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# EFFECTS OF ZINC SUPPLEMENTATION ON REPRODUCTIVE PERFORMANCE IN CATTLE: A REVIEW

## Pengaruh Suplementasi Zink Terhadap Performa Reproduksi Pada Sapi: *A Review*

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**ABSTRACT**

Zinc is a vital micronutrient involved in various reproductive processes in cattle. This review aims to evaluate the effects of zinc supplementation on cattle reproductive performance by analyzing research articles sourced from Scopus and PubMed databases. Findings indicate that zinc supplementation, provided in either organic or inorganic forms, positively influences reproductive parameters. In bulls, zinc enhances sperm motility, viability, and ejaculate volume. In female cattle, supplementation modulates endocrine hormone levels during both pre-calving and post-calving periods. Moreover, appropriate zinc dosages and supplementation durations contribute to improved reproductive efficiency in cows. These results support the conclusion that zinc supplementation is effective in enhancing reproductive performance in cattle.

**Keywords**: *Dosage, Reproductive Performance, Cattle, Zinc*

**ABSTRAK**

Zink merupakan mikronutrien penting yang berperan dalam berbagai proses reproduksi pada sapi. Review ini bertujuan untuk mengevaluasi pengaruh suplementasi zink terhadap performa reproduksi sapi melalui tinjauan artikel penelitian yang diperoleh dari basis data Scopus dan PubMed. Hasil menunjukkan bahwa suplementasi zink, baik dalam bentuk organik maupun anorganik, memberikan efek positif terhadap parameter reproduksi. Pada pejantan, zink meningkatkan motilitas, viabilitas, dan volume ejakulasi sperma. Pada sapi betina, suplementasi zink memodulasi kadar hormon endokrin baik pada masa pra-kelahiran maupun pasca-kelahiran. Selain itu, pemberian zink dengan dosis dan durasi yang tepat dapat meningkatkan efisiensi reproduksi pada sapi betina. Kesimpulannya, suplementasi zink efektif dalam meningkatkan performa reproduksi sapi.

**Kata Kunci:** Dosis, Performa Reproduksi, Sapi, Zink

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## INTRODUCTION

Zinc (Zn) is an essential trace mineral required for optimal growth, immune competence, and reproductive performance in cattle (Nielsen, 2012). Functioning as a cofactor for more than 200 metalloenzymes, zinc plays a vital role in numerous biological processes, including protein synthesis, antioxidant defense, and the structural stabilization of DNA and RNA (Smith and Akinbamizo, 2000). It is also critical in regulating cell division, differentiation, and nucleic acid metabolism throughout the life cycle (McDonald et al., 2007).

Zinc contributes significantly to hormonal activity, influencing the synthesis, storage, and secretion of key reproductive hormones. Additionally, it supports immune function and maintains electrolyte and acid–base balance, which are essential for maintaining systemic homeostasis (McDonald et al., 2007). Given these roles, even marginal zinc deficiency can disrupt physiological functions and negatively impact reproductive efficiency.

Zinc deficiency has been widely associated with various reproductive impairments, including reduced fertility, prolonged postpartum anestrus, retained placenta, increased services per conception, and early embryonic loss. These reproductive dysfunctions have been reported in multiple species, including cattle, rats, goats, monkeys, poultry, and humans (Nawan et al., 2018; Liu et al., 2019; Galarza et al., 2020; Javari et al., 2021; Vickram et al., 2021). At the cellular level, zinc influences spermatozoa through its regulatory role in capacitation and the acrosome reaction—two critical events required for successful fertilization (Michailov et al., 2014).

In cattle, semen quality is a key determinant of reproductive success, particularly in artificial insemination (AI) programs. Parameters such as motility, morphology, concentration, membrane integrity, and DNA stability are commonly used to assess semen quality. Zinc has been shown to influence many of these parameters, primarily through its antioxidant properties and its involvement in membrane stabilization and chromatin condensation. Despite growing interest in the role of trace minerals in male fertility, there remains a need to consolidate existing evidence on the effects of zinc supplementation on semen quality in bulls.

