalline CuO. The synthesized nanoparticles also exhibited enhanced antibacterial activity.

Zinc Oxide (ZnO) Nanoparticles

Elumalai et al. [34] developed a simple and ecofriendly chemical method for synthesizing zinc oxide nanoparticles (ZnO NPs) using *Moringa oleifera* leaf extract. The synthesized nanoparticles were characterized through UV–Vis spectroscopy, XRD, FESEM, EDX, FT–IR, and PL analyses. XRD results confirmed the formation of ZnO nanoparticles with a hexagonal wurtzite crystal structure, while FT–IR analysis demonstrated that the functional groups present in the leaf extract acted as stabilizing agents during nanoparticle formation. FE-SEM observations revealed spherical and agglomerated nanoparticle morphologies with particle sizes ranging from 16 to 20 nm. UV–Vis spectroscopy further showed the characteristic absorption peak of ZnO nanoparticles. Antimicrobial studies indicated that the synthesized ZnO NPs exhibited significant inhibitory activity against microorganisms.

Jose V. González-Fernández et al., [35] investigated the green synthesis of zinc oxide nanoparticles (ZnO-NPs) using *Moringa oleifera* extract as a natural reducing and stabilizing agent. The synthesized nanoparticles were characterized through UV–Vis spectroscopy, dynamic light scattering (DLS), zeta potential analysis, X-ray diffraction (XRD), attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR), and field-emission scanning electron microscopy (FE-SEM). The characterization results confirmed the formation of predominantly spherical ZnO nanoparticles, with an average hydrodynamic size of 47.2 nm measured by DLS and an average particle diameter of approximately 25 nm observed by FE-SEM. FE-SEM images also revealed a uniform distribution of particles without noticeable aggregation, agglomeration, or large clusters. XRD findings demonstrated that thermal annealing enhanced crystallite growth and promoted the development of highly crystalline, single-crystal structures. The analyses further verified the successful synthesis of pure ZnO nanoparticles and showed that annealed samples were free from organic impurities. Owing to their favorable properties and cost-effective production process, these biologically synthesized ZnO nanoparticles have strong potential for a wide range of practical applications.

F Adam, A Himawan et al.,[36] synthesized Zinc oxide nanoparticles (ZnO-NPs) through an environmentally friendly approach using aqueous extract of *Moringa oleifera* leaves. The nanoparticles were produced by precipitation and subsequently calcined at temperatures of 300, 350, 400, 450, and 500°C before characterization. The synthesized ZnO-NPs were analyzed using Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Ultraviolet–Visible (UV–Vis) spectroscopy. Their photocatalytic performance was evaluated by monitoring the degradation of methylene blue dye in aqueous solution. FTIR results confirmed the formation of ZnO through characteristic Zn–O stretching vibrations observed between 422 and 497 cm^{-1} , while the intensity of the O–H absorption band at 3417 cm^{-1} gradually decreased as the calcination temperature increased. XRD analysis indicated enhanced crystallinity and improved structural properties with rising calcination temperatures. The sample calcined at 500°C exhibited the highest photocatalytic efficiency, achieving approximately 80% degradation of methylene blue within 60 minutes of irradiation. These findings demonstrate that *Moringa oleifera* aqueous extract serves as an effective green reducing and stabilizing agent for ZnO nanoparticle synthesis, and that calcination temperature plays a crucial role in determining the photocatalytic activity of the resulting nanoparticles.

In another study [37], *Moringa oleifera* leaf extracts were employed as effective chelating, oxidizing, and reducing agents for the biosynthesis of both NiO and ZnO nanoparticles from $\text{Ni}(\text{H}_2\text{O})_6^{2+}$ and $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ precursors. The structural and optical properties of these semiconducting nanoparticles, synthesized through the same process, were investigated using XRD, ATR-FTIR, UV-Vis-NIR, and photoluminescence (PL) techniques.

Extract	Yield (%)	Total Phenolics (mg GAE/g)	Flavonoids (mg QE/g)	Tannins (mg TAE/g)
Hexane	5.3 ± 0.4	12.5 ± 1.1	8.2 ± 0.7	3.1 ± 0.3
Ethanol	19.7 ± 0.8	148.6 ± 3.2	86.4 ± 2.1	24.7 ± 1.5
Aqueous	28.4 ± 1.2	132.8 ± 2.7	72.5 ± 1.8	35.2 ± 1.9
Ultrasound-Assisted Extraction (UAE)	22.1 ± 0.9	167.3 ± 3.5*	102.6 ± 2.4*	28.9 ± 1.6

Table 2:- Extraction yields and phytochemical composition of *Moringa oleifera* leaf extract[38]

Metal Oxide NPs	Characterization	Result	Reference
FeO	SEM	RT MO- Slightly aggregated ST MO- Highly aggregated	Samson O. Aisida et al.[26]
	UV	RT MO- 668 nm ST MO- No peak	
	XRD	RT MO- 26.2nm ST MO-19.6nm	
	FTIR	600 cm^{-1} – FeO bond	
	VSM	RT-MONPs (2.07 emu/g) SD-MONPs (1.17 emu/g)	

