

# **Hepatoprotective Effect of *Parkia biglobosa* on Acute Ethanol-Induced Oxidative Stress in Wistar Rats**

## **ABSTRACT**

**Aim:** This study is aimed at investigating the hepatoprotective effect of *Parkia biglobosa* on acute ethanol-induced oxidative stress in wistar rats.

**Methods:** *P. biglobosa* was purchased from a local market at Orita-Challenge area of Ibadan, Nigeria. They were sun dried and milled into powder using an electronic blender (Moulinex). The powder was extracted using standard method. Twenty adult male wistar rats with body weight between 120 and 150 g were purchased from the Central Animal House, College of Medicine, University of Ibadan, Nigeria. They were housed in Imrat animal house, Ibadan. They were acclimatized for seven (7) days during which they were fed *ad libitum* with standard feed and drinking water. They were randomly divided into four groups of five rats each. Animals in groups 1 and 2 were administered normal saline solution while those in groups 3 and 4 were administered *P. biglobosa* extract for twenty-one days. The animals were administered the extract and saline solution at a dose of 4 ml per 100 g body weight 12 hourly via oral route of administration. At the end of the treatment, they were fasted overnight and animals in groups 2 and 4 were exposed to a single dose of 70% ethanol at 12 ml/kg body weight to induce oxidative stress. After 12 hours of ethanol administration, the animals were anaesthetized using diethyl ether and were sacrificed. Liver was excised, weighed and homogenized in 50 mmol/l Tris-HCl buffer (pH 7.4) and then centrifuged at 5000 × g for 15 minutes for biochemical analysis. Supernatants were immediately kept frozen until when needed.

**Results:** Ethanol-induced oxidative stress significantly increased the activities of AST, ALT, LDH, LPO, CAT and SOD but decrease GSH. However, it has no effect on GPX. These effects were regulated by *P. biglobosa* administration.

**Conclusion:** *P. biglobosa* was able to remedy the effect of ethanol by regulating the oxidative stress biomarkers, thus possesses prophylactic efficacy against ethanol-induced oxidative stress and can protect the liver against free radicals arising from oxidative stress.

**Keywords:** *Parkia biglobosa*, ethanol, oxidative stress, hepatoprotective

## **1. INTRODUCTION**

Excessive acute or chronic alcohol consumption poses a serious health hazard and can result into several metabolic disorders in hepatic and extra-hepatic diseases [1]. Alcohol is a commonly used hepatotoxin in experimental hepatopathy. Although the pathogenesis of alcohol-induced liver disease is not clearly defined, there is evidence that ethanol-induced liver injury is due to oxidative stress that leads to fibrosis and impaired liver functions [2,3].

Alcohol overuse is also characterized by central nervous system (CNS) intoxication symptoms, impaired brain activity, poor motor coordination, and behavioral changes [4]. Excessive alcohol consumption commonly causes hepatic, gastrointestinal, nervous and cardiovascular injuries leading to physiological dysfunctions [6]. Cellular disturbances resulting from excessive alcohol consumption results in increased formation of oxidative stress biomarkers such as malondialdehyde (MDA); reduction in the level of reduced glutathione level and a decrease in the

activities of antioxidant enzymes [7,8]. Free radicals and reactive oxygen species (ROS) have been implicated in the oxidative damage of biomolecules and various organs of the body. Studies have shown the crucial role free radicals play in the pathogenesis of many human diseases namely, cardiovascular and pulmonary diseases, some types of cancer, immune/autoimmune diseases, inflammation, diabetes, cataracts and brain dysfunction such as Parkinson and Alzheimer [9]. However, the deleterious effect of free radicals can be corrected by antioxidants – both enzymatic and nonenzymatic. Oxidative stress is known to arise when there is an imbalance between free radical production (especially reactive oxygen species; ROS) and endogenous antioxidant defense system. This shift in balance is associated with oxidative damage to a wide range of biomolecules including lipids, proteins, and nucleic acids, which may eventually impair normal functions of various tissues and organs [10].

