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Original Article

Ameliorative Effects of *Tinospora Cordifolia* Root Extract on Histopathological and Biochemical Changes Induced by Aflatoxin-B_1 in Mice Kidney

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ABSTRACT

The present study was planned to investigate the ability of the *Tinospora cordifolia* to scavenge free radicals generated during aflatoxicosis. A total no. of 48 male Swiss albino mice (30 ± 5 g) were exposed to Aflatoxin B^1 (AFB^1) (2 μg/30 g b.wt, orally) either individually or in combination with *T. cordifolia* (50, 100, 200 mg/kg, orally) once daily for 25 days. AFB^1 exposure led to significant rise in thiobarbituric acid reactive substances (TBARS) and fall in superoxide dismutase (SOD), catalase (CAT), reduced glutathione (GSH), glutathione-S-transferase (GST), glutathione peroxidase (GPx), glutathione reductase (GR), ascorbic acid, and protein content. *T. cordifolia* was found to show protective effect by lowering down the content of TBARS and enhancing the GSH, ascorbic acid, protein, and the activities of antioxidant enzymes viz., SOD, CAT, glutathione peroxidase, GST, and GR in kidney. Histopathological analysis of kidney samples also confirmed the protective values and antioxidant activity of ethanolic extract of herb. *T. cordifolia* showed protection against aflatoxin-induced nephrotoxicity due to the presence of alkaloids such as a choline, tinosporin, isocolumbin, palmatine, tetrahydropalmatine, and magnoflorine.

Key words: Aflatoxin, antioxidant, mice, oxidative stress, *Tinospora cordifolia*

INTRODUCTION

Aflatoxin (AF) is polysubstituted bifuranocoumarins that are secondary fungal metabolites produced by the *flavus/parasiticus* group of the genus *Aspergillus*.[1] The toxic effects of AF in livestock have been well documented. When livestock eat AF-contaminated feed, it may cause many health problems.[2] Epidemiological and experimental studies have shown that AF is hepatotoxic, hepatocarcinogenic, mutagenic, and teratogenic.[3] AF cause oxidative stress by increasing lipid peroxidation and decreasing enzymatic and nonenzymatic antioxidants in treated animals.[4] Oxidative damage in the cell or tissue occurs when the concentration of reactive oxygen species (superoxide radical, hydroxyl radical, and hydrogen peroxide) generated exceeds the antioxidant capacity of the cell[5] or when the antioxidant capacity of the cell decreases. Levels of nonenzymatic antioxidants (glutathione, ascorbic acid) and enzymatic antioxidants glutathione peroxidase, catalase [CAT], and superoxide dismutase [SOD]) are the major determinants of the antioxidant defense mechanism of the cell.

Management of AF toxicity without any side effect is still a challenge to the medicinal field, as presently available drugs for aflatoxicosis have one or other adverse effects.

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In recent years, the herbal remedy for the unsolved medicinal problems is gaining importance in research field. *Tinospora cordifolia* (Menispermaceae) is widely used in Ayurvedic medicine as a tonic, vitalizer, and as a remedy for metabolic disorder. The plant stem has been considered as an indigenous source of medicines to have antidiabetic, immunomodulatory, antihepatotoxic, and antipyretic[6] actions. The roots of *T. cordifolia* possess antiulcer and antistress[7] action. In the present study, the attempts were made to evaluate the anticarcinogenic activity of *T. cordifolia*, its effect on the kidney morphology and biochemical variables in AF-toxicated kidney of mice, since AF nephropathy is one of the major complication in long-term aflatoxicosis.

MATERIAL AND METHODS

Chemicals

Crystalline aflatoxin B_1 (AFB_1) (from *Aspergillus flavus*) was purchased from HIMEDIA (India). All other chemicals used were of analytical grade and obtained from SD fine chemicals (Mumbai, India), SRL (India), CDH (India), and Qualigens (India/Germany).

