GVU-J.SHT *GVU Journal of Science, Health and Technology*

GVU-J. SHT 2025,**10**; **1**, 68–71, doi:10.5281/zenodo.15347125

Safeguarding Benefits of Curcumin on DNA Damage in Benzo(a)anthracene Treated Male Wistar Rats

Kolade, O. Y.[1*], Oladiji, A. T.[2], Igunnu, A.[3]

[1] *Nigerian Institute for Oceanography and Marine Research, P. M. B. 12729, Victoria Island, Lagos, Nigeria*
[2,3] *Department of Biochemistry, Faculty of Life Sciences, University of Ilorin, Ilorin, Kwara State, Nigeria*

*Corresponding author. E-mail: kemmystick2006@gmail.com, Phone: +234-8030749318

Received: *30 January 2025 []* ***Published:*** *13 April 2025*

The integrity of genomic material is vital for organismal health, yet it is frequently compromised by environmental toxicants. This study evaluated the protective effects of curcumin against benzo[a]anthracene-induced DNA damage in male Wistar rats. Five treatment groups were established: benzo[a]anthracene (1 mg) alone, benzo[a]anthracene (1 mg/kg bw) with curcumin at 50 mg/kg bw, 100 mg/kg bw, or 200 mg/kg bw, and a control group receiving neither treatment. Following a 7-day acclimatisation period, rats were orally administered benzo[a]anthracene and curcumin every other day for 6 weeks. After sacrifice, liver tissues were extracted, and DNA damage was assessed using an Oxidative DNA Damage ELISA Kit (8-OHdG Determination). A significant increase in DNA damage was observed in the livers of benzo[a]anthracene-treated rats compared to controls. Conversely, co-treatment with curcumin significantly reduced DNA damage ($p < 0.05$) in a dose-dependent manner compared to the benzo[a]anthracene-only group. These results demonstrate curcumin's efficacy in mitigating the genotoxic effects of benzo[a]anthracene, highlighting its potential as a protective agent against environmental toxicants.

Keywords: benzo[a]anthracene, curcumin, DNA damage, Wistar rats

Introduction

Food smoking is a widely adopted fish processing technique that enhances organoleptic attributes such as colour, flavour, fragrance, and visual appeal, extending beyond its traditional role in shelf-life preservation (Fasano et al., 2016). However, this method introduces significant drawbacks, including contamination with hazardous and carcinogenic compounds such as polycyclic aromatic hydrocarbons (PAHs), N-nitrosamines, and heterocyclic aromatic amines (Ledesma et al., 2016). These toxic substances, formed during the smoking process, pose considerable health risks through the consumption of contaminated foods (Adeyeye et al., 2016). PAHs constitute a diverse group of organic compounds characterised by two or more fused aromatic rings (Lawal, 2017). Ubiquitous in the environment through airborne transmission, PAHs arise from the incomplete combustion of organic materials (Purcaro et al., 2013).

The European Commission has designated four primary PAHs (PAH4) in foods—benzo[a]pyrene, benz[a]anthracene, benzo[b]fluoranthene, and chrysene—as critical contaminants (EU Commission Regulation, 2011). Classified as mutagenic, genotoxic, and carcinogenic by the International Agency for Research on Cancer (IARC) and the European Commission, these compounds raise significant safety concerns (Sampaio et al., 2021). The European Food Safety Authority (EFSA) recognises the cumulative levels of PAH4 as a reliable measure of total PAH contamination in food products (Ingenbleek et al., 2019).

Natural plant-derived compounds, particularly polyphenols, have been utilised to address various health conditions due to their safety, potent antioxidant, and anti-inflammatory properties (Mahmud et al., 2020). As naturally occurring substances in plants, polyphenols contribute significantly to human health and well-being (Biao, 2022). Their diverse chemical structures enable them to serve as effective prophylactic agents against severe and degenerative diseases (Zhang et al., 2022). Defined by a benzene ring with two or more phenolic hydroxyl groups, polyphenols are categorised into two main groups—flavonoids and phenolic acids—based on their structural characteristics (Zhang et al., 2021). Prominent examples include quercetin, rutin, myricetin, curcumin, fisetin, apigenin, luteolin, and resveratrol.