Therefore, the objective of this review is thus to describe current research on the effects of zinc supplementation on reproductive performance in cattle. Elucidating the physiological role of zinc, particularly in relation to male reproductive function, is critical for the formulation of precise nutritional strategies aimed at optimizing reproductive efficiency. Such insights are expected to contribute to enhanced fertility outcomes and improved productivity in cattle breeding programs.

## DATA COLLECTION

A comprehensive literature search was conducted using Publish or Perish (PoP) software version 8 to identify relevant studies on the effects of zinc supplementation on reproductive performance in cattle. The search was performed using the keywords *"zinc supplementation"* and *"reproductive performance in cattle"* across three major databases: PubMed, ScienceDirect, and Google Scholar. The inclusion criteria encompassed peer-reviewed articles published between 2007 and 2025. All retrieved references were exported in RIS format and processed using the CADIMA web-based systematic review tool (CADIMA, 2020). After removing duplicates, a total of 30 unique records were identified. These records were randomized and subjected to full-text screening based on predefined eligibility criteria. Ultimately, five studies were included in the final review, all of which met the relevance and quality standards within the scope of reproductive performance.

## FORMS OF ZINC SUPPLEMENTATION

Zinc supplementation in cattle diets is commonly administered in two primary forms: inorganic and organic. Inorganic sources such as zinc sulfate and zinc oxide have traditionally been used due to their availability and cost-effectiveness (NRC, 2012). However, these forms often exhibit lower bioavailability because of their tendency to form insoluble complexes in the

gastrointestinal tract, which limits absorption. In contrast, organic zinc sources—such as zinc methionine, zinc proteinate, and zinc amino acid chelates—demonstrate higher bioavailability and greater biological efficacy due to their improved stability and absorption across the intestinal mucosa. Comparative studies have shown that organic zinc is more effective in enhancing reproductive parameters, likely due to its superior capacity to reach target tissues, including the testes and accessory sex glands. The choice of zinc form is thus critical for optimizing its reproductive benefits (Fallah et al., 2018).

**Table 1.** Zinc supplementation and its effects on reproductive performance in cattle

| No | Cattle | Zinc Type | Dose | Reference |
|---|---|---|---|---|
| 1 | Crossbred cattle (*Bos indicus* x Bos taurus) | Inorganic and organic | 0, 35, and 70 ppm | Kumar et al., 2006 |
| 2 | Kankrej bulls | Organic | 100 ppm | Patil et al., 2023 |
| 3 | Frieshwal bulls | Inorganic and organic | | Chauhan et al., 2021 |

Zinc supplementation, whether in inorganic or organic form, significantly improves both the quantitative and qualitative characteristics of semen in crossbred bulls. According to Kumar et al. (2006), dietary inclusion of zinc resulted in a statistically significant increase in semen volume, sperm concentration, progressive motility, and viability after six months of supplementation. Furthermore, functional assessments such as the bovine cervical mucus penetration test (BCMPT) and hypo-osmotic swelling test (HOST) revealed enhanced sperm membrane integrity and functional competence in zinc-treated bulls. Enzymatic analysis demonstrated elevated alkaline and acid phosphatase activities in the seminal plasma of supplemented groups, suggesting improved secretory function of the accessory sex glands. Conversely, a notable reduction in GOT and GPT activity in bulls receiving organic zinc (zinc propionate) may indicate reduced oxidative stress and enhanced seminal plasma quality. Additionally, serum testosterone levels were significantly higher in bulls supplemented with higher doses of zinc, particularly in the group receiving organic zinc, highlighting zinc's role in modulating the endocrine axis involved in reproductive function. Collectively, these findings support the beneficial effects of zinc—especially in organic form—in enhancing reproductive efficiency in male cattle.