Animals

Healthy male Swiss albino mice (*Mus musculus*) were procured from Haryana Agricultural University, Hissar (Haryana, India). Only male mice were used because previous studies have indicated that these were more sensitive to AF treatment than female. The animals were housed under standard laboratory conditions of light (12 hours light-dark cycle); temperature, 25 ± 2°C; humidity, 55 ± 5%, and fed with standard mice pellet diet (Hindustan Liver Limited, India) and tap water *ad libitum* in animal house of Banasthali University according to internationally accepted principle. A prior approval was obtained from the institutional animal ethics committee for the study protocol. After 1 week of acclimatization, mice were used for experimental purpose.

Preparation of aflatoxin B_1 and ethanolic extract of *Tinospora cordifolia*

Crystalline AFB_1 was dissolved in dimethylsulfoxide and further diluted with distilled water to the required concentration. The final gavage solution of AFB_1 contained 1% dimethylsulfoxide.

The experimental plant material was collected from medicinal plant garden, Banasthali University, India. It was identified as *T. cordifolia* by a plant taxonomist of our department and its sample has been preserved and documented in the herbarium of our University. The hanging aerial roots were washed thoroughly with distilled water and shade-dried. Ethanolic extract of the dried roots of *T. cordifolia* was prepared by Soxhlet method using 300 ml ethanol for 50 g (dry weight) of dried root powder. The ethanolic extract thus obtained was dried under reduced pressure at a room temperature not exceeding 40°C to get a yield of 7% from the crude extract. The extract, devoid of alcohol, was used for required concentration.

Experimental design

Male Swiss albino mice (30 ± 5 g) were randomized into eight groups comprising of six animals in each groups and were administered orally by gavage, once daily as below, for 25 days-

Group I - Control (Normal saline, 0.9%)

Group II- AFB_1 (2 μg/30 g body weight)

Group III- *T. cordifolia* (50 mg/kg body weight)

Group IV- *T. cordifolia* (100 mg/kg body weight)

Group V- *T. cordifolia* (200 mg/kg body weight)

Group VI- AFB_1 + *T. cordifolia* (50 mg/kg body weight)

Group VII- AFB_1 + *T. cordifolia* (100 mg/kg body weight)

Group VIII- AFB_1 + *T. cordifolia* (200 mg/kg body weight)

On 25th day of the study, the animals were scarified by cervical dislocation. Kidney sample from the sacrificed mice were quickly removed and cleaned to make them free of extraneous material and perfused with ice-cold saline for biochemical and histopathological evaluation. Post-mitochondrial supernatant was prepared using method of Mohandas *et al.*,[8] with some modifications. The various biochemical variables viz., lipid peroxidation,[9] SOD,[10] CAT,[11] glutathione-S-transferase (GST),[12] reduced glutathione (GSH),[13] glutathione peroxidase,[14] glutathione reductase (GR),[15] ascorbic acid,[16] and protein[17] were analyzed. Histopathological evaluation of kidney tissue was done according to the method of Luna.[18]

Statistical analysis

The results are expressed as mean ± standard error (S.E.M.). Statistical significance between the different groups was determined by one way analysis of variance (ANOVA) using the SPSS software package16. Post hoc testing was performed for inter-group comparisons using the Tukey multiple comparison test. The level of significance was set at $P<0.05$.

RESULTS AND DISCUSSION

The biochemical status of animals, i.e., levels of LPO, SOD, CAT, GSH, GST, GPx, GR, ascorbic acid, and protein content are given in Table 1. AFB_1 exposure led to significant rise ($P<0.01$) in thiobarbituric acid reactive substances

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(TBARS) (20.71 ± 0.92 nmoles TBARS $h^{-1}g^{-1}$) and fall in SOD (5.12 ± 0.61 Unit mg^{-1}protein h^{-1}), CAT (43.86 ± 2.08 μmol H_2O_2 consumed $min^{-1}mg^{-1}$protein), GSH (154.88 ± 7.36 nmolsGSHg^{-1}tissue), GST (97.65 ± 2.20 nmoles CDNB conjugates formed $min^{-1}mg^{-1}$ protein), GPx (14.20 ± 0.26 μg of glutathione utilized $min^{-1}mg^{-1}$protein), GR (115.09 ± 1.06 nmoles NADPH oxidized $min^{-1}mg^{-1}$protein), ascorbic acid (3.75 ± 0.17 mg ascorbic acid/g tissue), and protein content (32.71 ± 0.94 mg g^{-1}fresh wt) as compared with respective control values ($P<0.01$). Significant increase ($P<0.05$) in CAT activity was shown in group III and group IV mice, whereas group of mice which received plant extract alone (group III, group IV, and group V) showed significant enhancement ($P<0.01$) in protein content. Glutathione peroxidase activity was significantly increased ($P<0.01$) in the group III and group V mice, whereas GSH activity was also significantly improved ($P<0.01$) in group of mice which received RTc (50) and RTc (100).

