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Protective Prospect of Green Synthesized Selenium Nanoparticles Using *Jatropha tanjorensis* against Cadmium-Induced Nephrotoxicity in Rats

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ABSTRACT

Cadmium (Cd) is a toxic heavy metal widely distributed in the environment and known to cause severe renal dysfunction through oxidative stress, inflammation, and apoptosis. The present study investigated the protective effects of green-synthesized selenium nanoparticles (SeNPs) using Jatropha tanjorensis leaf extract against cadmium-induced nephrotoxicity in male albino rats. The SeNPs were synthesized via a green, eco-friendly reduction method using ethanolic Jatropha tanjorensis extract and characterized by UV–Vis spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray diffraction (XRD), dynamic light scattering (DLS), and transmission electron microscopy (TEM). The nanoparticles exhibited a mean particle size of 37.67 nm, with absorption maxima at 320 nm, confirming successful synthesis and stability. Forty male rats were divided into eight groups: control, Cd-only, Jatropha tanjorensis extract (JTLE), SeNPs, JTLE-SeNPs, Cd+JTLE, Cd+SeNPs, and Cd+JTLE-SeNPs. Cadmium exposure (0.5 mg/kg BW) for 28 days resulted in significant oxidative stress, marked by elevated levels of malondialdehyde (MDA), lactate dehydrogenase (LDH), and tumor necrosis factor-alpha (TNF-α), alongside reduced activities of antioxidant enzymes—superoxide dismutase (SOD), catalase (CAT), glutathione (GSH), glutathione peroxidase (GPx), and total antioxidant capacity (TAC). Cd exposure also increased Bax gene expression and cadmium accumulation in the serum and kidney tissues. Treatment with JTLE, SeNPs, and particularly JTLE-SeNPs markedly ameliorated these alterations, reducing Cd accumulation, restoring antioxidant balance, and normalizing Bax gene expression to near-control levels. The combined JTLE-SeNPs formulation exhibited the strongest nephroprotective effect. In conclusion, green-synthesized selenium nanoparticles derived from Jatropha tanjorensis demonstrate potent antioxidative, anti-inflammatory, and anti-apoptotic properties that effectively mitigate cadmium-induced renal damage. The findings highlight the therapeutic potential of Jatropha tanjorensis-mediated SeNPs as a sustainable and biocompatible approach to counteract heavy metal-induced nephrotoxicity.

***Keywords*— *Jatropha tanjorensis*, Selenium nanoparticles, Cadmium, Nephrotoxicity, Oxidative stress, Antioxidant, Green synthesis**

I. INTRODUCTION

Heavy metal contamination in the environment has become a growing concern worldwide due to its detrimental effects on human health. Cadmium (Cd), a non-essential toxic metal, is among the most pervasive pollutants, with sources ranging from industrial activities to agricultural practices. Cadmium pollution is as a result of Anthropogenic (human-caused) activities such as smoking, mining and metal scavengers [1]. Other sources of pollution includes contaminated food water and beverages. Due to its high toxicity and non-degradable nature, cadmium is more persistent and hence has long-term impacts on the ecosystem. The presence of excessive quantities of Cd in the environment have negative consequences on various omics (microbiome, transcriptome, proteome and metabolome) which in turn affect overall health and disruption of the biota ([2]; [3], and [4]). Consequently, humans and other organisms exposed to cadmium pollution are at high risk, as it can cause a debilitating and a wide range of health disorders, including perturbed genomics, proteomes, metabolites (multi-omics) which subsequently led to neurotoxicity, hepato-renal nephrotoxicity, dysfunction, erectile dysfunction as well as oxidative damage, DNA damage, thyroid and haemato-pathological disorders ([5]; [6]; [7]). Prolonged exposure to cadmium has been linked to severe nephrotoxicity, making it imperative to explore effective strategies for mitigating its harmful impact on renal function [8]. The accumulation of these metals is a complex interaction of edaphic and environmental factors [9].

In recent years, nanotechnology has emerged as a promising avenue for combating the toxic effects of heavy metals. Among the various nanomaterials investigated, selenium nanoparticles (SeNPs) have garnered significant attention for their unique physicochemical properties and potential health benefits. Selenium, an essential trace element, is known for its antioxidant properties and its role in protecting cells from oxidative stress [10].

