SAR Journal of Anatomy and Physiology

Abbreviated Key Title: *SAR J Anat Physiol*
Home page: https://sarpublication.com/journal/sarjap/home
DOI: https://doi.org/10.36346/sarjap.2025.v06i04.003

OPEN ACCESS

ISSN 2707-7713 (P)
ISSN 2709-6874 (O)

Original Research Article

# Protective Role of Alpha-Tocopherol Against Propoxur-Induced Gonadotoxicity in Male Wistar Rats: Modulation of Oxidative Stress and Histopathological Changes

**Eweoya, O.O[1*], Enyioma-Alozie, S[3], Oyewopo, A.O.[2], Ibrahim, N.O.[2], Onochie, M.N.[1], Adeniyi, J[1]**
[1]Dept. of Anatomical Sciences, University of Abuja, Nigeria
[2]Department of Anatomy, University of Ilorin
[3]Department of Anatomy, Baze University

***Corresponding Author:** Eweoya. O.O
Dept. of Anatomical Sciences, University of Abuja, Nigeria

**Article History:** | Received: 07.06.2025 | Accepted: 15.07.2025 | Published: 29.07.2025 |

**Abstract:** Infertility is a global health concern, with growing evidence suggesting that environmental and toxic chemicals contribute significantly to its prevalence. Propoxur, a widely used pesticide for controlling mosquitoes, insects, and pests, has been implicated in gonadotoxicity, primarily through oxidative stress mechanisms affecting male reproductive organs. This study investigates the protective effect of alpha-tocopherol on propoxur-induced gonadotoxicity in male Wistar rats, focusing on biochemical markers, hormonal levels, and histological alterations in the testes. Twenty adult male Wistar rats were randomly assigned into four groups (n=5 per group): Control (Group I), Propoxur-treated (Group II), Alpha-tocopherol-treated (Group III), and Propoxur plus Alpha-tocopherol-treated (Group IV). Biochemical assays, oxidative stress markers—including malondialdehyde (MDA), superoxide dismutase (SOD), and reactive oxygen species (ROS)—and histological analyses were conducted. Propoxur administration resulted in a significant increase in MDA and ROS levels ($P<0.05$), alongside a significant reduction in SOD activity ($P<0.05$), indicating oxidative stress-induced damage. Histological examination of testes from the propoxur-treated group revealed pronounced disruption of the seminiferous tubules. In contrast, co-administration of alpha-tocopherol significantly attenuated these alterations, as evidenced by restored antioxidant enzyme activity, reduced lipid peroxidation, and preserved testicular architecture. Alpha-tocopherol demonstrates a protective effect against propoxur-induced gonadotoxicity by mitigating oxidative stress and reversing histological damage to the seminiferous tubules. These findings suggest its potential therapeutic role in protecting male reproductive health against environmental toxicants.

**Keywords:** MDA (Malondialdehyde), SOD (Superoxide dismutase), ROS (Reactive oxygen species), Alpha tocopherol, Wistar rats, Reproductive parameters.



## INTRODUCTION

Infertility is a universal health issue and it has been estimated that 8 to 12% of the couples worldwide are infertile (Bovin, *et al.,* 2007). Estimates suggest that between 48 million and 186 million couples live with infertility globally, half of these infertile couples are living in Sub-Saharan Africa (SSA) and South Asia (Rutstein & Shah, 2004; Mascarenhas*, et al.,* 2012).

The prevalence of infertility varies considerably across different regions, and previous studies have shown higher infertility rates in South Asia, Sub-Saharan Africa, and the Middle East compared to Western countries (Mascarenhas*, et al.,* 2012). In some African countries, infertility rate can be as high as 30%, which was largely due to untreated infections and reproductive tract diseases (Cates *et al.,* 1985; Etuk, 2009). Infertility can result from a variety of factors, such as age which significantly impacts fertility, especially for women, (whose fertility declines with advancing maternal age) (Velde, 2002). Also, lifestyle factors, such as smoking, alcohol consumption, and obesity, affects fertility

**Citation:** Eweoya, O.O, Enyioma-Alozie, S, Oyewopo, A.O., Ibrahim, N.O., Onochie, M.N., Adeniyi, J (2025). Protective Role of Alpha-Tocopherol Against Propoxur-Induced Gonadotoxicity in Male Wistar Rats: Modulation of Oxidative Stress and Histopathological Changes, *SAR J Anat Physiol*, *6*(4), 126-133.

(Bellver, *et al.,* 2010; Choudhary, *et al.,* 2025**).** In addition, environmental pollutants and occupational exposures can adversely impact reproductive health (Claman, 2004; Abdouli, *et al.,* 2022).

Oxidative stress (OS), a state characterized by an imbalance between pro-oxidant molecules including reactive oxygen and nitrogen species, and antioxidant defenses, has been identified to play a key role in the pathogenesis of subfertility in both males and females, (Agarwal, *et al.,* 2012). Reactive Oxidative Species (ROS) are highly reactive molecules containing oxygen, such as superoxide radicals, hydrogen peroxide, and hydroxyl radicals, which are generated during normal cellular metabolism and in response to environmental stressors. When ROS levels exceed the antioxidant capacity of the cell, they can cause damage to lipids, proteins, and DNA, leading to cellular dysfunction and tissue injury (Valko, *et al.,* 2007).