Among polyphenols, curcumin stands out for its chemopreventive properties, largely attributed to its antioxidant capabilities (Hussain et al., 2017). Traditionally employed in medicinal practices, curcumin exhibits a broad spectrum of pharmacological effects, including antioxidant, antiviral, antitumour, anti-inflammatory, and nephroprotective activities, with demonstrated potential in preclinical and clinical studies (Peng et al., 2021; Zia et al., 2021; Ming et al., 2022; Tomasa et al.,

2023). Despite its established chemoprotective role, the impact of curcumin on PAH-induced toxicity remains largely unexplored.

Numerous studies have investigated the toxicity of individual PAHs, particularly benzo[a]pyrene, revealing a range of adverse effects (Alzohairy et al., 2021; Barnwal et al., 2018; Zhu et al., 2014; Kim et al., 2019; Liu et al., 2015; Satpathy and Parida, 2021). However, data on the toxicological effects of benzo[a]anthracene in animals are scarce. This study aims to examine the hazardous impacts of benzo[a]anthracene (B[a]A), a member of PAH4, on the DNA of Wistar rats and to evaluate the potential protective effects of curcumin against benzo[a]anthracene-induced toxicity. By addressing these objectives, the study seeks to contribute to strategies for mitigating the health risks associated with PAH exposure in food systems.

Materials and Methods

Materials

Animals

The experiment utilised male Wistar rats (*Rattus norvegicus*), aged 6–8 weeks, with body weights ranging from 130 g to 140 g. These rats were sourced from the Animal Holding Unit, Department of Biochemistry, Faculty of Life Sciences, University of Ilorin, Ilorin, Nigeria. Prior to the experiment, the animals were acclimatised for one week to laboratory conditions, including feeding regimes and handling procedures.

Reagents

Industrially purified benzo[a]anthracene (B[a]A) and curcumin were used for the study.

Methods

Preparation and Dosage of Polycyclic Aromatic Hydrocarbons (PAHs)

Benzo[a]anthracene was freshly dissolved in olive oil and orally administered to the rats at a dose of 1 mg/kg body weight, thrice weekly for 6 weeks.

Preparation and Dosage of Curcumin

Curcumin was solubilised in olive oil and orally administered to the rats at doses of 50 mg/kg, 100 mg/kg, and 200 mg/kg body weight, thrice weekly for 6 weeks.

Experimental Design

Thirty male Wistar rats, with a mean body weight of 130–140 g, were obtained from the Animal Holding Unit, Department of Biochemistry, University of Ilorin, Ilorin, Nigeria. The rats were divided into five treatment groups, each consisting of six rats.

Experimental Set-Up

The rats were assigned to five groups, each comprising six animals, as follows:

Control Group (Group I): Rats received standard feed and tap water only.

Group II: Rats were administered 1 mg/kg body weight of benzo[a]anthracene thrice weekly.

Group III: Rats were administered 1 mg/kg body weight of benzo[a]anthracene + 50 mg/kg body weight of curcumin thrice weekly.

Group IV: Rats were administered 1 mg/kg body weight of benzo[a]anthracene + 100 mg/kg body weight of curcumin thrice weekly.

Group V: Rats were administered 1 mg/kg body weight of benzo[a]anthracene + 200 mg/kg body weight of curcumin thrice weekly.

Isolation of Organs from Rats

At the conclusion of the 6-week experiment, rats were rendered unconscious by exposure to diethyl ether vapours using ether-soaked cotton. The rats were then dissected, and their livers were extracted and placed in a chilled 0.25 M sucrose solution. The liver was chosen as the primary organ for analysis due to its role in metabolism and detoxification. Each liver was weighed, finely chopped, and homogenised using a chilled pestle and mortar. The resulting homogenate was diluted with 0.25 M sucrose solution to achieve a 1:5 dilution.