When all the doses of *T. cordifolia* root extract were administered along with AF, it was found that all doses significantly decreased ($P<0.01$) the level of Lipid peroxidation (13.26 ± 0.42; 12.54 ± 1.28; 15.19 ± 0.94 nmoles TBARS $h^{-1}g^{-1}$) as compared with AF-treated animal. Coadministration of plant with all doses along with AF significantly increased ($P<0.01$) the CAT (62.15 ± 1.92; 65.78 ± 3.28; 58.75 ± 2.42 μmol H_2O_2 consumed $min^{-1}mg^{-1}$protein), GSH (260.12 ± 3.29; 254.35 ± 3.36; 265.65 ± 6.19 nmols GSHg^{-1}tissue), GST (125.89 ± 2.61; 119.58 ± 4.15; 129.42 ± 2.21 nmoles CDNB conjugates formed $min^{-1}mg^{-1}$ protein), GPx (18.93 ± 0.29; 20.95 ± 1.64; 17.43 ± 0.58 μg of glutathione utilized $min^{-1}mg^{-1}$protein), GR (123.87 ± 1.43; 121.01 ± 1.26; 125.57 ± 2.30 nmoles NADPH oxidized $min^{-1}mg^{-1}$protein), ascorbic acid (4.50 ± 0.20; 4.92 ± 0.05; 4.18 ± 0.10 mg ascorbic acid/g tissue), and protein content (41.21 ± 0.92; 42.56 ± 0.81; 40.88 ± 1.06 mg g^{-1}fresh wt) as compared with respective values of group II mice. Group VI and group VIII mice also showed significant improvement ($P<0.01$) in SOD (8.21 ± 0.43; 8.59 ± 0.86 Unit mg^{-1}protein h^{-1}), whereas group VII mice showed significant improvement ($P<0.05$) in SOD (7.92 ± 1.07 Unit mg^{-1}protein h^{-1}) as compared with the values of AF-administered group (group II).

Histopathological examination of the mice kidney revealed normal architecture in control (a), RTc (50) (c), RTc (100) (d), and RTc (200) (e) treated group. However, kidney from AFB_1-treated mice (b) revealed the vacuolar degeneration of tubular epithelial cells. The kidney of mice treated with AFB_1 + RTc (50) (f) shows normal tubules with congested glomerulus and AFB_1 + RTc (100) (g) showed congested glomerulus and tubules with vacuolated epithelial cells, whereas AFB_1 + RTc (200) (h) showed vacuolation of tubular epithelium but no shedding of tubular cells into the lumen [Figure 1].

Table 1: Effect of ethanolic extract of Tinospora cordifolia root on non-enzymatic, enzymatic parameters and level of TBARS in the kidney of mice treated with aflatoxin B[1]