There is an increasing global interest concerning the use of medicinal plants in the prevention and treatment of different pathologies [11, 12]. The beneficial effects of plants are attributed to the presence of secondary metabolites such as polyphenols, tannins, terpenoids, alkaloids, flavonoids [13]. Considering the central role played by free radicals in the initiation and progression of many diseases, the use of natural products with antioxidant constituents has been proposed as an effective therapeutic and/or preventive strategy against diseases and the search for potent and cost-effective antioxidants of plant origin has since increased [14]. Many plants have been shown to possess antioxidant potentials [15,16]. This has thus raised interest in the investigation of commonly consumed plants for their phytochemicals with nutritional and chemotherapeutic potentials. Therefore, the need to argument synthetic chemotherapeutic compounds with natural products is the drive for the exploitation of natural products from plants; as they may have little or no side effects yet meeting the nutritional, chemotherapeutic and economic needs [17,18]. Moreover, despite the efforts of pharmaceutical companies in the production of synthetic antibiotics, there yet exists a marked increase in pathogen population exacerbated by multi drug resistant microorganisms. Consequently, there is increased research into phytochemicals for the effective therapeutics combat of this menace.

The therapeutic effects of plant-based drugs have been documented to be due to the phytochemicals that constitute the plants [19,20]. These constituents selectively target toxins and pathogens without significant detrimental effect on the human host.

*Parkia biglobosa* is a perennial tropical plant legume predominantly distributed within the savannah region of West Africa [21]. *P. biglobosa* is also known as African locust bean while in Nigeria its local names include; Origili in Igbo, Dorowa in Hausa and Iru in Yoruba [22]. The African locust bean has gained its popularity from the consumption and economic value of its bean seeds. In West Africa especially Nigeria, the beans are usually fermented to yield a product popularly called “Dawadawa”. Dawadawa is a black, tasty seasoning, rich in protein which is commonly used as condiment in local soups and as a dietary protein source [23,24,25]. Furthermore, other parts of the plant such as the fruit and stem have also been exploited. The stem bark was reported to have anti-snake venom activities [26], the fresh fruit pulp can be used as mineral supplement [27]. Besides the culinary use of the African locust bean, its chemotherapeutic attributes have been explored [22,28,29]. In traditional medicine practices, a decoction of the stem bark has been used as a hot mouthwash to relieve toothaches [30]. A mixture of the root and leaves has been reported to be an efficacious remedy for the treatment of sore eyes and dental caries [31]. This study is therefore aimed at investigating the hepatoprotective effect of *P. biglobosa* on acute ethanol-induced oxidative stress in wistar rats

## 2. MATERIALS AND METHODS

### 2.1 Sample Preparation

*P. biglobosa* (African locust bean) was purchased from a local market at Orita-Challenge area of Ibadan, Nigeria. They were sun dried and milled into powder using an electronic blender (Moulinex). The powder was extracted according to the method described by Airaodion *et al.* [22]. 2.5 kg powder of ALB was extracted with n-hexane (boiling point 40–60 °C) in a soxlet extractor (Sri Rudram Instrument, Chennai, India) for 18 hours. The defatted, dried sample was repacked and then extracted with methanol. Briefly, the dried marc was extracted with methanol in the soxlet apparatus for 10

hours. The methanol solution was subsequently concentrated in a rotatory evaporator at 40 °C.

## 2.2. Animal Treatment

Twenty adult male wistar rats with body weight between 120 and 150 g were purchased from the Central Animal House, College of Medicine, University of Ibadan, Nigeria. They were housed in Imrat animal house, Ibadan. They were acclimatized for seven (7) days during which they were fed *ad libitum* with standard feed and drinking water and were housed in clean cages placed in well-ventilated housing conditions (under humid tropical conditions) throughout the experiment. All the animals received humane care according to the criteria outlined in the 'Guide for the Care and Use of Laboratory Animals' prepared by the National Academy of Science and published by the National Institute of Health. They were randomly divided into four groups of five rats each. Animals in groups 1 and 2 were administered normal saline solution while those in groups 3 and 4 were administered *Parkia biglobosa* extract for twenty-one days. The animals were administered the extract and saline solution at a dose of 4 ml per 100 g body weight 12 hourly via oral route of administration. At the end of the treatment, they were fasted overnight and animals in groups 2 and 4 were exposed to a single dose of 70% ethanol at 12 ml/kg body weight to induce oxidative stress. The dosage of ethanol used in this study has been documented to induce tissue toxicity and oxidative damage in rats [32]. After 12 hours of ethanol administration, the animals were anaesthetized using diethyl ether and were sacrificed. Liver was excised, weighed and homogenized in 50 mmol/l Tris-HCl buffer (pH 7.4) and then centrifuged at 5000 × g for 15 minutes for biochemical analysis. Supernatants were immediately kept frozen until when needed.

