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Modulatory Effects of Ethanol Root Extract of *Mucuna pruriens* (EREMP) on Lead-Induced Hepatic Injury: Biochemical and Histological Evidence

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ABSTRACT

Background and Purpose: Lead toxicity remains a significant environmental health concern due to its ability to induce oxidative stress and hepatic injury. Medicinal plants possessing antioxidant properties have attracted considerable interest as potential therapeutic agents. This study evaluated the restorative effects of ethanol root extract of *Mucuna pruriens* (EREMP) on lead-induced hepatic injury in adult female Wistar rats.

Methods: Thirty adult female Wistar rats were randomly assigned to six groups (n=5). Group 1 served as the normal control and received normal saline (1 mL/kg). Hepatotoxicity was induced in Groups 2 to 6 by oral administration of lead acetate (120 mg/kg/day) for 10 consecutive days. Thereafter, group 2 received no treatment; groups 3 to 5 were treated with EREMP at doses of 100, 150, and 200 mg/kg, respectively, while group 6 received vitamin E (100 mg/kg) as a reference. Treatment was by gavage for 14 consecutive days. Body weight, liver enzyme activities: alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP); oxidative stress biomarkers: malondialdehyde (MDA) and superoxide dismutase (SOD); and liver histomorphology were evaluated.

Results: Lead exposure significantly increased ALT and ALP activities and caused marked histological alterations, including periportal inflammation and disruption of normal hepatic architecture. Treatment with EREMP significantly attenuated oxidative stress, as evidenced by reduced MDA levels and increased SOD activity. Furthermore, EREMP improved liver enzyme profiles and restored hepatic histoarchitecture in a dose-dependent manner, with the medium-and high-dose groups showing marked recovery comparable to the vitamin E-treated group.

Conclusion: Ethanol root extract of *Mucuna pruriens* ameliorates lead-induced hepatic injury and oxidative stress in adult female Wistar rats.

INTRODUCTION

Liver diseases constitute a significant global health burden, contributing substantially to morbidity and mortality worldwide (Devarbhavi *et al*., 2023). Liver diseases account for two million deaths annually and is responsible for 4% of all deaths (Devarbhavi *et al.,* 2023). The liver plays a central role in metabolism, detoxification, and xenobiotic clearance, making it particularly vulnerable to environmental toxicants such as heavy metals.

Lead is one of the most pervasive environmental contaminants, with widespread human exposure occurring through industrial, occupational, and domestic sources (Tchounwou *et al*., 2012; Laoye *et al*., 2025). Continuous environmental and occupational exposure may contribute to renal, nervous, hepatic, hematological, and reproductive disorders in man and animals (Laoye *et al*., 2025). Exposure occurs mainly through the respiratory and gastrointestinal systems, and the ingested and absorbed lead is stored primarily in soft tissues and bone. Autopsy studies of lead-exposed patients indicate that the liver is the largest repository of lead among soft tissues (33%), followed by the kidney (Mudipally, 2007; Wani *et al*., 2015).

Lead-induced hepatotoxicity is primarily mediated by oxidative stress, including the generation of reactive oxygen species (ROS), lipid peroxidation, and disruption of antioxidant defense systems (Atuadu *et al.,* 2021; Makena *et al*., 2021). These processes compromise hepatocellular integrity, resulting in altered liver enzyme activity, inflammation, and structural damage. Elevated serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) are widely recognized biomarkers of hepatic injury and dysfunction (Bazabang *et al*., 2018). Despite advances in modern medicine, the management of liver diseases remains challenging, with limited availability of effective and safe hepatoprotective agents. Additionally, the availability and affordability of conventional medical therapies can be limited in those countries; thus, affordable, readily available treatment is necessary. As a result, the percentage of people who use medicinal plants for basic health care is high due to their relatively low cost, availability, and perceived safety (James *et al*., 2018). This highlights the need to consider plant-based therapies as a potential alternative to the treatment of liver diseases in resource-restricted settings.