Moreover, the synthesis of selenium nanoparticles through green and eco-friendly methods has gained prominence in the quest for sustainable solutions to environmental challenges. Plant extract are effective precursors for the production of metallic nanoparticles [11]. Selenium nanoparticles (SeNps) show superior activity to elemental selenium (Se) because of its antimicrobial properties at low concentration. SeNps display exceptional bioavailability, low toxicity and potent antioxidant and antibacterial effects ([12], [13]). A simple and rapid method for green synthesized metal nanoparticles using plant extract as reducing and capping agents is preferred [14]. Such synthesis is green, eco-friendly, bio-reductive, one step, cost effective and requires shorter reaction time and fewer solvents [15]. Green selenium nanoparticles have been synthesized using various plants such as Citrus lemon [16], and, Moringa oleifera [17], to mention but a few.

Jatropha tanjorensis belong to the family of Eupherbiaceae, which has been consumed as leafy vegetable and as medicinal plant in Nigeria. The choice of J. tanjorensis is because of it show of hematological, antimalarial, antimicrobial, hypoglyceamic, hypolipidermic and antihypertensive activities [18]. Nutrition analysis of J. tanjorensis revealed that it is nutritionally rich in vitamin A, B1 and C .and possess antioxidant properties that could effectively ameliorate oxidative stress [19]. [20] documents the traditional uses of *Jatropha tanjorensis* in treatment of malaria, diabetes, and hypertension. However, specific quatitative evidence for antihypertensive and hypolipidemic activities are limited. This study is aimed at synthesizing and characterizing green selenium nanoparticles with an ethanolic *Jatropha tanjorensis* leaf extract, and to study the in vivo protective outcome of green synthesized particle as treatment for nephrotoxicity caused by cadmium in male rats..

II. MATERIALS AND METHODS

A. Collection of samples

The Jatropha tanjorensis leaves (JTL) were freshly obtained from the forest of The Federal Polytechnic Ado-Ekiti, Ekiti State, Nigeria and authenticated by a Herbarium and taxonomist Mr Felix Olorunfemi Omotayo of Ekiti State Univerty Ado-Ekiti with herbarium No. UHAE 2026019 dated 25th Feb.2025. The leaves were air- dried at room temperature for four weeks. The crispy leaves were ground into powder using high-speed milling device. Three hundred grams (300g) of powder was extracted in absolute ethanol for 48 hours then filtered twice through filter paper with 2 µm pore size. The resultant extract was concentrated and evaporated to dryness using a rotary evaporator at 40–45 ^{0}C. The residual yield of JTL extract was 17.8 g/300 g of dried powder. The obtained extract was kept at 4^{0}C until use.

B. Synthesis of selenium Nanoparticles (SeNPs)

0.5 M sodium hydroxide (NaOH) solution was prepared by dissolving 20 g of sodium hydroxide pellets in 1 L of deionized water which was stirred to dissolve completely. 5 g of sodium selenite (Na_2SeO_3) was weighed out and was added to 100 mL of deionized water in a 250 mL flask and was stirred until the sodium selenite is completely dissolved. And 10 mL of 0.5 M sodium hydroxide solution was added slowly to the flask containing the sodium selenite solution, while stirring continuously with a magnetic stir bar. The pH of the solution with a pH meter or indicator paper was carefully monitored and adjusted as necessary to maintain a pH of around 10-11.

A solution of 0.02 M sodium borohydride was prepared by dissolving 1.2 g of sodium borohydride in 100 mL of deionized water which was stirred to dissolve completely. The 0.02 M sodium borohydride solution

was added to the flask containing the sodium selenite solution, while stirring continuously with a magnetic stir bar. The reaction mixture turned yellow or orange as the reduction of selenite ions to selenium nanoparticles occurs. This was Stirred Continuously for 2 hours at 70 – 90 OC

After the reaction was completed, 5mL of ethanol was added to the flask to stop the reaction was Stirred for an additional 30 minutes to ensure complete mixing. The reaction mixture was transferred into a centrifuge tube and was centrifuged at 5000 rpm for 15 minutes to separate the selenium nanoparticles from the solution. The supernatant was then discarded, and the selenium nanoparticles were washed several times with deionized water to remove any remaining impurities.

A few drops of hydrochloric acid were added into the selenium nanoparticle suspension to stabilize the nanoparticles and the pH was adjusted to around 2-3. The selenium nanoparticle suspension was Stored in a dark, cool place until ready for use.

