Research Article

Phytochemical profiling, green synthesis, and characterization of Silver Nanoparticles from *Momordica cymbalaria* extract with promising Anti-Inflammatory and Antioxidant potential

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ABSTRACT

Recent advancements in nanotechnology have revolutionized biomedical research, offering innovative solutions for disease management. The synthesis of silver nanoparticles (AgNPs) using phyto-extracts has gotten significant attention due to its environmentally benign and economical approach. *Momordica cymbalaria*, a well-known therapeutic properties containing plant, was utilized for the biosynthesis of AgNPs. Extensive phytochemical analyses, including qualitative and quantitative assessments, were conducted to determine the presence of bioactive constituents facilitating nanoparticle synthesis. A range of micro & spectroscopic methods were utilized to characterize the MCAgNPs. Furthermore, their potential anti-inflammatory and anti-oxidant properties were evaluated through in vitro assays. The results suggest that *Momordica cymbalaria* mediated AgNPs exhibit promising biological activity, making them potential candidates for therapeutic applications in inflammation-related diseases.

Keywords: Momordica cymbalaria, phytochemical, antioxidants, Nanoparticles

1. INTRODUCTION

The phytoconstituents found in therapeutic herbs have played a vital role in healthcare for centuries, with a growing global emphasis on plant-based medicines [1]. The search for novel plant species with diverse pharmacological properties is crucial, along with the need to establish a sustainable raw material base for medicinal plant resources. [2]

M. cymbalaria, a Cucurbitaceae species, has been traditionally recognized for its therapeutic and healing properties [3]. Indigenous to the tropical regions of Asia, it is also known as Momordica tuberosa Roxb. and Luffa tuberosa Roxb. Commonly referred to as Athalakkai in Tamil, it serves as both an edible vegetable and a medicinal plant. The plant contains an abundance of bioactive constituents, particularly saponins, flavonoids and alkaloids, which are responsible for its wide range of pharmacological activities and plays a significant role in attenuating inflammation and oxidative stress by scavenging reactive oxygen species and modulating redox-sensitive inflammatory pathways [4] [5]. Alkaloids exhibit antimicrobial and anticancer activities, while flavonoids possess significant anti-inflammatory and antioxidant effects [6]. Moreover, several studies have reported the anti-diabetic potential of saponins [7]. Hence, the phytochemicals found in Momordica species have attracted considerable scientific attention due to their roles in managing diabetes, cardiovascular diseases [8] and ulcers [5]. Additionally, *M. cymbalaria* has been reported to possess antioxidant, hepatoprotective, nephroprotective, hypoglycemic, wound healing, and anti-infertility properties.

Nanotechnology has garnered immense attention for its diverse applications, particularly in metallic nanoparticle synthesis. [9] Metallic nanoparticles, including those of zinc [10], magnesium [11], gold [12], titanium [13], copper [14], and silver [15], exhibit unique physicochemical and biological properties, enhancing their utility in medicine, material science, electronics, and optics. Among various metal-based nanoparticles, silver nanoparticles are stand out for their remarkable chemical stability, catalytic efficiency, biocompatibility and broad therapeutic potential. AgNPs have demonstrated significant anti-inflammatory and antioxidant properties by mitigating redox imbalance and neutralizing reactive oxygen species, thereby positioning them as promising materials for biomedical uses [16]. Green synthesis using pharmacologically active flora has emerged as an environmentally sustainable and economically viable approach to nanoparticle inventions [17]. This method is sustainable, rapid, and utilizes diverse plant parts such as bark, roots, leaves, seeds and flowers. While Traditional herbal based synthesis has been widely explored, the potential of wild and underutilized plant species remains largely untapped, offering new avenues for biomedical and pharmaceutical advancements.

The current study focuses on the green synthesis of silver nanoparticles using *Momordica cymbalaria*, a medicinal plant with potential bioactive properties. The phytochemical constituents of *Momordica cymbalaria* act as natural reducing and capping agents, facilitating the reduction of Ag^+ ions to Ag^0 and enabling the eco-friendly synthesis and stabilization of silver nanoparticles. The prepared silver nanoparticles were analyzed and evaluated to explore their potential and highlight their prospective biomedical applications.