The supplementation of 100 ppm zinc propionate in Kankrej bulls markedly improved both the quantitative and qualitative parameters of semen, underscoring the essential role of zinc in male reproductive physiology. Moreover, improvements in mass motility and the percentage of live sperm post-supplementation indicate enhanced sperm vitality and functionality, which are critical determinants of fertility. These findings align with zinc's known role as a cofactor in testicular steroidogenesis and membrane stabilization, particularly in the context of testosterone regulation via Leydig cell function. Given the widespread zinc deficiency in Indian soils, the study emphasizes the practical relevance of targeted mineral supplementation in improving semen quality, thereby supporting reproductive performance and efficiency in indigenous cattle breeds such as Kankrej (Patil et al., 2023).

Chauhan et al. (2021) reported that combined dietary supplementation of selenium (0.20 mg/kg DMI) and zinc (35 mg/kg DMI) in Frieswal bulls significantly enhanced semen quality and sperm output compared to non-supplemented controls. Bulls receiving the combined treatment (T2) exhibited marked improvements in semen volume, sperm concentration per ejaculate, gross motility, and progressive motility, suggesting enhanced spermatogenic efficiency and sperm functional integrity. These parameters are crucial indicators of male fertility potential, and the synergistic effects of selenium and zinc likely support antioxidative defense mechanisms and testosterone biosynthesis, both essential for optimal sperm development and motility. Although sperm concentration per milliliter was unexpectedly highest in the control group (T0),

the total sperm yield per ejaculate and motility metrics were superior in the supplemented groups, indicating that selenium and zinc may contribute more significantly to overall reproductive output than to sperm density alone. These results reinforce the relevance of trace mineral supplementation in improving reproductive performance in breeding bulls, particularly under practical feeding conditions (Chauhan et al., 2021).

## EFFECT ZINC ON SEMEN QUALITY PARAMETERS

Zinc plays a pivotal role in maintaining and improving semen quality parameters in bulls. It is a crucial structural and functional component of numerous enzymes involved in spermatogenesis. Supplementation with zinc has been associated with significant improvements in sperm concentration, motility, viability, and membrane integrity (Esfiokhi et al., 2023). Several studies report that zinc supports the maintenance of acrosomal integrity, reduces sperm abnormalities, and limits DNA fragmentation, all of which are essential for fertilization capability (Oliveira et al., 2004; Fadl et al., 2022). Moreover, zinc contributes to the stabilization of sperm chromatin and the protection of membrane lipids from oxidative damage through its role as an antioxidant.

**Table 2.** Zinc effects on cattle semen quality

| Parameter | Effect on Semen Quality | Reference |
|---|---|---|
| Sperm Motility | Significant increase in total and progressive motility | Galarza et al., 2020 |
| Sperm Morphology | No significant change; trend towards improvement | Kumar et al., 2006 |
| Sperm Viability | Increased viability and membrane integrity | Kumar et al., 2006; Esfiokhi et al., 2023 |
| Sperm Concentration | Increased sperm concentration and ejaculate volume | Kumar et al., 2006 |
| DNA Integrity | Likely protective via antioxidant activity | Esfiokhi et al., 2023 |

## HORMONAL REGULATION AND TESTICULAR FUNCTION

Zinc is essential for the regulation of testicular function and endocrine signaling pathways that govern male fertility. It directly influences the synthesis and secretion of testosterone by Leydig cells and supports the function of Sertoli cells, which are responsible for nurturing developing germ cells. Zinc also modulates the secretion of gonadotropins, particularly luteinizing hormone (LH) and follicle-stimulating hormone (FSH), through its involvement in hypothalamic–pituitary axis regulation. Deficiency in zinc has been associated with impaired testicular histology, reduced seminiferous tubule diameter, and decreased sperm output. Conversely, adequate zinc levels promote the proliferation and differentiation of spermatogenic cells, supporting efficient spermatogenesis and optimal testicular morphology.