In reproductive health, oxidative stress has been implicated in infertility, miscarriage, and other reproductive disorders by affecting sperm quality, oocytes viability, and embryo development (Agarwal and Allamaneni, 2004).

Propoxur (Baygon), chemically known as 2-isopropoxyphenyl N-methylcarbamate, is a broad-spectrum carbamate insecticide commonly used in residential settings for controlling household pests such as cockroaches, mosquitoes and ants, as well as in agriculture for protecting crops from insect damage. Despite its effectiveness against targeted insects & pests, propoxur usage has raised concerns due to its adverse effect on human health and the environment, **(**US EPA, 1999; Mehrpour, *et al.,* 2014). Acute exposure to Propoxur (Baygon) can result in a range of symptoms depending on the route of exposure (inhalation, ingestion, or skin contact).

Previous studies have reported a link between prolonged exposure to propoxur and an increased risk of developing chronic respiratory conditions, neurological disorders, and potential carcinogenic effects (Chander, *et al.,* 2024). Several adverse effects of propoxur on humans, including damage to the male reproductive system, have been documented (Mnif, *et al.,* 2011; Oyewopo*, et al.,* 2022). Considering the role of oxidative stress in reproductive dysfunction and the adverse effects associated with propoxur, it becomes important to explore possible protective interventions.

Alpha-tocopherol, commonly known as vitamin E, is a fat-soluble antioxidant that plays a critical role in protecting cells from oxidative damage caused by free radicals (Traber and Atkinson, 2007). Alpha-tocopherol being a potent scavenger of reactive oxygen species (ROS), has been shown to enhance the activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD) and catalase, thereby strengthening cellular defense mechanisms against oxidative stress (Sen, *et al.,* 2007). It is in this regard that this study aims to investigate the protective role of alpha-tocopherol on propoxur-induced gonadotoxicity in male Wistar rats

# METHODOLOGY

## Materials and Methods

### Animal Procurement and Grouping

Twenty male Wistar rats (average weight: 125 ± 10 g) were procured and housed in the Central Animal Facility of the College of Health Sciences, University of Ilorin. The animals were maintained under standard laboratory conditions: a 12-hour light/dark cycle, controlled room temperature, and unrestricted access to standard rat pellets and water. The rats were randomly assigned into four groups (n = 5 per group) as follows:

- **Group I (Control):** Received standard rat feed and water twice daily for 56 days.
- **Group II (Propoxur-only):** Exposed to Propoxur via inhalation for 1 hour daily (10:42–11:42 AM) for 56 days.
- **Group III (Vitamin E-only):** Administered 0.2 mL/kg of alpha-tocopherol orally once daily for 56 days.
- **Group IV (Combined Treatment):** Exposed to Propoxur for 1 hour daily, followed by oral administration of 0.2 mL/kg alpha-tocopherol for 56 days.

Body weights were recorded daily to adjust the vitamin E dosage accordingly. On day 56, behavioral assessments were conducted on all rats before sacrifice. The study protocol adhered strictly to the ethical guidelines of the Institutional Ethical Review Committee of the University of Ilorin, Kwara State, Nigeria.

### Animal Sacrifice and Sample Collection

On the 56$^{th}$ day, the rats were weighed, and euthanized via cervical dislocation. A midline incision was made to expose the thoracic and abdominal cavities. Using a 21G needle attached to a 5 mL syringe, at least 2 mL of blood was collected from the apex of the heart. Blood samples were transferred into both EDTA-containing and plain tubes. Samples in plain tubes were centrifuged at 3000 rpm for 10 minutes to separate the serum. The caudal epididymis and testes were excised. The testes were fixed in 10% formal saline for 48 hours in preparation for histological analysis.

### Sperm Analysis

Sperm parameters including count, motility, concentration, and morphology were evaluated according to the methods described by Rouge and Bowen, (2021); and Oyewopo, *et al.,* (2021)

### Histological Examination

The excised testes were fixed in 10% formaldehyde for 24–48 hours. Post-fixation, the tissues were dehydrated in ascending grades of ethanol, cleared in xylene, and embedded in paraffin wax. Sections of 5 µm thickness were prepared using a rotary microtome,

mounted on glass slides, and stained with hematoxylin and eosin (H&E) for histological evaluation under light microscopy.

**Biochemical Assays**

Levels of superoxide dismutase (SOD), malondialdehyde (MDA), and reactive oxygen species (ROS) were determined in serum samples.

- **Lipid Peroxidation:** MDA levels were measured using a commercial ELISA kit (Product code: MAK085; sensitivity: 1 nmol/mL; Monobind Inc., Lake Forest, CA, USA) based on the thiobarbituric acid-reactive substances (TBARS) method (Todorova *et al.,* 2005).
- **Superoxide Dismutase Activity:** SOD activity was determined based on the inhibition of nitro-blue tetrazolium (NBT) reduction as described by Christine *et al.* (1993) and Ashish *et al.* (2016). The reaction mixture included phosphate buffer (0.067 M, pH 7.8), riboflavin (0.05 mL of 0.12 M), NBT (0.1 mL of 1.5 mM), methionine (0.01 M), and enzyme samples. The mixture was exposed to uniform illumination for 10 minutes using a 15 W fluorescent lamp, and absorbance was read at 560 nm.
- **Reactive Oxygen Species (ROS):** ROS levels were assessed using a ROS Assay Kit (Abcam, Cambridge, UK). Fluorescence was measured at excitation/emission wavelengths of 485/535 nm.