## 2.3 Biochemical Analyses

### 2.3.1 Determination of ALP, AST, ALT and LDH Activities

Alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and lactate dehydrogenase (LDH) activities were determined using Randox commercial Enzyme kits according to the method of Reitman and Frankel [33].

### 2.3.2 Assessment of Lipid Peroxidation (LPO)

Lipid peroxidation was determined according to the method of Varshney and Kale [34] based on the reaction between 2-thiobarbituric acid (TBA) and malondialdehyde (MDA): an end product of lipid peroxidation. Briefly, 0.4 ml of the sample was mixed with 1.6 ml of Tris-KCl buffer and 0.5 ml of trichloroacetic acid (TCA, 30%). This was followed by the addition of 0.5 ml of TBA (0.75%). The reaction mixture was heated in a water bath for 45 minutes at 80 °C, cooled in ice and centrifuged at 3000 × g for 5 minutes. Absorbance of the resulting supernatant was determined at 532 nm against a reference blank of distilled water. Lipid peroxidation in units/mg protein was computed with a molar extinction coefficient of  $1.56 \times 10^5 \text{ m}^{-1} \text{ cm}^{-1}$ .

### 2.3.3 Reduced Glutathione (GSH) Assay

The method of Jollow et al. [35] was used in estimating the concentration of reduced glutathione (GSH). Liver homogenates were deproteinized by the addition of 0.15 M sulphosalicylic acid (1:1, v/v). The protein precipitate was centrifuged at 4000 × g for 5 min. Thereafter, 0.5 ml of the supernatant was added to 4.5 ml of 0.001 M Ellman's reagent (5,5'-dithiobis-(2-nitrobenzoic acid) or DTNB). At 412 nm, absorbance of the mixture was read against a blank consisting of 0.5 ml of deproteinizing agent diluted with water (1:1) and 4.5 ml of 0.001 M DTNB. The concentration of reduced glutathione is proportional to the absorbance. GSH concentration was extrapolated from calibration curve prepared with GSH standards.

### 2.3.4 Estimation of Catalase (CAT) Activity

Catalase (CAT) activity was determined by the method of Sinha [36] based on the reduction of dichromate (in acetic acid) to chromic acetate in the presence of H<sub>2</sub>O<sub>2</sub>. Briefly, the assay mixture contained 4 ml of H<sub>2</sub>O<sub>2</sub> solution (800 mol) and 5 ml of phosphate buffer (0.01 M, pH 7.0). 1 ml of diluted sample (1:10) was rapidly mixed with the reaction mixture at room temperature. 1 ml portion of the reaction mixture was withdrawn and blown into 2 ml dichromate/acetic acid reagent (1:3 by volume) at 60 s intervals. The chromic acetate then produced is measured calorimetrically at 570 nm for 3 min at 60 s intervals after heating the reaction mixture in a boiling water bath for 10 min. Catalase activity

expressed as mol H<sub>2</sub>O<sub>2</sub> consumed/min/mg protein.

### 2.3.5 Estimation of Superoxide Dismutase (SOD) Activity

The activity of SOD was determined by using Oxiselect Superoxide Dismutase Activity Assay described by Mohammad *et al.* [37]. Tissues were homogenized on ice using mortar and pestle in 7 mL of cold 1X Lysis Buffer per gram tissue followed by centrifugation at 12000 ×g for 10 minutes. The supernatant of tissue lysate was then collected and kept at -80°C until further analysis. Superoxide anions generated by Xanthine/Xanthine Oxidase system were detected with a Chromagen Solution by measuring the absorbance reading at 490 nm using POLARstar Omega Reader. The activity of SOD was determined as the inhibition percentage of chromagen reduction.

