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Oxidative Stress–Mediated Hepatotoxicity Induced by Chronic Mosquito Coil Smoke Exposure and the Protective Role of *Emblica officinalis* in Wistar Rats

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A B S T R A C T

Continuous exposure to mosquito coil smoke is a significant source of indoor air pollution and may induce toxic effects in mammals through oxidative stress–mediated mechanisms. The present study was undertaken to evaluate the hepatotoxic effects of prolonged mosquito coil smoke exposure and the protective role of *Emblica officinalis* (amla) fruit extract in male Wistar rats. Experimental animals were divided into four groups: control, mosquito coil smoke-exposed, amla-treated, and mosquito coil smoke with supplementation of amla. The animals were exposed to mosquito coil smoke for 8 hours per day till 40 days. Serum biochemical parameters, including alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and total bilirubin, were assessed along with hepatic oxidative stress markers such as malondialdehyde (MDA), superoxide dismutase (SOD), and catalase (CAT) in Wistar albino rats. Results demonstrated a significant increase in serum ALT, AST, ALP, and bilirubin levels in the mosquito smoke-exposed group, indicating hepatocellular damage. A marked elevation in MDA levels suggested enhanced lipid peroxidation, while a significant reduction in SOD and CAT activities reflected impaired antioxidant defense mechanisms. However, treatment with *Emblica officinalis* fruit extract significantly ameliorated these alterations by reducing liver enzyme levels, decreasing lipid peroxidation, and restoring antioxidant enzyme activities toward normal values. In conclusion, mosquito coil smoke induces oxidative stress–mediated hepatic injury, whereas *Emblica officinalis* exhibits potent hepatoprotective and antioxidant properties. Therefore, it may serve as a promising natural therapeutic agent against pollutant-induced liver damage.

Introduction

Indoor air pollution has become a significant environmental and public health concern in developing countries. Various domestic practices contribute to indoor pollution, including burning biomass fuels, incense sticks and mosquito coils. Mosquito coils are commonly used as an inexpensive and easily available method to control mosquito populations, particularly in tropical regions. However, the combustion of mosquito coils releases numerous toxic substances such as particulate matter, carbon monoxide, aldehydes and pyrethroid-based insecticides. These compounds can adversely affect biological systems when inhaled continuously. Previous experimental observations have demonstrated that long-term inhalation of mosquito coil smoke may produce toxicological changes in several organs including lungs, kidneys and liver (Liu *et al*.1987). Increased serum transaminase levels and inflammatory responses have been observed following chronic exposure to mosquito coil smoke (Okine *et al*. 2004). The liver plays a major role in detoxification and metabolism of xenobiotics, therefore exposure to environmental pollutants may lead to hepatocellular injury (WHO, 2014). One of the important mechanisms involved in toxin-induced liver damage is oxidative stress. Reactive oxygen species generated during metabolism of toxic compounds can attack cellular lipids, proteins and DNA. This leads to lipid peroxidation, disruption of membrane integrity and reduction in endogenous antioxidant enzymes such as superoxide dismutase and catalase (Duthie *et al*. 2003; Singh *et.al* 2020). Therefore antioxidants are considered important therapeutic agents in protecting biological tissues from oxidative damage.

Medicinal plants have been extensively studied for their antioxidant potential. *Emblica officinalis* Gaertn., commonly known as Indian gooseberry or amla, is a well-known medicinal plant used in traditional Ayurvedic medicine. The fruit contains large quantities of vitamin C, polyphenols, flavonoids and tannins which contribute to its strong antioxidant activity (Baliga 2013). Experimental studies have reported hepatoprotective properties of amla against several toxic agents including alcohol, heavy metals and chemical hepatotoxins (Bhuvaneswari *et al*.2014; Sharma *et al*. 2012). Considering these protective properties, the present investigation was undertaken to evaluate the hepatotoxic effects of chronic mosquito coil smoke exposure and to examine the protective role of *Emblica officinalis* fruit extract in Wistar albino rats.

Materials and Methods

Experimental Animals- Adult Wistar rats weighing 150–200 g were maintained under controlled laboratory conditions with standard pellet diet and water ad libitum. Animals were acclimatized prior to the experiment. All experimental procedures followed standard ethical guidelines for laboratory animal experimentation.

Experimental Design- Animals were randomly divided into the following groups and the experiment continued for 40 days for 8 hr/day.

Group I – Control

Rats were kept on a normal diet with ambient air .

Group II – Mosquito Coil Smoke

Rats were exposed to mosquito coil smoke for approximately 8hr/day for 40 days.