**Hormonal Assays**

Serum concentrations of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) were quantified using enzyme immunoassay (EIA) kits, following the protocol of the World Health Organization's matched reagent program (manual, version: December 1998). Kits were supplied by the National Institute of Diabetes and Digestive and Kidney Diseases (NIADDK-NIH, USA). Serum samples were aliquoted and stored at –20°C to avoid repeated freeze-thaw cycles.

**Statistical Analysis**

Data were expressed as mean ± standard error of the mean (SEM). Statistical comparisons among groups were made using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc multiple comparison test. Analyses were performed using Graph Pad Prism version 8.0.2 (Graph Pad Software, San Diego, CA, USA). Differences were considered statistically significant at $p < 0.05$.

## RESULTS

**Biochemical Result**

**Table 1: Showing Mean and SEM of the effect of propoxur and alpha tocopherol on biochemical and hormonal parameters**

| PARAMETER | Group 1 (n=5) | Group II (n=5) | Group III (n=5) | Group IV (n=5) |
|---|---|---|---|---|
| LH | 0.361 ± 0.209 | 0.348 ± 0.203 | 0.356 ± 0.214 | 0.553 ± 0.207 |
| FSH | 1.396 ± 0.479 | 1.374 ± 0.492 | 1.401 ± 0.472 | 1.403 ± 0.471 |
| ROS | 5.708 ± 2.173 | 6.480 ± 2.595 | 6.411 ± 2.487 | 6.115 ± 2.173 |
| MDA | 0.688 ± 0.027 | 0.696 ± 0.025 | 0.674 ± 0.035 | 0.690 ± 0.026 |
| SOD | 1.662 ± 0.048 | 1.630 ± 0.029 | 1.720 ± 0.063 | 1.729 ± 0.063 |

Values are Mean ± S.E.M. n = 5 in each group

P values: LH (P<0.05), FSH (P<0.05), ROS (P>0.05), MDA (P>0.05), SOD (P>0.05)

Control 2ml $H_2O$/kg bwt; Propoxur (3ppm) 56 days; Alpha tocopherol (0.2ml/bwt) 56 days, Propoxur (3ppm) + alpha tocopherol (0.2ml/bwt) 56 days.

**KEYS:** LH= Luteinizing hormone, FSH= Follicle stimulating hormone, ROS= Reactive oxygen species, MDA= Malondialdehyde, SOD= Superoxide dismustase, CON= Control, PRO= Propoxur, ALPHA T= Alpha tocopherol, P + ALPHA T= Propoxur & Alpha Tocopherol.

**Effect of alpha tocopherol and propoxur on LH levels.**

From the result, the level of LH is significantly reduced in the propoxur treated group (p<0.05) compared to the control group. There is a difference between the LH level of propoxur and the alpha tocopherol treated group suggesting a potential protective effect of Alpha tocopherol. The combination of propoxur and alpha tocopherol shows a highly significant increase in LH levels compared to the Propoxur group, indicating the strong protective and possibly restorative effect of Alpha Tocopherol.

**Effect of alpha tocopherol and propoxur on FSH levels**

There is a significant decrease in FSH levels in the propoxur group compared to the control (P<0.05). The difference between the Propoxur and Alpha tocopherol group is highly significant (P<0.05), indicating a strong stimulatory effect of Alpha tocopherol. The combination of Propoxur and Alpha tocopherol shows a highly significant increase in FSH levels compared to the Propoxur (P<0.05), highlighting the strong protective and possibly restorative effect of Alpha tocopherol.

**Effect of alpha tocopherol and propoxur on MDA levels**

Propoxur group increases significantly (P<0.05) compared to the control. There is a significant decrease (P<0.05) in alpha tocopherol treated group compared to the propoxur. Combination of propoxur and alpha tocopherol shows a slight decrease in MDA level (P<0.05) compared to propoxur thus indicating the protective effect of alpha tocopherol.

**Effect of alpha tocopherol and propoxur on ROS level**

From the result, it will be observed that the level of ROS increased significantly in the propoxur treated group (P>0.05) compared to the control. The combination of Alpha Tocopherol and propoxur treated group shows a significant reduction in ROS levels compared to the Propoxur group (P<0.05), indicating the protective effect of Alpha tocopherol.

**Effect of alpha tocopherol and propoxur on SOD level**

There is a significant decrease (P<0.05) in the level of SOD in propoxur treated group compared to the control. There is a significant increase of SOD in propoxur and alpha tocopherol treated group when compared to propoxur group indicating the protective effect of alpha tocopherol.

**Effect of alpha tocopherol and propoxur on Testosterone level**

The testosterone level in the propoxur treated group is significantly lower than the control group (P< 0.005). The alpha tocopherol group has a higher testosterone level compared to the propoxur treated indicating a protective effect (P< 0.005). The combination of propoxur and alpha tocopherol shows a higher level of testosterone compared to the propoxur group (p<0.05).

