

Protective Effects of Baobab (*Adansonia Digitata* L.) Fruit Extract on Lead-induced Nephrotoxicity in Wistar rats (*rattus norvegicus*).

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Abstract

Lead acetate is a known nephrotoxic agent that induces oxidative stress and renal damage. In this study, twelve (12) Wistar rats were randomly divided into four groups each having three (3) rats: A control group, a group administered only lead acetate, and three treatment groups given varying doses (low, medium, and high) of baobab (*Adansonia digitata* L.) fruit extract after lead exposure. The study spanned 21 days, during which biochemical, histological, and morphological changes in the kidneys were assessed. Results showed that lead exposure caused renal damage, as evidenced by increased levels of serum creatinine and urea, and distorted kidney histoarchitecture. However, rats treated with baobab fruit extract showed a dose-dependent improvement in renal function and tissue architecture. These findings suggest that baobab fruit extract has nephroprotective effects, likely due to its antioxidant properties.

Keywords: *Adansonia digitata*, Lead-acetate, Kidney, Wistar rat, Anti-oxidant

INTRODUCTION

The kidneys are vital organs of the body that maintain fluid and electrolyte balance, filter waste, and regulate blood pressure (Juffre & Gumz, 2024). However, exposure to nephrotoxic chemicals such as lead (Pb) has been linked to significant kidney damage and dysfunction (Orr & Bridges, 2017). Oxidative stress has been identified as one of the primary causes of lead-induced kidney injury. Lead disrupts the balance between the production of reactive oxygen species (ROS) and antioxidant defence mechanisms, leading to lipid peroxidation, DNA damage, and protein denaturation in kidney cells. Therefore, one strategy to reduce this damage is to use antioxidants as a therapeutic means (Flora *et al.*, 2018).

Natural antioxidants have garnered interest for their ability to reduce nephrotoxicity. Rich in antioxidants, vitamins, and polyphenols (Al-Waili *et al.*, 2017), the fruit of the medicinal plant baobab (*Adansonia digitata* L.) is well recognised for its ability to protect against oxidative stress-induced damage (Althwab *et al.*, 2019). Because of industrial exposure and environmental contamination, lead-induced nephrotoxicity continues to be a global health problem. Renal fibrosis, tubular degeneration, and glomerular dysfunction are the consequences of chronic lead exposure, which impairs kidney function (Gopalakrishnan, 2025). The increasing prevalence of environmental lead exposure and its associated renal complications necessitate the exploration of alternative protective agents. Baobab fruit has

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been widely used in traditional medicine for its therapeutic benefits, including antioxidative and anti-inflammatory effects (Badu *et al.*, 2025). Investigating its nephroprotective potential will provide scientific evidence supporting its use in mitigating kidney damage caused by nephrotoxic agents.

The kidneys are vital excretory and regulatory organs located retroperitoneally in the upper abdominal cavity, on either side of the vertebral column between T12 and L3. Each adult kidney measures about 11 cm long, 6 cm wide, and weighs about 120–150 g. It is encapsulated by a fibrous renal capsule and surrounded by adipose tissue, which provides protection (Moore & Dalley, 2018). The interstitial cells, blood vessels, and glomerular basement membrane are targets of toxic injury (Gaut & Liapis, 2021).

Lead (Pb) is a heavy metal that accumulates in renal tissues and causes cellular damage via: oxidative stress (leads to lipid peroxidation and mitochondrial dysfunction); DNA damage (causes apoptosis of renal tubular cells); Inflammatory response (increases cytokines like TNF- α and IL-1 β); Glomerular injury (reduces glomerular filtration and induces sclerosis); Histopathological changes which include (tubular epithelial degeneration, interstitial fibrosis, glomerular atrophy and vascular congestion (Sanchez, 2018; Balali-Mood *et al.*, 2021).

