THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
Popular article
June, 2026 Vol.6(6), 1782-1786

Bull Subfertility: The Hidden Challenge in Bovine Reproduction

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doi.org/10.5281/ScienceWorld.20998075

1. Introduction

Reproductive efficiency is one of the major determinants of profitability in dairy and buffalo farming. Considerable emphasis has traditionally been placed on improving female fertility however the fertility of breeding bulls is equally important because a single bull contributes genetically to hundreds or even thousands of offspring through artificial insemination (AI). Interestingly, research has demonstrated that bulls possessing apparently normal semen motility and morphology may still differ in fertility by as much as 20 percentage points under field conditions (Fair & Lonergan, 2018). Unlike infertility, which refers to the complete inability to produce offspring, bull subfertility is characterized by reduced reproductive performance despite the production of apparently normal semen and the absence of obvious clinical abnormalities. Such bulls often escape routine breeding soundness examinations because conventional semen evaluation does not always reflect actual fertilizing capacity (Fair & Lonergan, 2018). Consequently, even a small reduction in bull fertility can lead to significant economic losses due to decreased conception rates, increased insemination costs, prolonged calving intervals, reduced milk yield and slower genetic improvement (Parkinson, 2004; Fair & Lonergan, 2018). Although the concept of subfertility has been widely described in females as failure to establish pregnancy despite normal reproductive cycling (Royal et al., 2000) in breeding bulls it generally denotes reduced conception rates resulting from defects in libido, sperm function, semen quality or fertilizing ability.

Subfertility is one of the leading causes of disposal of breeding bulls maintained in semen production centres worldwide. Studies conducted in India have demonstrated that poor libido, poor semen quality and poor semen freezability are responsible for a considerable proportion of bull were removed in organized breeding programmes (Mukhopadhyay et al., 2010; Khatun et al., 2013). Earlier observations by Suryaprakasam and Rao (1993) also indicated that poor seminal characteristics were primarily responsible for culling Murrah buffalo and crossbred dairy bulls. Breed differences also influence reproductive performance. Indigenous breeds such as Sahiwal generally exhibit better seminal characteristics than many crossbred cattle. In contrast, crossbred bulls frequently produce ejaculates with reduced mass activity, lower sperm concentration and inferior post-thaw semen quality (Mukhopadhyay et al., 2010). In an evaluation of Frieswal breeding bulls only 45.09% consistently produced semen suitable for cryopreservation, whereas more than half produced poor-quality ejaculates unsuitable for routine freezing (Tyagi et al., 2000).These findings highlight that bull subfertility is not merely an occasional clinical problem but an important constraint affecting the efficiency of artificial insemination programmes and national genetic improvement strategies.

2.Importance of determining male Fertility

For many years, reproductive research has focused predominantly on female fertility. However fertility in the male is an equally complex trait involving coordinated interactions among the reproductive, endocrine, nervous and immune systems. Normal spermatogenesis, sperm maturation, ejaculation, libido and fertilization all contribute to successful conception (Parkinson, 2004). This observation emphasizes that conventional semen examination alone cannot explain the biological complexity of fertilization. The importance of sire fertility is further illustrated by studies showing that insemination timing exerts minimal influence when semen from highly fertile bulls is used. Conversely, conception rates decline significantly when semen from below-average fertility bulls is inseminated during early or mid-oestrus, indicating that sire fertility itself is a critical determinant of reproductive success (Macmillan & Curnow, 1977).

3. Major Causes of Bull Subfertility

Bull fertility is influenced by numerous interacting genetic, physiological and environmental factors. Consequently subfertility is considered a multifactorial disorder rather than the consequence of a single abnormality.

3.1 Poor Libido and Serving Capacity

Libido represents the willingness of a bull to seek, mount and successfully mate with a receptive female. Bulls exhibiting reduced sexual behaviour often fail to complete natural

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mating or provide semen of acceptable quality for artificial insemination. Libido may be affected by age, temperament, lameness, nutritional status, environmental stress and endocrine disturbances. Chenoweth (1986; 1997) concluded that libido testing alone cannot accurately identify fertile bulls; however, when combined with breeding soundness examination, it substantially improves the detection of subfertile animals.