Medicinal plants have historically served as a major source of bioactive compounds with antioxidant (Etukudo *et al*., 2025), anti-inflammatory (Atuadu *et al*., 2021; Ajayi *et al*., 2023), nootropic (Finbarrs-Bello *et al*., 2016; Ben-Azu *et al*., 2024), renoprotective (Makena *et al*., 2025) and hepatoprotective (Tratrat *et al*., 2025) properties. *Mucuna pruriens*, commonly known as velvet bean, is a tropical leguminous plant widely distributed across Africa, Asia, and the Caribbean. It is used in ethnomedicine to treat neurological disorders (Hammoud *et al*., 2025), inflammation (Misra and Wagner, 2007), and metabolic conditions (Larner *et al*., 1998). The plant is a rich source of bioactive compounds, including levodopa, flavonoids, alkaloids, and phenolic compounds, which are known to possess antioxidant and free-radical-scavenging properties (Lampariello *et al*., 2012; Atuadu *et al*., 2022). All parts of *Mucuna pruriens* possess valuable medicinal properties. For example, the antimicrobial and antioxidant properties of the leaves have been explored (Ogundare, 2007; Ogunmoyole *et al*, 2021; Otoe *et al*., 2025). The seeds are widely utilized in Ayurvedic medicine because of their antioxidant, anti-inflammatory, anti-venom, antidiabetic, aphrodisiac, and antiparkinsonian properties (Misra and Wagner, 2007; Guerranti et a., 2008; Ogunmoyole *et al*, 2021; Hammoud *et al*., 2025; Pal *et al*., 2025). The root is known for its neuro and renoprotective properties (Atuadu *et al*., 2020; Atuadu *et al*., 2022) while the whole plant has been employed for its antioxidant and anti-diabetic properties (Larner *et al*., 1998). Additionally, velvet bean seeds are effective in treating conditions such as menstrual disorder, oedema, fever, tuberculosis, and constipation (Dora and Kumar, 2017). While extensive research has focused on its neurological benefits, particularly in Parkinson's disease (Hammoud *et al*., 2025), relatively few studies have explored its potential effects on hepatic function, particularly with root extract. Emerging evidence suggests that antioxidant phytochemicals may mitigate heavy metal–induced toxicity by neutralizing reactive oxygen species and enhancing endogenous defense mechanisms (Ifie *et al*., 2025; Oyem *et al*., 2021).

Only a few studies examined the medicinal potential of its root, and no study has investigated the efficacy of its ethanol root extract on the management of liver disease. Therefore, this study aimed to investigate the histomorphological and biochemical efficacy of the ethanol root extract of *Mucuna pruriens* in managing liver dysfunction following lead acetate exposure.

MATERIALS AND METHODS

Plant Material

Fresh roots of *Mucuna pruriens* were obtained from a local vendor in Obinagu, Amechi-Idodo, Nkanu-East Local Government Area, Enugu State, Nigeria, in August 2022. The plant material was authenticated by a taxonomist in the Department of Agricultural Science, Enugu State University of Science and Technology (ESUT), Agbani Campus. A voucher specimen was prepared and deposited in the departmental herbarium for reference, with the reference number ESUT/AGR/2022/016.

Preparation of Ethanol Root Extract

The ethanol root extract of Mucuna pruriens (EREMP) was prepared according to a modified method described by Ogunmoyole *et al*. (2021). Ethanol was selected as the extraction solvent because of its efficiency in extracting both polar and moderately nonpolar bioactive phytoconstituents associated with antioxidant and hepatoprotective activities (Jitpimai *et al*., 2025). Fresh roots were thoroughly washed under running tap water, cut into smaller pieces, and air-dried in the shade for two weeks. The dried roots were pulverized using an electric grinder. A quantity (500 g) of the powdered material of the root was macerated in 1 L of absolute ethanol in a sealed container and agitated intermittently for 48 h to ensure optimal extraction. The mixture was filtered using Whatman No. 1 filter paper, and the filtrate was concentrated over a water bath at 50°C. The semi-solid extract was further dried in a vacuum desiccator. Thereafter, 48 g of the crude extract was obtained from 500 g of powdered root material, corresponding to a yield of 9.6% w/w. The ethanol root extract of *Mucuna pruriens* (EREMP) was stored in an airtight container at 4°C until use. The EREMP doses used (100, 150, and 200 mg/kg) were selected based on a previous study (Atuadu *et al*., 2020). Fresh stock solutions of the extract were prepared every four days and stored at 4°C. All treatments were administered orally via gavage, and doses were calculated based on individual body weight.

Experimental Animals

Thirty (30) adult female Wistar rats weighing 180–200 g were obtained from the Animal Facility of the College of Medicine, University of Nigeria, Enugu Campus. The animals were housed in well-ventilated cages under standard laboratory conditions (temperature: 24±2°C; relative humidity: 60–70%; 12-h light/dark cycle) at the ESUT College of Medicine Animal Facility. The rats were allowed to acclimatize for 14 days with free access to standard feed (growers' mash) and water. All experimental procedures were approved by the ethical committee of the Department of Human Anatomy, Faculty of Basic Medical Sciences, College of Medicine, Enugu State University, with reference number ESUCOM/FBMS/ETR/2024/021 and conducted in accordance with the ARRIVE 2.0 guidelines for animal research (Percie *et al*., 2020).

