Bio Vet Innovator Magazine

Volume 1 (Issue 1) JULY 2024

OPEN ACCESS
Popular Article

Influence of Oxidative Stress on Male Reproductive Performance in Farm Animals

*Kishan Kumar Fataniya[1], Anand Kumar Yadav[1], Sakshi Payasi[1]
[1]SRS of ICAR-NDRI, Bangalore.
*Corresponding Author: kk28700@gmail.com
DOI - https://doi.org/10.5281/zenodo.13121255

Received: July 25, 2024
Published: July 29, 2024

Abstract
Oxidative stress, characterized by an imbalance between reactive oxygen species (ROS) production and antioxidant defences, significantly impacts male reproductive performance in farm animals. ROS can damage sperm DNA, lipids, and proteins, leading to reduced sperm motility, viability, and integrity. Antioxidant systems, including enzymes like superoxide dismutase, catalase, and glutathione peroxidase, play crucial roles in mitigating oxidative damage. This article discusses the factors of oxidative stress in farm animals, such as environmental factors, nutrition, and management practices, antioxidant defences. Understanding the intricate relationship between oxidative stress and male fertility is essential for developing effective interventions to improve reproductive performance in farm animals, ultimately enhancing productivity and sustainability in livestock production.

Introduction:

Oxidative stress refers to a breakdown in the control of redox signalling brought on by either an excess of reactive oxygen species (ROS) or a depletion of regulating antioxidant mechanisms (Peña *et al*., 2019). Although ROS are commonly believed to have harmful effects that result in oxidative stress pathologies, there is growing recognition that ROS can also be innocuous byproducts of metabolism and that they are crucial elements of signalling pathways that are vital for regular cell function (Gibb *et al*., 2020). Male infertility has frequently been linked to oxidative stress as its aetiology. ROS in sperm are primarily produced by mitochondrial metabolism, L-amino acid oxidases, and NOXs in the plasma membrane of leukocytes and spermatozoa (Aitken, 2017). Spermatozoa are vulnerable to ROS attacks because to their low antioxidant defense and high polyunsaturated fatty acid (PUFA) concentration in their membranes further these PUFAs are particularly vulnerable to lipid peroxidation, an autocatalytic, self-propagating event that destroys the functionality and integrity of membranes, because their molecules contain double bonds (Pagl *et al*., 2006).

Apart from their harmful consequences, a limited quantity of ROS plays an important physiological role during fertilization by facilitating sperm capacitation, acrosome reaction, and sperm-zona pellucida binding. While oxidative stress has been linked to male fertility issues, the following article highlights the several mechanisms that contribute to oxidative stress and its impact on fertility in domestic animals.

Oxidative Stress in the Male: Intrinsic and Extrinsic Factors

Intrinsic factors	Extrinsic factors
• Sperm morphology and viability • Sperm metabolism • Leukocyte activation following inflammation or infection • Age • Genetics and phenotypic traits • Behaviour • Social rank	• Climate change • Seasonality • Radiation • Chemical pollutants • Sperm handling • Sperm storage • Media composition • Sperm selection procedures • Bacteriospermia

(Adapted from Pintus & Ros-Santaella, 2021)

The male's antioxidant defences:

Semen contains several enzymatic ROS scavengers, including CAT, SOD, GPx, GR, GST, and peroxiredoxins, seminal plasma also contains several non-enzymatic chemicals, including GSH, albumin, urate, taurine, hypotaurine, pyruvate, lactate, ascorbic acid, tocopherol, and L-ergothioneine, which may act as antioxidants and combat oxidative stress (Ball, 2008). Seminal plasma proteins 1 and 2 (HSP-1/2) in horses can protect enzymes like alcohol dehydrogenase by inhibiting lipid peroxidation (Kumar & Swamy, 2016), the antioxidant defenses of the ejaculate in bulls, for example, differ according on the type of antioxidant, the male's age, and the season. Seminal plasma contains antioxidants from the male reproductive tract, which contribute to its scavenging capability. For example, in boars, CAT activity in prostatic gland secretions is 2-3 times higher than in epididymal tails or vesicular glands (Koziorowska-Gilun *et al.*, 2010). In goats SOD activity is higher in the epididymal cauda compared to the corpus and caput. Sperm handling factors, including extender type, storage conditions, and sample homogenization, can impact antioxidant defense efficiency. For example, dilution of the semen has an impact on the activity of antioxidant enzymes in stallion ejaculates, while liquid storage at 5°C does not.

