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Protective effects of methanolic extract of *Andrographis paniculata* (Burm.f.) Nees leaves against arsenic-induced damage in rats

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Abstract

Background: Medicinal plants are natural sources of antioxidants effective in the treatment of oxidative stress-mediated diseases. This study aims to evaluate the hepato-renal protective efficacy of *Andrographis paniculata* leaves methanolic extract in arsenic-induced oxidative stress. Animals were divided into four groups of six animals per group. The rats in groups 1 and 2 received normal saline, while rats in groups 3 and 4 received 200 mg/kg body weight of *A. paniculata* or ascorbic acid per day, respectively, for 7 days orally. The rats in groups 2, 3, and 4 received a single dose of arsenic at 10 mg/kg body weight intraperitoneally on day 7, and 24 h later, rats in all the groups were killed and the blood, liver, and kidney samples were collected for biochemical/histological studies.

Results: Administration of arsenic to rats induced a significant increase in the levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), cholesterol, urea, creatinine, and triglycerides in the plasma, while it decreased superoxide dismutase (SOD), glutathione (GSH) and catalase (CAT) activities in the liver and kidney. It also significantly reduced the levels of white blood cells (WBC), red blood cells (RBC), platelet (PLT), and lymphocytes (LYM) in the blood. However, the levels of AST, ALT, cholesterol, urea, creatinine, and triglycerides in the plasma of groups of rats that received *A. paniculata* extract before administration of arsenic were decreased, while their SOD, GSH, and CAT levels were elevated in the liver and kidney. The values of their WBC, RBC, PLT, and LYM were also significantly increased when compared to the arsenic group rats. Histological observations showed varying degrees of liver damage in the arsenic group rats, while the histoarchitecture of the liver of rats that received *A. paniculata* extract were significantly improved.

Conclusions: This study demonstrated that *A. paniculata* extract ameliorates arsenic-induced hepato-renal toxicity and could be exploited in the management of toxicity effects associated with the arsenic.

Keywords: *Andrographis paniculata*, Arsenic, Hepato-renal, Histological, Lymphocytes

Background

Arsenic is a metalloid and environmental toxicant characterized by a high atomic weight, with a large proportion relatively absorbed by the gastrointestinal tract and diffused via the blood tissue primarily to the hepatic, renal, bladder, and muscular system (Stummann et al. 2008; Mazumderm 2005). Chronic ingestion of arsenic leads to the upregulation of the pro-oxidant system, and downregulation of the natural antioxidant system, thus resulting in oxidative stress as well as damage to biomolecules (DNA & protein damage), chromosomal abnormalities and apoptosis (Afsane et al. 2020). The damage to tissues by arsenic has been reported to lead to cancer and several epigenetic modifications (Afsane et al. 2020; Palma-Lara et al. 2020). Although arsenic remains essential in the treatment of acute myeloblastic

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leukaemia with several other agricultural and industrial relevance (Palma-Lara et al. 2020), it remains classified as a carcinogen toxicant. Minute exposure to arsenic, mostly via soil, air, contaminated food and drinking water greater than the recommended level of 10 µg/L could prove to be critical to human health (Owoade et al. 2019). Mechanisms by which arsenic exerts its toxicity include: the downregulation of mitogen-activated protein kinase MAPK family (includes essential members such as extracellular signal-regulated kinases (ERKs), c-Jun amino-terminal kinase 3(JNK) and p38), upregulation of activator protein-1 (AP-1), repression of essential PI3K/Akt cascades, and deactivation of constitutive nuclear-factor-kappa B (NF-kB) (Afsane et al. 2020; Ghosh et al. 2009). A recent in vivo study revealed that intraperitoneal administration of arsenic, induced cardiorenal dysfunction in male Wistar rats, as well as significantly increased heartbeat rate (Ademola et al. 2018). Similarly, arsenic was observed to increase protein carbonyl content (PCO) in myocardial tissues (Das et al. 2010; Manna et al. 2008).

The use of medicinal plants in management of the chronic and acute diseases has been on for ages recording notable success. Plants contain several phytoconstituent and phytochemicals available at considerable low cost, high efficacy and negligible side effects (Bhattacharya and Haldar 2013). *A. paniculata* is a traditional herbaceous plant of the family Acanthaceae. It is used in the management of various ailments and is widely cultivated across Europe and Asia (Kumar et al. 2020; Jiashu et al. 2019). Several bioactive compounds isolated from *A. paniculata* include andrographolide, 14-deoxy-11,12-didehydroandrographolide and 14-deoxy andrographolide (Rammohan et al. 2008), while 19 different bioactive compounds including andrographolide, deoxygrapholide quercetin, kaempferol, and apigenin were identified in *A. paniculata* leaves extract using Gas chromatography (GC) (Owoade et al. 2021). Various toxicity studies conducted on *A. paniculata* leaves extract revealed that the plant is safe for consumption with LD50 greater than 5000 mg/kg body weight in mice and rats (Burgos et al. 1997; Allan et al. 2009; Chandrasekaran et al. 2009; Worasuttayangkurn et al. 2019). Copious studies have explored the anticancer, anti-inflammatory, hypotensive property, antiangiogenic, antihyperglycemic and antimalarial properties of *A. paniculata* extract (Kumar et al. 2004; Sheeja et al. 2007). More so, research has highlighted the role of andrographolide (major bioactive compound of *A. paniculata*) as well as its antiviral potency; with notable ones being i) abatement of acute brain injury in Wistar rats (Tao et al. 2018), ii) amelioration of permanent middle cerebral artery occlusion (pMCAO) (Yen et al. 2016), reduced neurological deficits in mice (Yen et al. 2013) while positive results were obtained in studies aimed at determined its antiviral potency (Flores et al. 2014; Daneman and Prat 2015). Our study thus aims to research the antioxidant and protective efficacy of *A. paniculata* methanolic extract, in the quest to strengthen scientific knowledge for its possible use as an agent in the synthesis of novel drugs.