Chemicals and Reagents

Lead acetate (Sigma-Aldrich, St. Louis, MO, USA) was procured from a certified chemical supplier at Ogbete Main Market, Enugu, Nigeria**.** Vitamin E (α-tocopherol) capsules and ketamine hydrochloride ampoules (50 mg/mL) were bought from a registered pharmaceutical premises**.** All reagents and chemicals used in this study were of analytical grade. Lead acetate (120 mg/kg), EREMP were dissolved in normal saline, while vitamin E was dissolved in olive oil. Appropriate concentrations were prepared and administered orally based on reports from a previous study (Kadhum, 2019). The doses of lead and vitamin E were based on beneficial effects from previous studies (Atuadu etal., 2022).

Experimental Design

The animals were randomly assigned to six experimental groups (n=5). Treatment was in two phases. In the first phase, group 1 received normal saline (10 mL/kg/day, orally) as a normal control, while the remaining five groups received lead acetate (120 mg/kg/day, orally) for 10 consecutive days to induce hepatotoxicity. This phase was immediately followed by the second phase in which groups 1 and 2 received normal saline (10 mL/kg/day); groups 3, 4, and 5 received 100, 150, and 200 mg/kg/day EREMP orally; and group 6 received vitamin E (100 mg/kg/day). Treatment in the second phase lasted 14 consecutive days. Body weights of the animals were recorded at baseline, post-induction (end of first phase), and at the end of the second phase. Average body weights and percentage change in body weight were calculated for each group.

Animal Sacrifice and Tissue Collection

At the end of the treatment period, animals were anesthetized on day 25 using ketamine hydrochloride (50 mg/kg). The animals were quickly dissected, and a small portion of the liver tissue was homogenized at −20°C for biochemical analysis using a T10 basic ULTRA-TURRAX® handheld probe homogenizer (IKA®-Werke GmbH & Co. KG, Staufen, Germany).

Biochemical Assays

a) Assessment of Liver Function Enzymes

Liver function was assessed by measuring the liver function biomarkers ALT, AST, and ALP. ALT), and aspartate aminotransferase were investigated using the Randox Commercial Enzyme assay kit (RANDOX Laboratories Ltd, UK) and a spectrophotometer (VWR UV-6300PC). These two enzyme activities were determined as described by Reitman and Frankel (1957). ALT was measured via the colorimetric Reitman-Frankel method, based on the enzymatic reaction of L-alanine and α-ketoglutarate to form pyruvate and L-glutamate, while AST activity was similarly quantified by measuring oxaloacetate formation from L-aspartate and α-ketoglutarate. The resulting hydrazones from both transaminases were reacted with 2,4-dinitrophenylhydrazine (DNPH) to yield a colored complex, measured spectrophotometrically at 546 nm (Reitman and Frankel, 1957). ALP was determined using a commercially available enzyme kit (AGAPPE Diagnostics Ltd., Kerala, India), according to the method of Tietz (1995). The change in absorbance per minute (ΔOD/min) over a 3-min interval was measured at 405 nm.

b) Assessment of Oxidative Stress Markers

Liver tissues were homogenized and analyzed for oxidative stress markers. Malondialdehyde (MDA) levels were determined using the thiobarbituric acid reactive substances (TBARS) assay. The assay involves reacting lipid peroxidation products, primarily malondialdehyde (MDA), with thiobarbituric acid (TBA), forming MDA-TBA2 adducts called TBARS. TBARS yields a red-pink color that can be measured spectrophotometrically at 532 nm (Jesús and Chad, 2020). Superoxide dismutase (SOD) activity was determined using the method of Nishikimi et al. (1972), which measures superoxide radical production with reduced nicotinamide adenine dinucleotide (NADH) as the electron donor and phenazine methosulfate (PMS) as the electron acceptor. The generated superoxide radicals reduce nitroblue tetrazolium (NBT) to a blue-colored formazan product. The percent inhibition of NBT reduction was used as a measure of SOD activity (Nishikimi *et al*., 1972). While glutathione (GSH) was determined based on the reduction of 5,5-dithiobis (2-nitrobenzoic acid) (DTNB) with reduced GSH to produce a yellow compound. The reduced chromogen was directly proportional to GSH concentration, and its absorbance was measured at 405 nm by using a commercial kit (Biodiagnostic, Egypt) (Tietze, 1969).