2. MATERIALS & METHODS

Preparation and Processing of *Momordica cymbalaria* Fruit Extract

Fresh leaves of *Momordica cymbalaria* were collected and thoroughly cleaned with sterile distilled water, followed by surface sterilization using 10% (w/v) Bavistin solution for 5 minutes to eliminate fungal contaminants. The leaves were then rinsed several times with double distilled water to ensure complete removal of any excess residues. Subsequently, the samples were shade-dried for fifteen days and ground into a fine powder using a mechanical grinder. Ten grams of the powdered sample were mixed with 100 mL of distilled water and heated for 10 minutes to prepare the aqueous extract. The mixture was cooled at room temperature, filtered and centrifuged for 15 minutes at 8000 rpm to obtain a clear, cell-free extract. The resulting supernatant was stored at 4°C and utilized for nanoparticle synthesis within 10–12 days.

Phytochemical Profiling

Analytical Parameters

The physicochemical properties of *M. cymbalaria* were assessed, including: Total Ash Content – Determined by incineration at 600°C, Acid-Insoluble Ash – Measured by treating the total ash with dilute hydrochloric acid. Water-Soluble Ash – Estimated by dissolving ash in water and filtering the insoluble residue. Sulphated Ash – Evaluated by heating the sample with sulfuric acid. Crude Fiber Content – Determined by acid and alkali digestion. Water-Soluble and Alcohol Extractive Values – Calculated to assess the solubility of phytochemicals in different solvents.

Quantitative Analysis of Micronutrients in *Momordica cymbalaria* Fruit

1 gram of powdered fruit sample was digested using a 3:1 mixture of conc. perchloric acid (HClO) and nitric acid (HNO_3) at 110°C till a clear solution was attained. The digested sample was filtered, diluted with distilled water, and analyzed. Atomic Absorption Spectroscopy (AAS): Used for iron, copper, zinc, chromium, and manganese. UV-Visible Spectrophotometry: Sulfur (S) was measured using the turbidimetric method with barium chloride. Colorimetric Method: Boron (B) was quantified using Azomethine-H reagent at 420 nm. Micronutrient concentrations were recorded as % w/w per 100 g of dried fruit.

Quantitative Analysis of Macronutrients in *Momordica cymbalaria* Fruit

For macronutrient estimation, 1 g of powdered fruit sample was digested using a tri-acid mixture ($HClO_4$: H_2SO_4: HNO_3: in a 1:1:3 ratio) at 110°C until a clear solution was obtained. The digested sample was cooled, filtered, and diluted with distilled water to a final volume for further analysis. Potassium (K) and Calcium (Ca): Measured using Flame Photometry at their respective emission wavelengths. Phosphorus (P): Determined by the Vanadomolybdate yellow colorimetric method, with absorbance recorded at a wavelength of 420 nm using a UV–Vis spectrophotometer. Nitrogen (N): Estimated using the Kjeldahl method, which includes digestion, distillation, and titration to determine total nitrogen content. Magnesium (Mg): Quantified using Atomic Absorption Spectroscopy (AAS) at its specific wavelength. The macronutrient content was calculated per 100 g of dried fruit sample.

Green Biosynthesis of Silver Nanoparticles

The methanolic extract of *Momordica cymbalaria* acted as both a reducing and stabilizing agent, while $AgNO_3$ (silver nitrate) solution was prepared and gradually added with continuous stirring at ambient temperature. The pale yellow color transition to brown signified AgNP formation and the reaction mixure left undisturbed for 24 hours to ensure complete synthesis and stabilization. AgNPs were recovered by centrifugation for 15 minutes at 10,000 rpm, washed three times with deionized water, dried at 60°C, and stored in an airtight container for further characterization.

MC-AgNP physicochemical Characterization

Spectroscopic analysis

The optical characteristics and formation of the synthesized MC-AgNP were analyzed using UV-Vis spectroscopy. A distinct color change from clear white to light sandal ensures the formation of MC_ Ag nanoparticles and the absorbance spectrum was measured after 24 hours within the 350 to 500 Nano meter range.

Microscopic analysis

The morphology, particle size, and surface characteristics of the synthesized MC_Ag nanoparticles were analyzed using SEM. The AgNP suspension was ultrasonicated for 15 minutes to achieve uniform dispersion, and a drop was placed on a glass slide. After air drying, to enhance conductivity, the sample was coated with a thin gold layer. FEI Quanta 250 SEM at 10 kV was used for Morphological visualization. Additionally, TEM was used to further evaluate the structural characteristics and particle size.

