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Research Article
Determination of Some Phyto-constituents Present in *Terminalia catappa* Endocarp Flour and Biochemical Evaluation of its Ethanolic Extract on Hepatic Indices in Male Wistar Rats

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Abstract

Objective: This study assessed the determination of phyto-constituents present in *Terminalia catappa* endocarp (considered a waste) and biochemical evaluation of its ethanol extract on hepatic indices in male wistar rats using monosodium glutamate (MSG) to induce toxicity. **Materials and Methods:** Twenty four male wistar rats with mean weight of 120.61±15.15 g were divided into six groups (n = 4). Group 1, the normal control group (received distilled water), group II, the negative control (received 8 mg MSG/kg b.wt.), group III, the extract control (received 300 mg kg^{-1} b.wt., extract), group IV received 8 mg MSG/g b.wt.+100 mg extract/kg b.wt., group V received 8 mg MSG/g b.wt.+300 mg extract/kg b.wt. and group VI received 8 mg MSG/g b.wt.+500 mg extract/kg b.wt. daily by oral gavage for 14 days. Data were subjected to one-way ANOVA followed by Duncan *post-hoc* test at $p<0.05$. **Results:** Phytochemicals studies revealed the presence of flavonoids, saponins, alkaloids, steroids and cyanogenic glycosides, while antinutrients include phytates, oxalates, phenol and anthocyanin in the ethanol extract of *Terminalia catappa* endocarp flour. Results of the present study showed a significantly ($p<0.05$) higher serum aspartate transaminase (35.50 ± 3.86^{a}), alanine transaminase(121.25 ± 3.90^{a}), alkaline phosphatase (51.00 ± 7.36^{a}) activity in the monosodium glutamate-intoxicated rats, implying hepatocellular injury due to increased membrane permeability, but significant ($p<0.05$) decrease (25.50 ± 1.19^{b}, 61.00 ± 7.71^{b}, 29.65 ± 3.19^{b}) respectively, in the group treated with extract alone, indicating an apparent ameliorative potential of *Terminalia catappa* endocarp flour extract to improve the functional capacity of the liver associated with their release. Significant ($p<0.05$) increase in serum total protein concentration in the MSG-treated rats concomitantly administered with 100 mg kg^{-1} b.wt., of extract was revealed, while bilirubin concentration was significantly ($p<0.05$) decreased in similar groups compared to other groups, suggesting a protective effect against MSG-induced hepatotoxicity. Co-administration of MSG with varying concentrations of the extract attenuated MSG-induced toxicity in rats. **Conclusion:** Thus, the extract significantly improved the hepatic indices which possibly revealed that *Terminalia catappa* endocarp is relatively rich in some vital bioactive constituents, hence, could serve to provide medical or health benefits, as well as, reducing the hitherto waste generated from such inedible part of the fruit.

Key words: *Terminalia catappa*, phyto-constituents, biochemical evaluation, hepatic indices, MSG-intoxication

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Plants have served as the richest source of raw materials for traditional, as well as, modern medicine, particularly in Africa and Asia[1]. Natural plant-based phytochemicals are the possible source of bioactive compounds essential for the treatment and prevention of a number of diseases[2]. The study of chemical constituents contained in plants is very essential because most drugs used as medicines were produced after a careful study of their constituents and structures[3]. Problem however, remains that some drugs are scarce, costly and unavailable to the common man, hence a study of the medicinal importance of plants scientifically and a confirmation of the use of these plants towards curing diseases is a possible solution to development of less costly and effective drugs from our local raw materials[4,5].

Terminalia catappa is a common tropical fruit-bearing plant in the family Combretaceae which is known for its nutritional fruit and varied health benefits attributable to its varied phyto-constituent. Greater proportion of the total weight of *Terminalia catappa* is generated as waste, thus, contributing to environmental disturbances. However, it could serve some economic benefits. Flesh and kernel of the fruits are eaten raw, sun dried or roasted. The leaves, roots and barks are however used for treating diseases such as anaemia, hypertension, malaria, fever and asthma, while, the leaves have been shown to protect against acute liver injury produced by some hepato-toxicants, serve as analgesic, as well as, act as vermifuge[6,7]. The bark and root bark are useful for bilious fever, diarrhoea, thrush, remedy for sores and abscesses and recommended as a mild laxative and a galactagogue for women, but too frequent use causes diarrhea[6].