Natural products have gained attention for managing oxidative and inflammatory renal injuries. Compounds such as flavonoids, saponins, and phenolics from medicinal plants have been shown to scavenge free radicals, modulate immune response, and repair tissues (Tungmunthum *et al.*, 2018) The Baobab tree is native to Africa and grows up to 25 meters tall with a massive trunk. It is drought-resistant and can live for hundreds of years. The fruit is a large, ovoid capsule containing seeds embedded in a dry, powdery pulp. Rich in vitamin C, potassium, calcium, and polyphenols (Dharani, 2019). Baobab fruit contains vitamin C (boosts antioxidant defense); Polyphenols (anti-inflammatory and anti-apoptotic); Flavonoids (free radical scavengers); Tannins and saponins (protect cell membranes and proteins). These constituents have been shown to reduce malondialdehyde (MDA) levels and increase antioxidant enzymes like superoxide dismutase (SOD) and catalase (CAT), protecting tissues from oxidative injury (Otong *et al.*, 2022).



Plate I: Pictorial Representation of a Baobab (*Adansonia digitata L.*) fruit

MATERIALS AND METHODS

Materials

Lead acetate trihydrate [$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$], experimental animals, distilled water, plant extract, 10% formalin, ethanol, xylene, paraffin wax, H&E stains.

Study area

The experiment was carried out in the Animal House and Histology Laboratory of the Department of Anatomy, Faculty of Basic Medical Sciences, Bayero University Kano.

Research design

This study adopted a randomized, controlled, in vivo laboratory-based experimental design. Adult male Wistar rats were randomly assigned into four experimental groups and subjected to different treatment protocols to evaluate histological alterations in renal tissues following lead-induced nephrotoxicity and subsequent treatment with Baobab fruit extract.

Experimental animals

A total of twelve (12) healthy adult male Wistar rats weighing between 90 and 200 g were used for this study. The rats were housed in clean, well-ventilated polypropylene cages under standard laboratory conditions, with a temperature of 22–25°C, relative humidity of 50–60%, and a 12-hour light/dark cycle. They were provided with standard rat chow and clean drinking water *ad libitum*. All animals were allowed to acclimatise to the laboratory environment for seven (7) days before the commencement of the experiment.

Ethical considerations

Ethical approval for this study was obtained from the Animal Care and Use Research Ethics Committee (ACUREC) of Bayero University, Kano, under the Directorate of Research, Innovation and Partnership (DRIP). All procedures involving experimental animals were conducted in strict accordance with the *Guide for the Care and Use of Laboratory Animals* published by the National Institutes of Health (NIH, 2011), with every effort made to minimize animal pain, stress, and discomfort throughout the experimental period.

Plant Collection and Preparation

Mature fruits of *Adansonia digitata* L. (Baobab) were collected from their natural botanical habitat in Kano State, Nigeria. The plant material was authenticated by a qualified botanist in the Department of Plant Biology, Bayero University Kano, and a voucher specimen was deposited in the departmental herbarium for future reference.

Extraction Process

The collected Baobab fruits were manually cracked open to separate the dry pulp from the seeds. The pulp was air-dried under shade at room temperature for a period of 7–10 days and subsequently pulverized into a fine powder using a mechanical grinder.

Extraction method

Aqueous maceration was done by soaking 100 g of powdered pulp in 1000 ml of distilled water for 48 hours with intermittent shaking. The mixture was filtered using muslin cloth and Whatman No.1 filter paper. The filtrate was concentrated using a rotary evaporator at 40°C and stored in a refrigerator at 4°C until use (Mulatu, 2020).

Experimental Groupings and Treatments

The rats were randomly divided into four groups (n=3 per group):

Group I (Control): Received distilled water (2 mL/kg/day) orally for 21 days.

Group II: Received lead acetate (100 mg/kg body weight) orally for 21 days.

Group III: Received Baobab fruit extract (200 mg/kg body weight) for 21 days.

Group IV: Received lead acetate (100 mg/kg) and Baobab fruit extract (200 mg/kg body weight) for 21 days.