C. Synthesis of Jatropha Tanjorenesis-Mediated Leave Extract Selenium Nanoparticles (JATLE-SeNPs)

The green synthesis of selenium nanoparticles (SeNPs) nanoparticles using plant extract was performed by a bottom-up process approach and reduction technique by a single pot system revamping the procedure described by [11].

0.5 g of sodium selenite was dissolved in 50 mL of deionized water in a beaker. 0.2 g of ascorbic acid was dissolved in 50 mL of deionized water in a separate beaker. The Jatropha tanjorenesis extract was prepared by adding 10 g of dried and powdered leaves to 100 mL of distilled water in a flask. And the mixture was stirred under reflux for 30 minutes, and then the extract was filtered using a filter paper. 10 mL of the Jatropha tanjorenesis extract was added to the sodium selenite solution and the mixture was stirred for 10 minutes. 1 mL of the ascorbic acid solution was added to the mixture and then stirred for an additional 10 minutes. 1M of NaOH solution was added to the mixture until the pH reaches 10. The color of the mixture then changes from clear to yellow-green. And the mixture was placed on a magnetic stirrer and stirred for 2 hours.

A UV-Vis spectrophotometer was used to monitor the absorption spectrum of the mixture at different time intervals until the maximum absorption peak is reached, which is around 320 nm. The mixture was centrifuged at 10,000 rpm for 20 minutes to separate the green selenium nanoparticles. The supernatant was discarded, and the nanoparticles were washed several times with deionized water to remove any impurities.

The nanoparticles were dried in a kiln at 150°C for 1 hours and then the nanoparticle was again weighed to determine the yield. The resulting green selenium nanoparticles were characterized using various techniques such as transmission electron microscopy (TEM), X-ray diffraction (XRD), and Fourier-transform infrared spectroscopy (FTIR).

D. Animals and study protocol

Twenty (20 weeks +4 days) old male albino rats, with average BWs of 120–185 g was housed in Animal house, School of Science and Computer studies, Department of Science Technology, Federal polytechnic Ado-Ekiti, Ekiti State Nigeria. The Federal polytechnic Ado-Ekiti, Ekiti State animal care and use committee guideline was strictly followed. The animal ethical approval No.S/2029 dated April, 20th 2025 was obtained from the committee. All animals were housed in stainless steel cages and acclimated at 25^{O}C-27^{O}C, a relative humidity 30–50% and a 12-hour light-dark cycle. Rats were fed a standard rat pellet diet and allowed free access to food and water throughout the experimental period. All animals were cared for humanely according to the conditions stated in the Guide for the Care and Use of Laboratory Animals of the National Academy of Science (NAS), published by the National Institute of Health. The study also followed National Institutes of Health's recommendations for the care and use of laboratory animals, and adequate procedures were made to ensure that the animals were not subjected to excessive pain and discomfort during the study. Forty (40) Rats were randomly allocated into eight (8) equal groups (n =5).

(i) Experimental design and dose administration

Animals were randomly allocated into eight groups of five rats each and administered orally in the following ways:

Group I: control rats received 1mL of 0.9% deionized water.

Group 11: negative control received Cadmium (0.5mg/kg BW)

Group III: rats received JTLE (800 mg/kg BW).

Group IV: rats received SeNPs (0. 25 mg//kg BW).

Group V: rats received JTLE-SeNPs (0. 25mg//kg BW).

Group VI: rats received Cd (0.5 mg/kg BW) + JTLE (800 mg/kg BW).

Group VII: rats received Cd (0.5 mg/kg BW) + SeNPs (0.25 mg/kg BW).

Group VIII: rats received Cd (0.5 mg/kg BW) + JTLE-SeNP (0.25 mg/kg BW).

Gavage was day after day for 28 days, using a feeding needle. All animals were carefully observed throughout the experiment for any signs of intoxication or mortalities.

(ii) Blood and tissue sample collection

Twenty-four hours after the last treatment, the over-night-fasted rats were weighed and anesthetized with ketamine at the end of the dosing period. 2mL blood samples were collected from the rats via cardiac puncture. Blood was collected using a BD Vacutainer PST II Tubes, left for coagulation, then centrifuged at 322 x g for 20 min for serum separation. Sera were preserved at−20 °C until biochemical analysis. Kidney, liver and testis tissues were collected and divided into four portions. Thirty (30mg) was washed in cold saline and mix with RNA shield for storage before RNA extraction.