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	structural and superparamagnetic		Tovar et al. [27]
	SEM	RT- 16- 18 nm SL- 18-20 nm	Aisida et al. [28]
	XRD	RT- BCC lattice SL- Quasicrystalline	
	UV	585-620nm	
	SEM	16-20nm, Semi- spherical morphology	Henry F. Kiwumulo et al.,[29]
	XRD	16nm	
	UV	225 nm	
FeO	UV	210nm	Lebogang K. Seru, et al.,[39]
	XRD	17.4nm	
	FTIR	621cm ⁻¹	
	TEM	Spherical	
	XRD	20-30nm	S. K. Begum, et al.,[40]
	FTIR	500-600 cm ⁻¹	
	FESEM	pseudo-spherical, 16-45 nm	
CuO	VSM	6-13 emu/g	
	SEM	Nanorod like and tubed shaped	Imosobomeh L. Ikhioya et al.,[30]
	XRD	25.93 nm	
	UV	398 nm	
	XRD	19.6nm	G. Kalaiyan, et al[31]
	SEM	Pompon like structure	
	FTIR	678 cm ⁻¹	
	XRD	Monoclinical structure	K. Pagar, et al., [32]
	UV	386 nm	
	SEM	Hierachical microsphere	
	FTIR	666 cm ⁻¹	G. Kalaiyan et al., [33]
	XRD	monoclinic crystalline structure	
	SEM	sponge-like	
	FTIR	530cm ⁻¹	Mohammed Larbi Ben Amor, et al.,[41]
	UV	400 nm	
	FTIR	500-600 cm ⁻¹	
	XRD	18.5 – 19.7nm	
	SEM	Spherical, 80 nm	
ZnO	XRD	17 nm	Elumalai et al. [34]
	FESEM	Spherical agglomerated	
	FTIR	455cm ⁻¹	
	UV	374nm	
	DLS	Hydrodynamic size 47.2 nm	Jose V. González-Fernánde et al., [35]
	XRD	52.24nm	
	ATR- FTIR	470 cm ⁻¹	
	FE- SEM	Spherical, 23.1 nm	
	FTIR	422- 497 cm ⁻¹	F Adam, A Himawan et al.,[36]
	UV	420nm	
	XRD	22.34 nm	
	XRD	10.81nm	
	ATR-FTIR	450 cm ⁻¹	I. Ngom, et al.,[37]
	UV	380 nm	
	Zeta potential	-21.9 mV	
	XRD	5.52 - 41.59 nm	Meshayil M. Alsolmi et al.,[42]
	TEM	Spherical	
	FTIR	420 cm ⁻¹	

Table 3: Summary for biosynthesized metal oxide's using *Moringa oleifera* extract

4. Conclusion

Although numerous studies have investigated the nutritional composition, phytochemical constituents, and medicinal properties of *Moringa oleifera*, the available information is scattered across diverse disciplines, including botany,

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pharmacology, foodscience, biotechnology, and nanotechnology. A comprehensive review is therefore needed to consolidate these findings into a single, coherent source.

The increasing interest in eco-friendly and sustainable technologies has also highlighted *M. oleifera* as a promising plant for the green synthesis of metal and metal oxide nanoparticles. However, existing reviews often focus on only one aspect, such as nutrition, pharmacological activities, or nanoparticle synthesis, without integrating these topics. Moreover, differences in extraction methods, solvent selection, phytochemical composition, and biological activities have not been critically compared. This review aims to bridge these gaps by providing an up-to-date and comprehensive evaluation of the botanical characteristics, nutritional value, phytochemical profile, therapeutic properties, extraction strategies, and emerging applications of *M. oleifera*, particularly in green nanotechnology. It also identifies current research gaps, discusses existing limitations, and highlights future research directions to support the development of sustainable biomedical, pharmaceutical, and industrial applications.

Overall, from the study reviews, it is considered that green synthesis of nanomaterials is much safer and environmentally friendly than the physical and chemical methods. *Moringa oleifera* leaves contain bioactive compounds that act as reducing, capping, and stabilizing agents, enabling the biosynthesis of various metal oxide nanoparticles. Most of the metal oxide have its own environmental application which depend on it's characterization. Different reported methods show that these leaves can efficiently produce multiple types of nanoparticles. Biosynthesized metal oxide generally exhibit superior antibacterial activity compared to chemically synthesized nanoparticles. However, many studies do not clearly report how extract concentration or temperature influences nanoparticle size. Because of their beneficial features, biosynthesized nanoparticles are emerging as effective materials for drug delivery applications, offering considerable potential for healthcare improvements. Overall, nanoparticle size is typically controlled by adjusting the concentration of *Moringa oleifera* leaf extract and the synthesis temperature. It is anticipated that this review could further streamline the research on innovative methodological and clinical correlations in this area. In the meantime, solutions to health problems will be suggested by referring to this complex through scientific and research reports.

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