Dosage selection was based on prior toxicological and phytomedicinal studies confirming safety and efficacy (Jalali *et al.*, 2025).

Induction of nephrotoxicity

Lead-induced nephrotoxicity was achieved through oral administration of lead acetate at 100 mg/kg body weight daily for 21 days. This dosage is known to induce sub-chronic renal damage without causing acute mortality (Innih & Ubhenin, 2021).

Assessment of kidney function

At the end of the experimental period, the animals were anaesthetized and blood samples were collected via cardiac puncture. The blood samples were allowed to clot and centrifuged to obtain serum for biochemical analysis. Renal function was assessed by measuring serum creatinine (SCr) and blood urea nitrogen (BUN) levels, which are established indicators of glomerular filtration efficiency. Serum electrolyte levels, including sodium (Na⁺), potassium (K⁺), and chloride (Cl⁻), were also analyzed to evaluate possible electrolyte imbalances and tubular dysfunction associated with renal injury.

Histological Analysis

Following blood collection, the kidneys were carefully excised, cleared of adherent tissues, and weighed. The organs were then fixed in 10% neutral buffered formalin for histopathological evaluation. Fixed kidney tissues were processed using standard histological techniques, embedded in paraffin wax, and sectioned at a thickness of 5 µm using a rotary microtome. The sections were stained with hematoxylin and eosin (H&E) and examined under a light microscope to assess histomorphology alterations in renal architecture.

Data Analyses

Data were expressed as mean ± standard error of estimate (SEE). One-way ANOVA followed by Tukey's post-hoc test was used to compare groups. A p-value of <0.05 was deemed statistically significant. The analyses were done using SPSS version 20.

RESULTS

Table 1: Comparison of the serum creatinine level of each experimental group

Groups	Serum Creatinine (mg/dL)
Control (I)	0.72 ± 0.05
Lead-exposed (II)	1.45 ± 0.10*
Baobab extract only (III)	0.68 ± 0.04
Lead + Baobab extract (IV)	0.84 ± 0.06#

* Significant increase compared to control (p<0.05)

Significant reduction compared to lead-only group (p<0.05)

Table 1 showed Serum creatinine levels differed significantly among the experimental groups (p < 0.05). Rats exposed to lead acetate showed a significant increase in serum creatinine compared with the control group, indicating impaired renal filtration. Administration of baobab extract alone did not significantly affect serum creatinine levels relative to control. However, co-administration of baobab extract with lead acetate resulted in a significant reduction in serum creatinine levels compared with the lead-exposed group, suggesting a renoprotective effect of the extract.

Table 2: Comparison of the blood urea nitrogen (BUN) level of each experimental group

Groups	BUN (mg/dL)
Control (I)	18.6 ± 1.2
Lead-exposed (II)	34.2 ± 2.1*
Baobao extract only (III)	17.9 ± 1.0
Lead + Baobab extract (IV)	21.3 ± 1.5#

* Significant increase compared to control (p<0.05)

Significant reduction compared to lead-only group (p<0.05)

One-way ANOVA revealed a significant difference in blood urea nitrogen (BUN) levels (Table 2) among the experimental groups (p < 0.05). Post-hoc analysis showed that the lead-exposed group had a significantly higher BUN level compared with the control group, indicating impaired renal function. Administration of baobab extract alone did not significantly alter BUN levels compared with control. However, co-treatment with baobab extract significantly reduced BUN levels relative to the lead-exposed group, suggesting a protective effect against lead-induced nephrotoxicity.

