

POLYSTYRENE NANOPARTICLES' IMPACT ON LIPID PROFILE-TESTOSTERONE RELATIONSHIP IN TESTICULAR TOXICITY: *NIGELLA SATIVA* RESTORATION

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ABSTRACT

The study investigated the alteration inflicted by PS-NP on the lipid profile and its association with testosterone release, as well as the potential of *Nigella sativa* oil, a natural and readily accessible medicine, to mitigate this damage. In this regard, twenty male rats were randomly assigned into four groups as follows: the control group, the NSO group (500 mg/kg body weight of organic *Nigella sativa* oil), the PS-NP group (10 mg/kg body weight of polystyrene nanoparticles), and the NSO+PSNP group (500 mg/kg body weight of *Nigella sativa* oil, followed by 10 mg/kg body weight of polystyrene nanoparticles). Rats received oral doses by gavage three times each week for 60 days. The PSNP group exhibited increased cholesterol and triglyceride levels, coupled with decreased HDL and testosterone levels, and it showed cytoplasmic vacuolation, degeneration of spermatogenic cells, and vascular congestion in testicular tissue. Conversely, the group NSO+PSNP exhibited reduced cholesterol and triglyceride levels, with normal HDL and testosterone levels. The testicular tissue showed minor pathological alterations, including slightly congested blood vessels. In conclusion, *Nigella sativa* oil showed substantial effectiveness in mitigating the detrimental effects induced by PS-NP on the male hormone connected with lipid metabolic alteration.

Key words: Polystyrene nanoplastic; *Nigella sativa*; cholesterol; triglycerides; testosterone.

INTRODUCTION

Nanoplastics (NPs) pose a significant threat to human health owing to their prolonged environmental persistence and their ability to absorb various hazardous contaminants, including heavy

metals from the environment (Khedre *et al.*, 2023). In addition to their ability to enter the body through multiple routes, including ingestion, inhalation, and dermal contact (Allouzi *et al.*, 2021; Alaraby *et al.*, 2022). Due to their small size, nanoplastics (NPs) can penetrate biological barriers, including cellular membranes, the blood-brain barrier, and even the placental barrier, allowing them to reach critical organs and tissues (DeLoid *et al.*, 2024; Yang *et al.*, 2024). Polystyrene nanoparticle (PS-NPs) is a common type of nano-plastic, resistant to degradation (Yang *et al.*, 2022), and may

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enter the body or convey contaminants, causing health hazards (Senathirajah *et al.*, 2020). PS-NPs damage the lungs and may induce chronic respiratory illnesses (Zha *et al.*, 2023), while in the neurological system, they alter cognition, memory, and neurotransmitter function, possibly accelerating neurodegenerative diseases like Alzheimer's and Parkinson's (Jin *et al.*, 2022; Wang *et al.*, 2023). They also accumulate in the kidneys, causing inflammation and fibrosis damage (Wang *et al.*, 2020; Shen *et al.*, 2023). PS-NPs also reduce fertility (Huang *et al.*, 2022), impair placental function (Hu *et al.*, 2021), and increase fetal development risks (He and Yin, 2023). PS-NP was reported to cause digestive issues, such as changes in gut flora and metabolic disorders (Lu *et al.*, 2018). PS-NP exposure has been shown to impair cellular lipid metabolism, particularly in human macrophages, where it promotes the accumulation of lipid droplets within the cytoplasm and fosters macrophage differentiation into foam cells (Florance *et al.*, 2022). PS-NPs disrupted the blood-testicular barrier (Jin *et al.*, 2020), inducing apoptosis in testicular tissues (Hou *et al.*, 2020), disrupting male hormonal balance, which is essential for spermatogenesis (Sui *et al.*, 2023). Currently, investigations are exploring potential mitigation treatments, including the use of probiotics (Li *et al.*, 2024). *Nigella sativa* in research demonstrated its potential ameliorative effects on male reproductive-induced toxicity through its remarkable anti-inflammatory and antioxidant properties (Shahid *et al.*, 2021). This study investigates the potential of *Nigella sativa* oil extract, a natural and widely available remedy with numerous health benefits, in restoring damage caused by PS-NP in the male reproductive system related to lipid metabolic alteration.

MATERIALS AND METHODS

Ethical Considerations

The ethical committee of the Veterinary Medicine Faculty, Sohag University,

authorized this experimental protocol and procedures. The ethical approval number is Soh. Un. Vet/00064D.

1- Chemicals

Polystyrene nanoparticles were purchased from Nano-gate, Egypt. *Nigella Sativa* oil was sourced from a local herbarium and oil mill. Spectrum Diagnostics, Egypt, supplied kits for triglycerides, cholesterol, and high-density lipoproteins (HDL). The Testosterone Eliza kit was obtained from Calbiotech, USA.

2- Animals

Twenty male Sprague Dawley rats, with an average weight of (170±5 g), were allowed a 10-day acclimatization period before the experiment. Rats were housed in stainless steel cages padded with sawdust and had unrestricted access to water and rat feeding pellets. Maintained under controlled conditions of temperature 22±3 °C, relative humidity 45–60%, and a 12-hour light-dark cycle.