Histological Examination

Liver tissues were excised immediately after sacrifice, rinsed in normal saline, and fixed in 10% neutral buffered formalin for 72 h. The tissues were processed using standard histological techniques, including dehydration in graded alcohols, clearing in xylene, and paraffin wax embedding. Sections of 5 µm thickness were cut using a rotary microtome, mounted on glass slides, and stained with hematoxylin and eosin (H&E). The stained sections were examined under an Olympus BX43 light microscope (Olympus Corporation, Tokyo, Japan), and photomicrographs were captured using an AmScope MU1000 10-megapixel digital microscope camera (AmScope LLC, Irvine, CA, USA) at magnifications of ×100 and ×400. The histological examination was performed by an independent histopathologist blinded to treatment allocation to minimize observer bias.

Statistical Analysis

Data distribution was assessed using the Shapiro–Wilk normality test prior to statistical analysis. Outliers were screened using GraphPad ROUT analysis, and none met exclusion criteria. Data were expressed as mean ± standard error of the mean (SEM). Inferential analysis was performed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test using GraphPad version 9. Differences between groups were considered statistically significant at $P < 0.05$.

RESULTS

Modulation of Liver Function Enzymes by EREMP Following Lead-Induced Hepatic Injury

Liver tissue enzyme levels across the experimental groups were assessed and presented in Figure 1 (A-C). Exposure to lead acetate (LA, 120 mg/kg) resulted in a marked elevation of serum ALT and ALP levels compared to the normal control group, indicating hepatocellular injury. The increase in ALP was particularly pronounced in the lead-treated group, reflecting possible hepatobiliary dysfunction. However, no significant change was observed in AST levels across the groups. Treatment with EREMP produced a dose-dependent improvement in liver enzyme profiles. In the low-dose (100 mg/kg) group, there was a modest reduction in ALT and ALP levels compared to the lead-treated group, although values remained elevated relative to the normal control. The medium-dose (150 mg/kg) group had further reduction in enzyme levels, with a significant decrease in ALP compared to the lead-treated group (P<0.05). The high-dose (200 mg/kg) group showed the most pronounced effect, with substantial reductions in ALT and ALP levels toward near-normal values. The vitamin E-treated group also showed significant reductions in ALT and ALP levels compared to the lead-treated group (P<0.05), indicating hepatoprotective activity. However, the improvement in ALP levels was less pronounced compared to the high-dose EREMP group. Overall, these findings indicate that EREMP exerts a dose-dependent hepatoprotective effect, particularly in reducing ALP-associated hepatobiliary injury.

Attenuation of Lipid Peroxidation and Restoration of Antioxidant Enzymes by EREMP following Lead-induced Liver Toxicity

Figure 2 shows that exposure to lead acetate-induced liver toxicity caused a significant increase in the levels of malondialdehyde (MDA) and a reduction in antioxidant activities of SOD and GPx when compared to the normal control group (P<0.01). This validates the generation of oxidative stress and lipid peroxidation of hepatic tissues. EREMP treatment led to a dose-dependent reduction in oxidative stress marker levels. The low dose group (100 mg/kg) did not affect the levels of MDA but significantly (P<0.05) changed the levels of SOD. The medium dose of 150 mg/kg caused a greater decrease in the level of MDA and significantly (P<0.05) enhanced the level of SOD than the lead-treated group, and moderate improvement in GPx activity. The antioxidant effect was most pronounced in the high-dose group (200 mg/kg), in which MDA levels were reduced to near-normal levels, and SOD and GPx activities were highly restored (P<0.01 compared with the lead-treated group. These results indicate that oxidative stress was significantly attenuated at higher doses. Likewise,

vitamin E supplementation significantly reduced MDA levels, and antioxidant enzyme activities were enhanced relative to the lead-treated group, albeit with a less pronounced restoration of SOD activity than in the high-dose EREMP group. Overall, EREMP exhibited a good dose-dependent antioxidant effect that suppressed lead-induced oxidative stress in the hepatic tissue.