E. RT-PCR preparation of homogenate for apoptosis and stress related gene expression of Bax

RT-PCR analysis of apoptosis and stress related gene expression of Bax was analyzed using Ultra Turrax homogenizer in a cold solution of 0.015 M $NaHPO_4$ buffer and 0.15 M NaCl (1:6 w/v; pH 7.8) for homogenate preparation. The procedure described by [21], will be followed.

F. Serum and tissue cadmium analysis

One mL/mg of serum/tissues were digested with 10 mL analytical grade H_2O_2 (hydrogen peroxide) and HNO_3 (nitric acid) (1:1) in a Teflon beaker. The solution was then made up to 25 mL with distilled water. Hg concentration in samples were analysed with thermal decomposition couped atomic absorption spectrophotometry (AAS) [22]. All analysis were investigated in triplicate. Manual and internal blanks were deionized water and empty cuvette respectively and they were run intermittently during analysis to eradicate cadmium residues in the catalyser. We repeatedly measure blank until the results were consistently less than 0.02 µg cadmium which was the equipment's detection limit (Blank was run to check for background contaminants by the reagents and apparatus used). Both internal and manual blanks were run and recorded at the initial and final stages of all analysis. A certified and accurate reference material was used to confirm sensitivity and specificity of the analytical procedure.

G. Enzyme-linked immunosorbent assay (ELISA) for Inflammatory Cytokines Assessment of TNF-α

Level of TNF-α was determined using a standard ELISA kit (Elabscience Biotechnology Co., Ltd, USA). 100 µL of the standard and sample was added to each well, and incubated for 90 min at 37˚C. The liquid was then removed. 100 µL of Biotinylated Detection Ab. Solution was added and incubated for 1 hour at 37˚C. 3.8.0 Total RNA Extraction Total RNA was extracted from 0.1 to 0.2 g of rat kidney tissues by using Total RNA was extracted using Quick-RNA™ Miniprep Kit (Zymo Research) as per manufacturer's protocol. The quality and quantity of the isolated RNA were assessed using the 260/280 nm absorbance ratio (1.8–2.0 indicates a highly pure sample) using NanoDrop 2000c spectrophotometer (USA). Total RNA was used immediately.

H. Synthesis of cDNA and RT qPCR Quantification

cDNA synthesis was performed using the ProtoScript II First Strand cDNA Synthesis Kit (New England Biolabs Inc). 2x master mixes were prepared using 2 µl 10x Reverse Transcription buffers, 0.8 µL 25x dinucleotide triphosphate (dNTP) mix (100 mM), 2 µL 10x Reverse Transcription random primers, and 1 µL MultiScribe Reverse Transcriptase. For a 20 µL reaction mixture under the following conditions: 5.8 µL master mix; 2 µL of 2 µg RNA sample; 12.2 µL nuclease free water. For analysis of gene expression, the real-time RT-PCR was performed in an Chai Real-Time PCR thermocycler with touchscreen (Chai Inc U.S.A) using Chai Green qPCR Master (Chai Inc U.S.A) following the manufacturer's instructions and procedure described by [21].

I. Analyses of antioxidant biomarkers

Superoxide dismutase (SOD), glutathione peroxidase (GPx), malondialdehyde (MDA), catalase (CAT), and glutathione concentrations (GSH) were assessed using serum samples and the analysis kits as instructed by the manufacturer (Nanjing Jiancheng Bioengineering Institute, Nanjing, China). Mobi Microplate spectrophotometer (Sunnyvale, CA) was used for all analyses.

J. Statistical analysis of data

All obtained raw data were analyzed using a one-way analysis of variance (ANOVA) by using the SPSS 25.0 computer program followed by post hoc Tukey HSD multiple comparisons to determine the statistically significant variations between the various parameters in the experimental replicates. A p-value of < 0.05 was considered statistically significant. Data were shown as means ± SD. All graphs were generated using GraphPad Prism 8 (GraphPad Software Inc., San Diego, 189 CA, USA).

