



## Trace Mineral Nutrition in Breeding Bulls: A Scientific Approach to Improving Semen Quality

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### INTRODUCTION

A breeding bull is more than an individual animal in a herd; he is a biological multiplier. Through artificial insemination, semen from a superior bull can be used in many females, making bull fertility important for genetic improvement, conception rate and livestock productivity. In field conditions, poor nutrition, heat stress, disease, low conception rate, shortage of quality bulls and mineral deficiencies can restrict reproductive efficiency. Bull fertility cannot be improved by one factor alone. It requires proper nutrition, health care, heat-stress management, semen evaluation, genetic selection and skilled insemination. Within this system, trace minerals are small but powerful nutritional components.

### Why trace minerals matter in bull reproduction

Trace minerals are required in minute quantities, usually expressed in parts per million in the diet. They differ from macro-minerals such as calcium, phosphorus, magnesium, sodium, potassium, chloride and sulphur, which are needed in larger amounts. Therefore, magnesium should be classified as a macro-mineral, not a trace mineral. The major trace minerals related to bull reproduction include zinc, copper, selenium, manganese, cobalt, iodine and chromium. Iron is essential for metabolism, but unnecessary iron supplementation should be avoided because excess iron may promote oxidative stress and interfere with other trace minerals. Ferrer et al. (2024) summarized that trace minerals are involved in testicular function, sperm physiology, antioxidant protection, DNA protection and reproductive performance in bulls.

**Table 1.** Key trace minerals and their reproductive relevance in breeding bulls

Trace mineral	Major biological role	Reproductive importance
Zinc	Enzyme activity, testosterone metabolism, sperm membrane stability	Supports spermatogenesis, motility and membrane integrity
Copper	Cu-Zn superoxide dismutase, oxidative balance	Helps antioxidant defence and enzyme function
Selenium	Glutathione peroxidase, lipid peroxide control	Protects sperm membrane and supports semen freezability
Manganese	Mitochondrial antioxidant defence, enzyme activation	Supports motility and sperm structural protection
Cobalt	Vitamin B12 synthesis in rumen	Indirect support through energy metabolism
Iodine	Thyroid hormone synthesis	Supports metabolic and endocrine regulation
Chromium	Stress and glucose metabolism	Possible indirect reproductive support; direct role less established

### Sperm cells and oxidative stress

Spermatozoa are highly specialized cells. They must remain motile, maintain an intact plasma membrane, preserve acrosomal structure and carry undamaged genetic material. However, they are highly sensitive to oxidative damage because their membranes contain polyunsaturated fatty acids. Reactive oxygen species are produced during normal metabolism. In small amounts, they are involved in sperm function, but excessive reactive oxygen species damage sperm membranes, reduce motility, disturb acrosome integrity and impair fertilizing ability. The risk becomes greater during semen cooling, dilution, freezing and thawing. Trace minerals help by supporting antioxidant enzymes. Zinc and copper are associated with Cu-Zn superoxide dismutase, manganese supports mitochondrial superoxide dismutase and selenium supports glutathione peroxidase. These systems reduce lipid peroxidation and help protect sperm cells.

### Mineral availability and antagonism

Feeding minerals does not guarantee their absorption. In ruminants, mineral availability depends on soil, rainfall, fodder type, water quality, mineral source and nutrient

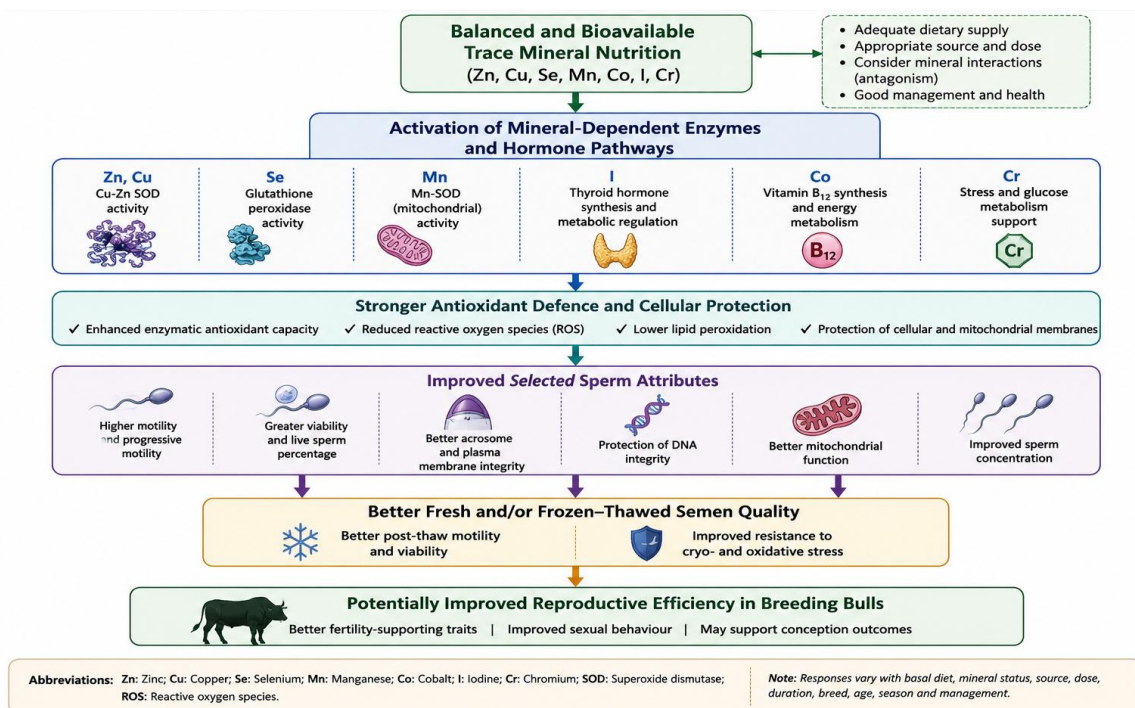
interactions. High molybdenum and sulphur can reduce copper availability. Excess iron may interfere with copper and zinc utilization. Some mineral sources have poor bioavailability. Thus, a ration may appear adequate on paper but may still fail to provide biologically available minerals. This is why mineral nutrition must focus on balance and bioavailability, not blind over-supplementation. Requirement-level supplementation meets normal needs. Deficiency correction restores low mineral status and is most likely to produce a response. Supranutritional supplementation means feeding above requirement but below toxic level; it may help under specific stress conditions, but response is not guaranteed.