Parameters	Treatments (mean ± S.E.M.)							
	Control (Group I)	AFB^1 (Group II)	RTc (50) (Group III)	RTc (100) (Group IV)	RTc (200) (Group V)	AFB^1+RTc (50) (Group VI)	AFB^1+RTc (100) (Group VII)	AFB^1+RTc (200) (Group VIII)
LPO (nmols TBARS $h^{-1}g^{-1}$tissue)	8.66 ± 0.14 ^{c}	20.71 ± 0.92 ^{a}	8.45 ± 0.54 ^{NS,c}	8.37 ± 0.34 ^{NS,c}	8.45 ± 0.47 ^{NS,c}	13.26 ± 0.42 ^{a,c}	12.54 ± 1.28 ^{a,c}	15.19 ± 0.94 ^{a,c}
SOD (Unit mg^{-1}Protein h^{-1}	12.40 ± 0.93 ^{c}	5.12 ± 0.61 ^{a}	12.92 ± 0.52 ^{NS,c}	12.63 ± 0.72 ^{NS,c}	13.19 ± 1.02 ^{NS,c}	8.21 ± 0.43 ^{a,c}	7.92 ± 1.07 ^{a,d}	8.59 ± 0.86 ^{a,c}
CAT (µ mol H_2O_2 consumed min^{-1} mg^{-1} protein)	83.86 ± 1.67 ^{c}	43.86 ± 2.08 ^{a}	87.12 ± 0.92 ^{b,c}	87.26 ± 1.85 ^{b,c}	85.35 ± 0.82 ^{NS,c}	62.15 ± 1.92 ^{a,c}	65.78 ± 3.28 ^{a,c}	58.75 ± 2.42 ^{a,c}
GSH (nmols GSH g^{-1} tissue)	261.4 ± 5.51 ^{c}	154.88 ± 7.36 ^{a}	275.19 ± 5.19 ^{a,c}	282.70 ± 6.60 ^{a,c}	267.46 ± 3.29 ^{NS,c}	260.12 ± 3.29 ^{NS,c}	254.35 ± 3.36 ^{NS,c}	265.65 ± 6.19 ^{NS,c}
GST (nmols CDNB conjugates formed $min^{-1}mg^{-1}$ protein)	164.17 ± 9.37 ^{c}	97.65 ± 2.20 ^{a}	163.26 ± 1.21 ^{NS,c}	165.70 ± 5.58 ^{NS,c}	162.54 ± 4.48 ^{NS,c}	125.89 ± 2.61 ^{a,c}	119.58 ± 4.15 ^{a,c}	129.42 ± 2.21 ^{a,c}
GPx (µg of glutathione utilized $min^{-1}mg^{-1}$protein)	24.39 ± 3.78 ^{c}	14.20 ± 0.26 ^{a}	31.67 ± 0.52 ^{a,c}	27.18 ± 0.47 ^{NS,c}	33.43 ± 1.90 ^{a,c}	18.93 ± 0.29 ^{NS,c}	20.95 ± 1.64 ^{NS,c}	17.43 ± 0.58 ^{NS,c}
GR (n moles NADPH oxidized $min^{-1}mg^{-1}$protein)	141.31 ± 0.88 ^{c}	115.09 ± 1.06 ^{a}	142.31 ± 1.62 ^{NS,c}	141.44 ± 1.86 ^{NS,c}	141.61 ± 1.93 ^{NS,c}	123.87 ± 1.43 ^{a,c}	121.01 ± 1.26 ^{a,c}	125.57 ± 2.30 ^{a,c}
Asc (mg ascorbic acid/g tissue)	5.69 ± 0.30 ^{c}	3.75 ± 0.17 ^{a}	5.62 ± 0.18 ^{NS,c}	5.89 ± 0.09 ^{NS,c}	5.43 ± 0.22 ^{NS,c}	4.50 ± 0.20 ^{a,c}	4.92 ± 0.05 ^{a,c}	4.18 ± 0.10 ^{a,c}
Protein (mg g^{-1}fresh wt)	41.03 ± 1.71 ^{c}	32.71 ± 0.94 ^{a}	65.09 ± 2.21 ^{a,c}	68.78 ± 2.53 ^{a,c}	63.91 ± 0.97 ^{a,c}	41.21 ± 0.92 ^{NS,c}	42.56 ± 0.81 ^{NS,c}	40.88 ± 1.06 ^{NS,c}

Values are mean ± SE of six mice. Significant differences in data are shown as a $P<0.01$ and b $P<0.05$ when compared with control (group I) and c $P<0.01$ and d $P<0.05$ when compared with aflatoxin treated group (group II).NS (Statically not significant), AFB^1, aflatoxin B^1; Asc, ascorbic acid; CAT, catalase; GPx, glutathione peroxidase; GR-glutathione reductase; GSH, reduced glutathione; GST, glutathione-S-transferase; SOD, superoxide dismutase; TBARS, thiobarbituric acid reactive substances

