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Solvent fractions of *Vitellaria paradoxa* root extract suppress phenylhydrazine-mediated jaundice in Wistar rats

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Abstract

Background In the first few days of life, jaundice has continued to be a major health concern. It typically manifests as a yellowing of the skin, mucous membranes, and sclera as a result of bilirubin deposition from excessively high concentrations in the body. It affects 80% of preterm and 60% of term new-borns within the first seven days of life, which is of great concern. According to the World Health Organization, the widespread acceptance of traditional medicines can be attributed to their accessibility and affordability. In West African arid savannah, there is a tree called *Vitellaria paradoxa* (Sapotaceae) that grows naturally. This well-known herb has numerous applications in medicine. Various plant components, including the leaves, roots, seeds, and fruit, have all been used in traditional medicine to cure a variety of illnesses. The purpose of this study is to objectively ascertain the efficacy of *V. paradoxa* root extracts on jaundice. Rats given phenylhydrazine (PHZ) to induce hyperbilirubinemia were orally administered ethylacetate, *n*-butanol, *n*-hexane, and aqueous fractions.

Result Results indicated the presence of terpenoids, flavonoids, and phenol. *n*-hexane and ethylacetate fractions showed activity against jaundice in rats. This observation was due to the fact that they significantly improved all biomarkers that were examined, namely body weight change, liver function parameters (total bilirubin, direct bilirubin, aspartate aminotransferase, albumin, and total protein), haematological parameters (white blood cells, haemoglobin, red blood cells, haematocrit, and platelets), and antioxidant enzymes (superoxide dismutase and malondialdehyde).

Conclusion *n*-Hexane and ethylacetate fractions of the extract showed significant activity against PHZ-induced jaundice in rats. However, *n*-hexane fraction was the most active fraction.

Keywords Jaundice, Hyperbilirubinemia, Phenylhydrazine, Antioxidants, Oxidative stress

Background

Lately, jaundice is now a serious health problem in neonates. According to Khoshnur et al. [13], jaundice is typically identified by the yellowing of the skin, mucous membranes, and sclera as a result of bilirubin deposition when the blood's bilirubin concentration is excessively high (>3 mg/dl). Changes in bilirubin metabolism often result in hyperbilirubinemia. Increased levels of unconjugated bilirubin are caused by higher rate of red blood cell breakdown, whereas higher levels of conjugated bilirubin are caused by liver injury and/or biliary system blockages

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[10]. Neonatal jaundice is the term used to describe jaundice in new-borns [6]. Within the first seven days of life, an alarming 60% of term and 80% of preterm new-borns develop jaundice [23]. The use of natural resources such as plant materials to treat or control illnesses is as old as man [27].

According to the World Health Organization, the widespread acceptance of traditional medicine can be attributed to its accessibility and affordability. With increased data generated from scientific research on the use of traditional medicine in the management of chronic diseases, usage is becoming more widespread [26]. An estimated 80% of people in impoverished nations like Nigeria use herbal medicine to treat common medical conditions like jaundice [9]. In the dry savannah region of West Africa, *Vitellaria paradoxa* (Sapotaceae) grows naturally [18]. This well-known herb has numerous applications in conventional medicine. It goes by several names: Ökwuma in Igbo, Ëmi in Yoruba, Kadanya in Hausa, Kareje in Fulfulde, and Shea butter in English [1]. Many African ethnic groups consider it to be a sacred tree, and it is used in many religious and cultural practices [18].

Various parts of *Vitellaria paradoxa*, such as leaves, roots, seeds, fruit, and stem bark, have been used in traditional medicine to treat microbial infections including helminths, dysentery, diarrhoea, and other infections affecting the gastrointestinal tract, skin, and wounds [2]. The stem bark has been reported to be used in the treatment of leprosy and cough [7]. The plant's kernels yield Shea butter, which is oil-rich and used as a source of edible oil in many homes throughout Sahel Africa especially Northern Nigeria. In addition, Shea butter is used to treat rheumatism, ulcers, dermatitis, rashes, and inflammation [16]. In the north and other parts of Nigeria, chewing sticks made from *Vitellaria paradoxa* roots are widely used to clean teeth and mouths. Root and root bark of *Vitellaria paradoxa* are typically made into a paste and administered orally [17]. The purpose of this study is to objectively establish if *Vitellaria paradoxa* root extracts are effective in treating jaundice.