FTIR

Functional groups responsible for the reduction, capping, and stabilization of MC-AgNPs were analyzed using FTIR. The FTIR spectra distinguish free functional groups from those bound to AgNPs, revealing surface chemistry variations. Dried synthesized AgNPs were analyzed using an FTIR spectrometer (Model: SHIMADZU-8400S) to assess functional group attachment and nanoparticle stabilization.

Evaluation of Anti-inflammatory Potential

Protein Denaturation Inhibition Assay

One milliliter of MC-AgNPs at varying concentrations of 20 µg to 100 µg per mL was mixed with 1 mL each of egg albumin and phosphate-buffered saline and incubated for 15 minutes at 37°C. The mixture was then heated at 70°C for 5 minutes. After cooling, the absorbance was recorded at 660 nm. diclofenac sodium used as the standard.

Proteinase Activity Inhibition Assay in (%)

Tris-HCl buffer (pH 7.4), Trypsin (0.06 mg) and MC-AgNPs with different concentrations was incubated for 5 minutes at 37°C. After adding casein and terminating with perchloric acid (70%), the supernatant's absorbance was measured at 210 nm.

Lipoxygenase Activity Inhibition Assay in (%)

A reaction mixture containing MC-AgNPs or indomethacin (as the standard drug) at varying concentrations was prepared with 250 µL of lipoxygenase enzyme (20,000 U/mL) and an equal volume of 2 M borate buffer (pH 9.0). The mixture was incubated at 25°C for 5 minutes, followed by the addition of 1 mL of 0.66 mM linoleic acid. The absorbance was then recorded at 234 nm [18].

% of Inhibition = Abs of control – Abs of MC-AgNPs. / Abs of control × 100%

Antioxidant activity

DPPH and ABTS Radical Scavenging Assays

For the DPPH assay, one mille Liter of 0.1 mille Molar DPPH solution in methanol was mixed with equal volume of MC_AgNPs varying concentrations of 20 to 100 µg per ml and incubated in the dark for 30 minutes at room temperature. Absorbance was measured at 517 nm. For the ABTS assay, one mille Liter of MC_AgNPs at various concentrations was mixed with one mille Liter of DMSO and 3 mL of ABTS reagent. After 20-minutes of incubation at room temperature, absorbance was recorded at

734 nm. Ascorbic acid served as the standard for both assays.

Activity (%) = Abs of control – Abs of MC-AgNPs / Abs of control × 100%

3. RESULTS

Histochemical color reactions of *Momordica cymbalaria*

The qualitative color reaction tests for the identification of plant components in *Momordica cymbalaria* were performed using different reagents. The results are summarized in the table below. Lignin was confirmed in the plant samples through distinct color changes observed with different reagents. Saffranine resulted in a deep red coloration, Phloroglucinol + HCl produced a pink color, and Aniline SO_4 + H_2SO_4 developed a yellow hue, indicating the presence of lignin. Mucilage was detected using Ruthenium red, which exhibited a deep blue color, and Methylene blue, which turned pink. Starch was confirmed by the weak iodine solution, resulting in a blue color change. These observations confirm the presence of lignin, mucilage, and starch in *Momordica cymbalaria*, supporting its phytochemical composition and potential functional properties.

Physiochemical properties of *Momordica cymbalaria* fruit

The analytical parameters of the dried fruit of *Momordica cymbalaria* were evaluated to determine its physicochemical characteristics. The total ash content was 3.16 ± 0.005%, with acid-insoluble and water-soluble ash values of 1.03 ± 0.003% and 2.01 ± 0.002%, respectively. Sulfated ash was recorded at 1.20 ± 0.02%. The moisture content, measured as loss on drying at 105°C, was 7.15 ± 0.16%, indicating the stability of the dried fruit. The crude fiber content was 4.92 ± 0.19%, reflecting its dietary fiber composition. Extractive values demonstrated higher solubility in water (19.25 ± 1.28%) than in alcohol (14.23 ± 1.76%), suggesting the presence of more water-soluble phytochemicals. These results contribute to the understanding of the physicochemical profile of *Momordica cymbalaria* dried fruit.