Determination of Deoxyribonucleic Acid (DNA) Damage

DNA damage was assessed using an Oxidative DNA Damage ELISA Kit for 8-hydroxy-2'-deoxyguanosine (8-OHdG) quantification. This competitive enzyme immunoassay enables rapid detection and quantification of 8-OHdG in body fluids, genetic material, or tissue samples. The 8-OHdG content in liver samples was determined by comparing their absorbance to a standard 8-OHdG curve (Patel et al., 2007).

Principle: The Oxidative DNA Damage ELISA Kit detects oxidised guanine derivatives, including 8-hydroxy-2'-deoxyguanosine from DNA, 8-hydroxyguanosine from RNA, and 8-hydroxyguanine from digested DNA or RNA.

Procedure: Liver samples containing unknown amounts of 8-OHdG were added to a microplate pre-coated with an 8-OHdG/BSA conjugate. After a brief incubation, an anti-8-OHdG monoclonal antibody was introduced, followed by a conjugated secondary antibody. The 8-OHdG content in the samples was quantified by comparison with a predetermined 8-OHdG standard curve.

Results

Table 1 Percentage DNA Fragmentation in Male Wistar Rats Treated Orally with Benzo[a]anthracene (B[a]A) and Curcumin

Groups	% DNA Fragmentation
Control	2.13 ± 0.18^{a}
B[a]A Only	50.86 ± 0.99^{b}
B[a]A + 50 mg/kg bw Curcumin	45.16 ± 0.17^{c}
B[a]A + 100 mg/kg bw Curcumin	44.72 ± 0.29^{c}
B[a]A + 200 mg/kg bw Curcumin	40.75 ± 0.72^{c}

Values are expressed as mean ± S.D. Values across columns carrying different superscripts are significantly different ($P < 0.05$).

Safeguarding Benefits of Curcumin Administration on Deoxyribonucleic Acid Damage in Rats Exposed to Benzo[a] anthracene (B[a]A)

The study demonstrated that oral administration of benzo[a]anth racene (B[a]A) induced significant deoxyribonucleic acid (DNA) fragmentation in male Wistar rats. Polycyclic aromatic hydrocarbons (PAHs) undergo metabolism, generating various metabolites and reactive oxygen species (ROS) (Moorty et al., 2015). During oxidative stress, ROS produced from PAH metabolism interact with biological macromolecules, such as membrane lipids, proteins, and nucleic acids, causing severe damage (Sanna and Fadda, 2022). This suggests that the primary mechanism of PAH-induced genotoxicity may involve oxidative damage triggered by PAH-derived free radicals. A plausible mechanism for B[a]A-induced genotoxicity could thus be oxidative damage, as studies indicate that PAH toxicity, including that of benzo[a]anthracene, stems from reactive by-products formed during metabolism, leading to redox imbalance (Farzan et al., 2016; Zhang et al., 2020).

Co-treatment of B[a]A-intoxicated rats with curcumin at doses of 50 mg/kg, 100 mg/kg, and 200 mg/kg body weight significantly reduced DNA fragmentation. The protective effect of curcumin against B[a]A-induced DNA damage is likely due to its antioxidant properties. Research has shown that curcumin reduces DNA damage by suppressing reactive oxygen species (ROS) levels (Thresiamman et al., 1998; Celik et al., 2013) and enhancing overall antioxidative capacity through regulation of lipid peroxidation and elevation of phase II detoxification enzymes, such as catalase, superoxide dismutase, and glutathione peroxidase (Dai et al., 2016). Curcumin's chemopreventive action against B[a]A-induced genotoxicity may be attributed to its potent ROS-scavenging capabilities, driven by its antioxidant properties. This scavenging activity is likely facilitated by the presence of methoxy and phenolic groups on the phenyl ring and the 1,3-diketone structure, which inhibit lipid peroxidation (Longobardi et al., 2021).

Conclusion

The study reveals that benzo[a]anthracene treatment induced significant DNA fragmentation in male Wistar rats, while curcumin administration effectively ameliorated these genotoxic effects. It is concluded that curcumin provides safeguarding benefits against DNA fragmentation in rats exposed to benzo[a]anthracene.