Methods

Collection and identification of plant material

Vitellaria paradoxa roots and fresh leaves were collected. A sample of the leaf was identified at a herbarium and a voucher number assigned. Roots of the plant were carefully washed in clean, chopped into tiny pieces, shade-dried for 14 days, pulverized, and stored in airtight containers.

Preparation of methanol extract

Methanol root extract *Vitellaria paradoxa* was made by macerating 1500 g of the pulverized material root in 9 litters of methanol for 72 h. It was then filtering using Whatman No. 1 filter paper, concentrated using a rotary evaporator at 40 °C. The extract obtained was freeze-dried giving rise to 7.3% w/w yield.

Fractionation of methanol extract of *Vitellaria paradoxa* root

Using Almohaimeed et al. [3] approach, methanol extract was partitioned into ethylacetate, *n*-butanol, *n*-hexane, and an aqueous fraction.

Qualitative phytochemical screening of *Vitellaria paradoxa* root

Using standard protocol as outlined by Shemishere et al. [20], a chemical test was performed to screen and identify phytochemicals (saponins, terpenoids, alkaloids, tannins, carbohydrates, phenols, steroids, flavonoids, and cardiac glycosides) in the methanol extract of *Vitellaria paradoxa* root.

Quantitative determination of total phenolic and flavonoid content of methanol extract of *Vitellaria paradoxa* root

Total phenol and flavonoid content of *Vitellaria paradoxa* methanol root extract was calculated using the method described by Shemishere et al. [21, 22].

Animal protocol

42 rats, ages 10 to 12 weeks and weighing between 70 and 90 g, were bought from a standard Animal House. The rats were kept in metal cages and given free access to food and water in a natural environment with a 12-h light/dark cycle for two weeks to acclimatize before administration. Rats were maintained in accordance with the Animal Ethics Committee's guide for the care and use of animals in research and education and the National Institutes of Health's guide for the care and use of laboratory animals (NIH Publications No. 8023, revised 1978). The experimental protocol was approved in accordance with ethical standards.

Rats were divided into 6 groups of 7 rats each and administered as follows. Rats except those in the control group received 1 dose of phenylhydrazine (PHZ) through intraperitoneal route at 40 mg/kg body weight for three consecutive days to induce jaundice. This approach slightly differs from that which Kolawole et al. [14] used. Rats were administered as follows for 21 days. Rats in PHZ + Aqueous group, PHZ + n-hexane, PHZ + n-butanol, PHZ + Ethylacetate, and PHZ alone group were each administered 50 mg/kg body weight of the extract fractions. The rats were killed twenty-four hours following the last administration.

Haemoglobin concentrations, blood platelets and haematocrit scores, white blood cell and red blood cells

counts, and haemoglobin concentration were measured after blood samples were drawn into EDTA specimen bottles. The residual blood sample was transferred into simple sample bottles, centrifuged, and serum extracted with care to measure the levels of malondialdehyde (MDA) and superoxide dismutase (SOD), total and direct bilirubin, aspartate aminotransferase, alkaline phosphatase, alanine amino transferase, albumin, and total protein using appropriate kits.

Body weight change determination

On days 0, 7, 14, 21, and 28 of the treatment, body weight was measured and recorded. Rats' body weight on day 0 was subtracted from their body weight on day 28 to calculate the changes in the body weight.

Determination of superoxide dismutase (SOD) activity

The activity of superoxide dismutase (SOD) was determined using the method of [25] with slight modifications. An aliquot of 0.4 ml of colon sample was added to 5 ml of 0.05 M carbonate buffer in a quartz cuvette and the reaction started by the addition 0.6 ml of 0.3 M adrenaline. Reference cuvette contained 5 ml of carbonate buffer, 0.6 ml of adrenaline and 0.4 ml of distilled water. Increase in absorbance at 480 nm was monitored every 30 s for 120 s. Enzyme activity was expressed as units/mg protein. One unit of an enzyme is defined as the enzyme activity that inhibits auto-oxidation of adrenaline by 50%.