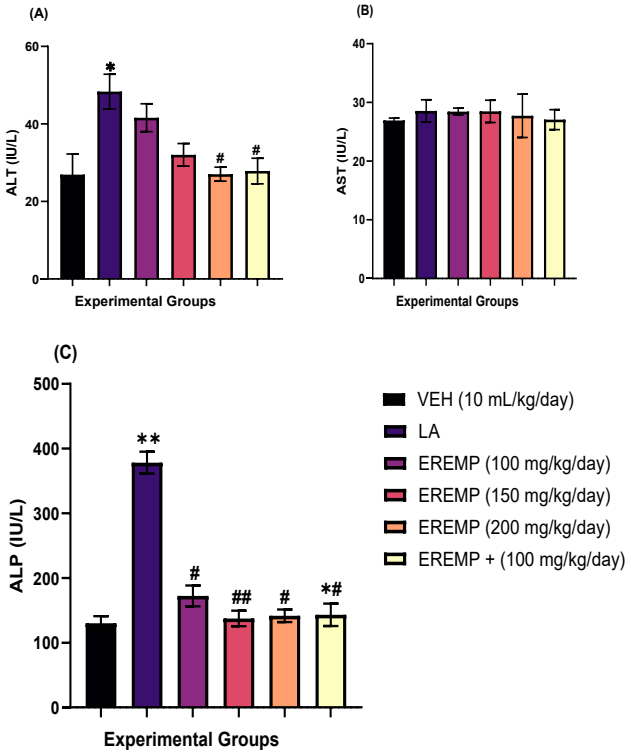

Figure 1: Effect of 14-day treatment with *Mucuna pruriens* ethanol root extract (EREMP) for 14 on liver ALT (A), AST (B), and ALP (C) levels of rats earlier exposed to lead acetate (120 mg/kg) for 10 days. Data = mean ± SEM (n=5), one-way ANOVA with Tukey's post hoc test. **P*<0.05, ***P*<0.01 vs VEH; $^{\#}P$<0.05, $^{\#\#}P$<0.01 vs LA. ALT – alanine aminotransferase; ALP – alkaline phosphatase; AST – aspartate aminotransferase.

Amelioration of Lead-Induced Weight Reduction by EREMP

The effects of EREMP on body weight and percentage weight change in the animals during the experiment are shown in Figure 3. Rats in the normal control group showed a steady increase in body weight throughout the experimental period. In contrast, lead acetate-treated rats exhibited a marked weight reduction (Figure 4A), with a significantly (*P*<0.01) smaller percentage increase (Figure 4B) compared to the control group, indicating the detrimental effect of lead on body weight. Treatment with EREMP improved body weight in a dose-dependent manner. The low-dose (100 mg/kg) group showed a slight increase in body weight compared to the lead-treated group. The medium-dose (150 mg/kg) group also demonstrated improved weight gain. The high-dose (200 mg/kg) group showed recovery in body weight, with a significant improvement in percentage weight change (*P*<0.05), indicating almost total reversal of lead-induced growth impairment. Similarly, the vitamin E-treated group exhibited significant improvement in body weight and percentage weight compared to the lead-treated group (*P*<0.05). Overall, these results suggest that EREMP reversed lead-induced weight loss with effects varying by dose.

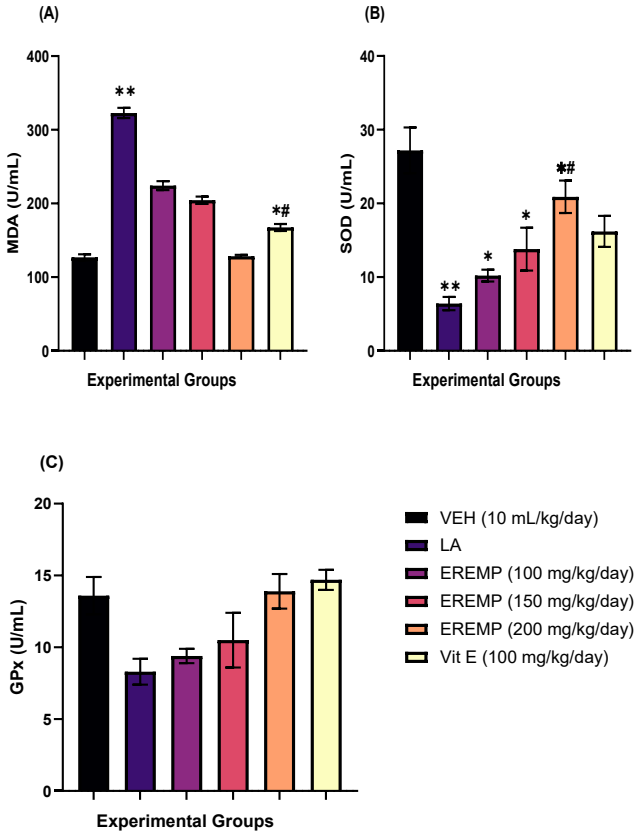

Figure 2: Effect of a 14-day treatment with ethanol root extract of *Mucuna pruriens* (EREMP) on liver tissue oxidative stress markers in rats after lead acetate administration for 10 consecutive days. A: malondialdehyde (MDA), B: superoxide dismutase (SOD), and C: glutathione peroxidase (GPx). Data are mean ± SEM (n=5), one-way ANOVA with Tukey's post hoc test. **P*<0.05, ***P*<0.01 vs. VEH; $^{\#}P$<0.05, $^{\#\#}P$<0.01 vs LA. VEH – vehicle; LA – lead acetate.