Methods

Reagents

Sodium arsenate ($NaAsO_2$), trichloroacetic acid (TCA), folin–ciocalteau reagent, gallic acid, thiobarbituric acid (TBA), nicotinamide adenine dinucleotide reduced (NADH) were obtained from Sigma–Aldrich Chemical Co. Ltd. (England). while nitrobluetetrazolium (NBT) was the product of Fluka (Buchs, Switzerland). All other chemicals used were of analytical grade.

Plant materials and extract preparation

The leaves of *A. paniculata* were obtained from a local farm at Ibadan, Oyo State. The plant identification and authentication was carried out at the Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso, by Prof A.J. Ogunkunle and a specimen was deposited in the herbarium with voucher number LH0738. The leaves were air-dried for two weeks at room temperature and pounded into powder. One hundred grams of the powdered A. *paniculata* leaves was soaked in 500 ml of methanol and shaken for 72 h; afterward, it was filtered and the supernatant was concentrated using a rotatory evaporator.

Animals

Twenty-four male Wistar rats with an average weight of 200 g were obtained from the experimental animal unit of the faculty of agriculture, Ladoke Akintola University of Technology, Ogbomosho, Nigeria. All rats were kept in cages in a room maintained at 26–29 °C with a 12-h light–dark cycle for 3-weeks to acclimatize and were allowed free access to food and water ad libitum. The faculty of basic medical science, Ladoke Akintola University of Technology, Ogbomoso, research ethics committee gave ethical approval for the study (FBMS2019/012). All the ethical protocols laid by the committee in line with ARRIVE guidelines, and the national institutes of health guide for the care and use of laboratory animals (NIH Publications No. 8023, revised 1978) were followed.

Experimental design

Three weeks after acclimatization the animals were divided into four groups of six animals per group. Group 1 rats received normal saline only and served as control. Group 2 rats received a single dose of arsenic dissolved in distilled water at 10 mg/kg body weight intraperitoneally

on the 7th day (Oyagbemi et al. 2018). Group 3 and 4 rats received 200 mg/kg body weight per day of *A. paniculata* (Borgohain and Kakoti 2019) or ascorbic acid both dissolved in saline solution orally for 7 days, respectively, and on the 7th day, a single dose of arsenic at 10 mg/kg body weight was administered intraperitoneally. The rats were killed twenty-four hours after administration of arsenic by cardiac puncture under light ether anaesthesia. Blood, liver, and kidney samples were removed from the animals and stored for biochemical analysis.

Determination of biochemical parameters in plasma

The concentrations of aspartate aminotransferase (AST), alanine aminotransferase (ALT), total protein, urea, creatinine, cholesterol and total triglycerides were determined in the plasma using enzymatic kits (CYPRESS® Diagnostics, Langdorp, Belgium) according to the manufacturer's instructions.

Preparation of liver and kidney homogenates

The liver and kidney samples are homogenized in phosphate buffer saline (PBS) to give a 10% (w/v) liver and kidney homogenate. The supernatant obtained after the homogenates were centrifuged at 12,000 rpm for 15 min was used for biochemical assay.

Determination of antioxidant enzyme activities and MDA levels

The concentration of reduced glutathione (GSH), superoxide dismutase (SOD), thiobarbituric acid-reactive product malondialdehyde (MDA) and catalase (CAT) in the liver and kidney homogenates was measured, as described by Jollow et al. (1974), Misra and Fridovish (1972), Buege and Aust (1978) and Sinha (1971), respectively. All enzyme activities were expressed as per mg of protein.

Haematological study

Fresh blood collected in EDTA bottles was analysed to determine haematological parameters using an automatic haematological assay analyser (ERMA PCE 210, ERMA, Japan).

Histopathological study

The liver tissue was harvested from the killed rats and immediately fixed in 10% formal saline and used for histomorphological studies.

Statistical analysis

The results of this study were expressed as mean ± SEM. One-way analysis of variance (ANOVA) followed by Turkey's test was used for statistical analysis, and p-value < 0.05 was considered statistically significant.

Results

Effect of *A. paniculata* on ALT and AST activities

Administration of arsenic significantly ($p < 0.05$) increased enzymatic activity of ALT and AST by 3.4 fold, and 3.1 fold, respectively, when compared with the normal levels. However, administration of 200 mg/kg body weight of *A. paniculata* extract or ascorbic acid before arsenic induction significantly reduced plasma ALT activity by 48.92 and 60.87%, respectively, and AST activity by 60.44 and 54.03%, respectively, when compared with rats that received arsenic only (Fig. 1).

Effect of *A. paniculata* on plasma biochemical parameters

Administration of arsenic significantly increased the plasma urea concentration by 2.5 fold, plasma creatinine by 5.6 fold, cholesterol by 4.4 fold and triglycerides by 3.5 fold, while it reduced total protein content by 24.97% when compared with normal rats. Administration of normal rats with the *A. paniculata* or ascorbic acid before arsenic induction significantly reduced urea, creatinine, cholesterol and triglycerides concentration, while it increased the total protein content when compared with rats that received arsenic only (Table 1).