Composition of macro and micronutrients of *Momordica cymbalaria* fruit

The quantitative analysis revealed the presence of essential micronutrients in *Momordica cymbalaria*. Zinc (2.78%), iron (2.20%), and manganese (1.20%) were found in significant amounts, while copper (0.18%) was present in lower concentrations. Additionally, trace elements such as chromium (0.45 ppm), sulphur (15.65 ppm), and boron (9 ppm) were detected, indicating the plant's potential nutritional and therapeutic value. The analysis of *Momordica cymbalaria* revealed a high potassium content (478 mg/100g), followed by calcium (89 mg/100g) and magnesium (3.32 mg/100g). Nitrogen (2.9 mg/100g) and phosphorus (0.45 mg/100g) were also present, highlighting the plant's rich nutritional profile.

Quantitative analysis of Phytochemical in *Momordica cymbalaria*

The analysis reveals the occurrence of diverse Phytoconstituents, such as terpenoids, flavonoids, phenols, alkaloids, saponins and tannins. The quantified values of these compounds are depicted in Table 1.

Table 1 - Quantitative analysis of Phytochemical in *Momordica cymbalaria*

S. No	Phytochemicals	*Momordica cymbalaria* /100g
1	Alkaloids	2.30 ± 0.06
2	Terpenoids	9.56 ± 0.65
3	Flavonoids	3.86 ± 0.356
4	Phenols	11.02 ± 1.23
5	Tannins	1.65 ± 0.002
6	Saponins	3.025 ± 0.23

The qualitative analysis of *Momordica cymbalaria* revealed the occurrence of various bioactive compounds across different extracts. Alkaloids, carbohydrates, proteins, amino acids, tannins, triterpenoids, saponins, flavonoids, and phenolic compounds were detected in varying degrees.

The methanolic and chloroform extracts exhibited a broader spectrum of phytoconstituents compared to the water extract. Notably, gum and mucilage were absent in all extracts, while the saponification test confirmed the presence of fixed oils and fats. The detailed results are depicted in Table 2.

Table 2 - Qualitative analysis of Phytochemical in Momordica cymbalaria

S.No	Qualitative Test	Water Extract	Methanolic Extract	Chloroform Extract
1	**Alkaloids**			
	a. Hager's test	+	+	+
	b. Dragendroff's test	+	+	+
	c. Wagner's test	+	+	+
	d. Mayer's test	+	+	+
2	**Carbohydrates and Glycosides**			
	a. Barfoed's test	+	+	+
	b. Borntrager's test	+	+	+
	c. Legal's test	+	+	+
	d. Fehling's test	+	+	+
	e. Molisch's test	+	+	+
	f. Benedict's test	+	+	+
3	**Proteins**			
	a. Ninhydrin test	+	+	+
	b. Biuret test	+	+	+
	Amino Acids			
	a. Salkowski's test	+	+	+
	b. Liebermann Sterol test	+	+	+
	c. Liebermann-Burchard test	-	+	+
4	**Tannins**			
	a. Lead acetate test	+	+	+
	b. Ferric chloride test	+	-	+
5	**Triterpenoids**			
	Tin and Thionyl chloride test	+	+	+
6	**Saponins**			
	a. Foam test	+	+	+
	b. Haemolysis test	+	+	-
7	**Gum and Mucilage**			
	a. Ruthenium red test	-	-	-
	b. Precipitation test with 95% alcohol	-	-	-
8	**Flavones and Flavanones**			
	a. Shinoda's test	+	+	+
	b. Aq. Sodium hydroxide	+	+	+
	c. Conc. Sulphuric acid	+	+	+
9	**Phenolic Compounds**			
	$FeCl_2$ test	+	+	+
10	**Fixed Oils and Fats**			
	Saponification test	+	+	+

Nanoparticle synthesis and characterization

Optical Property Assessment by UV–Vis Spectroscopy

The synthesized MC-Ag nanoparticles showed a noticeable absorption peak within the UV-Visible spectrum, indicating their distinct optical characteristics. In this study, the absorption signals at 226.7 nm, 396.3 nm, and 667.0 nm validate the formation of the nanostructure (Fig 1 A). Furthermore, the transition in color from pale to brown during the reaction process serves as visual evidence for the successful formation of nanoparticles. The observed peaks correspond to electronic transitions, supporting the successful synthesis of nanoparticles. (Fig 1 B)