**Sperm Analysis**

**Table 2: Showing the mean and SEM of the seminal analysis for each group**

| PARAMETERS | CONTROL | PROPOXUR | ALPHA TOCO | P+ALPHA TOCO |
|---|---|---|---|---|
| TT (ng/mol) | 1.571 ± 0.440 | 0.610 ± 0.063 | 1.749 ± 0.020 | 2.990 ± 0.007 |
| SC (10^6) | 53.160 ± 1.910 | 40.52 ± 3.276 | 53.760 ± 1.370 | 65.72 ± 7.119 |
| SM (%) | 80.05 ± 1.447 | 66.25 ± 1.555 | 82.13 ± 0.328 | 83.80 ± 1.847 |
| SMor (%) | 82.93 ± 1.441 | 64.20 ± 1.724 | 84.38 ± 1.496 | 85.13 ± 0.842 |

Values were expressed as Mean ± S.E.M. n= 5 in each group

P values: TT (P< 0.05), SC (P<0.05), SM (P<0.05), SMo (P<0.05), L&D (P<0.05)

**KEYS: TT=**Testosterone, SC = Sperm count (10^6), SM= Sperm motility (%), SMo= Sperm morphology, ALPHA T= Alpha tocopherol.

**Sperm count**

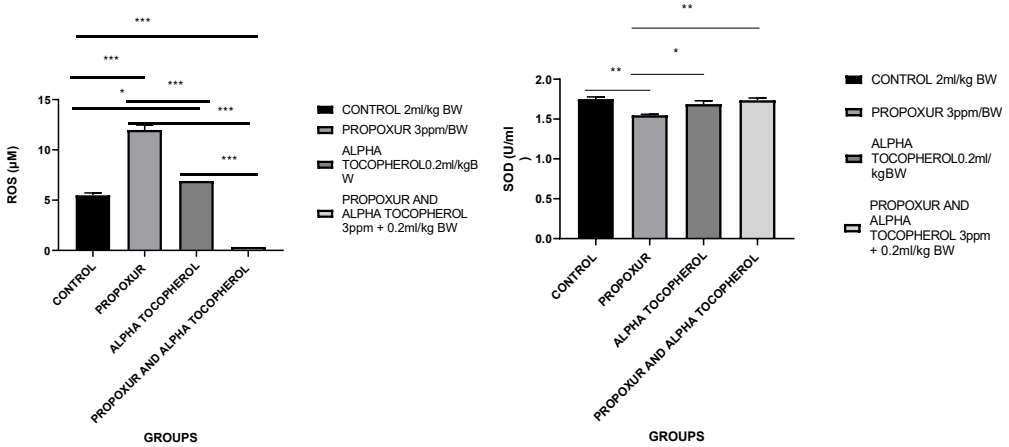
There is a significant reduction in sperm count level (p<0.005) when compared to the control group. There is also a significant increase in sperm count in the group treated with alpha tocopherol (P< 0.005) compared to the control indicating the positive effect of alpha tocopherol in boosting sperm count. The combination of alpha tocopherol and propoxur shows a significant increase in sperm count level compared to the propoxur indicating the protective effect of alpha tocopherol.

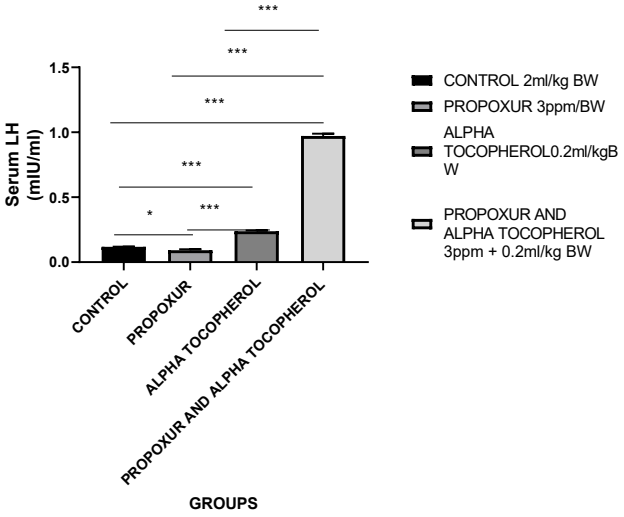
**Sperm morphology**

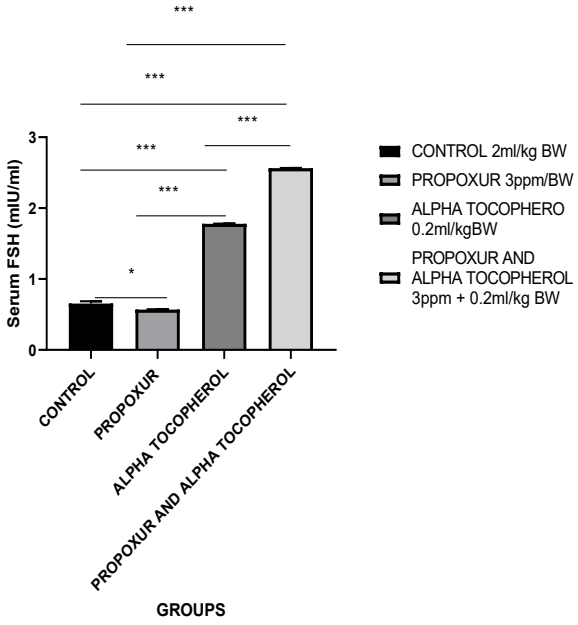
There is a decrease in the sperm morphology of propoxur (P<0.05) treated group compared to the control.