3- Experimental design

Rats were grouped (5 per group) randomly as follows: Control group (received distilled water), NSO group (500 mg/kg BW of organic *Nigella sativa* oil), PSNP (10 mg/kg BW of polystyrene nanoparticles), NSO+ PSNP group (received 500 mg/kg BW of *Nigella sativa* oil followed by 10 mg/kg BW of polystyrene nanoparticles). Rats were administered the doses orally through gavage three times weekly for 60 days. Animals were euthanized using diethyl ether. Blood samples were obtained by cardiac puncture; EDTA Vacutainer tubes were used for whole blood samples, whilst plain tubes were used for serum samples. Centrifugation was performed at 3000 rpm for 10 minutes to collect plasma and serum. Plasma was preserved in Eppendorf tubes and maintained at -80°C until hormonal analysis. Serum samples were utilized for the analysis of triglycerides, total cholesterol, and HDL. Testes and epididymides were collected and weighed.

The testis was immersed in a Formo-alcohol solution for histopathological examination.

4- Body and testicular weight

The animals' initial body weight was documented at the commencement of the study, and the final body weight was recorded just before euthanasia. The absolute Cauda-epididymis and testicular weights were documented at slaughter, and the relative organ weights were calculated relative to body weight.

5- Lipid profile

Total cholesterol (TC) was measured using the technique established by Ellefson and Caraway (1976). High-density lipoprotein cholesterol (HDL-C) was quantified according to Warnick and Wood (1995). Triglyceride (TG) was measured methodologically by Bucolo and David (1973) in serum.

6. Analysis of the Testosterone hormone

Testosterone levels were assessed in plasma using a commercial kit that employed a solid-phase competitive ELISA method (Chen *et al.*, 1991).

7- Histopathology

The testes were fixed in neutral formalin buffer (10%). Subsequently, the tissues were dehydrated and processed. The processed tissues were embedded in paraffin blocks, sectioned, and stained with hematoxylin and eosin (H&E), examined under an Olympus CX31 Light microscope with an Olympus C-5060 digital camera.

8- Statistical analysis

Data were statistically analyzed using SPSS software version 28, employing one-way ANOVA with Dunnett's *post hoc* test. Differences in data were considered significant if $P \leq 0.05$, and data were presented as mean $\pm$ SE (Hansen, 2005).

RESULTS

1- Body weight and organ coefficient

The analysis indicated no statistically significant differences in the body weights of the rats across all groups during the experiment. Additionally, the results showed no significant variations in the Cauda-epididymis weight and testicular weight of male rats, both in absolute (g) and relative (%) terms, among all groups throughout the experiment (Table 1)

Table 1: Impact of PSNP and NSO on body weight, relative and absolute testicular, and epididymal weights in male rats.

Tissue		Control	NSO	PSNP	NSO+PSNP
Right Testis	Absolute	1.47 $\pm$ 0.08	1.42 $\pm$ 0.04	1.59 $\pm$ 0.05	1.48 $\pm$ 0.05
	Relative	0.53 $\pm$ 0.03	0.52 $\pm$ 0.01	0.59 $\pm$ 0.03	0.56 $\pm$ 0.02
Left Testis	Absolute	1.49 $\pm$ 0.08	1.42 $\pm$ 0.03	1.57 $\pm$ 0.04	1.51 $\pm$ 0.08
	Relative	0.54 $\pm$ 0.03	0.52 $\pm$ 0.02	0.58 $\pm$ 0.02	0.57 $\pm$ 0.03
Right Cauda	Absolute	0.20 $\pm$ 0.02	0.17 $\pm$ 0.01	0.19 $\pm$ 0.01	0.17 $\pm$ 0.01
	Relative	0.07 $\pm$ 0.01	0.06 $\pm$ 0.00	0.07 $\pm$ 0.00	0.06 $\pm$ 0.00
Left Cauda	Absolute	0.20 $\pm$ 0.02	0.16 $\pm$ 0.01	0.19 $\pm$ 0.01	0.17 $\pm$ 0.02
	Relative	0.07 $\pm$ 0.01	0.06 $\pm$ 0.00	0.07 $\pm$ 0.00	0.06 $\pm$ 0.00
Body weight		274.33 $\pm$ 3.17	274 $\pm$ 5.81	265 $\pm$ 7.25	271.8 $\pm$ 7.65
Data represented as mean $\pm$ S.E.					

2- Lipid Panel analysis

Only the PSNP-treated group exhibited a significant increase in cholesterol levels. The NSO+PSNP group experienced a notable decline and a significant recovery difference in comparison with the PSNP-treated group. The PSNP group demonstrated a significant decrease in HDL levels compared to the other groups. The

NSO+PSNP group exhibited a significant increase in HDL levels compared to the PSNP group. Regarding triglycerides, both the PSNP and NSO+PSNP groups exhibited elevated TG levels compared to the control group; however, the NSO+PSNP group demonstrated more significantly recovered levels than the PSNP group (Table 2).