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We observed significant fall in the activities of kidney SOD and CAT in the mice fed with AF alone. SOD and CAT are the main antioxidant enzyme in the body, which scavenge unwanted $O_{2^{\cdot}}$, H_2O_2, and ROOH produced by free radical. SOD catalyzes superoxide radical dismutation and CAT decomposes hydrogen peroxide.[19] The decreased enzyme activities and increased TBARS levels produced by AFB_1 can be attributed to lower ability of the tissue, which cannot scavenge free radicals and prevent the action of lipid peroxidation. In present study, reduction in GSH, GST, and ascorbic acid content in the kidney was shown after AF treatment. GSH and GST play a critical role in the protection of tissues from deleterious effects of activated AFB_1. GSH is a tripeptide containing cysteine that has a reactive –SH group with reductive potency. It can act as a nonenzymatic antioxidant by direct interaction of –SH group with ROS, as a cofactor or coenzyme.[20] During the free radical scavenging action, ascorbic acid is transformed into L-dehydroascorbate.[21] GSH is required for conversion of L-dehydroascorbate back to ascorbate. The fall in the level of GSH decreases the conversion of L-dehydroascorbate to ascorbic acid in AF-treated animals. GST catalyzes the conjugation of AFB_1-8, 9-epoxide with GSH to form AFB_1-epoxide-GSH conjugate, thereby decreasing the intracellular glutathione content.[22] These observations support our findings where we observed a significant decline in the level of GSH and GST in AFB_1-induced animal.

However, cosupplementation of RTc extract with AFB_1 increased SOD and CAT activities and reduced TBARS levels. Any compound, natural or synthetic, with antioxidant property may inhibit free radical generation by direct scavenging of the free radicals and subsequent transformation of the antioxidant species into less toxic product. Therefore, removing $O_2^{\bullet}$ and $OH^{\cdot}$ is probably one of the most effective defense mechanism of living body against disease. Photochemical studies of *T. cordifolia* have revealed the presence of alkaloids such as a choline (V), tinosporin, isocolumbin, palmatine, tetrahydropalmatine (VI), and magnoflorine in the roots and these alkaloids are known to exhibit antioxidant property.[23] These constituent accelerates dismutation of superoxide radicals to hydrogen peroxide and molecular oxygen. Hydrogen