Group III – Amla Extract

Rats received *Emblica officinalis* fruit extract orally at a dose of 500 mg/kg body weight for 40 days.

Group IV – Smoke + Amla

Rats were exposed to mosquito coil smoke and simultaneously administered *Emblica officinalis* extract (500 mg/kg body weight) for 40 days.

Biochemical Analysis- At the end of the experimental period, blood samples were collected and serum was separated for biochemical analysis. Liver function parameters including ALT, AST and ALP were estimated using standard biochemical procedures.

Oxidative Stress Analysis- Liver tissues were homogenized in a phosphate buffer. Lipid peroxidation was assessed by measuring malondialdehyde levels. Antioxidant enzyme activities including superoxide dismutase and catalase were determined using established biochemical methods.

Statistical Analysis- Data were expressed as mean ± standard deviation. Statistical differences between groups were evaluated using analysis of variance. A probability value of $p < 0.05$ was considered statistically significant.

Results

Chronic exposure to mosquito coil smoke produced significant biochemical alterations in experimental animals for 40 days . Serum ALT, AST, ALP and total bilirubin levels were markedly elevated in the mosquito coil smoke-exposed group compared with the control group. Elevated MDA levels indicated enhanced lipid peroxidation while antioxidant enzymes SOD and CAT showed decreased activity. Administration of *Emblica officinalis* extract significantly mitigated the elevated liver enzyme levels and improved antioxidant enzyme activity.

Table 1 Effect of Mosquito Coil Smoke Exposure and *Emblica officinalis* Treatment on Serum Biochemical Parameters in Wistar Rats

Parameters	Control	Smoke	Amla	Smoke + Amla
ALT (U/L)	32 ± 3	78 ± 5	30 ± 2	40 ± 4
AST (U/L)	45 ± 4	110 ± 7	44 ± 3	58 ± 5
ALP (U/L)	85 ± 6	160 ± 10	83 ± 5	100 ± 8
Total Bilirubin (mg/dL)	0.6 ± 0.1	1.8 ± 0.2	0.5 ± 0.1	0.9 ± 0.1

Figure 1 Comparison of ALT, AST and ALP levels among experimental group

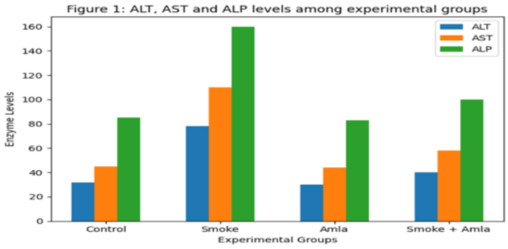

Figure 1 Comparison of ALT, AST and ALP levels among experimental groups.The mosquito coil smoke-exposed group shows increased ALT, AST and ALP levels, suggesting hepatocellular injury in comparison to the control group. *Emblica officinalis* administration lowers both enzyme levels, supporting hepatoprotective activity

Parameters	Control	Mosquito-coil Smoke	Amla	Smoke + Amla
MDA (nmol/mg protein)	2.1 ± 0.2	5.8 ± 0.4	2.0 ± 0.3	3.0 ± 0.3
SOD (U/mg protein)	8.5 ± 0.6	4.1 ± 0.5	8.7 ± 0.7	7.2 ± 0.6
CAT (U/mg protein)	52 ± 4	28 ± 3	54 ± 5	45 ± 4

Values are expressed as mean ± SD (n = 6).

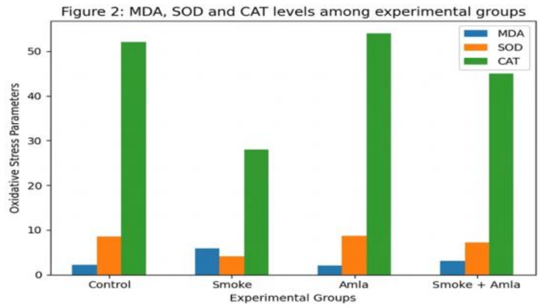

Figure 2 Comparison of oxidative stress parameters (MDA, SOD and CAT) in liver tissue.Mosquito coil smoke exposure increases MDA and decreases the antioxidant enzymes SOD and CAT. *Emblica officinalis* treatment reduces lipid peroxidation and restores antioxidant defense properties.