Effect of *A. paniculata* on hepatic and renal GSH levels

Administration of arsenic significantly decreased glutathione levels in both liver and kidney when compared to the control rats. However, rats that received 200 mg/kg *A. paniculata* or ascorbic acid before arsenic induction have their glutathione levels significantly increased ($p < 0.05$) in the liver by 65.77 and 131.67%, respectively, and in the kidney by 98.99 and 112.44%, respectively, when compared with rats in the arsenic group only (Fig. 2).

Effect of *A. paniculata* on the hepatic and renal SOD activity

Administration of arsenic caused a significant decreased in SOD activities in both liver and kidney homogenate by 81.04 and 76.98% when compared to the control rats. However, administration of 200 mg/kg *A. paniculata* or ascorbic acid to rats before arsenic induction significantly increased ($p < 0.05$) SOD activities in liver and kidney when compared with rats in the arsenic group only (Fig. 3).

Effect of *A. paniculata* on the hepatic and renal malonaldehyde levels

Administration of arsenic significantly raised MDA levels in the liver and kidney when compared with control rats. However, rats that received 200 mg/kg *A. paniculata* or ascorbic acid before arsenic administration have a significant ($p < 0.05$) reduction in the liver MDA levels by

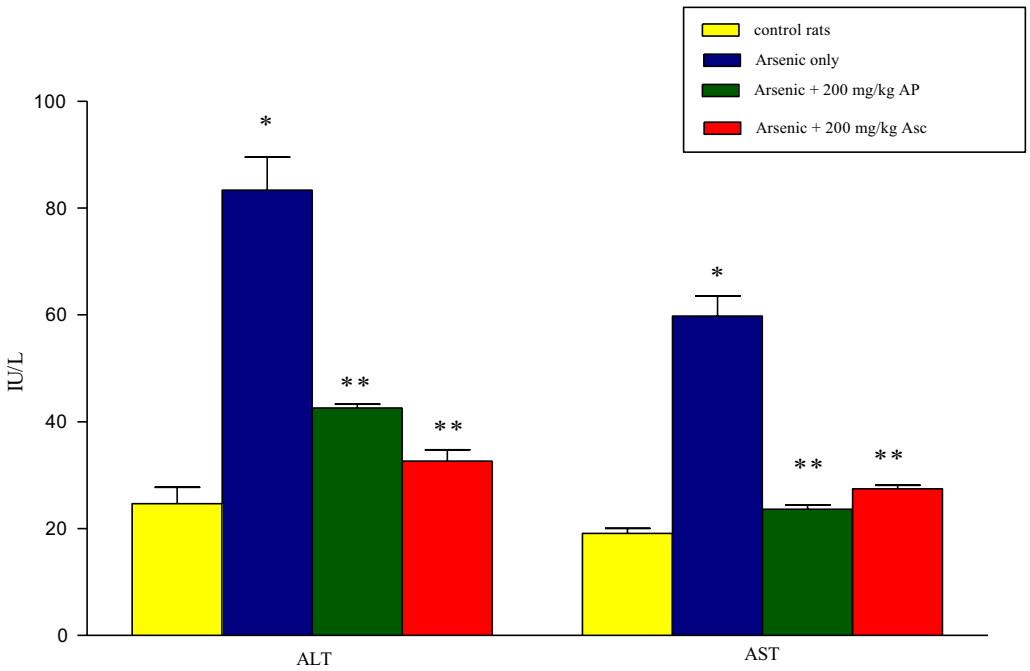

Fig. 1 Effect of methanolic extract of *A. paniculata* on activities of ALT and AST in arsenic-induced rats. Values are mean ± SEM ($n = 6$). *($p < 0.05$) Group 2: (arsenic group rats) compared with group 1: (control rats). **($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats, respectively) compared with group 2: (arsenic group rats)

Table 1 Effect of methanolic extract of *A. paniculata* on urea, creatinine, total protein, cholesterol and triglycerides in arsenic-induced rats

Parameter	Control	Arsenic only	Arsenic + 200 mg/kg *A. paniculata*	Arsenic + 200 mg/kg ascorbic acid
Urea (mg/dL)	25.77 ± 2.06	65.72 ± 3.40 *	39.05 ± 2.74**	31.63 ± 3.50**
Creatinine (mg/dL)	0.37 ± 0.07	2.10 ± 0.24*	0.77 ± 0.20**	0.91 ± 0.14**
Total protein (g/dL)	7.65 ± 0.29	5.74 ± 0.23*	6.43 ± 0.18**	7.50 ± 0.22**
Cholesterol (mg/dL)	55.89 ± 2.72	246.80 ± 28.60*	191.3 ± 13.16 **	92.72 ± 10.23**
Triglycerides (mg/dL)	47.52 ± 2.93	168.50 ± 9.12 *	69.43 ± 8.312**	103.0 ± 7.48**

Values are mean ± SEM ($n = 6$)

*($p < 0.05$) Groups 2: (arsenic group rats) compared with group 1: (control rats).

**($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats respectively) compared with group 2: (arsenic group rats)

44.25 and 60.90%, respectively, and kidney MDA levels by 54.35 and 63.19% when compared with rats in the arsenic group only (Fig. 4).