### 2.3.6 Estimation of Glutathione Peroxidase (GPX) Activity

Glutathione peroxidase enzyme was determined according to Rotruck *et al.* [38]. Briefly, 500 µl of

tissue homogenates were mixed with 500 µl of assay buffer (potassium phosphate 30 mM, pH 7.0), 100 µl of sodium azide (NaN<sub>3</sub>; 10 mM), 200 µl of reduced glutathione (GSH; 4 mM), 100 µl hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>; 2.5 mM), and 6 ml of distilled water. The whole reaction mixture was incubated at 37 °C for 3 min after which 0.5 ml of TCA (10%) was added and thereafter centrifuged at 3000 rpm for 5 minutes. 1 ml of the supernatants was added to 2 ml of K<sub>2</sub>HPO<sub>4</sub> (0.3 M) and 1 ml of DTNB and the absorbance was read at 412 nm.

### 2.4 Statistical Analysis

Results are expressed as mean ± standard error of the mean (S.E.M). The levels of homogeneity among the groups were assessed using One-way Analysis of Variance (ANOVA) followed by Turkey's test. All analyses were done using Graph Pad Prism Software Version 5.00 and p values < 0.05 were considered statistically significant

## 3. RESULTS AND DISCUSSION

**Table 1: Effect of *Parkia biglobosa* on Hepatic Marker Enzymes of Experimental Rats**

Hepatic Marker Enzymes	Control	70% Ethanol only	<i>P. biglobosa</i> Extract only	<i>P. biglobosa</i> Extract + 70% Ethanol
AST (IU/L)	110.27±3.22 <sup>a</sup>	132.84±5.78 <sup>b</sup>	108.89±4.82 <sup>a</sup>	114.84±3.34 <sup>a</sup>
ALT (IU/L)	46.85±2.17 <sup>a</sup>	56.49±3.64 <sup>b</sup>	45.28±3.72 <sup>a</sup>	48.49±3.64 <sup>a</sup>
ALP (IU/L)	15.60±2.57 <sup>ac</sup>	22.79±1.82 <sup>b</sup>	13.59±0.70 <sup>a</sup>	19.79±1.02 <sup>bc</sup>
LDH (IU/L)	184.40±9.13 <sup>ac</sup>	206.55±10.10 <sup>b</sup>	183.54±8.06 <sup>a</sup>	190.55±11.10 <sup>c</sup>

Values are presented as Mean±S.E.M, where n = 5. Values with different superscript along the same row are significantly different at p<0.05.

**Legend:** AST = Aspartate Amino Transferase, ALT = Alanine Amino Transferase, ALP = Alkaline Phosphatase, LDH = Lactate Dehydrogenase

**Table 2: Effect of *Parkia biglobosa* on Oxidative Stress Biomarkers of Experimental Rats**

Oxidative Stress Biomarkers	Control	70% Ethanol only	<i>P. biglobosa</i> Extract only	<i>P. biglobosa</i> Extract + 70% Ethanol
LPO (nmol MDA/mg protein)	11.76±1.08 <sup>a</sup>	18.91±2.27 <sup>b</sup>	10.25±1.41 <sup>a</sup>	10.30±0.92 <sup>a</sup>
GSH (mg/ml)	4.68±0.10 <sup>a</sup>	3.06 ±0.78 <sup>b</sup>	4.58±0.13 <sup>a</sup>	4.31±0.64 <sup>a</sup>
CAT (Mm H <sub>2</sub> O <sub>2</sub> /mg protein)	13.04±1.04 <sup>a</sup>	22.00±2.29 <sup>b</sup>	12.82±1.08 <sup>a</sup>	17.34±1.85 <sup>c</sup>
SOD (U/mg protein)	8.62±1.21 <sup>a</sup>	13.93±2.23 <sup>b</sup>	7.35±0.86 <sup>a</sup>	9.05±1.10 <sup>a</sup>
GPX (U/mg protein)	6.08±0.16 <sup>a</sup>	6.52 ±0.21 <sup>a</sup>	5.88±0.19 <sup>a</sup>	5.80±0.14 <sup>a</sup>

Values are presented as Mean±S.E.M, where n = 5. Values with different superscript along the same row are significantly different at p<0.05.

**Legend:** LPO = lipid peroxidation, GSH = Glutathione, CAT = Catalase, SOD = Superoxide Dismutase, GPX = Glutathione Peroxidase

Acute and chronic alcohol exposures have been documented to increase the generation of reactive oxygen species (ROS). Many investigations have revealed a decreased level of antioxidants and increased production of free radicals in animals and humans following excessive ethanol exposure [39,40]. The protective effect of antioxidants against alcohol-induced liver injury in many studies further supports the involvement of oxidative stress [41,42].