Table 2: Effects of NSO and PSNP on serum cholesterol, HDL, and triglyceride levels in male rats.

	Control	NSO	PSNP	NSO+PSNP
Cholesterol	84.75 ± 0.61	79.08 ± 3.48	109.93 ± 2.05 ^{ab}	76.21 ± 0.45 ^c
HDL	18.43 ± 0.83	20.52 ± 1.19	12.16 ± 0.83 ^{abd}	19.33 ± 1.27 ^c
Triglycerides	26.98 ± 1.24	22.82 ± 0.94	44.21 ± 0.41 ^{abd}	32.72 ± 0.96 ^c

Data represented as mean ± SE (N=5). Means with Superscripts a,b,c, and d denote significant differences at $P < 0.05$ from Control, NSO, PSNP, and NSO+PSNP, respectively. Groups lacking superscripts are similar to the reference group.

3- Plasma testosterone hormone analysis

The PSNP group showed a significant reduction in plasma testosterone levels as compared to the control and NSO groups. The mitigation group (NSO+PSNP) demonstrated significant restoration in testosterone levels as compared to the PSNP group. The NSO group exhibited a non-significant change in the levels of testosterone (Fig. 1).

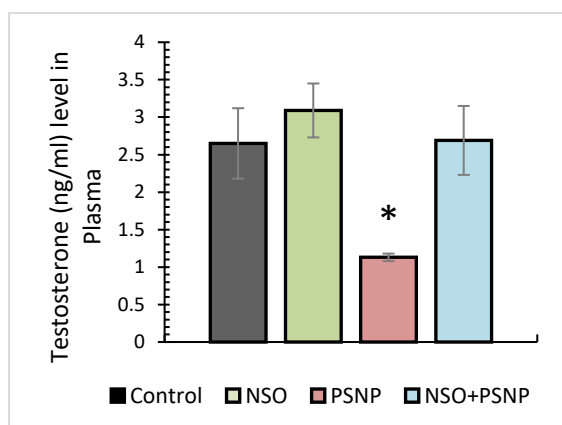


Fig. 1: Effects of Polystyrene Nanoplastic and *Nigella sativa* oil on testosterone (ng/ml) level in the plasma of male rats.

4 – Histopathology

Histopathological examination of testes in control and NSO groups showed normal histological architecture of testes in the two

months of exposure. As for the NSO+PSNP group, testicular tissue appeared normal with mild pathological changes, such as mildly congested blood vessels (Fig. 2. A, B). Meanwhile, the seminiferous tubules in the PSNP group showed cytoplasmic vaculation and degeneration of spermatogenic cells with congestion of blood vessels (Fig. 3. A, B).

DISCUSSION

In our investigation, the body weight of rats, together with the relative and absolute weights of the testes and epididymis, exhibited no significant changes, suggesting no detrimental effects from PSNP treatment. Despite PSNP exhibiting histological changes in the testicles, these modifications seemingly were not enough to affect their weight. Rafiee *et al.* (2017) reported no alterations in the body weights of rats exposed to polystyrene nanoparticles for five weeks, corroborating our findings.

This study demonstrated that the PSNP-treated group exhibited elevated cholesterol and triglyceride levels (bad fat), alongside reduced testosterone and HDL levels.

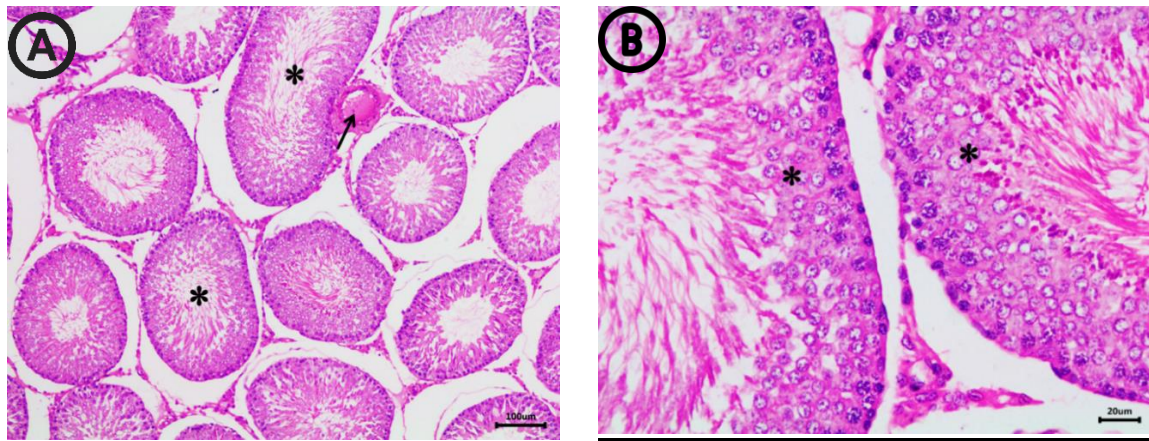


Fig. 2: Testicular histology of the NSO+PSNP group after 2 months showing: Normal seminiferous tubules (asterisks) and mildly congested blood vessels (arrow) in otherwise largely normal tissue architecture A) Low power, B) High power. H&E.