Amelioration of Hepatocellular Alterations by EREMP Following Lead-Induced Injury

The curative capacity of the ethanol root extract of *Mucuna pruriens* (EREMP) on the histology of the liver following lead acetate-induced hepatotoxicity is represented in Figure 4. The sections revealed distinct structural alterations across the experimental groups. The normal control group (Figure 4a) exhibited intact hepatic architecture characterized by well-defined hepatic lobules, radiating hepatocyte cords, and normal sinusoids converging toward the central vein.

Portal triads containing the hepatic artery, hepatic vein, and bile duct were normal. In contrast, the lead acetate-treated group (Figure 4b) showed clear evidence of hepatotoxicity, including mild periportal hepatitis, moderate hepatocellular necrosis, and infiltration of mononuclear inflammatory cells, indicating hepatic injury. Treatment with EREMP demonstrated dose-dependent histological improvement. The low-dose group (100 mg/kg; Figure 4c) showed mild periportal inflammatory infiltration with partial preservation of hepatic structure. The medium-dose group (150 mg/kg; Figure 4d) exhibited marked improvement, with reduced inflammatory changes and restoration of hepatocyte organization. The high-dose group (200 mg/kg; Figure 4e) showed near-complete restoration of normal hepatic architecture, comparable to the control group, with minimal pathological alterations. The vitamin E-treated group (Figure 4f) showed partial recovery, with mild periportal inflammatory infiltration still evident, indicating a less pronounced histological improvement than with the higher EREMP doses. Overall, these findings indicate that EREMP exerts a dose-dependent hepatoprotective effect against lead-induced hepatic injury, with maximal structural restoration observed at higher doses.

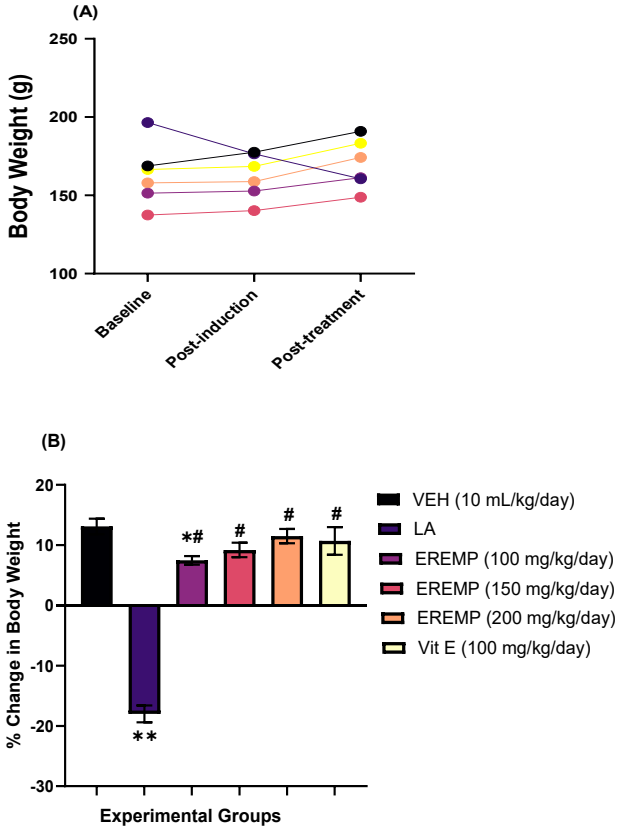

Figure 3: Effect of a 14-day treatment with ethanol root extract of *Mucuna pruriens* on average body weight (A) and percentage change in body weight (B) of rats previously administered lead acetate (LA) for 10 consecutive days. Data = mean ± SEM (n=5), one-way ANOVA with Tukey's post hoc test. **P*<0.05, ***P*<0.01 vs VEH; #*P*<0.05, ##*P*<0.01 vs LA VEH – vehicle; LA – lead acetate.