The use and possible abuse of food additives is rampant with a seeming disregard of the associated health risks by the public[8,9]. Monosodium glutamate (MSG) is one of the most popular flavor enhancers used by various food industries[10,11]. Its consumption has increased worldwide owing to its flavor enhancing capability[12]. However, its use as a flavor has been challenged due to a number of reports describing its toxic effects in humans, as manifested by the Chinese restaurant syndrome characterized by headache, burning sensation along the back of the neck, chest tightness, stomach ache, weakness, diarrhea, nausea and sweating[13-15]. However, people consume large doses of monosodium glutamate with possible adverse effects that could be due to increased physiological concentration of the dissociation products of monosodium glutamate-glutamate and sodium ions[16].

There are growing interest in the use of fruits and vegetable wastes (one of the main sources of municipal waste) as natural sources of bioactive compounds which when utilized in diets and drugs could improve food supply, health and the environment[17]. Therefore, the present study aimed at using extract prepared from such food wastes to find out whether they could ameliorate monosodium glutamate-induced effects, hence, monosodium glutamate treatment was used based on earlier report[15]. This study assessed the determination of phyto-constituents present in *Terminalia catappa* endocarp (considered a waste) and biochemical evaluation of its ethanol extract on hepatic indices in male wistar rats using monosodium glutamate (MSG) to induce toxicity.

MATERIALS AND METHODS

Plant materials and authentication: Fruits of *Terminalia catappa* were harvested from College of Pure and Applied Sciences (COLPAS) of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria., during the morning hours between June 1 to June 21, 2015. The plant was identified and authenticated by Mr. N. Ibe of Forestry and Environmental Management, College of Natural Resources and Environmental Management, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Preparation of plant materials: The fresh fruits of *Terminalia catappa* were washed, peeled (to remove the edible ectocarp), air dried at room temperature (to remove excess moisture), deshelled and the resultant shell (endocarp) milled. The ethanol extract was prepared by soaking 250 g of *Terminalia catappa* flour in 1 L of 95% ethanol for 72 h at room temperature with vigorous shaking. The mixture was filtered with Whatman filter paper No.1. The filtrate was then dried at a temperature of 50°C in oven and stored in refrigerator for further use and percentage yield was calculated.

Phytochemical studies

Determination of alkaloids: The determination of the concentration of alkaloid in the milled endocarp was carried out using alkaline precipitation gravimetric method as described by Harborne[18].

Determination of saponins: The saponins content of the milled sample was determined by double extraction gravimetric method as described by Harborne[18].

Determination of tannins: The tannins content of the sample was determined using the Folin-Dennis spectrophotometric method as described by Pearson[19].

Determination of cyanogenic glycosides: Cyanogenic glycoside was determined using the method of Onwuka[20].

Determination of flavonoid: The amount of flavonoids in the stem bark extracts was also determined by using the aluminum colorimetric assay method[21].

Determination of antinutrients

Phytic acid determination: Phytic acid in the sample was determined using the method described by Lucas and Markakes[22].

Determination of phenol: The concentration of phenols in the sample was determined using the Folin-ciocalteau colorimetric method described by Pearson[19].

Animal studies: A total of 24 Wistar rats (male) having mean body weight of 120.61±15.15 g were used in this experiment. Rats were bought from the animal house of University of Nigeria, Nsukka and housed in animal cage in the animal house of Department of Biochemistry, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria. After 7 days of acclimatization, they were equally divided into 6 groups of 4 rats each according to their weight in a completely randomized design. This study was carried out in accordance with ethical guidelines for animal welfare as approved by Biochemistry Department, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria. Rats in Group 1 (the control) were given only distilled water, Rats in group 2 were given only MSG (8 mg g^{-1}) while rats in group 3 received only the ethanol extract (300 mg kg^{-1} b.wt.) of *Terminalia catappa* milled endocarp. On the other hand, rats in Groups 4, 5 and 6 were co-treated with MSG (8 mg g^{-1} b.wt.) and extract (100, 300 and 500 mg kg^{-1} b.wt.), respectively. The doses were calculated and adjusted based on the WHO recommended daily oral intake for an average person of 70 kg. Exposure was per oral and lasted for 14 consecutive days.

Sample collection and preparation: At the end of the experiment, the rats were anaesthetized in chloroform chamber and blood samples were obtained by cardiac puncture using sterile plain and EDTA capillary tubes, followed immediately by excision to obtain the liver and kidney samples. Blood samples were collected into EDTA containers (plasma for hematological tests) and plain containers (serum for enzyme assays) and washed containers for other biochemical assays.

Evaluation of biochemical parameters

Determination of serum alanine aminotransferase (ALT) activity: The determination of alanine aminotransferase in serum was according to the method of Reitman and Frankel[23]. ALT was measured by monitoring the concentration of pyruvate hydrazone formed with 2, 4-dinitrophenylhydrazine. The colour intensity was measured against the blank at 540 nm.