Table 3: Comparison of the electrolyte levels (Na⁺, K⁺, Cl⁻) of each experimental group

Electrolyte	Control	Lead-exposed	Baobab only	Lead + Baobab
Sodium (Na ⁺) (mmol/L)	140.2 ± 2.1	132.4 ± 3.2*	139.5 ± 2.4	136.7 ± 2.8#
Potassium (K ⁺) (mmol/L)	4.1 ± 0.3	5.6 ± 0.4*	4.0 ± 0.2	4.5 ± 0.3#
Chloride (Cl ⁻) (mmol/L)	102.5 ± 1.8	96.1 ± 2.5*	101.9 ± 1.7	99.4 ± 2.0#

*Significant difference compared to the control group (p<0.05)

#Significant improvement compared to the lead-only group (p<0.05)

Table 3 showed Lead acetate exposure caused significant alterations in serum electrolyte levels compared with the control group, including a decrease in sodium and chloride and an increase in potassium (p < 0.05), reflecting tubular dysfunction. Administration of baobab extract alone did not significantly alter electrolyte levels. However, co-treatment with baobab extract significantly ameliorated the lead-induced electrolyte disturbances, with sodium, potassium, and chloride levels approaching those of the control group (p < 0.05), indicating a protective effect on renal tubular function.

Histological findings

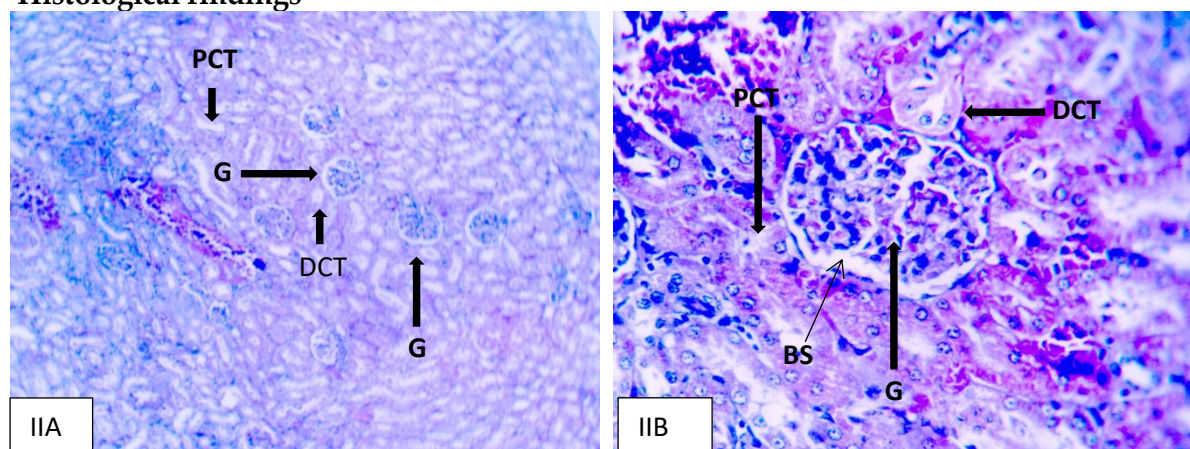


Plate II: H&E photomicrographs of the kidney sections from the control group showed normal renal architecture, intact glomeruli (G), normal proximal convoluted tubules (PCT) and distal convoluted tubules (DCT) with normal Bowman's space (BS). Mag. IIA(X100) and IIB(X400)