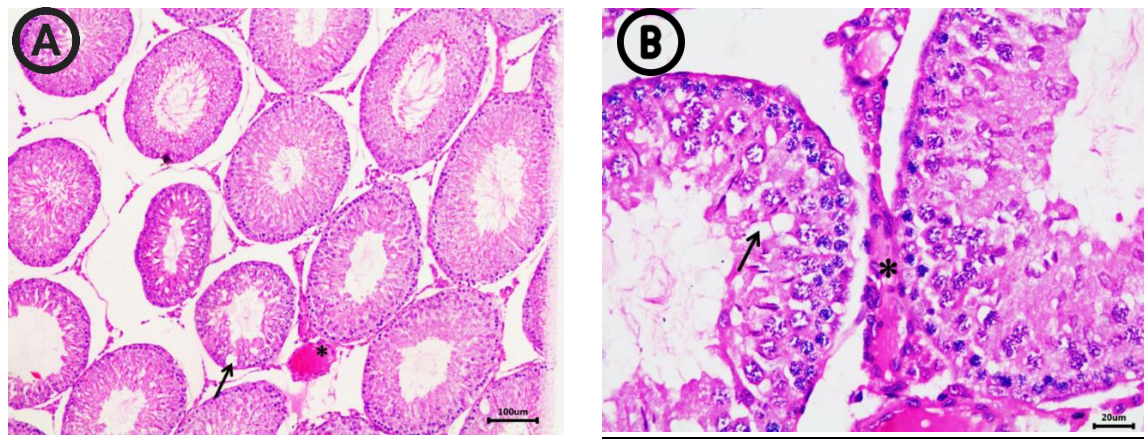


Fig. 3: Histopathological alterations in testicular tissue of the PSNP group after 2-month exposure showing cytoplasmic vacuolation & degeneration of spermatogonic cells (arrow), congestion of blood vessels (asterisks). A) Low power, B) High power. H and E

In contrast, the group co-exposed to polystyrene nanoparticles and *Nigella sativa* oil maintained lower cholesterol and triglyceride levels, as well as normal HDL (good fat) and testosterone levels. The relationship between testosterone hormone and lipid profile levels is complex. Cholesterol serves as an essential component for Leydig cells in the synthesis of testosterone (Tyagi *et al.*, 2017). However, some studies indicate no association between testosterone and serum cholesterol levels (Gomes *et al.*, 2023), while other studies suggested that testosterone treatment may reduce cholesterol levels (Yassin *et al.*, 2025). HDL, which is considered good cholesterol, participates in testosterone synthesis through carrying cholesterol into Leydig

cells (Thorngate & Williams, 2004) or by acting as an anti-inflammatory in the testicular tissue (Rovira-Llopis *et al.*, 2017). Clinical studies have linked increased testosterone production to a higher ratio of HDL to non-HDL cholesterol (Mei *et al.*, 2025). Research studies indicated that elevated triglyceride levels contributed to decreased testosterone production by increasing inflammatory cytokines, which adversely affect Leydig cells' function. This may also result from high triglycerides and subsequently increased reactive oxygen species (ROS), resulting in damage to testicular tissue, including Leydig cells, or by causing endothelial dysfunction that impairs nutrient flow to the testicular tissue (Jarvis *et al.*, 2020; Grandys *et al.*, 2021). These

studies are inconsistent with our findings of elevated cholesterol and triglyceride levels accompanied by a decline in testosterone concentration in the PSNP-treated group. Prior research explained that polystyrene nanoparticles induce lipid disorders by influencing the activity of lipid metabolism-related enzymes and their gene expression, while also causing fluctuations in triglyceride levels and HDL, contingent upon PSNP concentration (Li *et al.*, 2023; Yu *et al.*, 2024).

Nigella sativa oil boosts testosterone owing to its benefits. It has been shown to enhance lipid metabolism by reducing cholesterol and triglyceride levels while increasing HDL levels, thereby promoting testosterone production (Bashandy *et al.*, 2006; Rashidmayvan *et al.*, 2019). It possesses anti-inflammatory and antioxidant properties that safeguard against testicular damage (Almujaydil *et al.*, 2023). The histopathological investigation results indicated that the testicular tissue of rats exposed to polystyrene nanoparticles had histological alterations, indicative of toxic damage, two months after exposure. The alterations included cytoplasmic vacuolation, disruption of spermatogenic cells, and degeneration. Meanwhile, the testicular tissue of rats subjected to *Nigella sativa* oil in conjunction with PSNP exhibited little damage and enhanced histological structure, suggesting that N.S. oil effectively mitigated the detrimental histological changes in the testis induced by PSNP. Cytoplasmic vacuolation and spermatogenic cell degeneration may be regarded as chemically induced damage, likely indicative of steroidogenesis disruption.