Determination of serum alkaline phosphatase (ALP) activity: The determination of alkaline phosphatase in serum was according to the method of Englehardt[24].

The principle of this method is based on the reaction involving serum alkaline phosphatase and a colourless substrate of phenolphthalein monophosphate, giving rise to phosphoric acid and phenolphthalein which at alkaline pH values turn pink that can be determined spectrophotometrically.

Determination of aspartate aminotransferase (AST) activity: The determination of aspartate aminotransferase in serum was according to the method of Reitman and Frankel[23]. AST was measured by monitoring the concentration of oxaloacetate hydrazone formed with 2, 4-dinitrophenylhydrazine. The colour intensity was measured against the blank at 546 nm.

Determination of total serum protein: The serum total protein was estimated by the biuret method[25]. This is based on the method that Cupric ion in the Biuret reagent interacts with peptide bonds in protein forming a violet colour in an alkaline medium. The intensity of the colour formed is measured photometrically at 540 nm and is proportional to the concentration of total protein in the sample.

Determination of serum albumin: Serum Albumin was determined using dye binding method as described Doumas[26]. Determination of albumin depends on its quantitative dye binding to the indicator 3,3,5,5,-tetrabromo-m-cresol sulphonephthelein (bromocresol green, BCG) in a buffered solution. As bromocresol green forms green colored complex with albumin (albumin-BCG-complex) which absorbs maximally at 630 nm, the absorbance being directly proportional to the amount of albumin present in serum.

Statistical analysis: Data were analyzed using one-way ANOVA followed by Duncan *post-hoc* test was applied at $p<0.05$.

RESULTS

Results of the phytochemical compositions of milled *Terminalia catappa* endocarp flour are presented in Table 1. Saponins (6.39±0.13 g/100 g) was recorded as the highest phytochemical while the least was cyanogenic glycosides (0.04±0.00 g/100 g).

Results of the antinutrients of milled *Terminalia catappa* endocarp flour are presented in Table 2. The highest antinutrient composition was anthocyanin (1.50±0.49 g/100 g) while the least was phenol (0.28±0.00 g/100 g).

The effect of ethanol extract of *Terminalia catappa* endocarp on liver function indices is shown in Table 3. MSG group (II) showed a significant ($p<0.05$) increase in the activities of the liver enzymes, AST, ALT and ALP when compared with the normal control group (group 1) respectively. Treatment with variable concentrations of the ethanol extract of *Terminalia catappa* endocarp reduced the enzyme activities when compared to normal group (I) and MSG group (II). Total bilirubin (0.13 ± 0.03^{b}) showed a significant ($p<0.05$) decrease in the extract-alone treated group (III) compared to the MSG group (2.40 ± 0.08^{a}) and normal group (1.26 ± 0.46^{a}). The albumin (5.68 ± 0.02^{a}) and total protein (10.27 ± 0.32^{a}) levels showed a significant ($p<0.05$) increase in MSG-extract cotreated group (IV) compared to MSG group.

Table 1: Phytochemical composition of *Terminalia catappa* endocarp flour

Phytochemical	Concentration (g/100 g)
Flavonoids	1.80±0.78
Alkaloids	3.27±0.21
Saponins	6.39±0.13
Tannins	1.24±0.28
Steroids	0.89±0.00
Cyanogenic glycosides	0.04±0.00

Values are means and standard deviations of triplicate determinations

Table 2: Antinutrients composition of *Terminalia catappa* endocarp flour

Antinutrient	Concentration (g/100 g)
Phytate	0.62±0.03
Oxalates	0.28±0.00
Anthocyanin	1.50±0.49
Phenol	0.07±0.00

Values are means and standard deviations of triplicate determinations

DISCUSSION

Phytochemical studies revealed the presence of flavonoids, saponins, alkaloids, steroids and cyanogenic glycosides, while antinutrients include phytates, oxalates, phenol and anthocyanin in the ethanol extract of *Terminalia catappa* endocarp flour (Table 1). Saponins, alkaloids and flavonoids were present in high amounts. The presence of saponins may contribute to the bitter taste of the fruit due to its alkali nature. Several biological activities such as antihepatotoxic, antioxidant, anticytotoxic etc. property have been reported for saponins[27]. This might partially account for the hepatoprotective effect of the extract. However, according to Asiimwe, research showed that xenobiotics like saponins and tannins cause haemolysis, nutrient malabsorption and abnormal hematopoiesis which could arise from liver and kidney damage[28]. Some alkaloids have cytotoxic effect on organism by damaging the cells of the liver, lungs, heart and kidney. Flavonoids may account for the anti-inflammatory, anticancer and antioxidant and antiviral effects of the fruit since flavonoids are known to possess such properties[29]. Any antioxidant property possessed by the fruit could be as a result of the presence of other phytochemicals such as alkaloids. Oduro reported that alkaloids were found to be present in the pulp of yellow and red varieties[30]. Phytochemicals are known to exhibit different biochemical