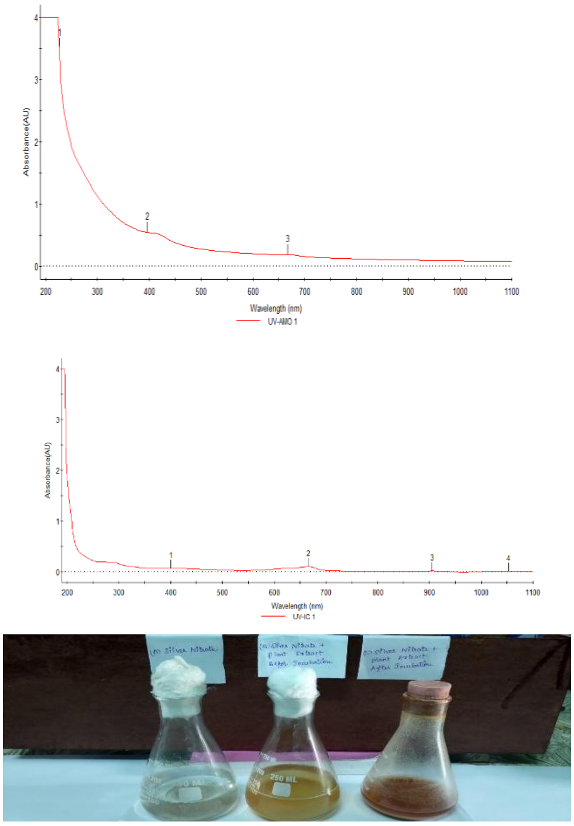
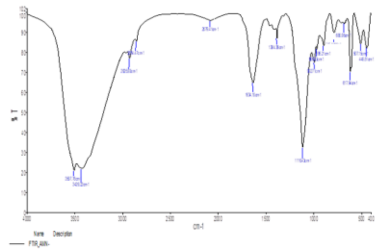


Figure 1. (A) UV–Vis spectrum of ss-AgNPs, aqueous extract solution (B) Colour intensity upon Nanoparticle synthesis

FTIR

The FTIR spectral analysis revealed functional groups for the reduction and stabilization of the MC-AgNps. The broad peak around 3200–3500 cm^{-1} indicates O-H stretching, while peaks at 2924 cm^{-1} and 2854 cm^{-1} correspond to C-H stretching. The band at 1634 cm^{-1} suggests C=O stretching & the 1100 cm^{-1} peak represents C-O-C stretching.

(A)



S. No	Frequency Range	Bond	Functional group
1	3408.61	N-H stretch	secondary amines
2	2925.97	C-H asymmetric stretch	Fatty acids
3	2875.42	C-H symmetric stretching	Essential fatty acids
4	1712.09	C=O stretch	Fatty acids
5	1602.63	C=C stretch	Lipids
6	1441.29	CH_2 bending	Alkanes
7	1383.20	CH_3 bending	Alkanes
8	1303.70	C-O stretch	Esters
9	1153.80	C-H bending	Aromatic Alkenes
10	1078.79	C-O stretch	Fatty acids
11	943.81	PH bend	Phosphines
12	693.78	CH_2 bend	Alkanes

Figure 2. (A) FTIR result (B) Frequency range and respective function group

Anti-oxidant activity of Silver nanoparticle

Antioxidant Evaluation of Silver Nanoparticles via DPPH Assay

Peaks in the 500–700 cm^{-1} range confirm Ag-O bonding, validating nanoparticle formation (Fig. 2A&B).

The results indicates, radical scavenging activity increases progressively with rising concentrations of the sample. At 100µg/mL, the maximum scavenging activity observed was 72.15%, while the standard antioxidant, ascorbic acid, exhibited 78.62% scavenging at the same concentration. The IC_{50} value of MC-Ag NPs was 36.85 ± 3.95 µg/mL, compared to 26.75 ± 2.80 µg/mL for ascorbic acid (Fig 3 A).

Free Radical Quenching Efficiency by ABTS Assay

In the ABTS assay, Mc-Ag NPs displayed notable radical scavenging potential, with optimum inhibitory potential of 71.2% at 100 µg/mL and 81.3% scavenging at the same concentration in Ascorbic acid (standard drug). The IC_{50} value of Mc-Ag NPs was determined to be 41.51 ± 2.0 µg/mL, whereas ascorbic acid exhibited a lower IC_{50} value of 23.36 ± 1.5 µg/mL, indicating its comparatively stronger antioxidant potential. Although Mc-Ag NPs showed substantial free radical neutralization, their effectiveness was marginally lower compared to that of ascorbic acid (Fig. 3 B). These results show that the synthesized silver nanoparticles exhibit notable antioxidant potential, though slightly lower than the standard.