Cytoplasmic vacuolation is considered an indicator of blood-testicular barrier disruption (Johnson, 2014). Polystyrene microplastics have been shown to compromise the integrity of the blood-testis barrier via reactive oxygen species (Wei *et al.*, 2021). In harmony with our study, PSNP can build up in the testes, cause

oxidative stress, alter gene expression linked to inflammation and apoptosis, and impair energy metabolism, all of which can lead to damage to the microstructure and functioning of the testicles (Xu *et al.*, 2023). In line with our findings, oral gavage of PS-NPs in mice for 60 days caused morphological changes in spermatogenic cells and a decrease in spermatogonia count (Liang *et al.*, 2024). *Nigella sativa* has been shown to decrease apoptosis markers and redox status, thereby supporting our study findings (Almujaydil *et al.*, 2023).

CONCLUSION

Exposure to PS-NPs for two months did not affect body weight or organ coefficients; however, it resulted in disorders in lipid metabolism, decreased testosterone levels, and testicular tissue damage. *Nigella sativa* oil could alleviate the adverse effects of PS-NP exposure through its advantageous properties.

DISCLOSURE STATEMENT

The authors have no competing interests to report.

REFERENCES

- Alaraby, M.; Abass, D.; Domenech, J.; Hernández, A. and Marcos, R. (2022): Hazard assessment of ingested polystyrene nanoplastics in *Drosophila* larvae. *Environmental Science Nano*, 9(5), 1845–1857. <https://doi.org/10.1039/d1en01199e>
- Allouzi, M.M.A.; Tang, D.Y.Y.; Chew, K.W.; Rinklebe, J.; Bolan, N.; Allouzi, S.M.A. and Show, P.L. (2021): Micro (nano) plastic pollution: The ecological influence on soil-plant system and human health. *The Science of the Total Environment*, 788, 147815. <https://doi.org/10.1016/j.scitotenv.2021.147815>
- Almujaydil, M.S.; Algheshairy, R.M.; Alhomaid, R.M.; Alharbi, H.F. and

- Ali, H.A. (2023): Nigella sativa-Floral Honey and Multi-Floral Honey versus Nigella sativa Oil against Testicular Degeneration Rat Model: The Possible Protective Mechanisms. *Nutrients*, 15(7), 1693. <https://doi.org/10.3390/nu15071693>
- Bashandy, A.S. (2006): Effect of fixed oil of nigella sativa on male fertility in normal and hyperlipidemic rats. *International Journal of Pharmacology*, 3(1), 27–33. <https://doi.org/10.3923/ijp.2007.27.33>
- Bucolo, G. and David, H. (1973): Quantitative determination of serum triglycerides by the use of enzymes. *Clinical Chemistry*, 19(5), 476–482. <https://doi.org/10.1093/clinchem/19.5.476>
- Chen, A.; Bookstein, J.J. and Meldrum, D.R. (1991): Diagnosis of a testosterone-secreting adrenal adenoma by selective venous catheterization. *Fertility and Sterility*, 55(6), 1202–1203. [https://doi.org/10.1016/s0015-0282\(16\)54378-7](https://doi.org/10.1016/s0015-0282(16)54378-7)
- DeLoid, G.M.; Yang, Z.; Bazina, L.; Kharaghani, D.; Sadrieh, F. and Demokritou, P. (2024): Mechanisms of ingested polystyrene micro-nanoplastics (MNPs) uptake and translocation in an in vitro tri-culture small intestinal epithelium. *Journal of Hazardous Materials*, 473, 134706. <https://doi.org/10.1016/j.jhazmat.2024.134706>
- Ellefson, R. and Caraway, W.T. (1976): Fundamentals of clinical chemistry Ed Tietz NW; p506.
- Florance, I.; Chandrasekaran, N.; Gopinath, P.M. and Mukherjee, A. (2022): Exposure to polystyrene nanoplastics impairs lipid metabolism in human and murine macrophages in vitro. *Ecotoxicology and Environmental Safety*, 238, 113612. <https://doi.org/10.1016/j.ecoenv.2022.113612>
- Gomes, G.K.; De Branco, F.M.S.; Santos, H.O.; Pereira, J.L.; Orsatti, F.L. and De Oliveira, E.P. (2023): Cholesterol intake and serum total cholesterol levels are not associated with total testosterone levels in men: a cross-sectional study from NHANES 2013–2014. *Lipids in Health and Disease*, 22(1). <https://doi.org/10.1186/s12944-023-01928-7>
- Grandys, M.; Majerczak, J.; Zapart-Bukowska, J.; Duda, K.; Kulpa, J.K. and Zoladz, J.A. (2021): Lowered serum testosterone concentration is associated with enhanced inflammation and worsened lipid profile in men. *Frontiers in Endocrinology*, 12. <https://doi.org/10.3389/fendo.2021.735638>
- Hansen, J. (2005): Using SPSS for Windows and Macintosh: Analyzing and understanding data. *The American Statistician*, 59(1), 113. <https://doi.org/10.1198/tas.2005.s139>
- He, Y. and Yin, R. (2023): The reproductive and transgenerational toxicity of microplastics and nanoplastics: A threat to mammalian fertility in both sexes. *Journal of Applied Toxicology*, 44(1), 66–85. <https://doi.org/10.1002/jat.4510>
- Hou, B.; Wang, F.; Liu, T. and Wang, Z. (2020): Reproductive toxicity of polystyrene microplastics: In vivo experimental study on testicular toxicity in mice. *Journal of Hazardous Materials*, 405, 124028. <https://doi.org/10.1016/j.jhazmat.2020.124028>
- Hu, J.; Qin, X.; Zhang, J.; Zhu, Y.; Zeng, W.; Lin, Y. and Liu, X. (2021): Polystyrene microplastics disturb maternal-fetal immune balance and cause reproductive toxicity in pregnant mice. *Reproductive Toxicology*, 106, 42–50. <https://doi.org/10.1016/j.reprotox.2021.10.002>