Effect of A. *paniculata* on the hepatic and renal catalase activity

Administration of arsenic caused a significant reduction in CAT activities in both liver and kidney homogenate by 363.89 and 140.76% when compared to the control rats. However, rats administered with 200 mg/kg *A. paniculata* or ascorbic acid have the CAT activities significantly increased ($p < 0.05$) in the liver and kidney when compared with rats in the arsenic group only (Fig. 5).

Haematological parameters

Administration of arsenic did not significantly affect the levels of HCT, HGB, MCV, MCH, RDW-SD, RDW-SV, P-LCR, MPV, PDW, MCHC and PTC, while the values of WBC, RBC, PLT and LYM were significantly lowered when compared with control animals. However, the values of all lowered parameters were significantly increased ($p < 0.05$) in rats that received 200 mg/kg *A. paniculata*

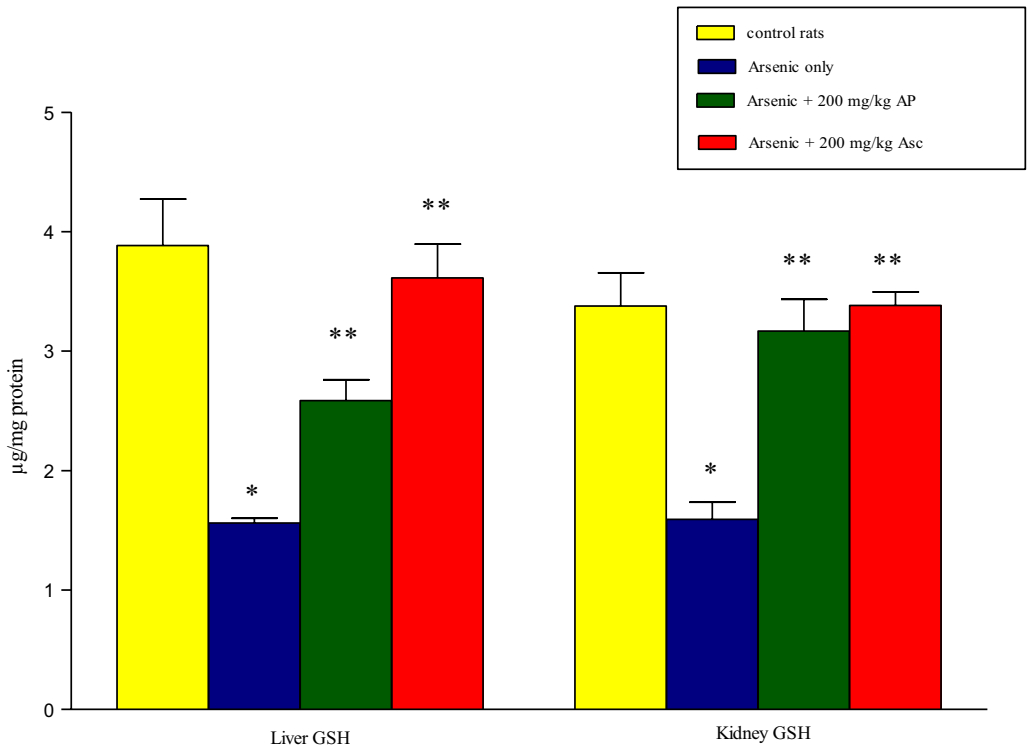

Fig. 2 Effect of methanolic extract of *A. paniculata* on hepatic and renal GSH levels in arsenic-induced rats. Values are mean ± SEM ($n = 6$). *($p < 0.05$) Group 2: (arsenic group rats) compared with group 1: (control rats). **($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats, respectively) compared with group 2: (arsenic group rats)

or ascorbic acid before arsenic administration when compared with rats in the arsenic group only (Table 2).

Histopathological studies of the liver in the control and prophylactic groups

The hepatic cells from the arsenic group relative to the control group and other groups that received *A. paniculata* or ascorbic acid were characterized by severe infiltration of cytoplasm (blue arrow), necrosis (green arrow), and congested sinusoids (slender arrow) [Fig. 6(2)]. The hepatic cells from the *A. paniculata* extract [Fig. 6(3)] and ascorbic acid [Fig. 6(4)] prophylactic groups showed similar morphological organization to the control group [Fig. 6(1)].

Discussion

Ingestion of arsenic at extremely high concentrations has led to the generation of free radicals, also capable of bypassing the blood–brain barrier, causing neurological deficits, cancer, chromosomal abnormalities and several epigenetic modifications (Afsane et al. 2020; Palma-Lara et al. 2020). The prevalence of exposure to arsenic brought about the need to discover and develop therapeutic agents from natural sources to combat the negative effects of oxidative stress associated with arsenic exposure. In this study, *A. paniculata* methanolic extract was found to be protective against the harmful effects associated with arsenic administration. Assessment of liver functioning is mostly evaluated using AST, ALT, and ALP assays. An increase in the activities of the hepatic enzymes in the plasma is an indication of liver dysfunction/ abnormalities (Rajesh and Latha 2004). There were elevated activities of AST and ALT in the plasma during arsenic-induced oxidative damage. However, rats that received *A. paniculata* methanolic extract or ascorbic acid before arsenic induction have a significant reduction in their AST and ALT activities when compared with rats administered with arsenic only. This confirms the hepatoprotective properties attributed to *A. paniculata* (Kapil et al. 1993).