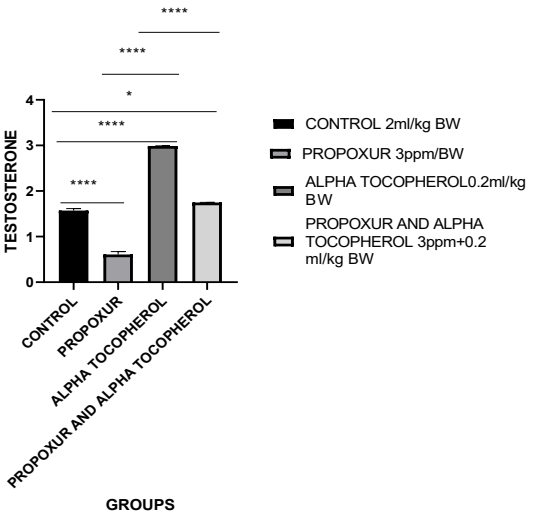
**Sperm Motility**

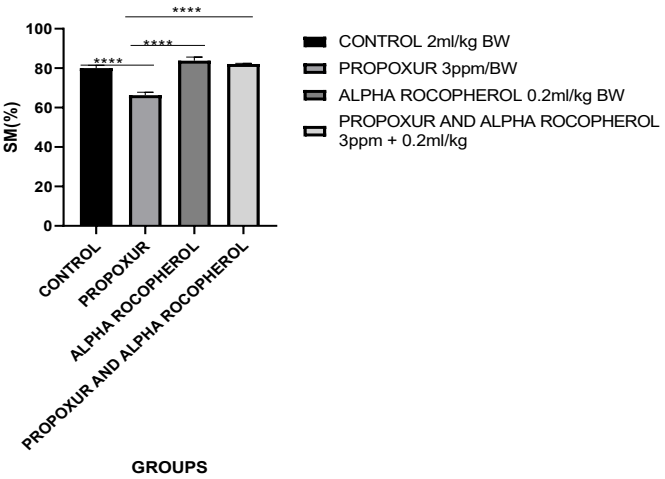
Sperm motility is higher in the control compared to the propoxur treated group at a significance level of (P<0.005). The combination of alpha tocopherol and propoxur group shows improved sperm motility compared to the propoxur group (p<0.005) suggesting that Alpha tocopherol mitigates the negative effect of propoxur on sperm motility.

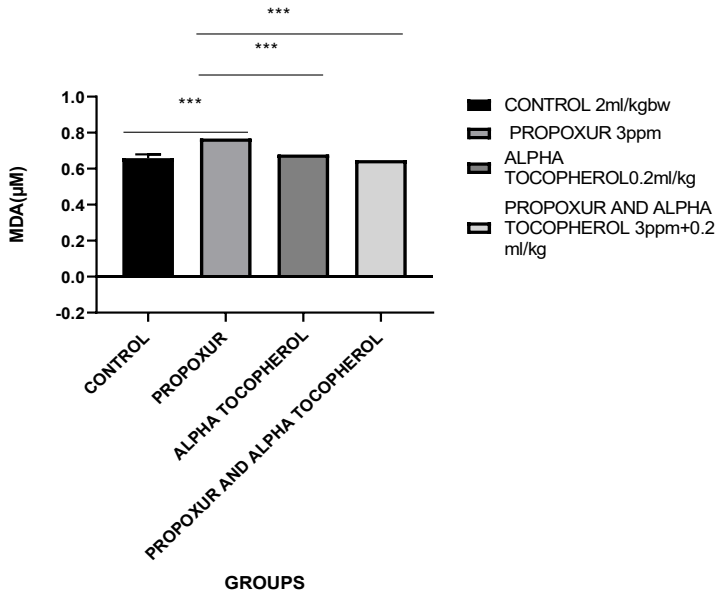



Serum LH (mIU/ml)
1.5
1.0
0.5
0.0
CONTROL
PROPOXUR
ALPHA TOCOPHEROL
PROPOXUR AND ALPHA TOCOPHEROL
GROUPS
CONTROL 2ml/kg BW
PROPOXUR 3ppm/BW
ALPHA TOCOPHEROL0.2ml/kgBW
PROPOXUR AND ALPHA TOCOPHEROL 3ppm + 0.2ml/kg BW