References

Adeyeye, S. A. O., Oyewole, O. B., Obadina, O., Adeniran, O. E., Oyedele, H. A., Olugbile, A., & Omemu, A. M. (2016). Effect of smoking methods on microbial safety, polycyclic aromatic hydrocarbon, and heavy metal concentrations of traditional smoked fish from Lagos State, Nigeria. *Journal of Culinary Science & Technology*, *14*, 91–106.

Alzohairy, M. A., Khan, A. A., Ansari, M. A., Babiker, A. Y., Alsahli, M. A., Almatroodi, S. A., & Rahmani, A. H. (2021). Protective effect of quercetin, a flavonol against benzo(a)pyrene-induced lung injury via inflammation, oxidative stress, angiogenesis and cyclooxygenase-2 signalling molecule. *Applied Sciences*, *11*, 8675.

Barnwal, P., Vafa, A., Afzal, S. M., Shahid, A., Hasan, S. K., Alpashree, A., & Sultana, S. (2018). Benzo(a)pyrene induces lung toxicity and inflammation in mice: Prevention by carvacrol. *Human & Experimental Toxicology*, *37*, 752–761.

Biao, J. (2022). Polyphenols and its classification. *Oxidants and Antioxidants in Medical Science*, *11*(1), 1.

Çelik, A., Eke, D., Ekinci, S. Y., & Yildirim, S. (2013). The protective role of curcumin on perfluorooctane sulfonate-induced genotoxicity: Single cell gel electrophoresis and micronucleus test. *Food and Chemical Toxicology*, *53*, 249–255.

Commission Regulation (EU) No 835/2011 of 19 August 2011 amending Regulations (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs. *Official Journal of the European Union*, *L215*, 4–8.

Dai, C., Li, B., Zhou, S., Li, H., Xiang, X., & Tang, S. (2016). Curcumin attenuates quinocetone induced apoptosis and inflammation via the opposite modulation of Nrf2/HO-1 and NF-kB pathway in human hepatocyte L02 cells. *Food and Chemical Toxicology*, *95*, 52–63.

Fasano, E., Yebra-Pimentel, I., Martinez-Carballo, E., & Simal-Gandara, J. (2016). Profiling, distribution and levels of carcinogenic polycyclic aromatic hydrocarbon in traditional smoked plant and animal foods. *Food Control*, *59*, 581–590.

Farzan, S. F., Chen, Y., Trachtman, H., & Trasande, L. (2016). Urinary polycyclic aromatic hydrocarbons and measures of oxidative stress, inflammation and renal function in adolescents: NHANES 2003–2008. *Environmental Research*, *144*, 149–157.

Hussain, S. (2017). Comparative efficacy of the curcumin against H_2O_2 induced ROS in cervical cancer biopsies and HeLa cell line. *International Journal of Advanced Pharmaceutical Medicine and Bioallied Sciences*, *5*, 2.

Kim, K. S., Kim, N. Y., Son, J. Y., Park, J. H., Lee, S. H., Kim, H. R., Kim, B., Kim, Y. G., Jeong, H. G., Lee, B. M., & Kim, H. S. (2019). Curcumin ameliorates benzo[a]pyrene-induced DNA damages in stomach tissues of Sprague-Dawley rats. *International Journal of Molecular Sciences*, *20*(22), 5533.

Lawal, A. T. (2017). Polycyclic aromatic hydrocarbons: A review. *Cogent Environmental Science*, *3*, 1339841.

Ledesma, E., Rendueles, M., & Díaz, M. (2016). Contamination of meat products during smoking by polycyclic aromatic hydrocarbons: Processes and prevention. *Food Control*, *60*, 64–87.

Liu, Y., Wu, Y. M., & Zhang, P. Y. (2015). Protective effects of curcumin and quercetin during benzo(a)pyrene induced lung carcinogenesis in mice. *European Review for Medical and Pharmacological Sciences*, *19*, 1736–1743.

Longobardi, C., Damiano, S., Andretta, E., Prisco, F., Russo, V., Pagnini, F., Florio, S., & Ciarcia, R. (2021). Curcumin modulates nitrosative stress, inflammation, and DNA damage and protects against ochratoxin A-induced hepatotoxicity and nephrotoxicity in rats. *Antioxidants*, *10*, 1239.