Blood urea and creatinine levels are used to assess kidney function levels. The level of plasma creatinine is used to determine the glomerular filtration rate while urea is used to determine the nephrotoxic profile of xenobiotics (El-Wessemy 2008). There were significant increases ($p < 0.05$) in blood urea and creatinine levels in rats administered with arsenic only when compared to the control group. Administration of *A. paniculata* or

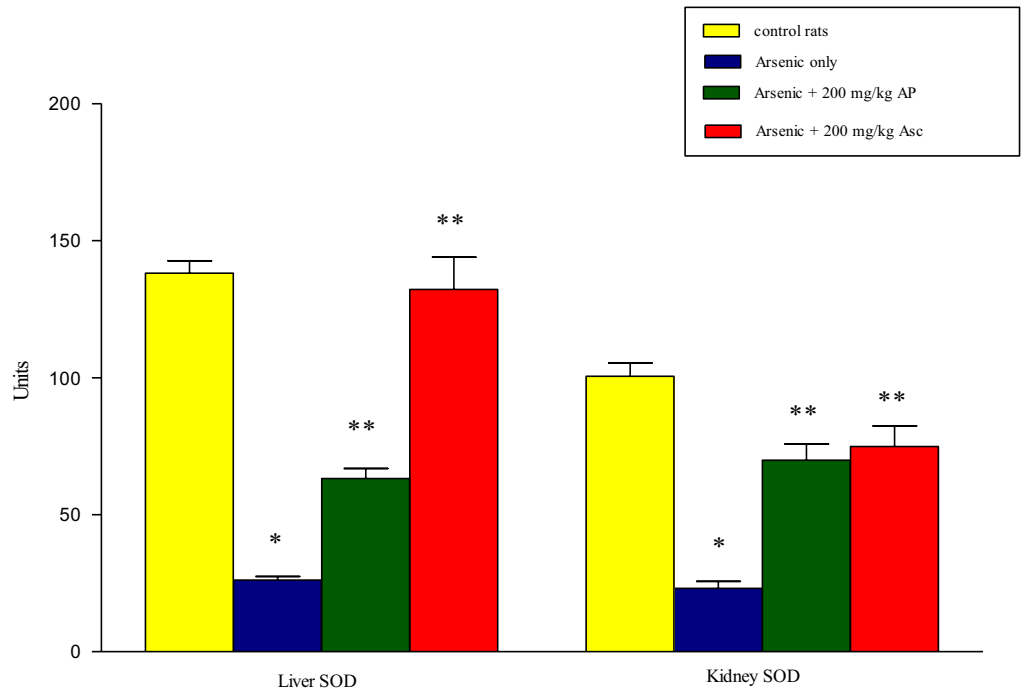

Fig. 3 Effect of methanolic extract of *A. paniculata* on hepatic and renal SOD activities in arsenic-induced rats. Values are mean ± SEM ($n = 6$). *($p < 0.05$) Group 2: (arsenic group rats) compared with group 1: (control rats). **($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats, respectively) compared with group 2: (arsenic group rats)

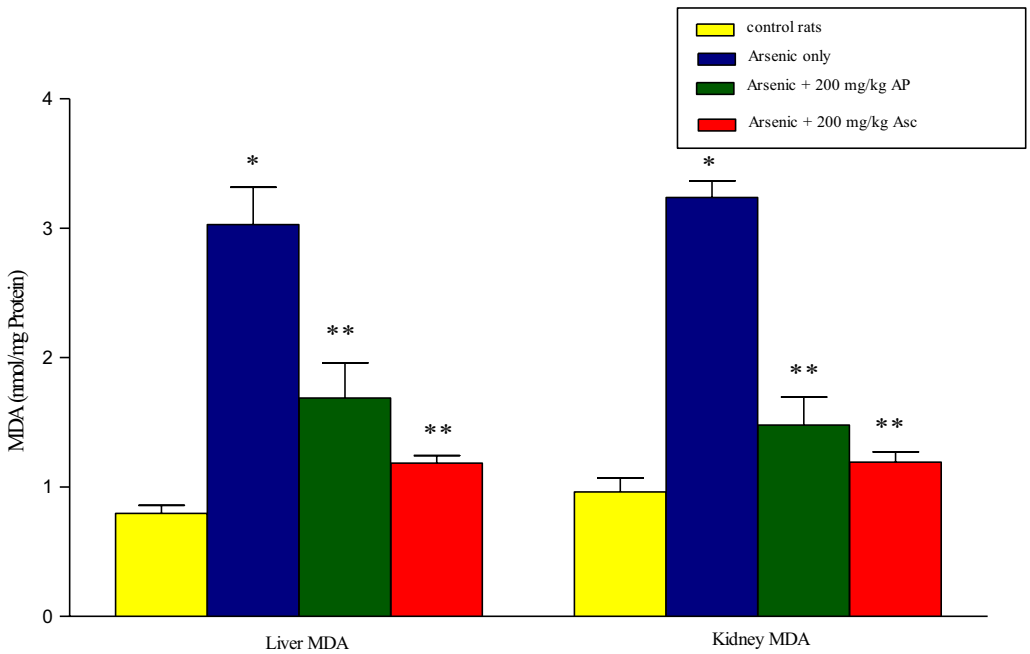

Fig. 4 Effect of methanolic extract of *A. paniculata* on hepatic and renal MDA levels in arsenic-induced rats. Values are mean ± SEM ($n = 6$). *($p < 0.05$) Group 2: (arsenic group rats) compared with group 1: (control rats). **($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats, respectively) compared with group 2: (arsenic group rats)