- Huang, J.; Zou, L.; Bao, M.; Feng, Q.; Xia, W. and Zhu, C. (2022): Toxicity of polystyrene nanoparticles for mouse ovary and cultured human granulosa cells. *Ecotoxicology and Environmental Safety*, 249, 114371. <https://doi.org/10.1016/j.ecoenv.2022.114371>
- Jarvis, S.; Gethings, L.A.; Samanta, L.; Pedroni, S.M.A.; Withers, D.J.; Gray, N.; Plumb, R.S.; Winston, R.M.L.; Williamson, C. and Bevan, C.L. (2020): High fat diet causes distinct aberrations in the testicular proteome. *International Journal of Obesity*, 44(9), 1958–1969. <https://doi.org/10.1038/s41366-020-0595-6>
- Jin, H.; Ma, T.; Sha, X.; Liu, Z.; Zhou, Y.; Meng, X.; Chen, Y.; Han, X. and Ding, J. (2020): Polystyrene microplastics induced male reproductive toxicity in mice. *Journal of Hazardous Materials*, 401, 123430. <https://doi.org/10.1016/j.jhazmat.2020.123430>
- Jin, H.; Yang, C.; Jiang, C.; Li, L.; Pan, M.; Li, D.; Han, X. and Ding, J. (2022): Evaluation of Neurotoxicity in BALB/c Mice following Chronic Exposure to Polystyrene Microplastics. *Environmental Health Perspectives*, 130(10). <https://doi.org/10.1289/ehp10255>
- Johnson, K.J. (2014): Testicular histopathology associated with disruption of the Sertoli cell cytoskeleton. *Spermatogenesis*, 4(2), e979106. <https://doi.org/10.4161/21565562.2014.979106>
- Khdre, A.M.; Ramadan, S.A.; Ashry, A. and Alaraby, M. (2023): Chironomus sp. as a Bioindicator for Assessing Microplastic Contamination and the Heavy Metals Associated with It in the Sediment of Wastewater in Sohag Governorate, Egypt. *Water Air & Soil Pollution*, 234(3). <https://doi.org/10.1007/s11270-023-06179-x>
- Li, Y.; Ye, Y.; Rihan, N.; Zhu, B.; Jiang, Q.; Liu, X.; Zhao, Y. and Che, X. (2023): Polystyrene nanoplastics induce lipid metabolism disorder and alter fatty acid composition in the hepatopancreas of Pacific whiteleg shrimp (*Litopenaeus vannamei*). *The Science of the Total Environment*, 906, 167616. <https://doi.org/10.1016/j.scitotenv.2023.167616>
- Li, Z.; Chen, F.; Liu, J.; Zhi, L.; Junaid, M.; Chen, G.; Xiao, Z.; Wang, J. and Chong, Y. (2024): Polystyrene nanoplastics sequester the toxicity mitigating potential of probiotics by altering gut microbiota in grass carp (*Ctenopharyngodon idella*). *Journal of Hazardous Materials*, 484, 136778. <https://doi.org/10.1016/j.jhazmat.2024.136778>
- Liang, Y.; Yang, Y.; Lu, C.; Cheng, Y.; Jiang, X.; Yang, B.; Li, Y.; Chen, Q.; Ao, L.; Cao, J.; Han, F.; Liu, J. and Zhao, L. (2024): Polystyrene nanoplastics exposure triggers spermatogenic cell senescence via the Sirt1/ROS axis. *Ecotoxicology and Environmental Safety*, 279, 116461. <https://doi.org/10.1016/j.ecoenv.2024.116461>
- Lu, L.; Wan, Z.; Luo, T.; Fu, Z. and Jin, Y. (2018): Polystyrene microplastics induce gut microbiota dysbiosis and hepatic lipid metabolism disorder in mice. *The Science of the Total Environment*, 631–632, 449–458. <https://doi.org/10.1016/j.scitotenv.2018.03.051>
- Mei, Y.; Chen, Y.; Wang, X.; Xu, R.; Xu, R. and Feng, X. (2025): The inverse relationship between the non-high-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio and testosterone in adult males in the United States: a cross-sectional study based on the NHANES database. *Frontiers in Endocrinology*, 16.