Discussion

The present investigation revealed that prolonged exposure to mosquito coil smoke results in significant hepatic impairment and oxidative stress in experimental animals. The increased serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and bilirubin observed in the mosquito coil smoke-exposed group are well-marked indicators of hepatocellular injury, loss of membrane integrity, and subsequent leakage of intracellular enzymes into circulation. These biochemical alterations strongly emphasise structural and functional disruption of hepatic tissue in Wistar albino rats. Similar findings have been made related to mosquito coil-smoke by Liu *et al*. (1987) and Okine *et al*. (2004) who reported comparable elevations in liver enzyme activities, confirming that smoke-derived pollutants exert detrimental effects on liver physiology in rats. Singh *et al*. (2020) also Observed the broader biological impact of indoor air pollution, emphasizing its role in inducing systemic toxicity, including hepatic dysfunction. In addition, Mustafa *et al*. (2020) Stated that exposure to environmental tobacco smoke significantly elevates liver enzyme markers in albino rats, thereby supporting the present findings and indicating that airborne toxicants share common mechanisms of hepatic injury.

Oxidative stress appears to be a central mechanism underlying such toxic effects. In the present study, the significant increase in malondialdehyde (MDA) levels indicates enhanced lipid peroxidation, which is a hallmark of oxidative damage to cellular membranes.Concurrently, the observed decline in endogenous antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT) reflects a compromised antioxidant defense system. In a related context, Khanam *et al*. (2019) observed increased MDA levels together with reduced SOD and catalase activity following UVB radiation exposure, further confirming that oxidative stress is a common pathway in environmentally and induced tissue damage in albino rats.

These findings are in agreement with the established role of reactive oxygen species (ROS) in mediating cellular injury (Halliwell & Gutteridge, 2007; Sies, 1997). A large amount of scientific evidence supports the involvement of oxidative stress in tissue damage and disease progression. Free radicals are known to disrupt cellular homeostasis and initiate lipid, protein, and DNA damage (Aruoma, 1998; Droge, 2002). Moreover, antioxidants play a crucial role in neutralizing these reactive species and protecting biological systems (Young & Woodside, 2001; Valko *et al*., 2007). Dietary and plant-derived antioxidants have been extensively studied for their protective effects against oxidative stress-related disorders (Duthie *et al*., 2003; Ames *et al*., 1993). In the present study, the administration of *Emblica officinalis* (amla) demonstrated significant hepatoprotective and antioxidant effects in Wistar albino rats.The reduction in lipid peroxidation levels and the restoration of antioxidant enzyme activities in treated animals indicate its strong free radical scavenging potential. These beneficial effects can be attributed to its rich phytochemical composition, including vitamin C, tannins, gallic acid, and various polyphenolic compounds (Baliga, 2013; Prakash *et al*., 2007). Previous experimental studies further supported the present observations, Bhuvaneswari *et al*. (2014) reported significant recovery of altered liver enzyme levels and improvement in hepatic architecture following treatment with *Emblica officinalis* in toxin-induced animals. Similarly, Sharma *et al*. (2012) demonstrated its protective efficacy against oxidative stress-mediated biochemical alterations. Additional studies on plant phenolics and bioactive compounds also confirm their antioxidant and anti-inflammatory properties (Reddy & Reddanna, 2009; Suri & Prakash, 2007; Upadhyay & Prakash, 2007). Furthermore, Mustafa *et al*. (2020) reported that amla supplementation significantly attenuates biochemical disturbances caused by environmental toxicants, reinforcing its therapeutic potential. Taken together, the findings of the present study strongly support the hypothesis that natural antioxidants present in *Emblica officinalis* effectively mitigate oxidative stress and hepatic damage induced by mosquito coil smoke exposure. The study emphasizes the potential application of amla as a natural, cost-effective, and safe protective agent against pollutant-induced hepatotoxicity. These results also showed the importance of minimizing exposure to indoor air pollutants and promoting dietary antioxidants as a preventive strategy against oxidative stress-related disorders.

Conclusion

The present study conclusively focused on that the exposure to mosquito coil smoke induces significant hepatic damage and oxidative stress in experimental animals, as evidenced by elevated liver enzyme levels, increased lipid peroxidation, and reduced antioxidant defenses. These findings demonstrate the potential health risks associated with prolonged exposure to indoor air pollutants. Significantly, treatment with *Emblica officinalis* effectively mitigated these adverse effects by restoring liver function markers and enhancing antioxidant enzyme activities. The observed protective effects can be attributed to its rich composition of bioactive compounds with strong antioxidant and free radical scavenging properties. Thus, *Emblica officinalis* emerges as a promising natural hepatoprotective agent against pollutant-induced toxicity. The study also emphasizes the need for increased awareness regarding the harmful effects of mosquito coil smoke and supports the use of natural antioxidants as a preventive strategy against oxidative stress-related disorders.

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