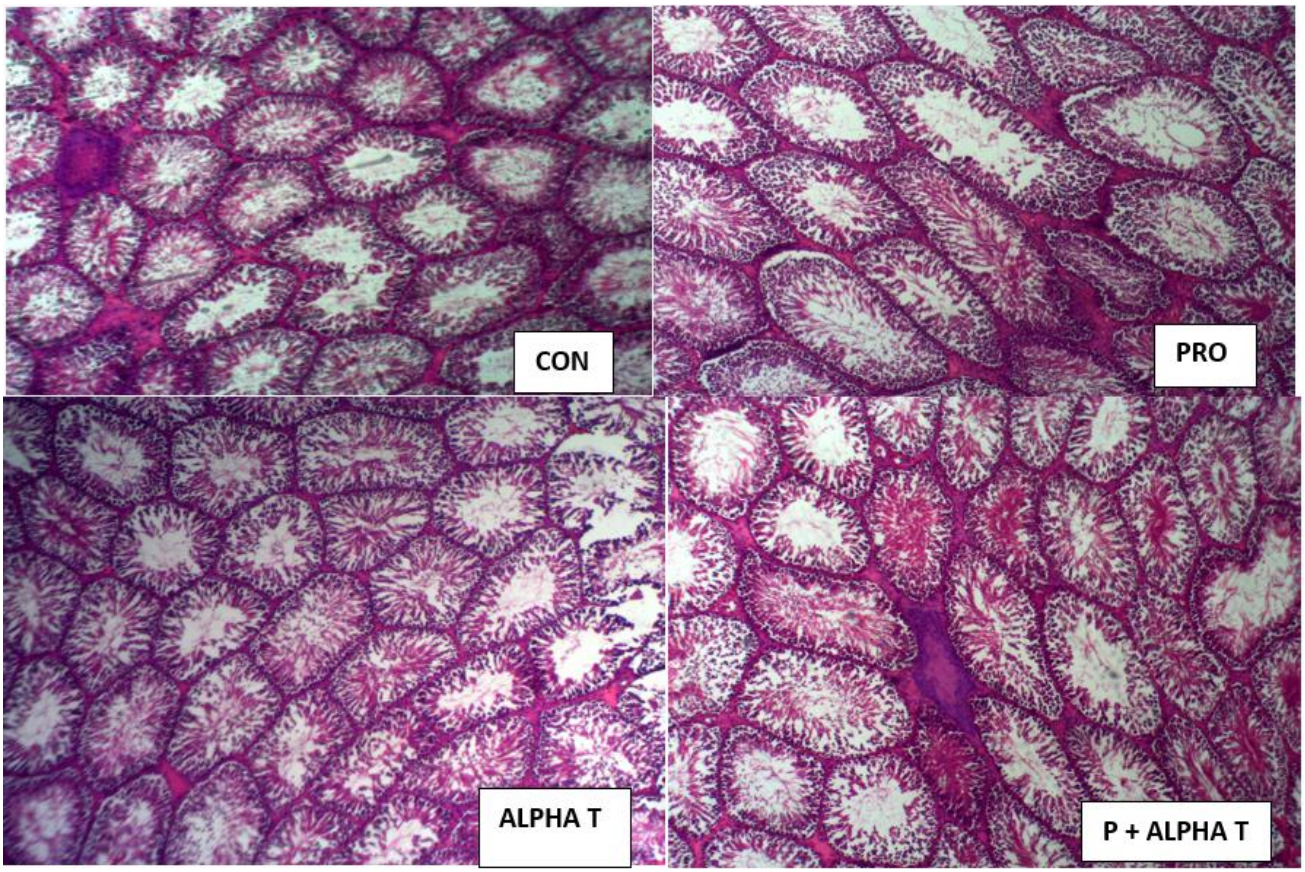

Serum FSH (mIU/ml)
3
2
1
0
CONTROL
PROPOXUR
ALPHA TOCOPHEROL
PROPOXUR AND ALPHA TOCOPHEROL
GROUPS
CONTROL 2ml/kg BW
PROPOXUR 3ppm/BW
ALPHA TOCOPHERO 0.2ml/kgBW
PROPOXUR AND ALPHA TOCOPHEROL 3ppm + 0.2ml/kg BW


TESTOSTERONE
4
3
2
1
0
CONTROL
PROPOXUR
ALPHA TOCOPHEROL
PROPOXUR AND ALPHA TOCOPHEROL
GROUPS
CONTROL 2ml/kg BW
PROPOXUR 3ppm/BW
ALPHA TOCOPHEROL0.2ml/kg BW
PROPOXUR AND ALPHA TOCOPHEROL 3ppm+0.2 ml/kg BW


SM(%)
100
80
60
40
20
0
CONTROL
PROPOXUR
ALPHA ROCOPHEROL
PROPOXUR AND ALPHA ROCOPHEROL
GROUPS
CONTROL 2ml/kg BW
PROPOXUR 3ppm/BW
ALPHA ROCOPHEROL 0.2ml/kg BW
PROPOXUR AND ALPHA ROCOPHEROL 3ppm + 0.2ml/kg


MDA(µM)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
CONTROL
PROPOXUR
ALPHA TOCOPHEROL
PROPOXUR AND ALPHA TOCOPHEROL
GROUPS
CONTROL 2ml/kgbw
PROPOXUR 3ppm
ALPHA TOCOPHEROL0.2ml/kg
PROPOXUR AND ALPHA TOCOPHEROL 3ppm+0.2 ml/kg

**Histological Results**




**Histological slides of Groups I- IV**

I. The control group shows normal testicular architecture without any observable signs of spermatogenic arrest. The lumen is visible and contains spermatozoa. The basement membrane is thin, and the interstitial space contains Leydig cells.

II. In the propoxur group, the seminiferous tubules exhibit irregular and disorganized layers of spermatogenic cells, indicating potential disruption of the spermatogenesis process. There is a reduced density of spermatogenic cells, suggesting cell loss or impaired spermatogenesis. Small, clear spaces are observed within some seminiferous tubules, indicating the presence of vacuoles, possibly due to cellular degeneration or apoptosis.

III. In the alpha-tocopherol group, the seminiferous tubules exhibit well-defined boundaries and a healthy structure. The cells are organized, progressing from spermatogonia at the periphery to mature spermatozoa toward the lumen. The basement membrane appears intact and continuous, providing structural support to the tubules.

IV. In the propoxur and alpha-tocopherol treated group, the seminiferous tubules appear more structurally organized compared to the propoxur group. The epithelial lining shows less necrosis, and there are fewer signs of hypertrophy. The Leydig cells are more numerous compared to the propoxur group.