Table 3: Effect of ethanol extract of *Terminalia catappa* endocarp flour (EETCEF) on serum liver function markers in normal and MSG-intoxicated wistar rats

Group	AST (IU)	ALT (IU)	ALP (IU)	Albumin (mg dL^{-1})	Total protein (mg dL^{-1})	Total bilirubin (mg dL^{-1})
Group I (normal control)	29.25 ± 1.75^{b}	73.50 ± 0.96^{b}	38.73 ± 6.19^{a}	5.13 ± 0.96^{a}	6.82 ± 1.30^{b}	1.26 ± 0.46^{a}
Group II (MSG group)	35.50 ± 3.86^{a}	121.25 ± 3.90^{a}	51.00 ± 7.36^{a}	3.22 ± 0.05^{b}	4.97 ± 0.47^{b}	2.40 ± 0.08^{a}
Group III (extract group)	25.50 ± 1.19^{b}	61.00 ± 7.71^{b}	29.65 ± 3.19^{b}	4.17 ± 0.41^{a}	7.07 ± 0.84^{b}	0.13 ± 0.03^{b}
Group IV (MSG+100 mg kg^{-1} extr.)	26.25 ± 1.11^{b}	79.00 ± 6.10^{b}	38.00 ± 0.41^{a}	5.68 ± 0.02^{a}	10.27 ± 0.32^{a}	1.37 ± 0.52^{a}
Group V (MSG+300 mg kg^{-1} extr.)	27.25 ± 0.48^{b}	82.00 ± 2.55^{b}	34.50 ± 4.87^{b}	5.09 ± 0.68^{a}	7.07 ± 1.24^{b}	1.22 ± 0.47^{a}
Group VI (MSG+500 mg kg^{-1} extr.)	29.25 ± 1.44^{b}	82.25 ± 12.45^{a}	36.00 ± 5.08^{a}	4.95 ± 1.07^{a}	5.60 ± 0.43^{b}	0.58 ± 0.44^{b}

Data are Mean±SEM (n = 4). Mean in the same column with different superscript letters are significantly different, $p<0.05$ (one-way ANOVA followed by Duncan *post-hoc* test. Group I: Normal Control (given distilled water), Group II: Negative Control (MSG-alone treated rats), Group III: Extract Control (Extract-alone treated rats), Group IV: MSG+100 mg kg^{-1} EETCEF, Group V: MSG+300 mg kg^{-1} EETCEF, Group VI: MSG+500 mg kg^{-1} EETCEF

and pharmacological actions ranging from cell toxicity to cell protective effect in different species of animals when ingested. The presence of some compounds such as saponin, glucosides, steroid, cardiac glycosides, tannins, volatile oils, phenols and balsam (gum) in members of the family combretaceae, to which *Terminalia catappa* belongs have been reported[31-32]. The quality and quantity of the phytochemicals identified in the study suggested that the family of combretaceae are rich in plant secondary metabolites, appreciable in the physiological and pharmacological effects of humans and probably animals.

The cyanogenic glycosides as reported in this study is 0.04±0.00 g which is relatively low when compared to 21.6 and 15.00 mg/100 g reported for *Terminalia catappa* and *Khaya senegalensis* respectively[33,34]. Cyanogenic glycosides per se are nontoxic but on hydrolysis by β-glycosidase, releases a sugar and a cyanohydrin which quickly decomposes further to toxic hydrocyanic acid (HCN) and an aldehyde or a ketone[35]. The toxicity of cyanogenic glycosides depends on this HCN released which readily and reversibly binds and inhibits a number of proteins and enzyme systems in the body. It significantly binds mitochondrial cytochrome oxidase system, the terminal enzyme of the mitochondrial electron transport chain, thereby, inhibiting oxidative phosphorylation and paralyzing the vital cellular process of aerobic respiration resulting in anoxic cell death. The *Terminalia catappa* seed may be consumed without any hydrogen cyanide related problem arising since the value is low. Cyanogenic glycosides found in *Ocinum gratissimum*, *Murraya koenigii* and *Corchorus olitorious* can be used to treat heart diseases like congestive heart failures and cardiac arrhythmia[36].