- <https://doi.org/10.3389/fendo.2025.1478124>
- Rafiee, M.; Dargahi, L.; Eslami, A.; Beirami, E.; Jahangiri-Rad, M.; Sabour, S. and Amereh, F. (2017): Neurobehavioral assessment of rats exposed to pristine polystyrene nanoplastics upon oral exposure. *Chemosphere*, 193, 745–753. <https://doi.org/10.1016/j.chemosphere.2017.11.076>
- Rashidmayvan, M.; Mohammadshahi, M.; Seyedian, S.S. and Haghighizadeh, M.H. (2019): The effect of Nigella sativa oil on serum levels of inflammatory markers, liver enzymes, lipid profile, insulin and fasting blood sugar in patients with non-alcoholic fatty liver. *Journal of Diabetes & Metabolic Disorders*, 18(2), 453–459. <https://doi.org/10.1007/s40200-019-00439-6>
- Rovira-Llopis, S.; Bañuls, C.; De Marañon, A.M.; Diaz-Morales, N.; Jover, A.; Garzon, S.; Rocha, M.; Victor, V.M. and Hernandez-Mijares, A. (2017): Low testosterone levels are related to oxidative stress, mitochondrial dysfunction and altered subclinical atherosclerotic markers in type 2 diabetic male patients. *Free Radical Biology and Medicine*, 108, 155–162. <https://doi.org/10.1016/j.freeradbiomed.2017.03.029>
- Senathirajah, K.; Attwood, S.; Bhagwat, G.; Carbery, M.; Wilson, S. and Palanisami, T. (2020): Estimation of the mass of microplastics ingested – A pivotal first step towards human health risk assessment. *Journal of Hazardous Materials*, 404, 124004. <https://doi.org/10.1016/j.jhazmat.2020.124004>
- Shahid, M.A.; Rahim, A.; Chowdhury, M.A. and Kashem, M.A. (2021): Development of antibacterial nanofibrous wound dressing and conceptual reaction mechanism to deactivate the viral protein by Nigella sativa extract. *Advances in Traditional Medicine*, 22(2), 283–291. <https://doi.org/10.1007/s13596-020-00538-3>
- Shen, T.; Zhang, W.; Wang, Y.; Li, H.; Wu, J.; Wang, Q.; Qin, L.; Zhang, L.; Liu, C. and Li, R. (2023): Effects of Microplastic (MP) Exposure at Environmentally Relevant Doses on the Structure, Function, and Transcriptome of the Kidney in Mice. *Molecules*, 28(20), 7104. <https://doi.org/10.3390/molecules28207104>
- Sui, A.; Yao, C.; Chen, Y.; Li, Y.; Yu, S.; Qu, J.; Wei, H.; Tang, J. and Chen, G. (2023): Polystyrene nanoplastics inhibit StAR expression by activating HIF-1 α via ERK1/2 MAPK and AKT pathways in TM3 Leydig cells and testicular tissues of mice. *Food and Chemical Toxicology*, 173, 113634. <https://doi.org/10.1016/j.fct.2023.113634>
- Thorngate, F.E. and Williams, D.L. (2004): Lipoproteins, HDL/LDL. In *Elsevier eBooks* (pp. 588–593). <https://doi.org/10.1016/b0-12-443710-9/00366-5>
- Tyagi, V.; Scordo, M.; Yoon, R.S.; Liporace, F.A. and Greene, L.W. (2017): Revisiting the role of testosterone: Are we missing something? *PubMed*, 19(1), 16–24. <https://doi.org/10.3909/riu0716>
- Wang, G.; Lin, Y. and Shen, H. (2023): Exposure to Polystyrene Microplastics Promotes the Progression of Cognitive Impairment in Alzheimer's Disease: Association with Induction of Microglial Pyroptosis. *Molecular Neurobiology*, 61(2), 900–907. <https://doi.org/10.1007/s12035-023-03625-z>
- Wang, L.; Wang, Y.; Xu, M.; Ma, J.; Zhang, S.; Liu, S.; Wang, K.; Tian, H. and Cui, J. (2020): Enhanced hepatic cytotoxicity of chemically transformed polystyrene microplastics by simulated gastric