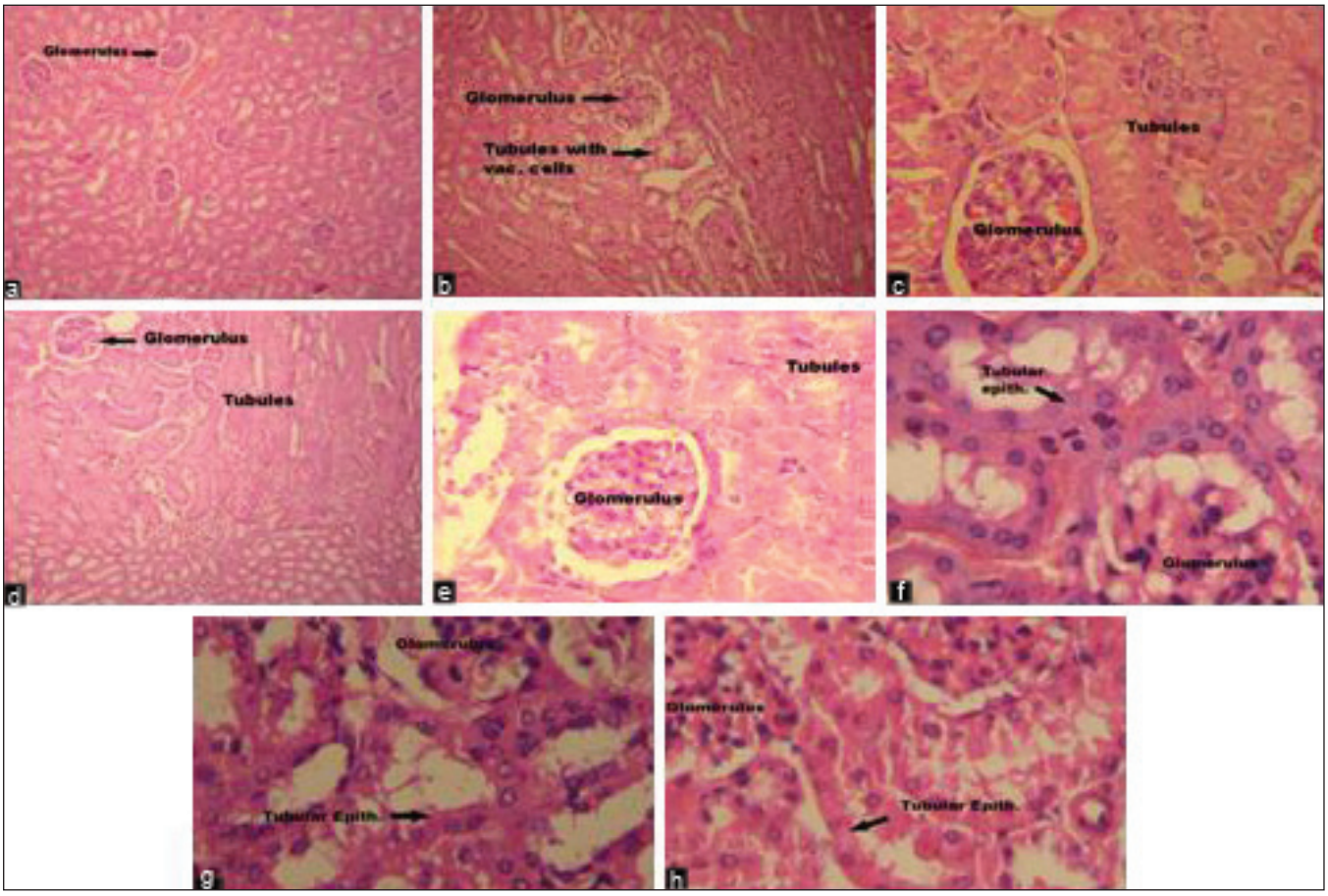


Figure 1: Cross section of kidney in mice treated with AFB_1 and RTc (40x). Kidney from control (a), RTc (50) (c), RTc (100) (d), and RTc (200) (e) treated mice show normal architecture. However, kidney from AFB[1]-treated mice (b) revealed the vacuolar degeneration of tubular epithelial cells. The kidney of mice treated with AFB_1 + RTc (50) (f) shows normal tubules with congested glomerulus and AFB_1 + RTc (100) (g) showed congested glomerulus and tubules with vacuolated epithelial cells, whereas AFB_1 + RTc (200) (h) showed vacuolation of tubular epithelium but no shedding of tubular cells into the lumen

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peroxide produced is further removed by CAT.[24] Therefore, *Tinospora* induced SOD activity, in conjugation with CAT antagonizes free-radical-induced injury. Extract treatment significantly reduced lipid peroxidation, as measured by Malondialdehyde production, and eliminates the possibility of oxidative stress due to the administration of AFB_1 to mice. It is also reported that *T. cordifolia* exhibits an appreciable amount of Vit C (41.36 mg/g of extract) and glutathione (6.86 mg/g of extract) and both of these are known to be effective in direct scavenging of a wide variety of free radicals.[25] Also, Vit (C) and GSH present in *T. cordifolia* are potent lipid peroxidation chain-breaking agent and therefore further add to the protective role of the herbs against lipid peroxidation. Thus, *Tinospora* induced unregulated antioxidant enzyme status, owing to an increase in the specific activities of SOD, CAT points to an extended functional balance between pro-oxidant and antioxidant pathways. The results of present study demonstrate that *T. cordifolia* showed protection against AF-induced nephrotoxicity due to the presence of alkaloids such as a choline (V), tinosporin, isocolumbin, palmatine, tetrahydropalmatine (VI), and magnoflorine. The treatment with *Tinospora* resulted in striking induction in the specific activities of detoxifying enzymes in the kidney, which strongly suggests a possible role of *T. cordifolia* in cancer chemoprevention.