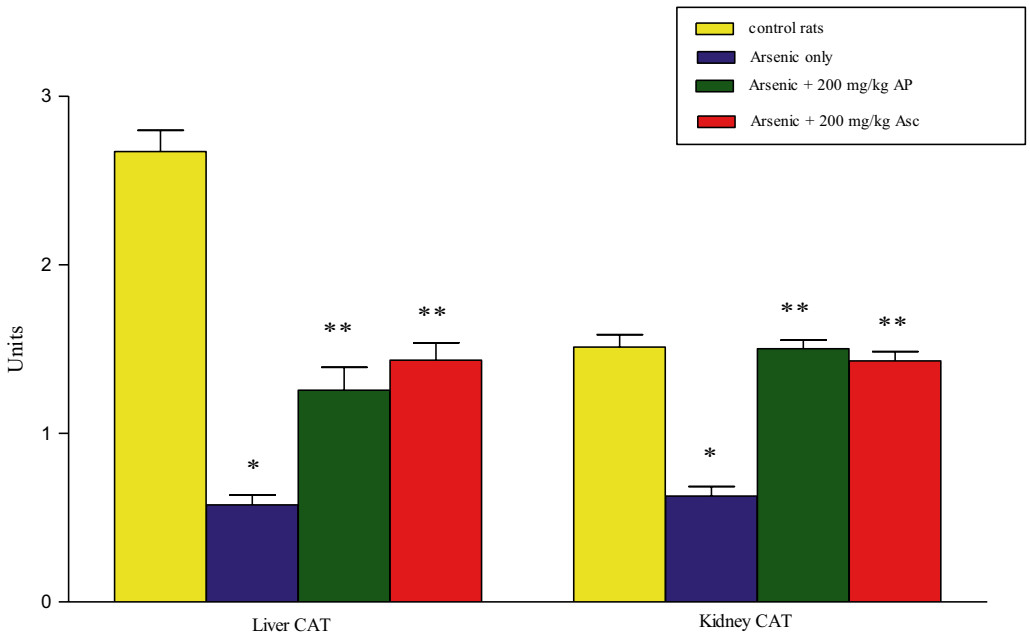

Fig. 5 Effect of methanolic extract of *A. paniculata* on hepatic and renal CAT activities in arsenic-induced rats. Values are mean ± SEM ($n = 6$). *($p < 0.05$) Group 2: (arsenic group rats) compared with group 1: (control rats). **($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats, respectively) compared with group 2: (arsenic group rats)

Table 2 Effect of arsenic administration on haematological parameters of rats

Parameter	Control	Arsenic only	Arsenic + 200 mg/kg body weight *A. paniculata*	Arsenic + 200 mg/kg body weight ascorbic acid
WBC	10.13 ± 1.48	4.26 ± 0.71*	8.86 ± 2.46**	8.13 ± 2.56**
RBC	8.45 ± 0.26	5.31 ± 0.57*	7.508 ± 0.19**	7.02 ± 0.20**
HGB	13.65 ± 0.44	12.00 ± 0.54	12.30 ± 0.13	14.04 ± 0.86
HCT	46.05 ± 1.54	39.80 ± 1.44	40.78 ± 0.61	41.88 ± 3.25
LYM	85.05 ± 2.16	60.10 ± 2.67*	95.06 ± 0.72**	78.18 ± 2.05**
PLT	740.50 ± 98.50	341.70 ± 26.61*	714.50 ± 26.92**	833.00 ± 51.41**
MCV	57.24 ± 1.07	59.82 ± 1.88	54.36 ± 0.63	72.62 ± 1.06
MCH	16.70 ± 0.53	17.96 ± 0.49	16.94 ± 0.22	17.06 ± 1.460
MCHC	29.18 ± 0.55	30.04 ± 0.20	30.18 ± 0.28	37.29 ± 2.07
RDW-SD	27.06 ± 0.49	30.56 ± 1.40	27.58 ± 0.26	27.78 ± 0.25
RDW-CV	10.54 ± 0.77	11.92 ± 0.44	11.50 ± 0.44	10.08 ± 0.24
PDW	7.18 ± 0.11	7.70 ± 0.26	9.24 ± 0.24	10.09 ± 1.10
MPV	6.54 ± 0.20	6.76 ± 0.08	7.20 ± 0.08	6.90 ± 0.26
P-LCR	8.72 ± 0.46	9.50 ± 0.59	9.42 ± 0.73	10.77 ± 1.84
PTC	0.42 ± 0.07	0.39 ± 0.29	0.35 ± 0.02	0.50 ± 0.04

Values are mean ± SEM ($n = 6$)

* ($p < 0.05$) Group 2: (arsenic group rats) compared with group 1: (control rats)

**($p < 0.05$) Groups 3 and 4: (*A. paniculata* or ascorbic acid administered rats, respectively) compared with group 2: (arsenic group rats)

ascorbic acid significantly lowered the levels of urea and creatinine in the blood when compared with rats that received arsenic only; this signifies that administration of *A. paniculata* or ascorbic acid protects the renal cells to combat the negative impact of arsenic.