## DISCUSSION

This study explored the mitigating effects of alpha-tocopherol on oxidative stress induced by Propoxur in Wistar rats. Biochemical analyses, including hormonal levels and oxidative markers such as malondialdehyde (MDA), superoxide dismutase (SOD), and reactive oxygen species (ROS), along with histological assessments of the testes, provided a comprehensive evaluation of the protective role of alpha-tocopherol.

**Histology**

Our findings demonstrated a significant increase in oxidative stress markers, including MDA and ROS, in Propoxur-treated rats, indicating heightened lipid peroxidation and oxidative damage. Conversely, SOD activity, a crucial antioxidant enzyme, was markedly reduced, suggesting a compromised antioxidant defense system. These alterations corroborate existing literature highlighting Propoxur's capacity to induce oxidative stress and disrupt cellular homeostasis (El-Shenawy, *et al.,*2011). Following the administration of alpha-tocopherol, a notable reduction in MDA and ROS levels was observed, alongside the restoration of SOD activity. These results align with

previous studies illustrating the potent antioxidant properties of alpha-tocopherol in mitigating oxidative damage and enhancing enzymatic antioxidant defenses (Traber and Atkinson, 2007). The attenuation of oxidative markers suggests that alpha-tocopherol effectively neutralizes free radicals and prevents lipid peroxidation.

**Hormonal Levels**

Hormonal analysis revealed a significant decline in testosterone levels in Propoxur-treated rats, indicating endocrine disruption. This finding is consistent with reports linking pesticide exposure to impaired steroidogenesis and hormonal imbalances (Oyewopo *et al.,* 2010; Abarikwu *et al.,* 2018). Notably, alpha-tocopherol supplementation improved testosterone levels, suggesting its role in preserving endocrine function. This protective effect may be attributed to alpha-tocopherol's ability to stabilize cell membranes and prevent oxidative damage to Leydig cells, which are critical for testosterone production, (Vigueras-Villaseñor *et al.,* 2011).

**Histological Changes**

Histological examination of the testes supported the biochemical findings, revealing pronounced degenerative changes in the seminiferous tubules and atrophy of Leydig cells in propoxur-treated rats. These structural alterations indicate severe testicular damage and impaired spermatogenesis, corroborating the findings of Kenfack *et al.,* (2017).

However, alpha-tocopherol treatment ameliorated these histopathological changes, preserving the integrity of the seminiferous tubules and maintaining normal spermatogenesis. The preservation of testicular architecture underscores alpha-tocopherol's protective effect against Propoxur-induced testicular toxicity.

**Cauda Epididymal Sperm Count**

The significant reduction in cauda epididymal sperm count in Propoxur-treated rats highlights the adverse impact of oxidative stress on sperm production and viability. This finding aligns with studies demonstrating the detrimental effects of oxidative stress on sperm quality and fertility (Aitken *et al.,* 2022).

The restoration of sperm count following alpha-tocopherol administration further supports its role in mitigating oxidative damage and enhancing reproductive health.

## CONCLUSION

In conclusion, this study demonstrates the protective effects of alpha-tocopherol against Propoxur-induced oxidative stress and reproductive toxicity in Wistar rats. By mitigating oxidative damage, preserving endocrine function, and maintaining testicular integrity, alpha-tocopherol emerges as a promising therapeutic agent for counteracting the adverse effects of environmental toxicants on reproductive health.

## DECLARATIONS

**Ethics Approval:** Was sought and obtained from the Institutional Ethical Review Committee of the University of Ilorin, Kwara State, Nigeria.

**Consent for publication:** The authors consented to the manuscript being published.

**Competing Interest:** The authors declare no conflict of interest.

**Funding:** This research did not receive funding from any organization or group.

**Authors' contribution:** EO, AO and NO conceived the idea.
EO and MN prepared the manuscript.
JA and SE analyse the data.
All the authors revised the work and accept responsibility.

## REFRENCES

1. Bovin, J., Bunting, L., Collins, J.A, Nygren, K. G. (2007). International estimates of infertility prevalence and treatment-seeking: potential need and demand for infertility medical care. *Hum Reprod.*, 22(6):1506-12.
2. Rutstein, S.O, & Shah, I.H. Infecundity, infertility, and childlessness in developing countries (2004). DHS Comp Rep No. 9. Calverton, MD: ORC Macro and WHO.
3. Mascarenhas, M.N, Flaxman, S.R, Boerma T, Vanderpoel S, Stevens, G.A. (2012). National, regional, and global trends in infertility prevalence since 1990: a systematic analysis of 277 health surveys. *PLoS Med*. 9(12): e1001356.
4. Cates W, Farley T, Rowe P. (1985). Worldwide patterns of infertility: is Africa different? *Lancet.* 326(8455):596-8.
5. Etuk, S. J. (2009). Reproductive health: global infertility trend. *Niger J Physiol Sci*., 24(2):85-90.
6. Velde, E.R, & Pearson, P.L. (2002). The variability of female reproductive ageing. *Hum Reprod* Update, 8(2):141-54.
7. Bellver J, Ayllon Y, Ferrando N, Melo M, Goyri E, Pellicer A, *et al.* (2010). Female obesity impairs in vitro fertilization outcome without affecting embryo quality. *Fertil Steril*., 93(2):447-54.
8. Choudhary P, Dogra P, Sharma K. (2025). Infertility and lifestyle factors: how habits shape reproductive health. *Middle East Fertil Soc J.*, 30:14. https://doi.org/10.1186/s43043-025-00228-7
9. Claman, P. (2004). Men at risk: occupation and male infertility. *Fertil Steril*., 81:19-26.
10. Abdoli S, Masoumi, S.Z, Kazemi, F. (2022). Environmental and occupational factors and higher risk of couple infertility: a systematic review study.