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REFERENCES

1. Harvey RB, Edrington TS, Kubena LF, Elissalde MH, Corrier DE, Rottinghaus GE. Effect of aflatoxin and diacetoxyscirpenol in Ewe lambs. Bull Environ Contam Toxicol 1995;54:325-30.
2. Patterson DS. Structure, metabolism and toxicity of the aflatoxin. Rev Can Nutr Diet 1976;2(Suppl):71-6.
3. Abdel-Wahhab MA, Aly SE. Antioxidant property of *Nigella sativa* (Black cumin) and *Syzygium aromaticum* (Clove) in rats during aflatoxicosis. J Appl Toxicol 2005;25:218-23.
4. El-Gibaly I, Meki AM, Abdel-Ghaffar SK. Novel B melatonin-loaded chitosan microcapsules: *in vitro* characterization and antiapoptosis efficacy for aflatoxin B_1-induced apoptosis in rat liver. Int J Pharm 2003;260:5-22.
5. Sies H. Oxidative stress: Oxidants and Antioxidants. Academic Press, San Diego, California. 1991.
6. Vedavathy S, Rao KN. Antipyretic activity of six indigenous medicinal plants of Tirumala Hills, Andhra Pradesh, India. J Ethenopharmacol 1991;33:193-6.
7. Sarma DN, Khosa RL, Chansouria JP, Sahai M. Antistress activity of *Tinospora cordifolia* and *Centella asiatica* (L.) extracts. Phytother Res 1996;10:181-3.
8. Mohandas J, Marshall JJ, Duggin GG, Horvath JS, Tiller DJ. Differential distribution of glutathione and glutathione related enzymes in rabbit kidney. Biochem Pharmacol 1984;33:1801-7.
9. Utley HC, Bernhein F, Hachslein P. Effect of sulphahydryl reagent on peroxidation in microsome. Arch Biochem Biophys 1976;260:521-31.
10. Dhindsa RS, Plumb, Dhindsa P, Thrope TA. Leaf senescence correlated with increased level of membrane permeability. Lipid peroxidation and decreased level of SOD and CAT. J Exp Bot 1981;32:93-01.
11. Claiborne A. Catalase activity. In: Greenwald, editor. Handbook of methods in oxygen radical research. Florida: Baca Raton; 1985. p. 283-4.
12. Habig WH, Pabst MJ, Jakoby WB. The first enzymatic step in mercapturic acid formation. J Biol Chem 1974;249:7130-9.
13. Jollow DJ, Mitchell JR, Zampaglione N, Gillette JR. Bromobenzene induced liver necrosis, Protective role of glutathione and evidence for 3,4-bromobenze oxides as the hepatotoxic metabolite. Pharmacology 1974;11:151-69.
14. Flohe L, Gunzler WA. Assays of glutathione peroxidase. Methods Enzymol 1984;105:114-21.
15. Carlberg I, Mannervik B. Glutathione reductase level in rat brain. J Biol Chem 1975;250:5475-80.
16. Majhi S, Jena BS, Patnaik BK. Effect of age on lipid peroxides, lipofuscin and ascorbic acid content of lungs of male garden lizard. Comp Biochem Physiol C Toxicol Pharmacol 2000;126:293-8.
17. Lowry OH, Roserbrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin phenol reagent. J Biol Chem 1951;193:265-75.
18. Luna LG. Manual of Histology: Staining Methods of Armed Force Institute of Pathology. 3rd ed. New York: McGraw-Hill; 1968. p. 38-9.
19. Wills ED. Mechanisms of lipid peroxide formation in animal tissues. Biochem J 1966;99:667-76.
20. Janssen YM, Van Houten B, Borm PJ, Mossman BT. Cell and tissue responses to oxidative damage. Lab Invest 1993;69:261-74.
21. Breimer LH. Molecular mechanism of oxygen radical carcinogenesis and mutagenesis: the role of DNA base damage. Mol Carcinog 1990;3:188-97.
22. Raney KD, Meyer DJ, Ketterer B, Harris TM, Guengerich FP. Glutathione conjugation of aflatoxin B^1 exo and endo-epoxides by rat and human glutathione-S-transferases. Chem Res Toxicol 1992;5:470-8.
23. Ng TB, Liu F, Wang ZT. Antioxidant activity of natural products from plants. Life Sci 2000;66:709-23.
24. Abei H. Catalase *in vitro*. In: Colowick SP, Kaplan NO, editors.,Vol. 105. Methods in Enzymology. New York: Academic press; 1984. p. 121-6.
25. Maslova GT, Boboriko TL. Effect of antioxidants on the status of the antioxidant system in cerebral ischemia and reperfusion injury. Ukr Biokhim Zh 1990;62:101-5.

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