Determination of malondialdehyde (MDA)

Colon tissue samples were subjected to the lipid peroxidation analysis using the methodology outlined by Ayodeji et al. [5]. This experiment is predicated on the reaction between MDA and 2-thiobarbituric acid, a chromogenic reagent. A pink chromophore with an absorbance maximum at 532 nm is produced when one molecule of MDA interacts with two molecules of 2-thiobarbituric acid by a Knoevenagel-type condensation. A mixture of 1.6 ml of phosphate buffer, 0.5 ml of colon sample, 0.5 ml of 30% TCA, and 0.5 ml of 75% 2-thiobarbituric acid (TBA) in 0.1 mol/l HCl comprised the reaction mixture. For two hours, the mixture was heated in a water bath at 90–95 °C. The resulting mixtures were centrifuged at 3000*g* for 15 min after being chilled on ice. At 532 nm, the absorbance of the turbidity-free supernatant was measured. The molar extinction coefficient concentration in nmole/L is used to compute MDA, which is equal to absorbance × (1000/1.56).

Determination of blood parameters

An auto-haematological analyser (Beckman Coulter, USA) was used to determine the red blood cell count (RBC), white blood cell count (WBC), haemoglobin concentration (HGB), blood platelet count (PLT), and haematocrit value (HCT) from blood samples collected in EDTA bottles.

Determination of Liver function parameters

Standard test kits from Ultracare Diagnostics were used to measure the following liver function parameters: total bilirubin (TB), direct bilirubin (DB), aspartate aminotransferase (AST), alanine amino transferase (ALT), and albumin (ALB). Standard kits from Randox, UK, were used to measure total protein (TP), aspartate aminotransferase (ALP), and albumin (ALB).

Data analysis

For testing significance levels ($p < 0.05$), the statistical programme for social sciences (SPSS) version 20 was utilized.

Results

Extract yield

The crude methanol extract yield at the conclusion of the extraction procedure was 19.75% (w/w). The percentage yields for the other fractions were as follows: 9.36 g, 2.41 g, 3.53 g, and 0.43 g for *n*-hexane, *n*-butanol, ethylacetate, and water, respectively.

Qualitative phytochemical constituents

According to the findings from the analysis of the phytochemical components of the methanol extracts, phenols were found to be present in significant amount. There was a medium concentration of terpenoids and carbohydrates, and trace amounts of saponins, alkaloids, tannins, steroids, and flavonoids. Heart glycosides, however, were not found in the sample (Table 1).

Table 1 Qualitative phytochemical constituents of methanol extract of *Vitellaria paradoxa* root

Phytochemicals	Status
Saponins	+
Terpenoids	++
Alkaloids	+
Tannins	+
Carbohydrates	++
Phenols	+++
Steroids	+
Flavonoids	+
Cardiac glycosides	–

+: Present in a trace concentration; ++: present in a medium concentration; +++: present in a high concentration; – absent or in negligible amount

Quantitative phytochemical constituents

Two phytochemicals, namely total phenol and total flavonoids, were quantified. Total phenols obtained were 39.85 ± 0.91 mg garlic acid equivalent per gram of extract. On the other hand, the total flavonoids obtained were 0.9 ± 0.04 mg quercetin equivalent per gram of extract (Table 2).

Effect of methanol and solvent fractions of *Vitellaria paradoxa* root extracts on body weight changes in phenylhydrazine-induced hyperbilirubinemic in Wistar rats

According to the body weight changes results, the PHZ alone group lost a substantial amount of weight in comparison with the control group. The PHZ + *n*-butanol, PHZ + ethylacetate, and PHZ + aqueous groups all gained weight as compared to the control group, but the weight gain was not statistically significant ($P < 0.05$). Rats in the PHZ + *n*-hexane group did not substantially vary in body weight gain from the control group. Overall, Table 3 shows that the PHZ + *n*-hexane fraction was more effective at reversing weight loss.

Effect of solvent fractions of *Vitellaria paradoxa* root extracts on SOD and MDA in phenylhydrazine-induced hyperbilirubinemic in Wistar rats

Data produced showed that, in comparison with the PHZ only group, the *n*-hexane fraction of the extract considerably enhanced the levels of SOD and decreased the levels of MDA. SOD levels in the *n*-hexane fraction increased to control values, with no discernible change ($P < 0.05$). The n-hexane fraction's activity resulted in a reduction of MDA levels, a sign of lipid peroxidation, according to the same observation. While SOD and MDA levels were improved by two other extract fractions, *n*-butanol and ethylacetate, the effects were not as great as they were in the PHZ only. For the two indicators tested, there was no discernible improvement in the extract's aqueous fraction (Table 4).