The mineral zinc (Zn) plays a crucial role in supporting male reproductive function, notably by stimulating Leydig cells to produce testosterone, which in turn induces libido (Fallah et al., 2018). During spermatogenesis, zinc is essential for ribonuclease activity at the early stages of spermatogenesis and contributes to the maturation of spermatozoa throughout the process, ultimately enhancing sperm motility in the later stages. Zinc also exhibits antioxidant properties, functioning to neutralize reactive oxygen species (ROS). Furthermore, zinc protects germ cells from oxidative stress, which can otherwise impair the structure and function of spermatozoa (Sahu et al., 2020).

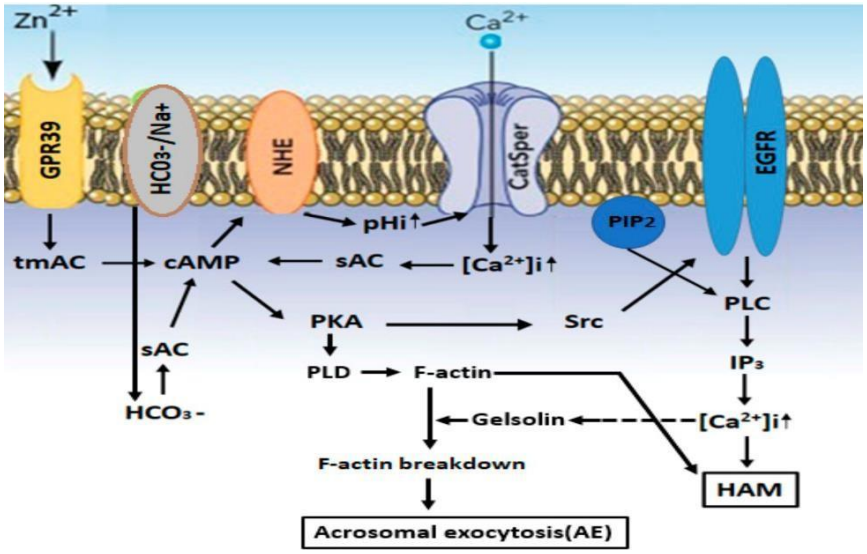


**Figure 1.** A model describing the mechanisms by $Zn^{2+}$ stimulates hyperactivated motility (HAM) and acrosomal exocytosis (AE): $Zn^{2+}$ binds to and activates the GPR39 receptor, which in turn stimulates transmembrane adenylyl cyclase (tmAC) to produce cyclic AMP (cAMP). This increase in cAMP activates the sodium/hudrogen exchanger (NHE), raising intracellular pH (pHi) and triggering CatSper activation. The resulting influx of $Ca^{2+}$, along with bicarbonate ions ($HCO_3^-$), activates soluble adenylyl cyclase (sAC), further elevating intracellular cAMP levels. Elevated cAMP activates protein kinase A (PKA), which then initiates the Src-EGFR-PLC signaling cascade, leading to inosotol triphosphate ($IP_3$) production. $IP_3$ mobilizes $Ca^{2+}$ Src-EGFR-PLC) cascade. This cascade results in the production of inosotol 1,4,5-trisphosphate ($IP_3$), which mobilizes $Ca^{2+}$ from intracellular acrosomal stores, thereby amplifying intracellular calcium concentrations and promoting hyperactivation. Concurrently, PKA activation stimulates phospholipase D1 (PLD1), facilating F-actin polymerization during sperm capacitation. Prior to AE, PLC hydrolyzes phosphatidylinositol 4,5-bisphosphate ($PIP_2$), leading to the release of the actin-severing protein gelsolin into the cytosol. Activated by $Ca^{2+}$, gelsolin induces F-actin depolymerization, thereby enabling acrosomal exocytosis. Adapted from Allouche-Fitoussi and Breitbart (2020).