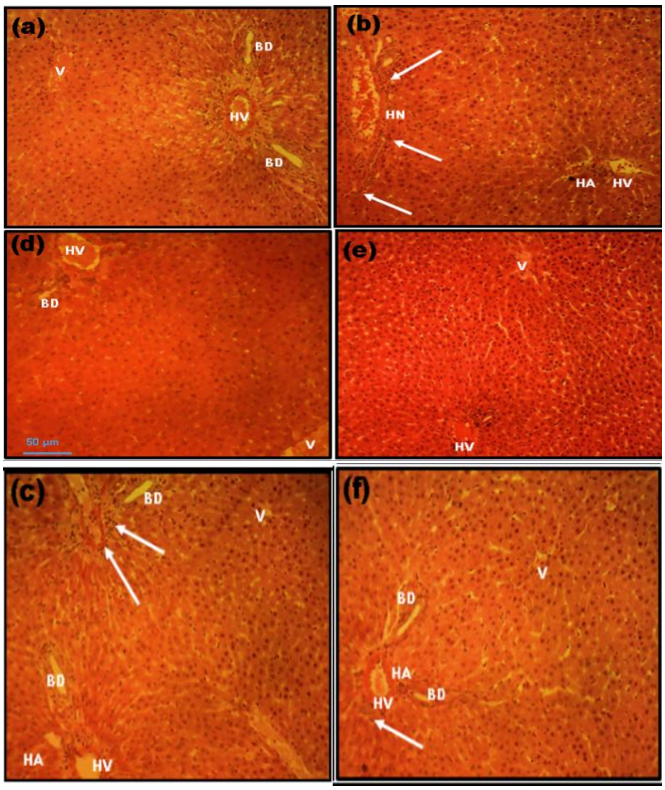

Figure 4: Effects of ethanol root extract of *Mucuna pruriens* (EREMP) on hepatic architecture following lead acetate-induced hepatotoxicity in adult female rats. Representative hematoxylin and eosin (H&E)-stained liver sections are shown. (a) **Normal control (1 mL/kg normal saline):** shows normal hepatic architecture with well-organized hepatic lobules; hepatocytes are arranged in radiating cords around the central vein (V), separated by normal hepatic sinusoids, and converging at portal areas containing the hepatic artery (HA), hepatic vein (HV), and bile duct (BD). (b) **Lead acetate (120 mg/kg):** shows features of hepatotoxicity, including mild periportal hepatitis, moderate random hepatocellular necrosis (HN), and infiltration of mononuclear inflammatory cells (arrows). (c) **Lead acetate + EREMP (100 mg/kg):** shows mild periportal inflammatory cell infiltration with partial preservation of hepatic architecture. (d) **Lead acetate + EREMP (150 mg/kg):** shows improved hepatic architecture with reduced inflammatory changes and restoration of hepatocellular arrangement. (e) **Lead acetate + EREMP (200 mg/kg):** shows near-normal hepatic architecture comparable to the control group, with minimal or no observable pathological changes. (f) **Lead acetate + Vitamin E (100 mg/kg):** shows mild periportal infiltration of mononuclear inflammatory cells (arrow), with partial improvement in hepatic structure. **Scale bar = 50 µm (**magnification ×400**).**

DISCUSSION

The present study investigated the curative and antioxidant effects of the ethanol root extract of *Mucuna pruriens* (EREMP) following lead acetate–induced hepatotoxicity in rats. The results show that lead causes severe hepatic damage, oxidative stress, and physiological dysfunction, and that EREMP treatment provides dose-dependent protection, restoring biochemical, histological, and

physiological parameters. Administration of lead acetate caused significant hepatic injury, as indicated by elevated serum ALT and ALP levels and histologic changes, including hepatocellular necrosis and periportal inflammation. These results are consistent with earlier reports indicating that lead toxicity compromises the integrity of the hepatocellular membrane, leading to the release of intracellular enzymes into the bloodstream (Szymański *et al*., 2014; Kumar *et al*., 2023). The significant increase in ALP in the current study also indicates hepatobiliary dysfunction, which is typically associated with cholestasis and bile duct damage following exposure to heavy metals (Siddique and Kowdley, 2012).

The biochemical results are supported by the histopathological findings, which showed necrosis and inflammatory cell infiltration in the lead-treated group. These structural changes are indicative of oxidative damage and inflammatory reactions evoked by lead toxicity (Kadhum *et al*., 2019; Atuadu *et al*., 2020). The liver is a major target organ for lead accumulation and toxicity because it is a central organ of detoxification and metabolism (Alya *et al*., 2015). The periportal hepatitis and hepatocellular degeneration observed in this study are like the results from previous studies that showed morphological disturbances in animals that had been exposed to lead (Ruan *et al*., 2013). One of the major mechanisms of lead-induced hepatotoxicity is oxidative stress (Kumar *et al*., 2023; Generalova *et al*., 2025). In the current study, lead exposure significantly increased hepatic malondialdehyde (MDA) levels while reducing antioxidant enzyme levels (SOD and GPx). These results agree with a substantial body of evidence that lead facilitates the production of reactive oxygen species and, at the same time, suppresses antioxidant enzymes by reacting with sulfhydryl groups (Patra *et al*., 2011). A meta-analysis supports the finding that lead exposure increases MDA and decreases SOD and GPx levels in animal models (Fan *et al*., 2020).