Investigating the use of plant materials as a potent remedy for various ailments has not only authenticated their efficacies, but has also identified the pharmacological roles of the individual bioconstituents of these plant materials. Phytochemistry of the pods of *Parkia biglobosa* has been reported to contain an array of medically important secondary metabolites including saponins, tannins, cardiac glycosides, flavonoids, carotenoids, steroids, terpenoids and reducing sugars which is a strong indication that the plant has potential medicinal values [43]. In addition, Airaodion *et al.* [locust bean] reported the effect of *Parkia biglobosa* on fasting blood sugar and lipid profile

of animals on albino rats. However, the action of *Parkia biglobosa* extract against ethanol-induced oxidative stress has not been reported so far.

Evaluation of liver function is very important when analyzing toxicity of drugs and plant extracts because of its relevance for the survival of the organism [44]. High levels of alkaline phosphatase (ALP), aspartate transaminase (AST), alanine transaminase (ALT) and lactate dehydrogenase (LDH) are an indicator of hepatotoxicity or liver diseases [45]. Studies on the alterations of these enzymes might reflect the metabolic abnormalities and cellular injuries in some organs. The liver and kidney have extremely important function in detoxification and excretion of metabolic wastes and xenobiotics [46]. Exposure to toxic chemicals causes alterations in some tissue enzyme activities [47,48]. Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are distributed extensively in several different organs and have important roles in carbohydrate and amino acid metabolic pathways and their activities is established to change under several physiological and pathological circumstances [49].

In this study, the activities of AST, ALT, ALP and LDH were not significantly different when animals treated *P. biglobosa* extract only were compared with those of the control group at  $p < 0.05$ . A significant increase was observed when the activities of AST, ALT, ALP and LDH in animals induced with 70% ethanol without treatment with *P. biglobosa* extract were compared with those of the control and *P. biglobosa* extract only groups at  $p < 0.05$ . This might be an indication that ethanol causes liver damage to the animals. However, when animals treated with *P. biglobosa* extract before the induction of oxidative stress by ethanol were compared with those induced without pretreatment, a significant decrease was observed in the activities of AST, ALT and LDH. This could be that pretreatment with *P. biglobosa* extract resulted in increased transcription of some genes involved in glucose uptake, glycolysis and lipogenesis [50]. Glucose represses the induction of inducible operons by inhibiting the synthesis of cyclic Adenosine monophosphate (cAMP) a nucleotide that is required for the initiation of transcription of a large number of inducible enzyme systems including the Lac operon. Cyclic AMP (cAMP) is required to activate an allosteric protein called catabolite activator protein (CAP) which binds to the promoter CAP site and stimulates the binding of ribonucleic acid (RNA) polymerase to the promoter for the initiation of transcription, but cAMP must be available to bind to CAP which binds to deoxyribonucleic acid (DNA) to facilitate transcription. In the presence of glucose, adenylate cyclase (AC) activity is blocked. AC is required to synthesize cAMP from Adenosine Triphosphate (ATP) [51,52]. Therefore if cAMP levels are low, CAP is inactive and transcription does not occur. Thus the effect of glucose in suppressing these inducible enzymes is by lowering cyclic AMP level. The *P. biglobosa* extract might have lowered cAMP in animals thus causing inhibition of these inducible enzymes. ALT is considered most reliable hepatocellular injury because it is solely confined to the liver, unlike AST and LDH which are also abundantly present in other body organs such as the kidneys, brain, and hearts [53]. The significant decrease observed in the activities of ALT and AST in *P. biglobosa*-treated animals when compared to those induced without pretreatment showed that *P. biglobosa* protected the liver from damage by ethanol-induced oxidative stress.

Alkaline phosphatase (ALP) is involved in the hydrolysis of a wide range of phosphomonoester substrates. It is a marker enzyme for the plasma membrane and endoplasmic reticulum of tissues [54]. It is often employed to assess the integrity of the plasma membrane, since it is localized predominantly in the microvilli in the bile canaliculi, located in the plasma membrane. Since ALP hydrolyses phosphate monoesters, its significant increase in ethanol-induced animals without pretreatment could constitute a threat to the life of the cells that are dependent on a variety of phosphate esters for their vital process as it may lead to indiscriminate hydrolysis of phosphate ester metabolite of the liver [55]. Consequently, this may adversely affect the facilitation of the transfer of metabolites across the cell membrane of ethanol-induced animals without pretreatment. This effect was remedied by pretreatment with *P. biglobosa* extract.