- fluid. *Journal of Hazardous Materials*, 410, 124536. <https://doi.org/10.1016/j.jhazmat.2020.124536>
- Warnick, G.R. and Wood, P.D. (1995): National Cholesterol Education Program recommendations for measurement of high-density lipoprotein cholesterol: executive summary. The National Cholesterol Education Program Working Group on Lipoprotein Measurement. *Clinical Chemistry*, 41(10), 1427–1433. <https://doi.org/10.1093/clinchem/41.10.1427>
- Wei, Y.; Zhou, Y.; Long, C.; Wu, H.; Hong, Y.; Fu, Y.; Wang, J.; Wu, Y.; Shen, L. and Wei, G. (2021): Polystyrene microplastics disrupt the blood-testis barrier integrity through ROS-Mediated imbalance of mTORC1 and mTORC2. *Environmental Pollution*, 289, 117904. <https://doi.org/10.1016/j.envpol.2021.117904>
- Xu, W.; Yuan, Y.; Tian, Y.; Cheng, C.; Chen, Y.; Zeng, L.; Yuan, Y.; Li, D.; Zheng, L. and Luo, T. (2023): Oral exposure to polystyrene nanoplastics reduced male fertility and even caused male infertility by inducing testicular and sperm toxicities in mice. *Journal of Hazardous Materials*, 454, 131470. <https://doi.org/10.1016/j.jhazmat.2023.131470>
- Yang, H.; Dong, H.; Huang, Y.; Chen, G. and Wang, J. (2022): Interactions of microplastics and main pollutants and environmental behavior in soils. *The Science of the Total Environment*, 821, 153511. <https://doi.org/10.1016/j.scitotenv.2022.153511>
- Yang, S.; Zhang, T.; Ge, Y.; Yin, L.; Pu, Y. and Liang, G. (2024): Inhalation exposure to polystyrene nanoplastics induces chronic obstructive pulmonary disease-like lung injury in mice through multi-dimensional assessment. *Environmental Pollution*, 347, 123633. <https://doi.org/10.1016/j.envpol.2024.123633>
- Yassin, A.; Alzubaidi, R.T.; Kamkoun, H.; Mahdi, M.; El Akkad, M. and Al Ansari, A. (2025): Can Testosterone Treatment in Elderly Men with Hypogonadism Improve Metabolic Syndrome and Health-Related Quality of Life?. *Journal of Clinical Cardiology and Cardiology Research*, 4, 1. <https://doi.org/10.59657/2837-4673.brs.25.045>
- Yu, Z.; Fan, X.; Zhao, X.; He, T.; Li, X.; Du, H.; Zhao, M.; Zhu, R.; Li, M.; Zhang, Z. and Han, F. (2024): Polystyrene nanoplastics induce lipid metabolism disorder by activating the PERK-ATF4 signaling pathway in mice. *ACS Applied Materials & Interfaces*, 16(27), 34524–34537. <https://doi.org/10.1021/acsami.4c04416>
- Zha, H.; Xia, J.; Wang, K.; Xu, L.; Chang, K. and Li, L. (2023): Foodborne and airborne polyethersulfone nanoplastics respectively induce liver and lung injury in mice: Comparison with microplastics. *Environment International*, 183, 108350. <https://doi.org/10.1016/j.envint.2023.108350>

تأثير الجسيمات النانوية للبوليستيرين على العلاقة بين الدهون وهرمون التستوستيرون في حالات تسمم الخصية: دور زيت حبة البركة في استعادة التوازن

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كشفت هذه الدراسة عن التغيرات التي تسببها الجسيمات النانوية للبوليستيرين في مستويات الدهون وعلاقتها بإفراز هرمون التستوستيرون، كما بحثت في قدرة زيت حبة البركة - وهو علاج طبيعي متاح - على إصلاح هذا الضرر. تم تقسيم عشرين فأراً ذكراً إلى أربع مجموعات بشكل عشوائي: مجموعة مرجعية لم تتلق أي علاج، ومجموعة تلقت زيت حبة البركة بجرعة ٥٠٠ ملغ لكل كيلو غرام من وزن الجسم، ومجموعة تعرضت للجسيمات النانوية للبوليستيرين بجرعة ١٠ ملغ لكل كيلو غرام من وزن الجسم، ومجموعة رابعة تلقت كلا المادتين بنفس الجرعات. تم إعطاء الجرعات عن طريق الفم ثلاث مرات أسبوعياً لمدة ستين يوماً. أظهرت النتائج أن مجموعة الجسيمات النانوية للبوليستيرين سجلت ارتفاعاً ملحوظاً في مستويات الكوليسترول والدهون الثلاثية مع انخفاض في البروتين الدهني عالي الكثافة وهرمون التستوستيرون، بالإضافة إلى ظهور تغيرات نسيجية في الخصية تشمل تكون فجوات سيتوبلازمية وتلف خلايا تكوين الحيوانات المنوية وازدحام الأوعية الدموية. في المقابل، أظهرت المجموعة التي تلقت الجرعات المشتركة انخفاضاً في مستويات الكوليسترول والدهون الثلاثية مع الحفاظ على مستويات طبيعية من البروتين الدهني عالي الكثافة وهرمون التستوستيرون، كما لوحظت تغيرات مرضية بسيطة فقط في أنسجة الخصية. تخلص الدراسة إلى أن زيت حبة البركة يمتلك فعالية كبيرة في التخفيف من الآثار الضارة للجسيمات النانوية للبوليستيرين على الهرمونات الذكرية المرتبطة باضطرابات أيض الدهون.