III. RESULTS

All experimental groups showed no altered clinical observations or behavioral alterations except for Cd-exposed rats displayed a decreased activity, food consumption, and body weights with frequently increased urination when compared with the other experimental groups. Meanwhile, rats from the Cd-JTLE, Cd-SeNP and Cd-JTLE-SeNP groups were clinically normal and did not exhibit any signs of toxicity.

Table 1: Primer sequence

S/N	Gene	Forward (5–3′)	Reverse (5–3′)
1	Bax	CGAATTGGCGATGAACTGGA	CAAACATGTCAGCTGCCACAC

Figure 1: Green synthesized SeNPs

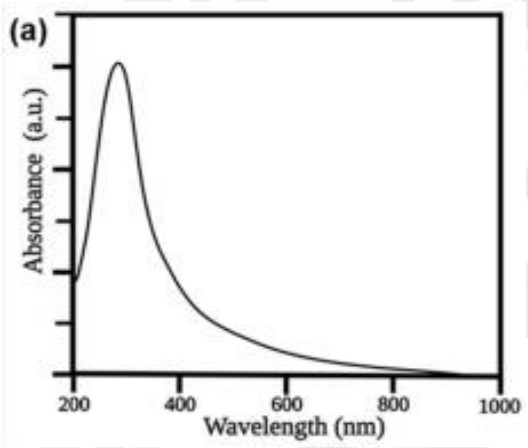

Figure 2: The UV–visible spectrum

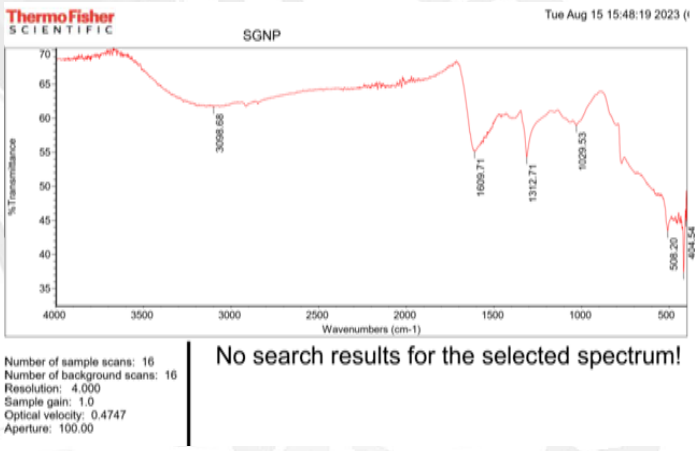

Figure 3: The FTIR spectra of the green Se-NPs

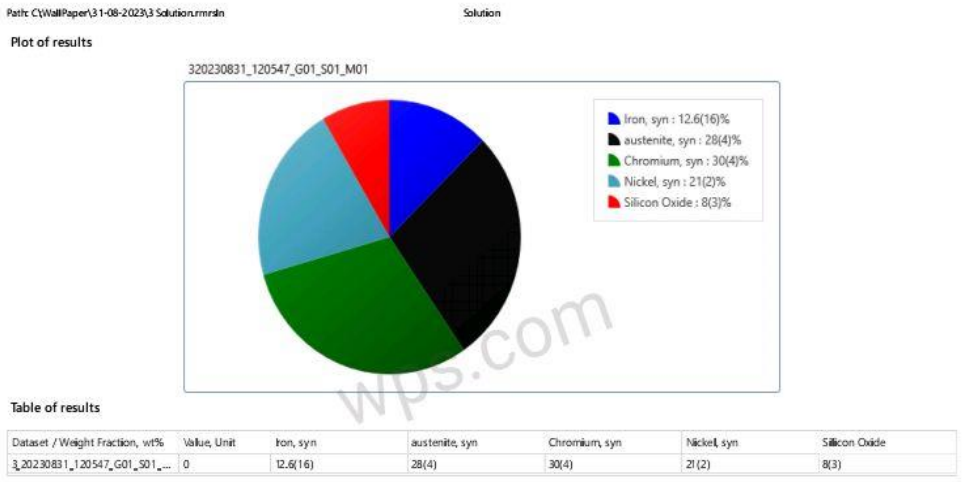

Figure 4: XRD Results of SeNps

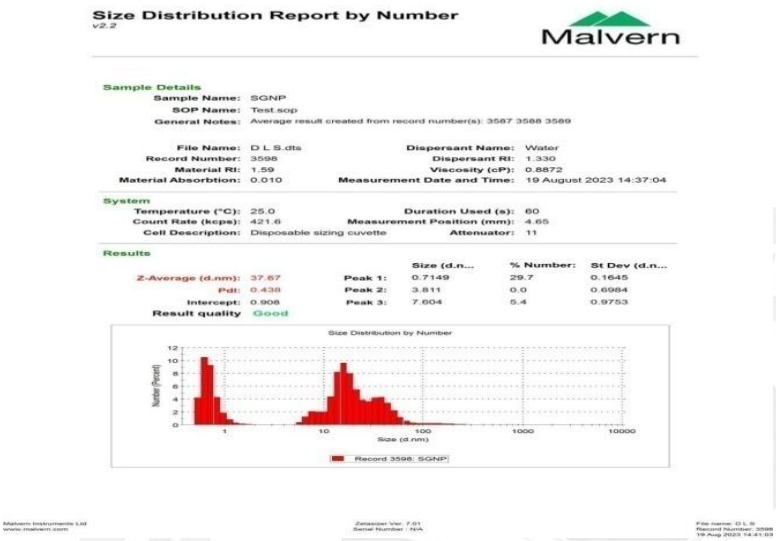

Figure 5: DLS of SeNPs

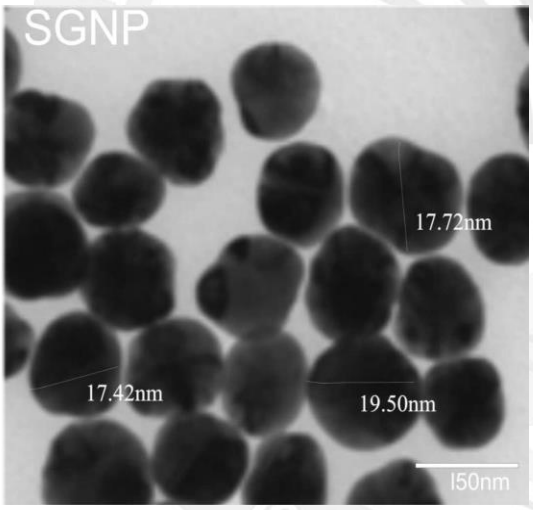

Figure 6: TEM Analysis

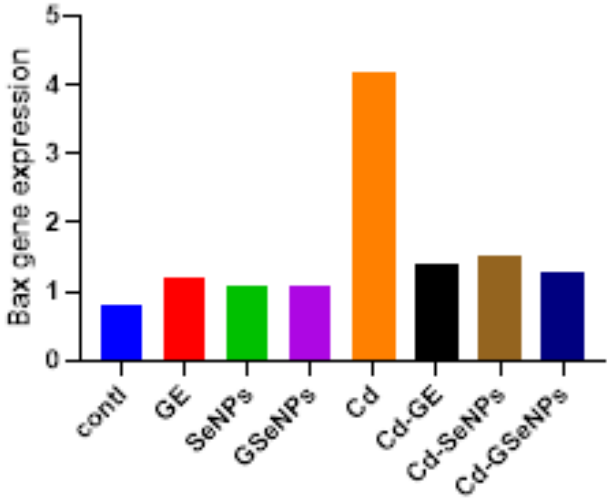

Figure 7: Bax Gene Expression in tissues
Note GE = JTLE, GSeNPs = JTLE-SeNPs

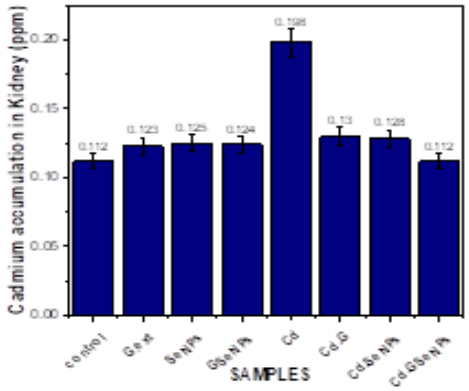

Figure 8: Cadmium accumulation in kidney

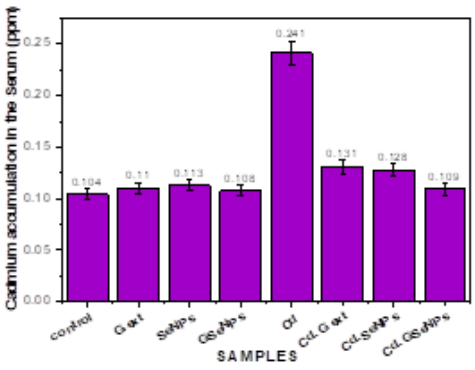

Figure 9: Cadmium accumulation in serum

Table 2: Oxidative stress

	Control	JTLE	SeNP	JTLE-SeNP	Cd	Cd-JTLE	Cd-SeNP	Cd-JTLE-SeNP
MDA (uM)	1.761±	3.993±	3.675±	3.831±	7.267±	3.104±	2.906±	2.514±
	0.219	0.320	0.320	0.253	0.411	0.213	0.234	0.241
SOD (U/mL)	2.822±	1.876±	1.617±	1.711±	0.563±	1.461±	1.517±	2.351±
	0.210	0.125	0.130	0.083	0.046	0.231	0.161	0.213
CATALASE (umol/ml/mins)	8.214±	4.505±	4.822±	4.493±	2.905±	4.987±	5.433±	6.418±