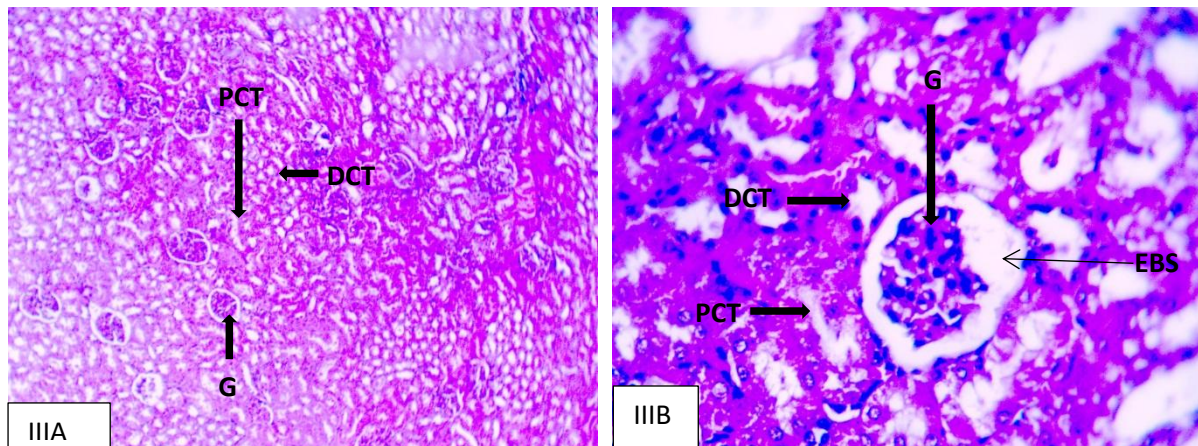


Plate III: H&E photomicrographs of the kidney sections from the lead-exposed group showed abnormal renal architecture, degeneration of the glomeruli (G), and proximal convoluted tubules (PCT) and distal convoluted tubules (DCT) with enlarged Bowman's spaces (EBS). Mag. IIIA(X100) and IIIB(X400)

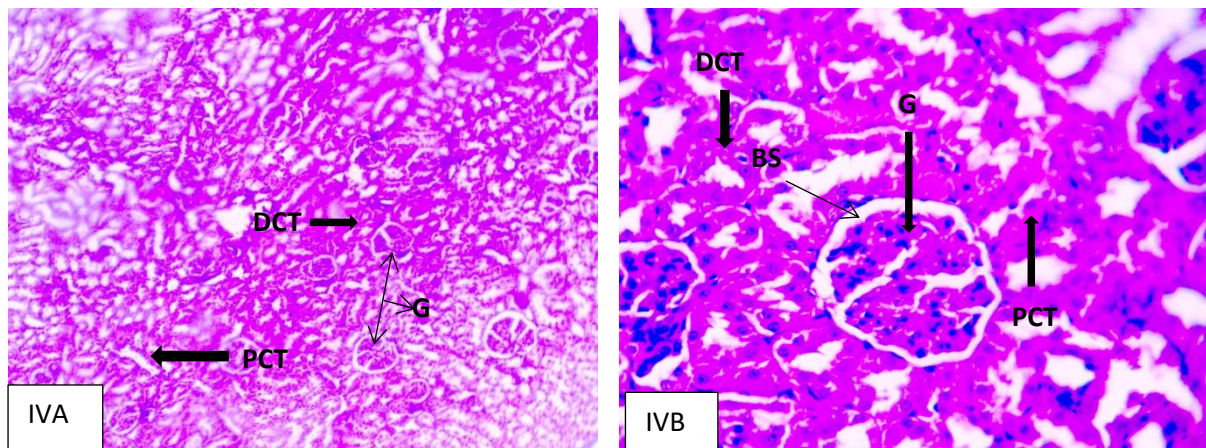


Plate IV: H&E photomicrographs of the kidney sections from the Baobab fruit extract group showed normal renal architecture, no degeneration of the glomeruli (G), and proximal convoluted tubules (PCT) and distal convoluted tubules (DCT). Mag. IVA(X100) and IVB(X400)