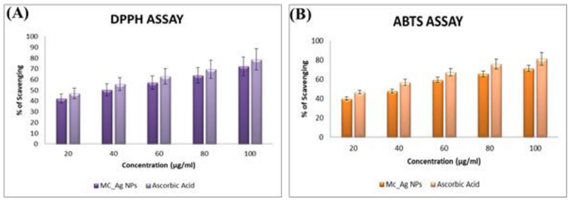
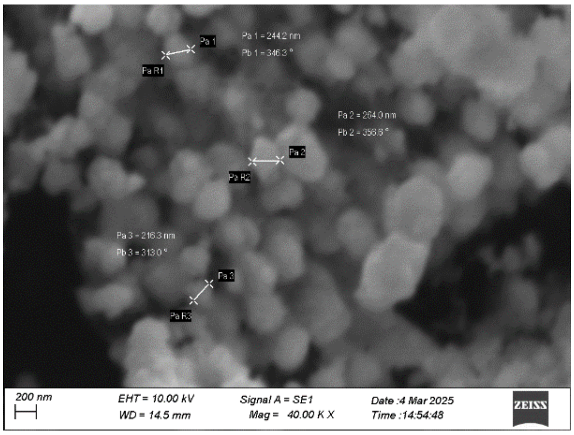
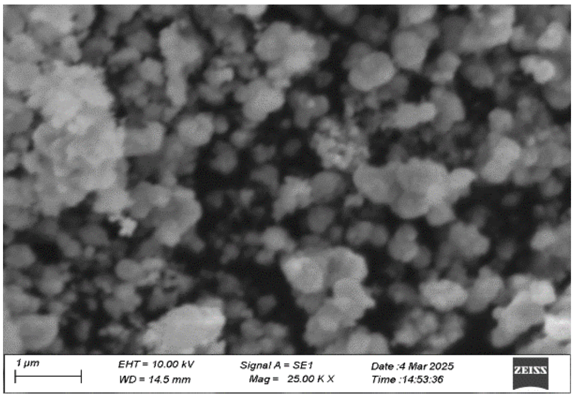


Figure 3. Comparative antioxidant efficiency of MC-AgNPs determined by (A) DPPH and (B) ABTS assays.

Morphological Characterization by TEM and SEM

TEM analysis confirms the spherical morphology and uniform distribution of the silver nanoparticles, with an particle dimensions confined to the nanometer scale. The high-resolution images reveal well-defined particle boundaries, indicating successful synthesis (Figure 4). SEM analysis further supports the agglomeration tendency of AgNPs, showcasing a rough and irregular surface texture. The observed morphology is consistent with the stabilization and formation of nanoparticles, confirming their successful synthesis (Figure 5).





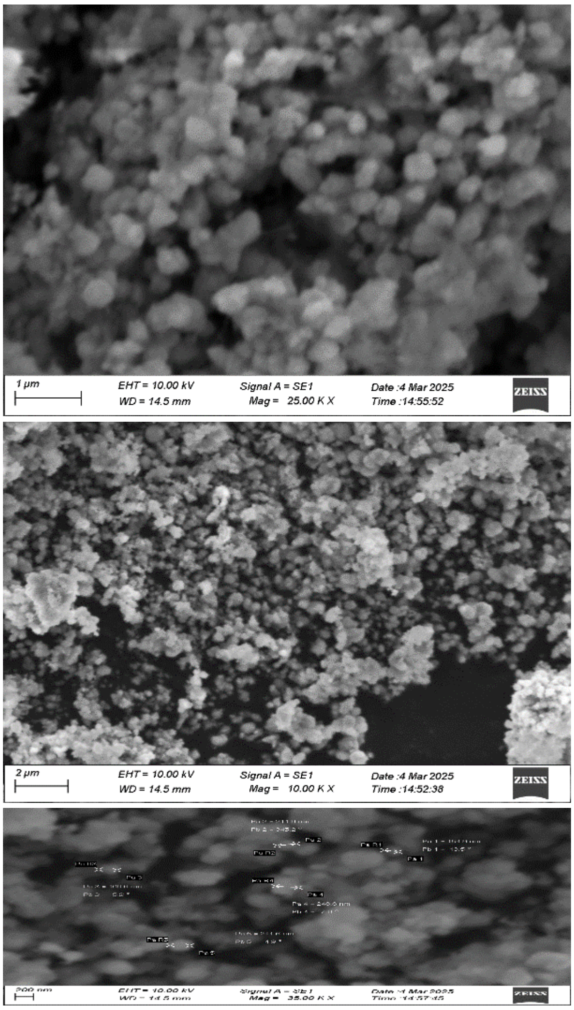


Figure 4. Scanning electron micrographs of biosynthesized MC-AgNPs at multiple magnification levels.