Middle East *Fertil Soc J*., 27:33. https://doi.org/10.1186/s43043-022-00124-4

11. Agarwal A, Aponte-Mellado A, Premkumar, B.J, Shaman A, Gupta S. (2012). The effects of oxidative stress on female reproduction: a review. *Reprod Biol Endocrinol*., 10:49. https://doi.org/10.1186/1477-7827-10-49
12. Valko M, Leibfritz D, Moncol J, Cronin, M.T, Mazur M, Telser J. (2007). Free radicals and antioxidants in normal physiological functions and human disease. *Int J Biochem Cell Biol.* 39(1):44-84.
13. Agarwal A, & Allamaneni, S.S. (2004). Role of free radicals in female reproductive diseases and assisted reproduction. *Reprod Biomed* Online. 9(3):338-47.
14. US Environmental Protection Agency (2002). Integrated Risk Information System (IRIS) on Baygon. Washington, DC: National Center for Environmental Assessment, Office of Research and Development; 1999. Updated 2002.
15. Mehrpour O, Karrari P, Zamani N, Tsatsakis, A.M, Abdollahi M. (2014). Occupational exposure to pesticides and consequences on male semen and fertility: a review. *Toxicol Lett.*, 230:146–56. https://doi.org/10.1016/j.toxlet.2014.01.029
16. Chander S, Reetu, Kushal T, Danish, Rakesh K, Su nil K, Amit, K.S. (2024). A systematic review of pesticide exposure, associated risks, and long-term human health impacts, *Science Direct, 13: 101840. https://doi.org/10.1016/j.toxrep.2024.101840*
17. Mnif W, Hassine, A.I.H, Boziz A, Bartegi A, Thomas O, Rouge B. (2011). Effect of endocrine disruptor pesticides: a review. *Int J Environ Res Public Health*, 8(6):2265-303.
18. Oyewopo, A.O, Dare, B.J, Eweoya, G.O. (2022). Propoxur (PPx) exposure as hormonal disruptor and spermatocidal in rat model. *Morphologie,* 106, 352: 23- 27
19. Traber, M.G, & Atkinson, J. (2007). Vitamin E, antioxidant and nothing more. Free Radic *Biol Med.*, 43(1):4-15.
20. Sen C, Khanna S, Roy S. (2007). Tocotrienols in health and diseases: the other half of the natural vitamin E family. *Mol Aspects Med*., 28(5-6):692-728.
21. Rouge B, & Bowen R. (2021). Collection and evaluation of semen. *Reprod Index Gloss*. 2002. [cited 2021 May 3].
22. Oyewopo, A.O, Adeleke, O, Johnson, O, Akingbade, A, Olaniyi, K.S, Areola, E.D, et al. (2021). Regulatory effects of quercetin on testicular histopathology induced by cyanide in Wistar rats. *Heliyon.*, 7(7): e07662.
23. El-Shenawy N, El-Ahmary B, Al-Eisa R. (2011). Mitigating effect of ginger against oxidative stress induced by atrazine herbicides in mice liver and kidney. *J Biofertil Biopestici*. 2(2). http://dx.doi.org/10.4172/2155-6202.1000107
24. Oyewopo, A.O, Saalu, L.C, Osinubi, A.A, Imosemi, I.O, Omotosho, G.O, Adefolaju, G.A. (2010). The attenuating effect of zinc on propoxur-induced oxidative stress, impaired spermatogenesis and deranged steroidogenesis in Wistar rats. *J Med Med Sci.*, 1(5):178-84.
25. Abarikwu, S.O, Njoku, R.C, Onuah, C.L. (2018). Aged coconut oil with a high peroxide value induces oxidative stress and tissue damage in mercury-treated rats. *J Basic Clin Physiol Pharmacol*., 29(4):365-76. doi: 10.1515/jbcpp-2016-0138. PMID: 29570447.
26. Vigueras-Villaseñor, R.M, Ojeda I, Gutierrez-Pérez O, Chavez-Saldaña M, Cuevas O, Maria, D.S, Rojas-Castañeda, J.C. (2011). Protective effect of α-tocopherol on damage to rat testes by experimental cryptorchidism. *Int J Exp Pathol.*, Apr; 92(2):131-9. doi: 10.1111/j.1365-2613.2010.00757. x. Epub 2011 Feb 12. PMID: 21314742; PMCID: PMC3081516.
27. Kenfack A, Ngoula F, Chombong, J.K, Vemo, N.B, Ndukum, J.A, Ngouateu OB, et al. (2017). Effects of propoxur on male fertility in wistar rat exposed neonatally. *Int J Reprod Contracept Obstet Gynecol*. ,3(4):898–902. https://www.ijrcog.org/index.php/ijrcog/article/view/1259
28. Aitken, R.J, Drevet, J.R, Moazamian, A, Gharagozloo, P. (2022). Male infertility and oxidative stress: a focus on the underlying mechanisms. *Antioxidants*., 11:306. doi: 10.3390/antiox11020306.