The elevation in the activities of markers such as ALT, AST and LDH in the liver tissue of animals without pretreatment with *P. biglobosa* might be due to cellular necrosis of hepatocytes, which causes increase in the permeability of the cell. Lactate dehydrogenase (LDH) is an index of cell damage including hepatotoxicity and the endothelial disruption in blood vessel. The significant increase observed in the activity of LDH might be suggestive of the beginning of cytolysis, which is a possible indication of membrane damage including the endothelial membranes of blood vessels. This disruption of endothelial membrane, directly or indirectly, as reported earlier, includes the generation of reactive oxygen species in endothelial cells [56]. According to Kottaimuthu [57], free radicals attack unsaturated fatty acids in the membranes resulting in membrane lipid peroxidation which decreases membrane fluidity, leakage of enzyme and loss of receptor activity as well as damage membrane proteins leading to cell inactivation. As lipid peroxidation progressively increased, antioxidant defense system decrease equivalently resulting in oxidative stress [58]. This suggests that the administration of ethanol might have weakened the liver membrane of the rats with subsequent penetration and elevation of AST, ALT and LDH in the liver.

Alcohol metabolism results in oxidative and nitrosative stress via elevation of NADH/NAD<sup>+</sup> redox ratios, induction of nitric oxide synthase (NOS) and NADPH/xanthine oxidase [60,61].

Lipid peroxidation, a primary mechanism of cell membrane destruction and cell damage is a common feature of both acute and chronic alcohol consumption [62,63]. The presence of a high concentration of oxidisable fatty acids and iron in liver significantly contributes to ROS production. A rise in lipid peroxidation level is only identified if there is oxidative damage due to the increase in free radical generation. Generally under normal conditions, the animals tend to maintain a balance between generation and neutralization of ROS in the tissues. But, when the organisms are subjected to xenobiotic stress, the rate of production of ROS including  $O_2^-$ ,  $H_2O_2$ ,  $OH^-$ ,  $ROO^-$ , exceeds their scavenging capacities. All the organisms have their own cellular antioxidant defense system composed of both enzymatic and non-enzymatic components. Enzymatic antioxidant pathway consists of SOD, CAT and GPX. Superoxide anion  $O_2^-$  is dismutated by SOD to  $H_2O_2$ , which is reduced to water and molecular oxygen by CAT or is neutralized by GPX, which catalyzes the reduction of  $H_2O_2$  to water and organic peroxide to alcohols using GSH as a source of reducing equivalent. Glutathione reductase (GR) regenerates GSH from oxidized glutathione (GSSG), which is a scavenger of ROS as well as a substrate for other enzymes. Glutathione S-transferase (GST) conjugates xenobiotics with GSH for exclusion.

In this study, acute ethanol exposure significantly elevated the malondialdehyde (MDA) levels in the liver indicating enhanced peroxidation and breakdown of the antioxidant defense mechanisms. Decomposition products of lipid hydroperoxide such as malonaldehyde and 4-hydroxynonenal, can cause chaotic cross-linkage with proteins and nucleic acids, which plays an important role in the process of carcinogenesis. In this investigation, hepatic lipid peroxidation (LPO) activities show significant increase due to ethanol intoxication. Furthermore, extensive damage to tissues in a free radical mediated LPO results in membrane damage and subsequently decreases the membrane fluid content. *P. biglobosa* pretreatment significantly reversed these alterations causing a significant decrease in MDA levels, suggesting its protective effects against ethanolic-induced oxidative damage. This is consistent with the study of Oyenihni et al. [56] who reported the hepato- and neuro-protective effects of watermelon juice on acute ethanol-induced oxidative stress in rats.