**Table 3.** Effect of zinc supplementation on endocrine hormones

| Hormone | Effect | References |
|---|---|---|
| Leptin (ng/ml) | Increases leptin concentration during pre-calving and post-calving | Chandra et al., 2018 |
| Insulin (ng/ml) | Increases insulin concentration during pre-calving and post-calving | Chandra et al., 2018 |
| Growth Hormone (ng/ml) | Increases growth hormone concentration during pre-calving and post-calving | Chandra et al., 2018 |
| IGF-1(nmol/l) | Increases IGF-1 concentration during pre-calving and post-calving | Chandra et al., 2018 |
| Cortisol (ng/ml) | Increases cortisol concentration during pre-calving and post-calving | Chandra et al., 2018 |
| Triidothyronine (ng/ml) | Increases triiodothyronine concentration during pre-calving and post-calving | Chandra et al., 2018 |
| Thyroxine (ng/ml) | Increases thyroxine concentration during pre-calving and post-calving | Chandra et al., 2018 |

Zinc supplementation during the periparturient period has a positive effect on female cattle by supporting their condition before and after calving. It has been shown that zinc reduces stress and helps maintain endocrine hormone concentrations.

Zinc supplementation during the pre-calving and post-calving periods, at appropriate doses and durations, can enhance the immune system (Chandra et al., 2018). Zinc functions as an antioxidant and supports immune defense through its critical role in cell replication and proliferation (Wessels et al., 2017). It also protects cell membranes from inflammatory responses and, mediated by phosphorus, facilitates the migration of blood neutrophils (Finamore et al., 2008). The inclusion of zinc in the diet has been shown to improve immunity in both cows and calves (Dang et al., 2011; Wo et al., 2022).

## DOSE AND DURATION OF SUPPLEMENTATION

The efficacy of zinc supplementation on reproductive outcomes is influenced by both the administered dose and the duration of supplementation. Studies have employed varying concentrations, generally ranging from 30 to 120 mg of zinc per kg of dry matter (DM), with positive reproductive effects often observed at mid-range levels (e.g., 60–80 mg/kg DM). Prolonged supplementation for periods of 8 to 12 weeks tends to yield significant improvements in semen quality, aligning with the full cycle of spermatogenesis in bulls. However, excessively high doses may pose toxicity risks or lead to antagonistic interactions with other trace minerals such as copper. Therefore, precise dosing based on animal requirements, zinc source, and physiological status is essential to maximize reproductive benefits without compromising overall mineral balance.

**Table 4.** Zink dosage and duration

| | Zinc Dosage | Duration (Days) | Effect | References |
|---|---|---|---|---|
| IVF Medium | 0.4, 0.8 and 1.2 (µg/mL) | 6 | Improved viability, functional sperm membrane integrity (HOST), and sperm motility | Galarza et al., 2020 |
| IVF medium | 0.4, 0.8 and 1.2 (µg/mL) | - | Increased fertilization rate | Galarza et al., 2020 |
| IVF medium | 0.4, 0.8 and 1.2 (µg/mL) | - | Enhanced cleavage, blastocyst, and hatching rates | Galarza et al., 2020 |
| Pre-calving | 80 ppm, 120 ppm | 45 | Reduced postpartum estrus interval and service period; improved conception rate in dairy cows | Patel et al., 2016 |
| Post-calving | 80 ppm, 120 ppm | 45 | Improved reproductive efficiency in dairy cows | Patel et al., 2016 |
| Beef Cow | 400 mg | 9 | Increased preovulatory follicle size, plasma progesterone concentration, and pregnancy rates | Anchordoquy et al., 2019 |

Zinc supplementation in IVF medium improves sperm quality in vitro. Zinc acts as an activator of enzymes involved in energy metabolism, such as dehydrogenases and transferases. The activity of these enzymes generates energy required to support sperm motility, ensuring optimal movement during the fertilization process (Kerns et al., 2018). Additionally, zinc plays a crucial role as a hormonal modulator in the maturation of oocytes and the formation of cumulus-oocyte complexes (COCs) in cattle (Pascua et al., 2020).

## CONCLUSION

Zinc supplementation at specific dosages and durations can improve the efficiency of reproductive performance in cattle.

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