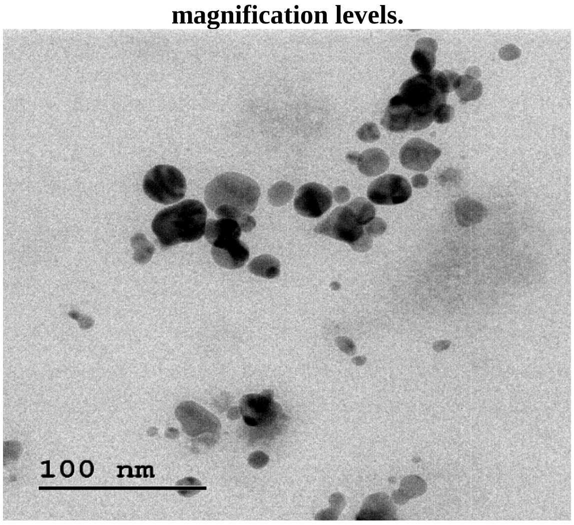


Figure 5. MC-AgNPs imaging using TEM.

3Anti-Inflammatory Activity of Mc-Ag NPs

Inhibition of Protein Denaturation

A progressive, concentration-dependent inhibition of denaturation of proteins was observed with Mc-Ag NPs, attaining 66.45% inhibition at 100 µg/mL. while diclofenac achieved 80.78% inhibition. The IC_{50} value for Mc-Ag NPs was 53.60 ± 2.68 µg/mL, significantly higher than diclofenac (27.85 ± 1.39 µg/mL), indicating moderate anti-inflammatory potential but lower efficacy compared to the standard drug (Fig. 7 A).

Anti-Proteinase Activity-The nanoparticles demonstrated effective proteinase inhibition, recording 70.89% inhibition at 100 µg/mL, whereas diclofenac showed 77.95% at the same dose. The IC_{50} value of Mc-Ag NPs was found to be 36.92 ± 1.76 µg/mL, .compared to 27.18 ± 1.40 µg/.mL for positive control, suggesting that while Mc-Ag NPs exhibit strong anti-proteinase activity, they are slightly less effective than the standard drug. (Fig 7 B)

Anti-Lipoxygenase Activity

The inhibition of the lipoxygenase enzyme by Mc-Ag NPs was dose-dependent, peaking at 65.47% for 100 µg/mL, while indomethacin achieved 79.54% inhibition. The IC_{50} value of Mc-Ag NPs (61.23 ± 2.14 µg/mL) was significantly higher. than that of indomethacin (28.72 ± 1.58 µg/mL), indicating a weaker but still promising lipoxygenase inhibitory potential (Fig. 7 C).

Mc-Ag NPs exhibited notable anti-inflammatory effects across all tested assays, including protein denaturation, proteinase inhibition, and lipoxygenase activity suppression. However, their efficacy remained lower than the respective standard drugs. These results indicate that Mc-Ag NPs possess promising anti-inflammatory properties, highlighting the need for further studies to optimize their therapeutic potential.

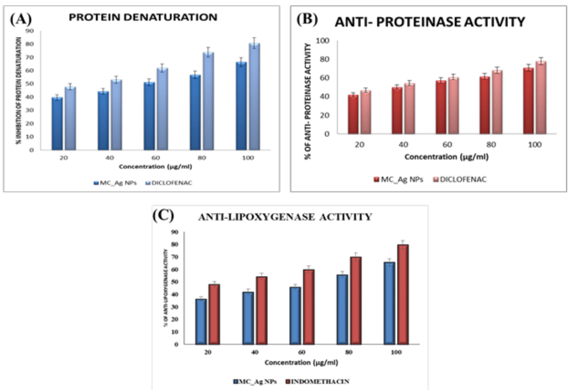


Figure 6. Anti-inflammatory evaluation of MC-AgNPs: (A) Inhibition. of protein denaturation, (B) Anti-.proteinase activity, and (C) Anti-lipoxygenase .activity.