Table 2 Total phenolic and flavonoid content of methanol extract of *Vitellaria paradoxa* root

Phytochemicals	Quantitative value
Total phenols (mg garlic acid equivalent/g of extract)	39.85 ± 0.91
Total flavonoids (mg Quercetin equivalent/g of extract)	0.90 ± 0.040

All values are expressed as mean ± SEM ($n = 3$)

Table 3 Body weight changes in phenylhydrazine-induced hyperbilirubinemic Wistar rats treated with solvent fraction of *Vitellaria paradoxa root extracts*

GROUP	DAY 1 (g)	DAY 28 (g)	BWC (g)
Control	81.77 ± 16.91	123.39 ± 17.21	+ 41.62 ± 0.30^{bc}
PHZ only	84.35 ± 18.16	53.17 ± 17.31	− 31.18 ± 0.85*
PHZ + *n*-hexane	85.21 ± 16.21	126.57 ± 17.02	+ 41.36 ± 0.81^{bc}
PHZ + *n*-butanol	86.50 ± 11.08	73.67 ± 13.3	+ 32.17 ± 2.22 *^{c}
PHZ + ethylacetate	73.29 ± 19.13	63.27 ± 20.21	− 10.02 ± 1.08*^{c}
PHZ + aqueous	83.86 ± 11.89	54.34 ± 13.54	− 29.52 ± 1.65*

50 mg/kg of phenylhydrazine intraperitoneal (PHZ): *n*-hexane, *n*-butanol, ethylacetate and aqueous represents the different fractions of the extracts: BWC: body weight change: values are presented as mean ± SD ($n = 7$):*values differ significantly from control ($p < 0.05$): ^{b}values are not significantly different from each other ($p < 0.05$): ^{c}values differ significantly as compared with PHZ only ($p < 0.05$)

Effect of solvent fractions of *Vitellaria paradoxa* root extracts on blood parameters in phenylhydrazine-induced hyperbilirubinemic in Wistar rats

Results showed that the *n*-hexane fraction of the plant extract significantly improved the blood parameters measured when different fractions of the extract were tested to determine their effects on some haematological parameters in PHZ-induced hyperbilirubinemia. Conversely, the extract's ethylacetate fraction was found to generally improve all blood parameters examined; however, only HCT and PLT showed significant ($P < 0.005$) improvements in comparison with the control group. When compared to the control group, the butanol fraction greatly improved the parameter, but not as much as it did when compared to the PHZ alone group. When compared to the control and PHZ alone groups, the aqueous extract had no significant impact on the haematological parameters (Table 5).

Table 4 Superoxide dismutase activity (SOD) and malondialdehyde (MDA) levels changes in phenylhydrazine-induced hyperbilirubinemic Wistar rats treated with solvent fraction of *Vitellaria paradoxa* root extracts

Group	SOD (units/mg)	MDA (nmol/l)
Control	2.64 ± 0.35^{bc}	24.35 ± 0.36^{bc}
PHZ only	1.22 ± 0.13*	44.08 ± 0.23*
PHZ + *n*-hexane	2.30 ± 0.35^{bc}	22.39 ± 0.81^{bc}
PHZ + *n*-butanol	1.29 ± 0.63*^{c}	39.92 ± 0.68*^{c}
PHZ + ethylacetate	1.38 ± 0.23*^{c}	38.74 ± 0.41*^{c}
PHZ + aqueous	1.43 ± 0.16*	38.04 ± 0.41*

50 mg/kg of phenylhydrazine intraperitoneal (PHZ): *n*-hexane, *n*-butanol, ethylacetate and aqueous represents the different fractions of the extracts: SOD: superoxide dismutase: MDA: malondialdehyde: values are presented as mean ± SD (n = 7):*values differ significantly from control ($p < 0.05$): ^{b}values are not significantly different from each other ($p < 0.05$): ^{c}values differ significantly as compared with PHZ only ($p < 0.05$)

Table 5 Changes in haematological parameters in phenylhydrazine-induced hyperbilirubinemic Wistar rats treated with solvent fractions of *Vitellaria paradoxa* root extracts