Glutathione (GSH) is a tripeptide (L- $\alpha$ -glutamylcysteinol glycine) which is highly abundant in all cell compartments and it is the major soluble antioxidant. Glutathione directly quenches ROS such as lipid peroxides, and also plays a major role in xenobiotic metabolism [63]. Glutathione detoxifies hydrogen peroxide and lipid peroxide by donating electron to hydrogen peroxide to reduce it to water and oxygen protecting macromolecules such as lipids from oxidation. In this study, the decrease in the reduced glutathione level in animals treated with ethanol only is connected with ethanol-induced oxidative stress and direct conjugation of GSH with acetaldehyde and other reactive intermediates of alcohol oxidation. This result is in agreement with the finding of Pinto et al. [39] who reported that acute ethanol treatment caused reduction in the glutathione levels in different tissues. The significant increase ( $P < 0.05$ ) in the glutathione levels in the liver of *P. biglobosa*-treated rats prior to ethanol-administration may be due to the direct ROS—scavenging effect of *P. biglobosa* or an increase in GSH synthesis.

Catalase (CAT) contributes to ethanol oxidation, by oxidizing a small amount of ethanol in the presence of a hydrogen peroxide ( $H_2O_2$ ) generating system to form acetaldehyde [64]. In this study, no significant difference was observed in the activity of catalase in control animals and those treated with *P. biglobosa* extract only when compared with ethanol-induced animals with *P. biglobosa* extract pretreatment. The activity of catalase in animals pretreated with *P. biglobosa* prior to ethanol induction was significantly reduced when compared with those without *P. biglobosa* pretreatment. This might be that ethanol-induced oxidative stress generated elevated ROS in the liver which CAT tend to combat, thereby increasing its activity. *P. biglobosa* was able to reduce the ROS generation with subsequent decrease in CAT activity due to its high phytochemical content and antioxidant potential as reported by Igbowe et al [2013]. Increased CAT activity in this study following acute ethanol exposure suggests elevated ethanol oxidation and formation of oxidising product-acetaldehyde. This is in agreement with the study of Oyenihni et al. [56] and Oh et al. [65] who reported a significantly higher CAT activity after ethanol treatment.

Superoxide dismutase (SOD) plays an important role in reducing the effect of free radicals attack, and SOD is the only enzymatic system quenching  $O_2^-$  to oxygen and  $H_2O_2$  and plays a significant role against oxidative stress [66]. These radicals have been reported to be deleterious to polyunsaturated fatty acids and proteins [67]. In this study, no significant difference was observed in the activity of SOD in control animals and those treated with *P. biglobosa* extract only when compared with ethanol-induced animals with *P. biglobosa* extract pretreatment. The activity of SOD in animals pretreated with *P. biglobosa* prior to ethanol induction was significantly reduced when compared with those without *P. biglobosa* pretreatment. This might be that ethanol-induced oxidative stress generated elevated ROS in the liver which SOD tend to combat thereby increasing its activity. *P. biglobosa* was able to reduce the ROS generation with subsequent decrease in SOD activity due to its high phytochemical content and antioxidant potential as reported by Igbowe et al [43]. The increased activity of SOD observed in ethanol induced animals contradicts the study of Halliwell B, Gutterberidge [68] who reported that SOD activity was considerably reduced during ethanol intoxication.

Glutathione peroxidase (GPX) is another enzymic antioxidant that acts as a defense against oxidative stress. The lack of significant effect in GPX activity observed in this study after ethanol treatment may be due to the duration of exposure to ethanol. This result is in agreement with the study of Yang et al. [69] who observed no difference in GPX activities in rats hepatocyte exposed to varying concentrations of ethanol at an incubation time of 12 h. The toxicity of ethanol is related to the product of its metabolic oxidation. Acetaldehyde and acetate, produced from the oxidative metabolism of alcohol are capable of forming adducts with cellular macromolecules, causing oxidative damage and affecting metabolic processes [64,70]. Catalase and glutathione peroxidase further detoxify  $H_2O_2$  into  $H_2O$  and  $O_2$  [67]. Thus, SOD, catalase and GPX function mutually as enzymatic antioxidative defense mechanism to counter the deleterious effect of ROS.

#### 4. CONCLUSION

The results of this study indicated that ethanol induced oxidative stress as seen in the

perturbation of the biomarkers. *P. biglobosa* was able to remedy this effect by regulating the oxidative stress biomarkers, thus possesses prophylactic efficacy against ethanol-induced oxidative stress and can protect the liver against free radicals arising from oxidative stress.

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