Administration of arsenic increases plasma cholesterol and triglycerides levels significantly when

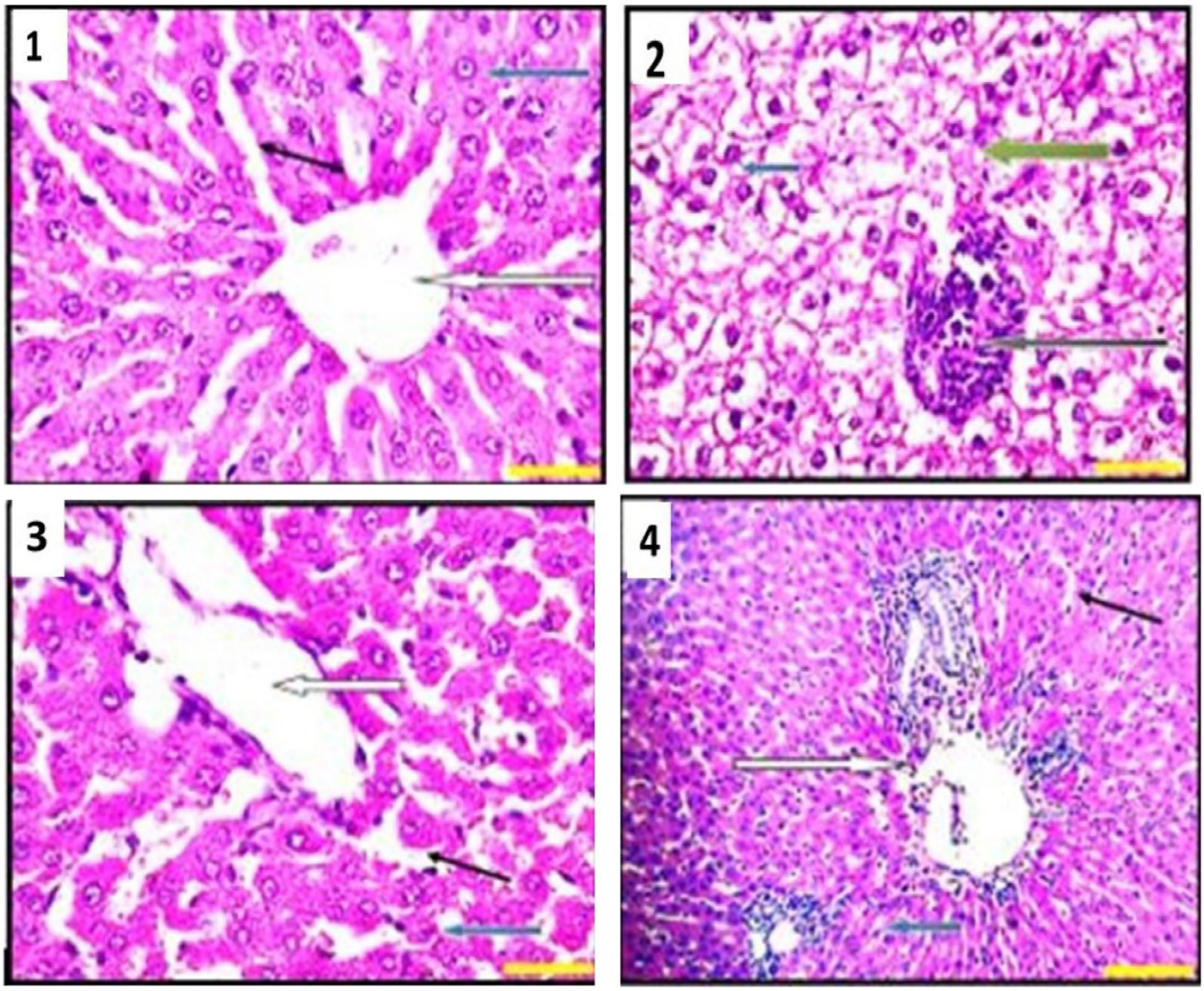

Fig. 6 Photomicrographs of liver section demonstrated by Haematoxylin and Eosin staining at low magnification (200 µm). The hepatocytes, sinusoids, portal triad (hepatic vein, hepatic artery and bile duct) are all visible across the various groups. **1** = group that received normal saline (control), **2** = group that received arsenic only, **3** = group that received *A. paniculata* extract and arsenic, **4** = group that received ascorbic acid and arsenic

compared with the control group which indicates disruption of lipid metabolism, in agreement with the previous study (Busher 1990). The cholesterol and triglycerides levels were reduced in the blood of rats that received *A. paniculata* or ascorbic acid before arsenic induction when compared with the arsenic group only. How *A. paniculata* extract was able to reduce the levels of cholesterol is not clear, but it may not be unconnected with its ability to modulate lipoprotein lipase activity or cholesterol metabolism in the liver (Ichikawa et al. 2005). There is a possibility that *A. paniculata* extracts chemical constituents, inactivates the enzymatic pathways, or reduces cholesterol biosynthesis or both.

The liver synthesizes most serum protein (Rosalki and Mcintyre 1999). Decreased serum total protein content may be a useful index of severity of hepatocellular damage (Folorunsho et al. 2019). In this study, administration of arsenic reduced total protein level when compared with control rats. However, rats that received *A. paniculata* or ascorbic acid have their total protein significantly increased ($p < 0.05$) to near normal, when compared with arsenic group rats which indicates repair of the hepatocellular damage caused by arsenic administration.