GROUP	WBC 10^3/uL	HGB g/dL	RBC 10^6/uL	HCT (%)	PLT 10^3/uL
Control	5.09 ± 1.58^{cb}	16.62 ± 0.98^{bc}	8.15 ± 0.11^{bc}	47.28 ± 0.33^{bc}	349.4 ± 12.1^{bc}
PHZ only	15.69 ± 1.57*	7.09 ± 0.49*	4.05 ± 0.33*	29.8 ± 0.50*	107.6 ± 9.21*
PHZ + *n*-hexane	4.92 ± 1.81*^{bc}	14.51 ± 0.23^{bc}	7.62 ± 3.15^{bc}	45.26 ± 0.18^{bc}	329.0 ± 10.3^{bc}
PHZ + *n*-butanol	13.09 ± 0.43*^{c}	7.86 ± 0.12*^{c}	4.10 ± 2.22*^{c}	32.24 ± 0.21*^{c}	109.2 ± 11.7*^{c}
PHZ + ethylacetate	4.51 ± 0.52*^{c}	15.98 ± 0.32*^{c}	7.36 ± 1.46*^{c}	44.98 ± 0.16^{bc}	339.2 ± 12.23^{bc}
PHZ + aqueous	14.12 ± 0.65*	9.05 ± 0.3*	4.53 ± 2.14*	30.05 ± 0.43*	109.3 ± 13.21*

50 mg/kg of phenylhydrazine intraperitoneal (PHZ): *n*-hexane, *n*-butanol, ethylacetate and aqueous represents the different fractions of the extracts: BWC: body weight change: values are presented as mean ± SD ($n = 7$):*values differ significantly from control ($p < 0.05$): [b]values are not significantly different from each other ($p < 0.05$): [c]values differ significantly as compared with PHZ only ($p < 0.05$)

Effect of solvent fraction of *Vitellaria paradoxa* root extracts TB, DB, AST, ALP, ALT, ALB and TP in phenylhydrazine-induced hyperbilirubinemic in Wistar rats

By lowering the levels of both TB and DB, the *n* hexane fraction successfully counteracted the effects of PHZ, according to the results of the biochemical assay used in this study. ALT, ALP, and AST all showed the same pattern. Conversely, in comparison with the control, there was a substantial ($P < 0.005$) rise in the levels of ALB and TP. Additionally, ethylacetate fraction was found to significantly lower TB and DB. The levels of AST, ALP, ALT, ALB, and TP improved, although the difference was not statistically significant ($P < 0.005$). All liver markers that were tested for indicated improvement in the butanol fraction as well, but the improvements were not statistically significant ($P < 0.005$) when compared to the control. The extract's aqueous fraction had no effect on the liver indicators tested for (Table 6).

Discussion

Data generated from this study have highlighted the importance of using scientific experiments to validate claims by traditional medical practitioners on the efficacy or otherwise on products used in the management and treatment of human ailments. Data from this study have shown the activity of *Vitellaria paradoxa* extracts on jaundice. The use of PHZ to induce jaundice in rats has long been established [12]. Its results obtained from this studies seem to show that only the n-hexane and ethylacetate fractions of the extract showed activity against jaundice. It is important to establish that data from previous study in which Wistar albino rats were exposed to root extract of *Vitellaria paradoxa* at a concentration of 50 mg/kg body weight did not show any toxic effect. At a dose of 100 mg/kg body weight some toxic effects were observed [8]. This informed the selection of the dose of 50 mg/kg body weight for this study.

Response to treatment in jaundice is usually associated with weight gain as shown from this study where n-hexane group showed significant weight gain when compared with the PHZ only group [12]. The anti-lipid peroxidative and antioxidant properties of phenols and flavonoids have been reported. Both phenols and flavonoids were detected from the screening process used to identify the phytochemical components present in the extract. Numerous sources of free radicals within cells have been identified. The xanthine oxidase system, the

Table 6 Changes in liver function parameters in phenylhydrazine-induced hyperbilirubinemic Wistar rats treated with solvent fraction of *Vitellaria paradoxa* root extracts