3.2 Poor Semen Quality

Semen quality remains the cornerstone of breeding soundness evaluation. Reduced sperm concentration, decreased progressive motility, abnormal morphology and impaired membrane integrity directly compromise fertilization. Numerous studies have shown that poor seminal quality is among the most common reasons for disposal of breeding bulls in organized AI centres (Mukhopadhyay et al., 2010; Khatun et al., 2013) which cannot be easily saignosed using conventional semen evaluations.

3.3 Poor Semen Freezability

Cryopreservation is essential for modern artificial insemination programmes. Many bulls consistently produce semen that performs satisfactorily before freezing but undergoes severe deterioration following thawing. Reduced post-thaw motility, membrane damage and impaired fertilizing capacity make such bulls unsuitable for commercial semen production despite apparently normal fresh semen characteristics (Khatun et al., 2013).

3.4 Genetic and Molecular Factors

Fertility is strongly influenced by genetic variation affecting spermatogenesis, sperm maturation and embryo development. Genome-wide association studies have identified several genomic regions linked with semen quality and fertility traits in cattle, although no single molecular marker currently predicts fertility with sufficient accuracy for routine breeding programmes (Puglisi et al., 2016).

3.5 Environmental and Management Factors

Management practices significantly influence reproductive performance. Heat stress, inadequate nutrition, trace mineral deficiencies, poor housing, excessive semen collection frequency, transportation stress and infectious diseases adversely affect spermatogenesis and semen quality. Seasonal variations also influence semen characteristics and even bulls producing freezable semen may generate poor-quality ejaculates under stressful environmental conditions (Bhakat et al., 2009). Thus, bull subfertility represents the cumulative outcome of complex interactions among genetics, physiology, nutrition, health and management rather than a defect in any single reproductive parameter.

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4. Diagnosis, Emerging Technologies and Future Perspectives

Early detection of subfertility is essential to prevent the use of low-fertility bulls in breeding programmes. Traditionally breeding bulls are evaluated through a Breeding Soundness Examination (BSE), which combines physical examination with reproductive assessment. A standard BSE includes evaluation of general health, body condition, locomotion, scrotal circumference, examination of the testes and accessory sex glands, libido assessment, serving capacity and semen quality (Chenoweth, 1997; Parkinson, 2004).Routine semen analysis remains the foundation of fertility assessment and includes measurement of ejaculate volume, sperm concentration, mass activity, progressive motility, viability and sperm morphology. These parameters are useful for identifying severely infertile bulls; however, they possess only moderate predictive value for field fertility because fertilization depends upon several sperm functions that cannot be evaluated under a light microscope (Parkinson, 2004).Several studies have demonstrated that bulls with acceptable post-thaw motility and normal sperm morphology may still exhibit conception rates differing by emphasizing that conventional semen evaluation alone cannot reliably distinguish fertile from subfertile bulls (Fair & Lonergan, 2018).Recognizing these limitations, researchers have developed numerous laboratory assays to evaluate sperm function. These include assessments of plasma membrane integrity, acrosome integrity, mitochondrial membrane potential, sperm chromatin stability, capacitation status, oxidative stress, reactive oxygen species (ROS) production and DNA fragmentation. Collectively, these tests provide greater insight into sperm functionality than routine semen evaluation alone (Sellem et al., 2015).Despite these advances, no single laboratory test has consistently demonstrated sufficient sensitivity and specificity to predict fertility under field conditions. Consequently, the current recommendation is to combine clinical examination, libido assessment, semen evaluation and selected functional assays to improve the accuracy of breeding soundness evaluation (Chenoweth, 1997; Parkinson, 2004). Future bull fertility assessment focus on molecular biomarkers and OMICS technologies, including genomics, proteomics, transcriptomics and sperm miRNAs, which offer improved prediction of fertility beyond conventional semen evaluation (Parent et al., 1999; Rahman et al., 2017; Puglisi et al., 2016). Coupled with sound management, balanced nutrition and routine breeding soundness evaluation, these approaches can facilitate early identification of subfertile bulls and enhance reproductive efficiency (Bhakat et al., 2009; Khatun et al., 2013; Fair & Lonergan, 2018).

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Conclusion

Bull subfertility is a multifactorial disorder that remains one of the leading causes of reproductive inefficiency in cattle and buffalo. Nevertheless no single laboratory test currently provides a definitive assessment of bull fertility. Therefore integrating clinical examination, semen evaluation, functional sperm tests and molecular biomarkers represents the most reliable strategy for identifying high-fertility bulls and enhancing the success of artificial insemination programmes.

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