Arsenic administration induced depletion in the levels of hepatic and renal glutathione, superoxide dismutase (SOD) and catalase (CAT). The decrease in the activity of SOD, GSH and CAT levels during arsenic-induced

oxidative stress may be due to excessive production of reactive oxygen species (Tan et al. 2019; Johnson and Lapadat 2002). The levels of liver and kidney GSH, SOD and Catalase, were preserved in rats that received *A. paniculata* or ascorbic acid. The maintenance of these enzymes suggests enhancement in the functional capability of the liver and kidney by the extract. Thus, administration of *A. paniculata* extract probably increases the biosynthesis of GSH, SOD and catalase or reduces the level of oxidative stress, or it may have both effects. Arsenic administration resulted in high levels of MDA contents in this study suggesting damage to the liver and kidney cells as observed in the previous study (Ademola et al. 2018). However, a significant reduction was obtained in MDA levels of rats that received *A. paniculata* or ascorbic acid before arsenic administration when compared to the arsenic group only, indicating that the extract and its constituents inhibit lipid damage in the liver and kidney.

The deleterious effects associated with arsenic administration can be evaluated through haematological parameters. The significant changes from normal haematological parameters levels would suggest the presence of disease conditions or toxicity (Oyedemi et al. 2010). Arsenic administration resulted in a significant reduction in RBC, WBC, LYM, and PLT in this study. The decrease in RBCs could be a result of blood loss due to gastrointestinal tract bleeding, poor iron absorption in the intestine and red blood cell haemolysis. White blood cells and LYM play a significant role in the fight against infections and foreign organisms' invasion as well as produce antibodies in immune response (Soetan et al. 2013). Arsenic administration leads to a reduction in WBC and LYM in this study suggesting that arsenic suppresses the immune system. Excessive blood loss would result during injury if blood platelets level is low because platelets are involved in blood clotting. The reduction of platelet observed in this study suggests that arsenic administration induced thrombocytopenia. However, rats that received *A. paniculata* or ascorbic acid have their RBC, WBC, LYM, and PLT significantly increased ($p < 0.05$) to near normal, when compared with arsenic group rats which indicates the preservation of haematological parameters by *A. paniculata* or ascorbic acid administration.

The histopathological study of hepatic cells of arsenic group rats was characterized by severe steatosis, infiltration of cytoplasm and necrosis which are characteristics of the severe pathological lesion. However, the administration of *A. paniculata* or ascorbic acid before arsenic induction significantly improved the general histoarchitecture of the liver when compared with the arsenic group rats.

The present results indicate that *A. paniculata* extract through its actions protects the rats against arsenic-induced hepato-renal damage. This may be due to the mopping up of excessive free radicals generated by the arsenic exposure or upregulation of the antioxidant defence system by the extract. The bioactive compounds present in *A. paniculata* methanolic extract (majorly andrographolide, 14-deoxy-11,12-didehydroandrographolide and 14-deoxy andrographolide) have been mentioned in the previous studies to prevent the toxicity cascade usually triggered by arsenic (Afsane et al. 2020; Kapahi et al. 2000; Kumagai and Sumi 2007). Several pharmacological activities of *A. paniculata* previously studied include cardiovascular, anticancer, hepatoprotective activity, hypotensive property, antiangiogenic, antihyperglycemic and antimalarial potentials (Kumar et al. 2004; Sheeja et al. 2007). These activities could be attributed to the diverse group of phytochemicals such as diterpenoids, diterpene glycosides, lactones, flavonoids and flavonoids glycosides present in *A. paniculata (*nees) leaves (Pholphana et al. 2004; Owoade et al. 2021). Flavonoids and terpenoids, in particular, have been speculated to be responsible for the great antioxidant and anti-inflammatory potentials of *A. paniculata* in the previous study (Ghorbanpour and Varma 2017), and these constituents may account for good pharmacological properties of *A. paniculata* extract obtained in this study.

Conclusions

From this study, it can be inferred that bioactive compound from *Andrographis paniculata* (nees) could offer a novel therapeutic strategy in the management of hepato-renal diseases (usually associated with cirrhosis, hyper-calcinuria, syphilis and some cardiovascular dysfunction). Administration of *A. paniculata* might be potent in maintaining renal and liver morphology.

Abbreviations

AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; GSH: Reduced glutathione; SOD: Superoxide dismutase; MDA: Malondialdehyde; CAT: Catalase; HGB: Haemoglobin; WBC: White blood cell; RBC: Red blood cells; LYM: Lymphocytes; HCT: Haematocrit; RDW%: Red cells; RDW: Red cells distribution width; MCH: Mean corpuscular haemoglobin; MCHC: Mean corpuscular haemoglobin concentration; PLT: Platelet; MPV: Mean platelet volume; MCV: Mean corpuscular volume; PCT: Platelet crit; PDW: Platelet distribution width.

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Author contributions

AOO conceived and designed the study, organized the data, and wrote the final draft of the manuscript. AOA conducted the research, collected the data, and wrote the initial draft of the manuscript. AA analysed and interpreted the data. AWO provided logistic supports and provided research materials All authors have read and approved the manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The faculty of basic medical science, Ladoke Akintola University of Technology, Ogbomoso, research ethics committee gave ethical approval number for the study (FBMS2019/012) in compliance with ARRIVE guidelines.

Consent for publication
Not applicable.

Competing interests
All authors declare no conflict of interest.

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