	0.360	0.351	0.316	0.300	0.239	0.397	0.341	0.395
GSH (mM)	0.344±	0.175±	0.195±	0.185±	0.032±	0.181±	0.202±	0.271±
	0.028	0.018	0.015	0.017	0.021	0.052	0.016	0.012
GPX (U/L)	89.570±	67.643±	69.624±	68.465±	43.103	68.231±	67.154±	79.817±
	9.064	4.147	5.074	4.416	2.862	4.284	5.721	4.605
TAC (mM/g tissue)	1.165±	0.705±	0.710±	0.739±	0.326±	0.743±	0.694±	0.971±
	0.022	0.042	0.020	0.040	0.024	0.021	0.043	0.046
LDH (U/L)	46.446±	73.643±	70.091±	7I.579±	187.324±	73.624±	76.151±	57.488±
	6.745	4.128	0.586	2.749	9.864	0.632	2.766	6.462
TNF-α (pg/ml)	18.423±	35.552±	33.140±	36.908±	75.541±	27.823±	25.935±	22.612±
	3.463	0.538	3.246	1.773	2.915	0.421	2.540	1.086

Mean ± SEM values oxidative stress across groups

IV. DISCUSSION

Selenium nanoparticles (SeNPs) were successfully synthesized through reduction processes, with the UV-Visible spectrophotometry revealing distinctive spectroscopic characteristics. The addition of JTLE (Jatropha leaf extract) filtrate triggered the reduction of Se, producing nanoparticles characterized by a distinctive brick-red color (Figure 1) resulting from surface plasmon resonance stimulation [23].

A. Selenium nanoparticles synthesis and characterization

The UV-Visible spectroscopic analysis specifically showed an absorbance peak at 320 nm (Figure 2), which is a unique spectroscopic marker for Se-NPs. This finding aligns with other studies demonstrating that SeNPs typically exhibit characteristic surface plasmon resonance bands, often in the 260-350 nm range ([24], [25]). The brick-red color and specific absorbance peak serve as reliable indicators of successful SeNPs formation, providing a straightforward method for preliminary nanoparticle identification.