The total oxalate content of almond-endocarp flour was 0.28±0.00 g/100 g (Table 2). Oxalate in large amount binds with calcium to form calcium oxalate, which is insoluble and not absorbed by the body. They are therefore considered poisonous but harmless when present in small amounts[37]. The value is low when compared to 26.4 mg/100 g reported for *Terminalia catappa* by Akpabio[33]. The total phytate content of almond endocarp flour was 0.62±0.03 g/100 g. Phytic acid, a hexaphosphate derivative of inositol is an important, storage form of phosphorus in plant. Phytate is an anti-nutrient that interferes with the absorption of minerals from the diet. It causes calcium and zinc deficiency in man when in excess, the deficiency of these minerals results in osteomalacia, anaemia and rickets[38]. The low level of phytic acid could be attributed to the presence of an enzyme phytase which degrade phytic acid in plants[39]. This value is comparable with 0.677 mg/100 g of phytate in *C. lanatus* seeds.

The liver enzymes alanine aminotransferase (ALT) formerly serum glutamate-pyruvate transaminase (SGPT) and aspartate aminotransferase (AST) formerly known as serum glutamic oxaloacetic transaminase have been established as makers of hepatocellular injury, while alkaline phosphatase (ALP) is a marker of cholestasis[40]. While ALT is cytosolic, AST has both cytosolic and mitochondria forms[41].

The AST activity was higher in the MSG-alone treated group than in other groups suggesting adverse effect on liver of the animals in that group. MSG caused overt toxicity at the tested dose and even at lower doses[8,15]. According to Thapa and Walia, increase in AST activity is an indicator for hepatocellular necrosis and that large increases in mitochondrial AST occur in serum after extensive tissue necrosis[42]. Because of this, assay of mitochondrial AST has been advocated in myocardial infarction. Although, the detailed mechanism by which enzymes are released from the cytosol and mitochondria of hepatocytes into the blood stream is not completely known, clinical observations and experimental studies have shown that subtle membrane changes are sufficient to allow passage of intracellular enzymes to the intracellular space[43]. A very large concentration gradient between the hepatocyte and the sinusoidal space usually exists for enzymes. Cell damage increases membrane permeability, causing cytosolic iso-enzymes to spill into the sinusoids and from there into the peripheral blood. Permeability of mitochondrial membranes is also increased[44].

The significantly ($p<0.05$) lower AST activity in the animals exposed to the extract alone (Group III) compared to group II implies the possible potential of *Terminalia catappa* endocarp flour extract to improve the functional capacity of the liver associated with AST release. This may be attributed to the stabilizing ability of the cell membrane preventing enzymes leakages[45].

The significantly ($p<0.05$) lower AST activity in the MSG- treated rats concomitantly administered with varying concentrations of the extract, suggest ameliorative role of the extract in the apparent MSG-induced adverse effect in the rats related to high AST activity. The observation is dose dependent, implying that *Terminalia catappa* extract could be effective in modulating such MSG-induced effect in rats at low doses.

Feng reported that natural plants and bioactive compounds isolated from plants, as well as, endogenous antioxidants showed strong antioxidative ability and hepato-protection effects[46]. Therefore, it is suggestive that the presence of flavonoids present in *Terminalia catappa* endocarp extract may have played crucial antioxidative role in protecting the liver against oxidative stress through an unknown mechanism.

ALT enzyme is abundant in the liver and is a more sensitive marker for liver damage compared to AST and can reveal the extent of damage of the liver[47]. Therefore, increase in serum ALT activity as observed in group II rats fed with MSG is symptomatic of liver injury. The result apparently agrees with the findings of Farombi and Onyema[13] that the activity of serum ALT increased in male rats that were fed MSG possibly due to MSG-induced oxidative stress in the liver. Hence, it could be concluded that MSG is hepatotoxic. The lower ALT activity in the group of rats exposed to extract alone (group III) compared to the controls could be attributed to the overall protective effect of *Terminalia catappa* against lipid peroxidation causing stabilization of membranes and prevents the leakage of enzymes. The significantly ($p<0.05$) lower ALT activity in the MSG-treated rats concomitantly administered with varying concentrations of the extract, suggest ameliorative potential of *Terminalia catappa*. Group VI did also showed a significant ($p<0.05$) decrease in ALT activity implying that *Terminalia catappa* had a dose-dependent ameliorative potential confirming that it may also be effect at a higher dose.