### Evidence from breeding bull studies

Several studies show that trace mineral supplementation may improve selected semen traits without affecting general feeding parameters. In Sahiwal bulls, Thakur et al. (2019) supplemented trace minerals for 120 days and reported no major effect on body weight, dry matter intake or nutrient digestibility, but observed improvement in most seminal parameters and antioxidant status, along with reduced lipid peroxidation in fresh and frozen semen. Tarun et al. (2020) evaluated

manganese, chromium and cobalt supplementation in 12 Sahiwal bulls for 120 days. Supplementation did not influence body weight gain, intake or digestibility, but improved mass motility, initial progressive motility, live spermatozoa, normal spermatozoa, intact acrosome and HOST-positive sperm count in fresh and frozen semen. Srivastava et al. (2023) studied a bull-specific trace mineral mixture in 12 Karan Fries crossbred bulls for 120 days. Supplementation at 889 mg/kg diet on a dry matter basis improved antioxidant status in blood and

semen, testosterone, semen quality, sperm concentration, sexual behaviour and in-vitro sperm function. However, responses are not always dramatic. Geary et al. (2019, 2021) reported that trace mineral supplementation improved some novel sperm measures, such as oxidative-stress resistance and sperm viability after incubation, but did not cause major improvement in all laboratory or chute-side fertility measures. This shows that response may be greater under deficiency, stress or mineral-antagonistic conditions.



**Figure 1:** Proposed mechanism through which balanced trace mineral nutrition supports semen quality in breeding bulls

### Fresh semen versus frozen semen

Fresh semen and frozen-thawed semen should be interpreted separately. A sample may appear acceptable before freezing but lose motility, membrane integrity or acrosome integrity after thawing. Freezing creates oxidative, osmotic and cold-shock stress. Therefore, trace minerals may be especially useful in semen stations because antioxidant defence protects sperm cells during cryopreservation. The practical goal is not simply to collect more semen, but to produce semen that remains viable after

dilution, cooling, freezing, transport, thawing and insemination.

### Hormones and sexual behaviour

Trace minerals may influence reproductive hormones through enzyme activity, thyroid function and the hypothalamic-pituitary-gonadal axis. Zinc and copper are associated with steroidogenic pathways, while iodine supports thyroid hormone synthesis. However, hormone claims must be made carefully. If testosterone, libido score or reaction time data are not presented, the correct wording is that

supplementation may support sexual behaviour indicators, not that it definitely improves libido in all bulls.

### Practical implications

Under Indian conditions, breeding bulls may face heat stress, variable feed quality, mineral antagonists and management stress. These factors increase oxidative pressure and may reduce semen quality. Trace mineral supplementation can support reproductive function, but it cannot compensate for poor management, infection, severe heat stress, poor semen handling or genetic infertility. A good bull fertility programme should include balanced ration formulation, reliable mineral mixture, clean water, disease control, deworming, heat-stress management, proper body condition, regular semen evaluation and careful semen processing.

### CONCLUSION

Trace minerals are small nutrients with large reproductive importance. In breeding bulls, they support antioxidant defence, sperm membrane stability, acrosome integrity, endocrine function and semen freezability. Studies in Sahiwal and crossbred bulls suggest that balanced supplementation of zinc, copper, selenium, manganese, cobalt, iodine and chromium may improve selected semen-quality and antioxidant indicators, especially in marginally deficient or stressed bulls. The scientifically correct approach is not more minerals for more fertility, but balanced, bioavailable and need-based mineral nutrition. Used correctly, trace minerals can become an important precision tool for improving breeding bull reproductive management and semen quality.

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