The FTIR spectra of green synthesized Se-NPs revealed multiple functional groups critical to nanoparticle formation and stabilization. The spectra showed key peaks: a 660 cm−1 peak indicating Se–O–Se bond stretching, and additional peaks between 3500-3000 cm−1, 1609.71 cm−1, 1312.71 cm−1, and 1029.53 cm−1 representing O–H, C=O, C–C, and C–N bond vibrations, respectively (Figure 3) . These functional groups, including phenolic hydroxyl groups, phenolic acids, terpenoids-phenols, and aliphatic amines, play a crucial role in reducing Se2- ions and acting as capping agents for the nanoparticles. The presence of these diverse functional groups demonstrates the complex chemical interactions underlying green selenium nanoparticle synthesis [26].

X-ray diffraction (XRD) analysis consistently confirms the high crystalline nature of green-synthesized selenium nanoparticles (Se-NPs) across multiple research studies. The specific XRD peaks at 2θ values of 28°, 33°, 35°, 41°, 49°, 54°, 57°, 62°, and 64° correspond to crystallographic planes (012), (110), (113), (202), (024), (116), (018), (214), and (300), (figure 4), indicating well-structured nanoparticles ([27],[28]). XRD have been used to validate the crystalline structure of Se-NPs synthesized through various green methods, including plant extracts and bacterial processes [2]. The consistent detection of these diffraction peaks across different synthesis techniques suggests a robust method for confirming the crystallographic integrity of selenium nanoparticles.