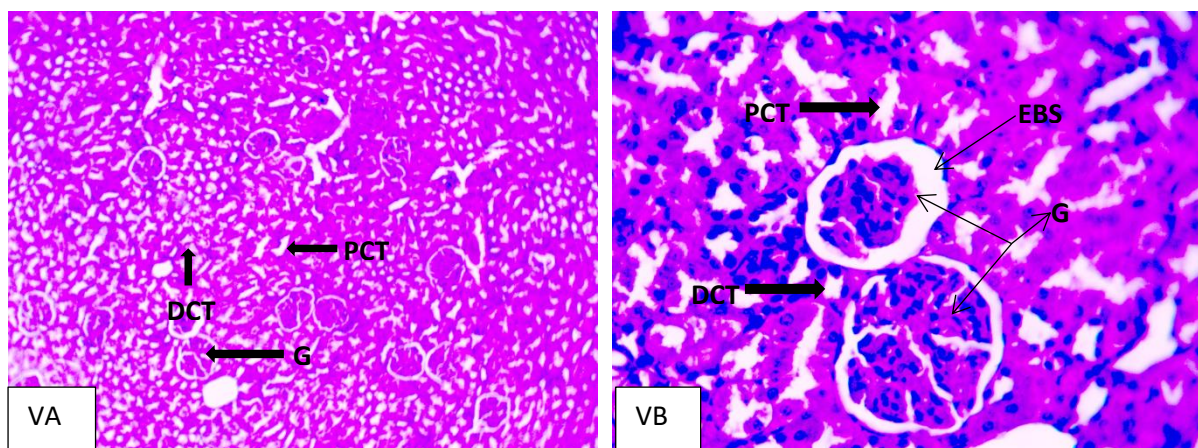


Plate V: H&E photomicrograph of the kidney sections from the Lead + Baobab Fruit Extract group showed marked improvement. The renal tubules and glomeruli (G) appeared relatively preserved, with mild tubular distortion and mildly enlarged Bowman's space (EBS). Mag. VA(X100) and VB(X400)

DISCUSSION

The present study demonstrated that administration of lead acetate significantly impaired renal function, as evidenced by elevated serum creatinine, blood urea nitrogen (BUN), and disturbances in electrolyte balance. These biochemical alterations were corroborated by histopathological findings, including tubular necrosis, glomerular atrophy, interstitial inflammation, and hyaline cast formation. Such findings are consistent with previous reports describing lead-induced nephrotoxicity, which is primarily mediated through oxidative stress, inflammation, and structural damage to renal tissues (Bhattacharjee *et al.*, 2021; Turkington *et al.*, 2025).

Co-treatment with baobab (*Adansonia digitata*) fruit extract produced significant improvements in both biochemical and histological parameters. Serum creatinine and BUN levels were markedly reduced compared to the lead-exposed group, indicating a restoration of glomerular filtration function. Similarly, serum electrolytes (Na^+ , K^+ , Cl^-) were stabilised, suggesting improved tubular reabsorption and secretion. Histological examination of the kidneys from the baobab-treated group revealed preservation of glomerular and tubular architecture, with only mild degenerative changes, highlighting the nephroprotective effect of the extract.

The observed protective effect of baobab fruit may be attributed to its high content of antioxidants, including vitamin C, flavonoids, polyphenols, and tannins. These bioactive compounds are known to scavenge reactive oxygen species (ROS), reduce lipid peroxidation, and modulate pro-inflammatory cytokine expression (Braca *et al.*, 2018; Althwab *et al.*, 2019; Oton *et al.*, 2022; Al-Safo *et al.*, 2025), thereby counteracting the oxidative stress and inflammatory pathways activated by lead exposure. Importantly, rats treated with baobab extract alone showed no adverse biochemical or histological changes, indicating that the extract is safe at the administered dose. This finding supports its potential use as a natural dietary supplement or adjuvant in mitigating heavy metal-induced renal toxicity.

Overall, the results of this study are in agreement with existing literature and provide further scientific validation for the ethnomedicinal use of baobab fruit as a protective agent against organ damage, particularly in the context of environmental toxicants such as lead.

CONCLUSION

Based on the findings of this study, it was concluded that lead-acetate induces significant nephrotoxicity in Wistar rats, characterized by elevated renal biomarkers and severe histological damage. Baobab (*Adansonia digitata L.*) fruit extract exhibits potent nephroprotective effects, as evidenced by improved kidney function and preserved renal histology. The protective effect was likely due to the antioxidant and anti-inflammatory properties of the phytochemicals present in the baobab fruit. Baobab fruit extract is safe and non-toxic at the studied dose.

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Conflict of interest: Declared none.

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