Ming, T., Tao, Q., Tang, S., Zhao, H., Yang, H., & Liu, M. (2022). Curcumin: An epigenetic regulator and its application in cancer. *Biomedicine & Pharmacotherapy*, *156*, 113956.

Moorthy, B., Chu, C., & Carlin, D. J. (2015). Polycyclic aromatic hydrocarbons: From metabolism to lung cancer. *Toxicological Sciences*, *145*(1), 5–15.

Patel, P. R., Bevan, R. J., Mistry, N., & Lunec, J. (2007). *Journal of Free Radicals in Biology and Medicine*, *42*, 552–558.

Peng, Y., Ao, M., Dong, B., Jiang, Y., Yu, L., & Chen, Z. (2021). Anti-inflammatory effects of curcumin in the inflammatory disease: Status, limitations and countermeasures. *Drug Design, Development and Therapy*, *15*, 4505–4525.

Purcaro, G., Moret, S., & Conte, L. S. (2013). Overview on polycyclic aromatic hydrocarbons: Occurrence, legislation and innovative determination in foods. *Talanta*, *105*, 292–305.

Sampaio, G. R., Guizellini, G. M., da Silva, S. A., de Almeida, A. P., Pinaffi-Langley, A. C. C., Rogero, M. M., de Camargo, A. C., & Torres, E. A. F. S. (2021). Polycyclic aromatic hydrocarbons in foods: Biological effects, legislation, occurrence, analytical methods, and strategies to reduce their formation. *International Journal of Molecular Sciences*, *22*, 6010.

Satpathy, L., & Parida, S. P. (2021). Neuroprotective role of curcumin against benzo[a]pyrene-induced neurodegeneration in zebrafish. *Biointerface Research in Applied Chemistry*, *12*(6), 7311–7320.

Sanna, D., & Fadda, A. (2022). Role of the hydroxyl radical-generating system in the estimation of the antioxidant activity of plant extracts by electron paramagnetic resonance (EPR). *Molecules*, *27*, 104.

Thresiamma, K. C., George, J., & Kuttan, R. (1998). Protective effect of curcumin, ellagic acid and bixin on radiation induced genotoxicity. *Journal of Experimental & Clinical Cancer Research*, *17*, 431–434.

Tomasa, A. M., Rachisan, A. L., Pandrea, S. L., Benea, A., Uifalean, A., Toma, C., Popa, R., Pârvu, A. E., & Junie, L. M. (2023). Curcumin and vitamin C attenuate gentamicin-induced nephrotoxicity by modulating distinctive reactive species. *Metabolites*, *13*, 49.

Zhang, M., Wang, J., Zhao, Q., Mishra, V., Fan, J., & Sun, Y. (2020). Polycyclic aromatic hydrocarbons (PAHs) and esophageal carcinoma in Handan-Xingtai district, North China: A preliminary study based on cancer risk assessment. *Environmental Monitoring and Assessment*, *192*, 596.

Zhang, H., Han, Y., Qiu, X., Wang, Y., Li, W., Liu, J., Chen, X., Li, R., Xu, F., & Chen, W. (2021). Association of internal exposure to polycyclic aromatic hydrocarbons with inflammation and oxidative stress in prediabetic and healthy individuals. *Chemosphere*, *253*, 126748.

Zhang, Z., Li, X., Sang, S., McClements, D. J., Chen, L., Long, J., Jiao, A., Jin, Z., & Qiu, C. (2022). Polyphenols as plant-based nutraceuticals: Health effects, encapsulation, nano-delivery, and application. *Foods*, *11*, 2189.

Zia, A., Farkhondeh, T., Pourbagher-Shahri, A. M., & Samarghandian, S. (2021). The role of curcumin in aging and senescence: Molecular mechanisms. *Biomedicine & Pharmacotherapy*, *134*, 111119.

Zhu, W., Cromie, M. M., Cai, Q., Lv, T., & Singh, K. (2014). Curcumin and vitamin E protect against adverse effects of benzo[a]pyrene in lung epithelial cells. *PLoS ONE*, *9*(3), e92992. https://doi.org/10.1371/journal.pone.0092992