Dynamic Light Scattering (DLS) is a powerful technique for measuring nanoparticle size by analyzing light scattering from Brownian motion of particles in suspension. The technique involves illuminating a sample with a laser beam and monitoring intensity fluctuations caused by particle movement [29]. By applying an autocorrelation function, researchers can calculate the hydrodynamic diameter of particles [30]. In this specific analysis, the particle distribution shows an average size of 37.67nm, with a size range from 0.7-7.6nm. Particles at 0.7nm predominating the sample. The JTLE-SeNPs dispersant rate was 1.59, with an absorption speed of 0.010 (Figure 5). This report aligns with the report of [31]. The method provides a rapid, non-destructive approach to characterizing nanoparticle sizes, offering insights into particle dynamics and distribution with high precision.

Transmission Electron Microscopy (TEM) show Particle sizes, shapes and distributions of the green nanoparticles. It is an exceptionally analytical tool for characterizing quantum wells and nanostructures with unprecedented precision. The report shows the sizes, shape (spherical) and the distributions of the nanoparticles (figure 6). The results were in agreement with the work of [32], who demonstrates TEM's ability to examine materials at microscale to atomic levels, providing critical insights into structural properties. The report also was supported by the work of [33], who showed that TEM can reliably determine dot shape, size, and density, while, [34] confirms its capability to reveal "real geometry of the structure" including width, height, and distribution. [35] further emphasizes TEM's versatility, noting that it can analyze "size, shape, arrangement and chemical composition" of nano-sized materials. The evidence spans multiple studies across semiconductor and nanomaterial research, consistently highlighting TEM's critical role in material science characterization.

B. Oxidative stress in Kidney parameters

The increase in the activities of MDA, LDH and TNF-α and decrease in the activities of CAT, GSH, GPx and TAC in rats that were exposed to Cd, respectively is an indication of oxidative stress initiation. Cadmium exposure significantly disrupts oxidative stress biomarkers, with notable increases in inflammatory markers (MDA, LDH, TNF-α) and decreases in protective enzymes (CAT, GSH, GPx, TAC) (Table 2). The result was in agreement with the report of [40], who asserts that nephrotoxicity result in oxidative stress via generation of oxygen free radicals. It went further to confirm the report of [43] who assert that Cd exposure could increase renal tubular injury via triggering oxidative stress and disturbing homeostasis of trace elements in duck, along with Cd-induced nephrocyte apoptosis through accumulation of renal MT and GSH thereby causing histopathological changes in birds. Results also affirm the works of [5]; [6]; and [7], who also reported that cadmium accumulation in human body lead to neurotoxicity, hepato-renal damage, erectile malfunction, oxidative damage, and DNA damage,

The research reveals that cadmium induces substantial oxidative stress in rat serum and kidney homogenates which was in agreement with the report of [44]. Specifically, cadmium induction leads to significant increases in inflammatory markers and decreases in antioxidant enzyme activities. Importantly, the administration of Cd-JTLE, Cd-SeNPs, and Cd-JTLE-SeNPs demonstrated a significant reversal of these effects, with the Cd-JTLE-SeNP treatment showing the most prominent protective impact (Table 2), This again align with the report of [15] who affirms that green selenium nanoparticles, can effectively mitigate mecury-induced oxidative stress.

V. CONCLUSION

Experimental findings revealed that cadmium exposure led to increased accumulation of Cd in the kidney and serum, accompanied by oxidative stress, lipid peroxidation, apoptosis (via Bax gene upregulation), and deterioration of antioxidant biomarkers (SOD, CAT, GSH, GPx, TAC). However, treatment with Jatropha tanjorensis extract, SeNPs, and particularly the combined JTLE-SeNPs formulation, significantly mitigated these effects. Further studies should advance toward preclinical and clinical trials to evaluate the safety, pharmacokinetics, and therapeutic efficacy of Jatropha tanjorensis-mediated SeNPs in humans exposed to cadmium or other nephrotoxic agents.

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