ALP is a membrane-bound enzyme localized to the bile canalicular pole of hepatocytes. ALP is markedly elevated in persons with biliary obstruction. However, high levels of this enzyme are not specific to cholestasis[48]. The ALP was higher in the MSG-alone treated group than in the other groups, suggesting a possible bone disease, presence of cholestasis or biliary obstruction. This finding however, disagrees with previous report of Egbuonu that there was a decrease in serum ALP activity observed in rats treated with MSG-alone[8]. The significantly ($p<0.05$) lower ALP activity in the group of rats exposed to extract alone (group III) compared to group I and II implies the possible potential of *Terminalia catappa* extract to improve the functional capacity of the organ associated with bile flow. Cholestasis is an impairment of bile formation and/or bile flow or could be caused by a disease that impairs bile formation in the liver which may clinically present with fatigue, pruritus and, in its most overt form, jaundice[8,49]. Reports according to the European Association for the Study of the Liver states that serum ALP increase could be seen in cholestatic liver diseases, as well as, certain rare disorders (e.g. progressive familial intrahepatic cholestasis (PFIC) 1 and 2, bile acid synthesis defects), nevertheless may also result from rapid bone growth (e.g., in children), bone disease (e.g. Paget's disease), or pregnancy[49]. Results obtained for group V showed a reduction of the increased activity of ALP suggesting the stabilizing effect of the extract.

The significantly ($p<0.05$) higher serum total protein concentration in the MSG-treated rats concomitantly administered with 100 mg kg^{-1} b.wt., of extract (group IV), suggest acute or chronic inflammation or a possible hyperproteinemia which may be seen in dehydration due to inadequate water intake or to excessive water loss (e.g, severe vomiting, diarrhea, Addison's disease and diabetic acidosis) or as a result of increased production of proteins or the possible potential of *Terminalia catappa* extract to improve the hepatic cells' secretory mechanisms as well as increased hepatic protein synthesis. The serum total protein of animals exposed to MSG-alone showed a non-significant ($p>0.05$) decrease when compared to the normal control. The decreased levels of total protein may be due to reduction in protein intake from the intestine[50]. The ability of the plant extract to protect against reduction in total protein may be attributed to its free radical scavenging properties[51].

Bilirubin is a catabolic intermediate of haem. Increased bilirubin concentration reflects the pathophysiology of the liver and one of the most sensitive and useful test to substantiate the functional integrity of the liver and severity of necrosis which measures the binding, conjugating and excretory capacity of hepatocytes that is proportional to the erythrocytes degradation rate[52]. The bilirubin concentration was significantly ($p<0.05$) decreased in group III and VI compared to other groups suggesting a protective effect against MSG-induced liver toxicity. *Terminalia catappa* endocarp extract perhaps protects the liver cell from damage, thereby enhancing bilirubin uptake and conjugation by the liver and subsequent secretion into the bile ducts. These results are consistent with the findings of Farombi[53].

Photomicrographs from sections of the liver collected from the animals in the control group (Fig. 1) showed the normal liver architecture for laboratory rats showing intact hepatocytes. Sections of the liver collected from rats treated with only MSG (Fig. 2)

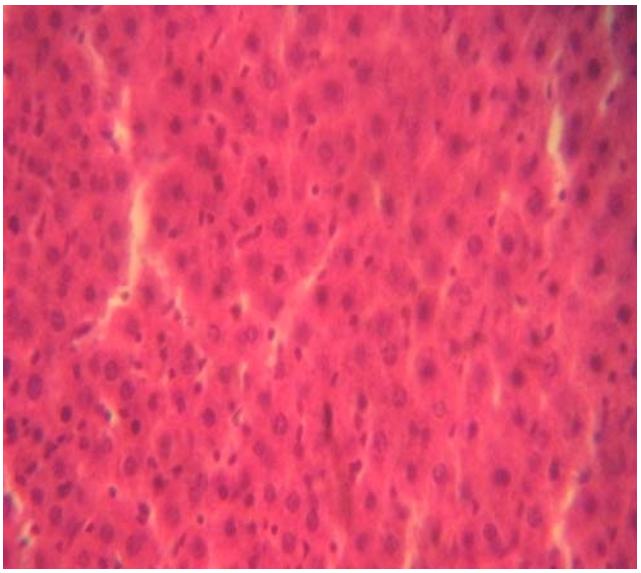

Fig. 1: Photomicrograph of normal liver architecture showing intact hepatocytes. H and E. mag x400