Treatment with EREMP significantly improved in biochemical as well as histological changes in a dose-dependent manner. The decrease in ALT and ALP levels in the EREMP-treated groups indicates stabilization of hepatocyte membranes and recovery of liver function. Interestingly, no significant alterations in AST levels were seen despite the clear hepatotoxicity. However, previous studies have shown that AST is a less specific diagnostic marker of liver toxicity than ALT because it is present in most extrahepatic tissues, including skeletal and cardiac muscle (Giannini *et al*., 2005; Xuan *et al*., 2024). Therefore, the pronounced elevation of ALT observed in this study serves as a more reliable indicator of direct hepatocyte structural damage. In the present study, the duration of lead exposure may have been more likely to impact hepatobiliary and hepatocellular membrane integrity, primarily, as evidenced by the increase in ALT and ALP levels (Kobayashi *et al*., 2020; Kwak *et al*., 2023). The rats administered the high dose of EREMP had enzyme levels and hepatic architecture comparable to those of the normal control group. This suggests an effective curative property by EREMP.

The antioxidant properties of EREMP are evident in its ability to significantly reduce MDA levels and restore SOD and GPx activities. This indicates that the extract alleviates oxidative stress not only by scavenging free radicals but also by increasing endogenous antioxidant defenses. The dose-dependent effect observed in this study is particularly significant, indicating a gradual recovery of redox balance as extract concentration increased. This effect may be partly attributed to the phytochemical constituents of *Mucuna pruriens*, such as levodopa, flavonoids, and phenolic compounds, which have been reported to possess potent antioxidant properties (Ogunmoyole *et al*., 2021; Hammoud *et al*., 2025). These bioactive compounds may enhance cellular antioxidant defenses by activating the Nrf2 signaling pathway, a key antioxidant regulatory pathway, leading to upregulation of endogenous antioxidant enzymes and attenuation of oxidative stress (Bai *et al*., 2023; Oyovwi *et al*., 2025; Chukwu *et al*., 2026). The observed reduction in MDA levels and improvement in SOD activity support a possible antioxidant-mediated mechanism.

Exposure to lead acetate caused severe weight loss, which is indicative of systemic toxicity popularly used as a casual marker for environmental toxicity. Body weight recovery after treatment with EREMP indicates improved physiological condition and a potential increase in nutrient utilization. The fact that EREMP has been shown to improve body weight in treated groups further supports its protective effect. A similar finding was observed in which the antioxidant therapy alleviated the systemic effects of lead toxicity and resulted in weight gain (Lamidi *et al*., 2017).

Interestingly, compared with vitamin E, a proven antioxidant, the high-dose EREMP group demonstrated histological recovery comparable to, and in some instances exceeding, that observed in the vitamin E-treated group. While vitamin E exerts its hepatoprotective effect primarily through free-radical scavenging and inhibition of lipid peroxidation (Niki, 2014), the structural preservation and biochemical recovery observed in the treated groups may be attributed to the synergistic actions of the phytoconstituents of *Mucuna pruriens* (Lampariello *et al*., 2012). The synergistic actions of these phytochemicals may have provided better antioxidant and cytoprotective effects, which could account for the enhanced restoration of hepatic architecture observed at higher extract doses.

One limitation of the study is that the histological evaluation was primarily descriptive and lacked quantitative morphometric assessment. Parameters such as quantification of necrotic area, inflammatory cell counts, and standardized lesion grading were not evaluated. Although the histological observations were consistent with the biochemical findings, future studies incorporating blinded quantitative histomorphometric analyses would provide a more objective assessment of the hepatoprotective effects of EREMP. Another limitation is the absence of an EREMP-only control group to further clarify the extract's intrinsic hepatic effects and safety profile independent of lead exposure. These limitations warrant further study.

CONCLUSION

In conclusion, the results of the present study suggest that EREMP possesses hepato-curative properties against lead-induced hepatotoxicity by attenuating oxidative stress and maintaining hepatocellular integrity. These effects are dose-dependent and underscore the importance of proper dosing to maximize benefits and minimize adverse effects. These findings support the use of *Mucuna pruriens* root extracts as a natural agent in the treatment of lead-induced hepatotoxicity, but further studies are needed to better understand the active constituents, molecular mechanisms, and safety profile.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS' CONTRIBUTION

Conceptualization, Methodology, Data Collection and Analysis, Writing (Original Draft)**:** IIK, OAO, AOK**.** Data Collection and Analysis, Supervision and Project Administration**:** MYH, ET, EN.

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No external funding was obtained for this study.

AUTHORS' DECLARATION

Conceptualization was led by VOO, AAN, and BB-A. Data curation was performed by VOO and AAN. The original draft was prepared by VOO, with subsequent review and editing by BB-A. Supervision was provided by BB-A. Funding acquisition responsibilities were shared among VOO and AAN. All authors have read and approved the final manuscript.

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