Group	TB (mg/dL)	DB (mg/d)	AST (U/L)	ALP (IU/L)	ALT (U/L)	ALB (g/dl)	TP (g/dL)
Control	0.91 ± 0.02^{bc}	0.31 ± 0.01^{bc}	19.12 ± 0.13^{bc}	69.21 ± 0.20^{bc}	36.23 ± 0.55^{bc}	3.61 ± 0.32^{bc}	7.93 ± 0.05^{bc}
PHZ only	2.30 ± 0.11*	0.90 ± 0.21*	36.18 ± 0.24*	152.10 ± 0.48*	61.02 ± 0.14*	1.85 ± 0.01*	3.43 ± 0.16*
PHZ + *n*-hexane	0.93 ± 0.31^{bc}	0.34 ± 0.13^{bc}	19.15 ± 0.11^{bc}	68.92 ± 0.32^{bc}	38.80 ± 0.13^{bc}	3.32 ± 0.15^{bc}	7.91 ± 0.02^{bc}
PHZ + *n*-butanol	2.15 ± 0.22*^{c}	0.85 ± 0.21*^{c}	32.04 ± 0.21*^{c}	149.00 ± 0.20*^{c}	57.00 ± 0.55*^{c}	1.95 ± 0.21*^{c}	3.25 ± 0.05*^{c}
PHZ + Ethylacetate	2.19 ± 0.12^{bc}	0.88 ± 0.22^{bc}	33.18 ± 0.19*^{c}	147.21 ± 0.65*^{c}	59.05 ± 0.54*^{c}	1.91 ± 0.05*^{c}	$3.40 \pm 0.13^{,bc}$
PHZ + Aqueous	2.27 ± 0.03*	0.87 ± 0.11*	31.16 ± 0.19*	148 ± 0.47*	59.80 ± 0.18*	1.94 ± 0.19*	3.16 ± 0.08*

50 mg/kg of phenylhydrazine intraperitoneal (PHZ): *n*-hexane, *n*-butanol, ethylacetate and aqueous represents the different fractions of the extracts: TB: total bilirubin: DB: direct bilirubin: AST: aspartate aminotransferase: ALP: alkaline phosphatase: ALT: alanine amino transferase: ALB: albumin: TP: total protein. Values are presented as mean ± SD ($n = 7$):*values differ significantly from control ($p < 0.05$): [b]values with the same alphabet are not significantly different at ($p < 0.05$): [c]values differ significantly as compared with PHZ only ($p < 0.05$)

mitochondrial electron transport system, and an increase in intracellular calcium levels are a few of the sources [4]. These free radicals set off series of biochemical reactions in vivo that disrupt cell membrane integrity and increase endotoxin release, changing how cells behave. The cell membrane finally disintegrates as a result of the injury. It is commonly recognized that oxidative stress and subsequent cell damage are reduced when enzymatic and non-enzymatic antioxidant levels in vivo increases [4]. One of the etiologic variables linked to the RBC breakdown and subsequent hyperbilirubinemia seen in anaemia has been identified as oxidative stress [4]. Oxidative stress occurs when the body's antioxidant system is unable to eliminate the free radicals that are produced. From the data presented in Table 4, *n*-hexane fraction of the extract significantly ($P<0.005$) increased the activity of SOD (2.60 ± 0.35) when compared to PHZ group. The administration of n-hexane fraction considerably decreased the levels of lipid peroxidative marker MDA when compared with the PHZ group. There was no significant variation found between the control and n-hexane group. This outcome is in line with the result of Uz et al. [24] where the levels of MDA in renal ischaemia and reperfusion (I/R) damage showed that ginger extract reduced I/R damage but serum MDA levels did not show any difference between control and treatment group.

Elevated bilirubin levels, a by-product of red blood cell breakdown, are indicators of jaundice [4]. In other words, jaundice is a medical disorder whose course is determined solely by the health of the red blood cells. One essential step in determining if a treatment is successful in curing jaundice is assaying for red blood cells and other blood parameters. A study by Raicevic et al. [19] demonstrated the connection between the onset of neonatal jaundice and some haematological markers in new-borns. According to the research findings, newborns with low RBC and high bilirubin levels subsequently experienced jaundice. From our result in Table 5, the levels of RBC, HGB, HCT, and PLT all increased significantly for both the *n*-hexane and ethylacetate fraction when compared with control. In contrast, WBC decreased considerably in comparison with the PHZ alone group. Nan et al. [15] in a study on the relationship between maternal blood parameters and new-born jaundice found that mothers with high WBC and mean corpuscular volume (MCV) levels frequently give birth to infants who experience neonatal jaundice.