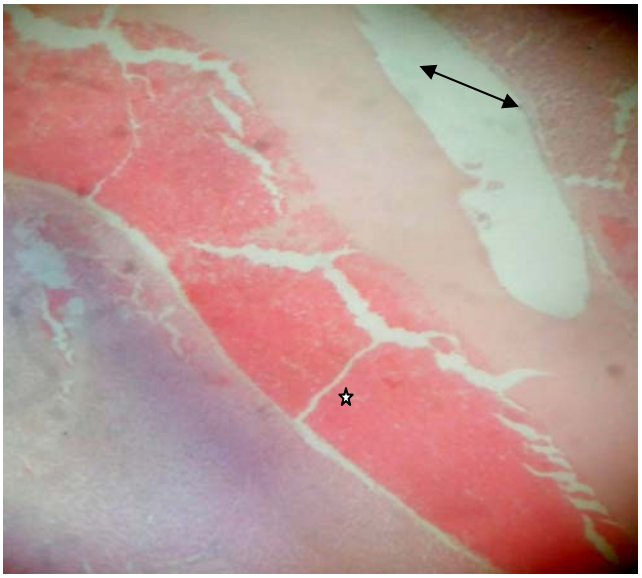

Fig. 2: Photomicrograph of liver section of Group II rats showing (1). increased pericellular fibrosis (black arrow). (2) Enlarged nodulations are also observed (star) (3). Dilatation of sinusoids (red arrow)

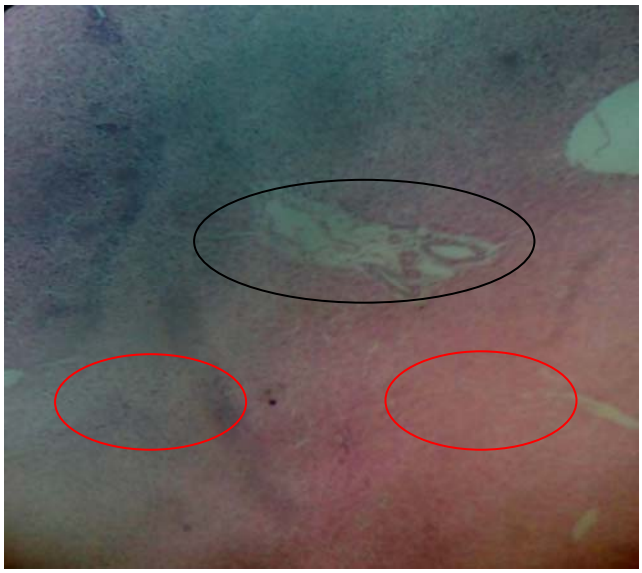

Fig. 3: Photomicrograph of liver section of Group III rats showing (1). Dilatation (double arrow) and congestion of the sinusoid (star). H and E. mag. 400X

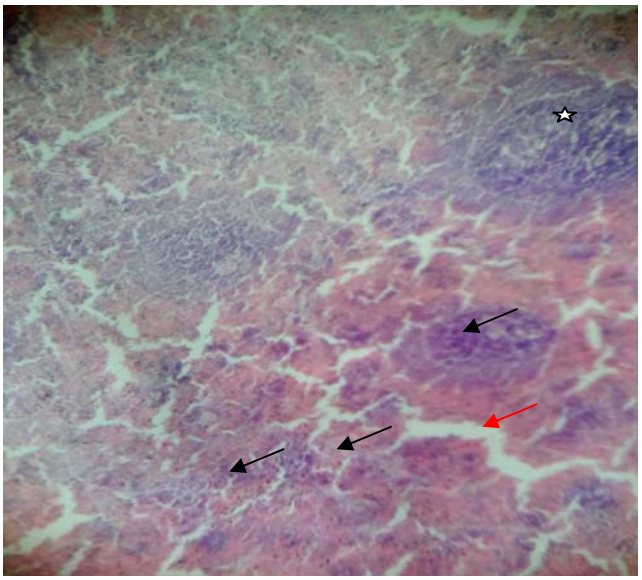

Fig. 4: Photomicrograph of liver section of Group IV rats showing (1). Dilatation of sinusoids (arrow head) with congestion (black arrow) and fragmentations of hepatic chords. H and E mag. 400X

showed very severe increased pericellular fibrosis due to prolonged hepatotoxicity compared to those of normal control group whose photomicrograph showed intact hepatocytes, sinusoids and kupffer cells. The less damage to the liver observed in the extract group (Fig. 3) and co-administration groups IV, V and VI (Fig. 4-6) may be due to the active substances present in *Terminalia catappa* and also it could be attributed to the antioxidant properties of the plant.