4. DISCUSSION

Inflammation. and redox imbalance are central pathophysiological mechanisms driving to the progression of numerous chronic diseases [19]. Conventional anti-inflammatory therapies, although their use is frequently limited by adverse side effects,, prompting the need for alternative strategies that are both safe and effective [20]. In recent years, green-synthesized nano-particles have appeared as promising therapeutic agents due. to their biocompatibility, multifunctionality, and ability to target multiple disease pathways simultaneously [21], [22]. Silver nanoparticles (AgNPs), in particular, have gained attention for their potent anti-inflammatory and antioxidant activities [16], [23].

In this study, silver nanoparticles were successfully synthesized using the fruit extract of (Mc-AgNPs) *Momordica cymbalaria* through an environmentally benign green synthesis approach. Phytochemical profiling identified several bioactive constituents, including flavonoids, phenols, alkaloids, terpenoids, tannins, and saponins, which likely contributed to the reduction and stabilization of the nanoparticles [24]. Phyto-constituents are well-known for their strong anti-inflammatory and radical scavenging properties, suggesting a synergistic contribution to the Mc-AgNP's biological activity.

ABTS and& DPPH assays were carried- out to demonstrate the anti-oxidant potential of Mc-AgNP's, showed a concentration-dependent increase in free-radical scavenging- activity. While slightly lower than the standard anti-oxidant ascorbic acid, the IC_{50} values confirmed their considerable radical-neutralizing capacity. This ability to attenuate oxidative stress is important, as excessive reactive oxygen species (ROS) not only damage cellular macromolecules but also exacerbate inflammatory responses. The reduction in oxidative load by Mc-AgNPs may, therefore, indirectly limit inflammatory signaling cascades.

The anti-inflammatory assays, including inhibition of protein denaturation, proteinase activity, and lipoxygenase activity, further validated the therapeutic potential of Mc-AgNPs. Protein denaturation, a key event in inflammatory disorders, was significantly inhibited in a dose-dependent manner. Similarly, Mc-AgNPs suppressed proteinase activity, which is responsible for tissue degradation in inflamed regions, and inhibited lipoxygenase activity, an enzyme critical in leukotriene biosynthesis and inflammatory mediator production. Although their efficacy was slightly lower than standard drugs such as diclofenac and indomethacin, Mc-AgNPs still demonstrated strong anti-inflammatory activity, indicating their potential as safer alternative agents.

The observed biological activities can be attributed to multiple mechanisms. The polyphenolic compounds present in *M. cymbalaria* may have acted synergistically with AgNPs to inhibit pro-inflammatory enzymes and cytokine release. Moreover, the nanoscale size and large surface area of Mc-AgNPs could have facilitated greater interaction with target biomolecules, enhancing their bioactivity. Previous studies have also reported that AgNPs can modulate signaling pathways such as NF-κB, thereby down regulating the expression of inflammatory mediators including Tumor Necrosis Factor-α and interleukins [25] [26].

Taken together, the current results demonstrate that Mc-AgNPs possess potent anti-inflammatory and antioxidant activities, making them suitable candidates for the prevention or treatment of inflammation-related conditions. Comprehensive in vivo studies are needed to clarify their underlying molecular mechanisms, evaluate pharmacokinetics, and confirm long-term safety.

5. CONCLUSION

Inflammation and oxidative. stress are key etiological factors in the pathogenesis of several long-term degenerative diseases, such as diabetes [27], cancer [28], and Neurological disorders [29]. The green synthesis. of silver nanoparticles using medicinal herbs extracts has gained noticeable attention. as a promising strategy for disease management due to their biocompatibility and therapeutic potential [30]. In this study, Mc-AgNPs demonstrated significant anti-inflammatory activity by proteinase activity, inhibiting protein denaturation and lipoxygenase activity. Although their efficacy was slightly lower than standard anti-inflammatory drugs, their potential as alternative therapeutic agents is evident. The IC50 values further substantiate their effectiveness in mitigating inflammation. Nevertheless, comprehensive in vivo investigations and mechanistic evaluations using established models such as LPS-induced inflammation, carrageenan-induced paw edema, and cotton pellet granuloma are required to substantiate their pharmacological efficacy and optimize their therapeutic applicability.

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