Effects of oxidative stress on male fertility:

Within the livestock sector, oxidative stress's effects on male reproduction are linked to decreased sperm quality and fertility as well as decreased progeny health, particularly with regard to embryo quality and survival. Simões *et al.*, 2013 discovered that lower sperm DNA integrity and embryo cleavage rate are linked to spermatozoa's vulnerability to oxidative stress in cattle. Ribas-Maynou *et al.*, 2020 discovered that after ARTs like IVF or intracytoplasmic sperm injection (ICSI), the effects of oxidative stress at the sperm level translate into lower rates of fertilization and blastocysts. Heat stress's effects on bull Sperm quality varies over the course of the harm caused by heat: for example, it increases sperm morphological defects seven days after heat stress, lipid peroxidation fourteen days later, and DNA fragmentation twenty-eight days later. Several domestic animal specie's semen has been shown to include contaminants including pesticides and heavy metals.

Environmentally sourced Pb and Cd levels in bovine semen are inversely correlated with sperm motility, CAT activity, and GSH levels, and positively correlated with ROS and lipid peroxidation (Tvrdá *et al.*, 2013). Similarly persistent organic pollutants like perfluorooctane sulfonate and perfluorohexane sulfonate in boars can cause oxidative stress and impair sperm capacitation by decreasing tyrosine phosphorylation in sperm head equatorial and acrosomal proteins (Oseguera-López *et al.*, 2020). Storing sperm cells in liquid or frozen form can also damage proteins, lipids, and nucleic acids due to oxidative stress.

Effect of spermatozoa's oxidative damage on embryo development:

Studies have revealed that OS in spermatozoa can significantly contribute to poor embryo development in experimental animal models as well as in humans undergoing ART. The most common effect of OS on spermatozoa is DNA damage. As a result, the majority of research in the literature have connected the embryonic response to sperm OS with reference to sperm DNA damage. Depending on the level of sperm DNA damage, the oocyte can repair the damage in spermatozoa and lead to a healthy embryo, successfully fertilize with the development of the faulty embryo, or lead to fertilization failure or embryo arrest (Champroux *et al.*, 2016). Exogenous oxidative stress generated in vitro via the xanthine/xanthine oxidase system has been demonstrated to impair frozen-thawed bull sperm motility, increase SDF, decrease fertilization rates, and lower blastocyst rates and quality. Pre-treatment with zinc, d-aspartate, and co-enzyme Q10 prior to exogenous OS prevented these effects (Barbato *et al.*, 2017). Oxidative stress-induced protein degradation in sperm is believed to be implicated in embryo degeneration during a progressive phase of pregnancy, potentially leading to pregnancy loss.

Strategies to Reduce Oxidative Stress and Improve Male fertility:

Given the range of intrinsic characteristics linked to male vulnerability to oxidative stress, the first step towards bettering livestock reproductive management is to select for genetic traits that give sperm cells more resistance to an imbalance between antioxidant defences and ROS levels. Lowering the ejaculate's oxidative stress levels, a few strategies that have been put out for this goal will be succinctly outlined here. Antioxidants can be supplemented through the food or added as an addition to semen extenders to improve the male reproductive performance of farm animals (Bathgate, 2011). For example, it has been demonstrated that adding GSH to the semen extender enhances sperm activity and the ability of animals to fertilize. It has also been suggested that adding homologous or heterologous seminal plasma can strengthen sperm cells' antioxidant defences against oxidative stress. More recently, it has been demonstrated that adding antioxidants from plant extracts improves the quality of sperm from pigs whether they are stored in liquid or are subjected to oxidative stress. In buffalos, sperm quality is increased and post-thaw ROS and lipid peroxidation levels are reduced by partially deoxygenating the extender before semen addition.

Conclusion:

ROS serves both useful and harmful purposes. They play a crucial role in cellular biochemistry and are necessary for life to exist. Andrologists should focus not only on scavenging ROS after an oxidative stress cascade, but also on preventing it before it starts. This approach should preserve the physiological functions of ROS. To improve ROS homeostasis, techniques such as using antioxidant precursors in vivo and in vitro may be implemented. Low ROS levels have been shown to improve sperm function, including chromatin crosslinking and increased sperm capacitation. In certain situations (e.g. cryopreservation, toxicant exposure, age), ROS levels can exceed the antioxidant defences of cells, leading to oxidative stress. This can impair sperm production and function, ultimately affecting offspring health.

REFERENCES:

Aitken, R. J. (2017). Reactive oxygen species as mediators of sperm capacitation and pathological damage. *Molecular Reproduction and Development*, *84*(10), 1039–1052.

Ball, B. A. (2008). Oxidative stress, osmotic stress and apoptosis: Impacts on sperm function and preservation in the horse. *Animal Reproduction Science*, *107*(3-4), 257–267.