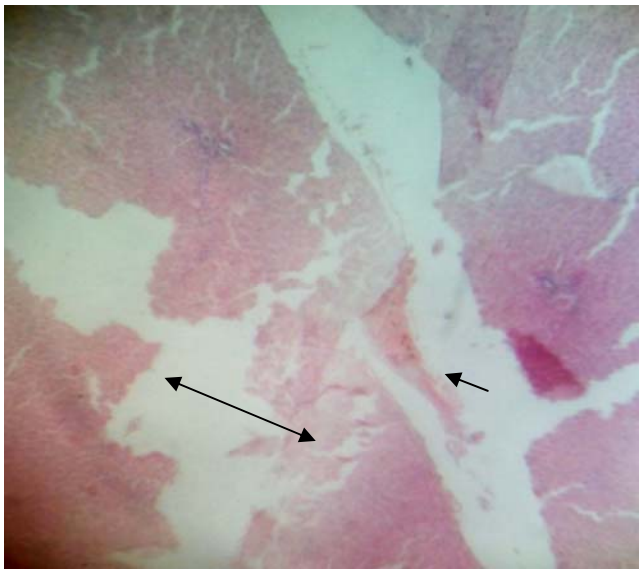

Fig. 5: Photomicrograph of liver section of Group V rats showing (1) Portal inflammation (black circles) (2) necrosis with loss of hepatocytes (red circles). H and E. mag. 100X

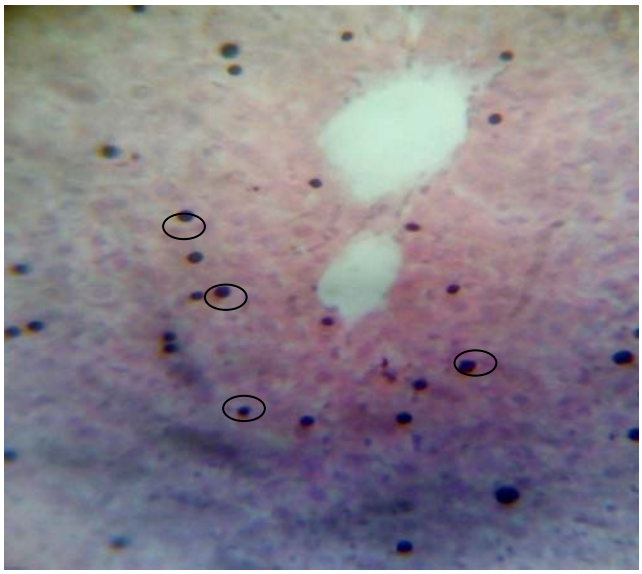

Fig. 6: Photomicrograph of liver section of Group VI rats showing (1). Ballooning of hepatocytes (circles) H and E. mag. 400X

CONCLUSION

The ethanol extract significantly improved the hepatic indices which possibly revealed that *Terminalia catappa* endocarp is relatively rich in some vital bioactive constituents, hence, could serve to provide medical or health benefits, as well as, reducing the hitherto waste generated from such inedible part of the fruit. Reports from this present study showed that the ethanol extract of *Terminalia catappa* endocarp possesses antihepatotoxic activity as demonstrated by its restoration of MSG-induced elevation of ALT, AST activity. The hepatoprotective effect may be attributed to the presence of antioxidants possessed by the plant which helped to combat the MSG-induced oxidative stress in the liver. Therefore, the potential of natural compounds to reduce suspected carcinogen-induced hepatotoxicity is believed to be related to their intrinsic antioxidant properties. The presence of high amounts of saponins, alkaloids and flavonoids present in *Terminalia catappa* endocarp might have played immense hepatoprotective action. Flavonoids present in *Terminalia catappa* plant might have played a role in the hepatoprotective action of the plant, since the chemoprotective potentials of flavonoids are related to their ability to inhibit oxidative and peroxidative damage. Although, Food and Drug Administration (FDA) has classified MSG as a food ingredient that's "generally recognized as safe," but its use remains controversial. For this reason, when MSG is added to food, there is need to list it on the label. Additionally, the use of *Terminalia catappa* endocarp flour extract may be advocated in curbing toxicity problems since the study revealed that the highest reverse of the MSG-induced toxicity in the treated rats was best observed in the group that received only the extract.

SIGNIFICANCE STATEMENT

This study discovered the beneficial role played by bioactive ingredients contained in plant extracts in conferring protection to liver as an organ of the body. This study was conducted using a part of plant (endocarp) considered as waste against the commonly used parts of plants such as bark and leaves. Thus, this uncovers a great potential that limiting waste believing that everything is useful.

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