In addition to providing information on liver cell damage, the liver function test panel makes it evident how functional the liver is. According to a study by Hayat et al. [11] on human subjects, jaundice is typically associated with abnormal levels of liver function indicators. In another study published by [4], treatment with ursodeoxycholic acid led to a significant decrease in the levels of AST, ALT, and GGT in rats that developed obstructive jaundice. This study's findings demonstrated that the *n*-hexane fraction considerably lowered the blood levels of TB, DB, AST, ALP, and ALT. In addition, the levels of TP and ALB were substantially higher than those of the PHZ alone group.

The liver function indices AST, ALT, urea, creatinine, uric acid, and bilirubin were all improved in a 2019 study by Ali utilizing an extract of *Vitellaria paradoxa* in diabetic rats. Following the injection of *Vitellaria paradoxa* extract, the activity of antioxidant enzymes such as SOD and CAT increased. The decrease in MDA levels followed the same pattern. This is in line with the study's findings, which indicated that the extract's *n*-hexane fraction was the only one that exhibited activity. This observation also suggests that the n-hexane fraction of the extract may likely contain the active component of the extract that accounts for the activity reported in this investigation.

Conclusion

Result from this study has shown that root extract of Vitellaria paradoxa reversed all the markers associated with jaundice induced in rats with PHZ. An attempt to also identify the solvent fraction of the extract containing the active principle was also achieved. *n*-hexane fraction of the root extract of Vitellaria paradoxa showed activity for all the markers of jaundice checked in this study. Following closely is the ethylacetate fraction of the extract which showed activity for all the haematological parameters. Findings from this studies are limited with regard to why *n*-hexane fraction showed positive result for all the markers assayed for as against the ethylacetate fraction which showed activity for only the haematological parameters assayed for. Further studies will be required to identify the active principle responsible for the observable activity and to unravel the biochemical basis of the action.

Abbreviations

WHO	World Health Organization
PHZ	Phenylhydrazine
EDTA	Ethylenediamine tetraacetic acid
SOD	Superoxide dismutase
MDA	Malondialdehyde
HCl	Hydrochloric acid
TCA	Tricarboxylic acid
RBC	Red blood cells
WBC	White blood cells
HGB	Haemoglobin
PLT	Platelet
HCT	Haematocrit
TB	Total bilirubin
DB	Direct bilirubin
ALT	Alanine amino transferase
AST	Aspartate aminotransferase
ALP	Aspartate aminotransferase

ALB	Albumin
TP	Total protein
BWC	Body weight change
MCV	Mean corpuscular volume
GGT	Gamma-glutamyl transferase
CAT	Catalase

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Plant identification
Fresh leaves and root of Vitellaria paradoxa were collected from Yelwa, Yauri local government area in Kebbi State, North-West Nigeria in August, 2023. Plant leaf sample was identified at the Herbarium section of the Federal University Birnin-Kebbi, and a sample of the authenticated materials with the voucher number FUBK/PIN/0219 was deposited.

Author contributions
DAA contributed to conceptualization; writing—original draft; writing—review and editing; project administration; supervision; resources; funding acquisition; and investigation. AAT was involved in writing—original draft; methodology; visualization; writing—review and editing; investigation; and formal analysis. ABY contributed to methodology; visualization; formal analysis; and investigation. UBS was involved in methodology; validation; formal analysis; investigation; and supervision. MIO contributed to methodology; formal analysis; writing—original draft; and investigation. YT was involved in methodology; visualization; formal analysis; and investigation

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

Declarations

Ethics approval and consent to participate
The guide of care and use of animals in research and teaching of the Animal Ethics Committee of Federal University Birnin Kebbi, Nigeria, in line with the National Institutes of Health guide for the care and use of Laboratory animals (NIH Publications No. 8023, revised 1978) were followed in maintaining the rats. Approval for the experimental procedure was obtained with the ethical code FUBK/AEC/FS/M1045.

Consent for publication
All authors have agreed and consented for this work to be published in your journal.

Competing interests
The authors declared that they have no conflict of interest.

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