Barbato, V., Talevi, R., Braun, S., Merolla, A., Sudhakaran, S., Longobardi, S., & Gualtieri, R. (2017). Supplementation of sperm media with zinc, D-aspartate and co-enzyme Q10 protects bull sperm against exogenous oxidative stress and improves their ability to support embryo development. *Zygote*, *25*(2), 168–175.

Bathgate, R. (2011). Antioxidant Mechanisms and their Benefit on Post-thaw Boar Sperm Quality. *Reproduction in Domestic Animals*, *46*, 23–25.

Champroux, A., Torres-Carreira, J., Gharagozloo, P., Drevet, J. R., & Kocer, A. (2016). Mammalian sperm nuclear organization: resiliencies and vulnerabilities. *Basic and Clinical Andrology*, *26*(1).

Gibb, Z., Griffin, R. A., Aitken, R. J., & De Iuliis, G. N. (2020).

Citation: Kishan Kumar Fataniya1, Anand Kumar Yadav1, Sakshi Payasi1. (2024). Influence of Oxidative Stress on Male Reproductive Performance in Farm Animals. BIO VET INNOVATOR Magazine, (Vol. 1, Issue 1, pp. 18–20). https://doi.org/10.5281/zenodo.13121255

Functions and effects of reactive oxygen species in male fertility. *Animal Reproduction Science*, *220*, 106456.

Koziorowska-Gilun, M., Koziorowski, M., Fraser, L., & Strzeżek, J. (2010). Antioxidant Defence System of Boar Cauda Epididymidal Spermatozoa and Reproductive Tract Fluids. *Reproduction in Domestic Animals*, *46*(3), 527–533.

Kumar, C. S., & Swamy, M. J. (2016). HSP-1/2, a major horse seminal plasma protein, acts as a chaperone against oxidative stress. *Biochemical and Biophysical Research Communications*, *473*(4), 1058–1063.

Oseguera-López, I., Pérez-Cerezales, S., Ortiz-Sánchez, P. B., Mondragon-Payne, O., Sánchez-Sánchez, R., Jiménez-Morales, I., Fierro, R., & González-Márquez, H. (2020). Perfluorooctane Sulfonate (PFOS) and Perfluorohexane Sulfonate (PFHxS) Alters Protein Phosphorylation, Increase ROS Levels and DNA Fragmentation during In Vitro Capacitation of Boar Spermatozoa. *Animals*, *10*(10), 1934.

Pagl, R., Aurich, J., & Aurich, C. (2006). Reactive oxygen species and their influence on stallion semen fertility - a review. *Pferdeheilkunde Equine Medicine*, *22*(2), 212–217.

Peña, F. J., O'Flaherty, C., Ortiz Rodríguez, J. M., Martín Cano, F. E., Gaitskell-Phillips, G. L., Gil, M. C., & Ortega Ferrusola, C. (2019). Redox Regulation and Oxidative Stress: The Particular Case of the Stallion Spermatozoa. *Antioxidants*, *8*(11), 567.

Pintus, E., & Ros-Santaella, J. L. (2021). Impact of Oxidative Stress on Male Reproduction in Domestic and Wild Animals. *Antioxidants*, *10*(7), 1154.

Ribas-Maynou, J., Yeste, M., & Salas-Huetos, A. (2020). The Relationship between Sperm Oxidative Stress Alterations and IVF/ICSI Outcomes: A Systematic Review from Nonhuman Mammals. *Biology*, *9*(7), 178.

Simões, R., Feitosa, W. B., Siqueira, A. F. P., Nichi, M., Paula-Lopes, F. F., Marques, M. G., Peres, M. A., Barnabe, V. H., Visintin, J. A., & Assumpção, M. E. O. (2013). Influence of bovine sperm DNA fragmentation and oxidative stress on early embryo in vitro development outcome. *REPRODUCTION*, *146*(5), 433–441.

Tvrdá, E., Kňažická, Z., Lukáčová, J., Schneidgenová, M., Goc, Z., Greń, A., Szabó, C., Massányi, P., & Lukáč, N. (2013). The impact of lead and cadmium on selected motility, prooxidant and antioxidant parameters of bovine seminal plasma and spermatozoa. *Journal of Environmental Science and Health, Part A*, *48*(10), 1292–1300.

Citation: Kishan Kumar Fataniya1, Anand Kumar Yadav1, Sakshi Payasi1. (2024). Influence of Oxidative Stress on Male Reproductive Performance in Farm Animals. BIO VET INNOVATOR Magazine, (Vol. 1, Issue 1, pp. 18–20). https://doi.org/10.5281/zenodo.13121255