

Repeat breeding in livestock: Multifactorial causes and reproductive management approaches

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ABSTRACT

One of the main causes of lower farm output and reproductive efficiency in livestock is repeat breeding, a reproductive disease. The failure of female animals to become pregnant after multiple reproductive services, even when they continue to display seemingly normal estrous cycles and lack clinically noticeable reproductive defects, is typically the hallmark of this illness. In addition to lower conception rates, the ensuing effects include higher insemination rates, longer calving intervals, higher production expenses, and worse overall economic performance. A complex interplay of physiological, pathological, dietary, environmental, and management factors results in repeat breeding, a multifactorial disorder. Individual animal traits, endocrine and hormonal illnesses, anomalies of the reproductive tract, dietary imbalances, viral infections, and inadequate reproductive management techniques are some of the variables that have been linked to this syndrome. The underlying pathophysiological mechanisms might manifest at many phases of reproduction, such as poor follicular development, inadequate fertilization, a lower-quality uterine environment, failure of embryo development, and early pregnancy maintenance. With a focus on normal reproductive physiology, definition and classification, etiology and risk factors, pathophysiological mechanisms, diagnostic techniques, prevention and control strategies, and recent research advancements, this review article sought to give a thorough overview of the concept of repeat breeding. It is anticipated that a greater comprehension of the principles underpinning repeat breeding will aid in the creation of more successful reproductive techniques to raise livestock production systems' sustainability and reproductive efficiency.

Introduction

Because it directly affects production performance, generation intervals, and the economic efficiency of livestock operations, reproductive efficiency is a crucial indication of the productivity and sustainability of livestock systems (Theodoridis and Melfou, 2025). An animal's ability to conceive and sustain a pregnancy in order to generate viable offspring are both factors that affect its reproductive success (Evans *et al.*, 2022). Repeated breeding is one of the many reproductive illnesses that can lower reproductive performance and result in large financial losses in livestock production techniques (Pongkapadang *et al.*, 2025).

The inability of a female animal to become pregnant following multiple reproductive services while still displaying seemingly normal estrous cycles and no clinically evident reproductive problems is known as repeat breeding (Pérez-Marín and Quintela, 2023). Due to its frequent occurrence in a variety of production systems and its contribution to low reproductive efficiency, this condition is a major problem in the field of veterinary reproduction (Moore *et al.*, 2021). In addition to affecting conception rates, repeat breeding also results in higher rates of insemination or mating, longer calving intervals, higher maintenance expenses, and worse overall productivity (Rafi *et al.*, 2026).

Because repeat breeding entails disturbances at different stages of reproduction, it is a complicated biological condition (Rofiqi *et al.*, 2023). Hormone modulation, follicle development, gamete quality, fertilization, embryo development, and the uterus' capacity to sustain an early pregnancy must all be precisely coordinated for a normal reproductive process (Nowicki, 2021). Before pregnancy can be sustained, imbalances in

one or more of these stages might decrease the likelihood of conception or cause embryo loss (Carbonari *et al.*, 2024). Because of its complexity, recurrent breeding is a multifactorial situation that is challenging to explain using a single process (Ravichandran *et al.*, 2026).

Repeated breeding has been linked to a number of issues, including individual animal traits, endocrine abnormalities, reproductive tract modifications, dietary status, viral infections, environmental factors, and reproductive management approaches (Eshete *et al.*, 2023). Each individual will have a distinct reproductive response depending on how these elements interact or function separately (Satrio *et al.*, 2025). Furthermore, it is frequently difficult to determine the cause of repeat breeding in reproductive practice because many cases occur subclinically without exhibiting anatomical alterations or particular clinical signs (Hermadi *et al.*, 2026).

Our knowledge of the mechanisms causing repeat breeding has expanded in recent decades due to advances in reproductive science (Stevenson and Britt, 2017). In order to understand the reasons behind recurring conception failure, research has started to incorporate molecular, physiological, immunological, and metabolic methods in addition to traditional assessments of anatomy and reproductive function (Pohler *et al.*, 2020). Additionally, potential for earlier diagnosis of reproductive alterations and improved accuracy of intervention strategies are presented by advances in diagnostic technologies (Balhara *et al.*, 2013). However, due to variations in livestock populations, husbandry systems, assessment techniques, and the complexity of the elements involved, the research findings that are now accessible still demonstrate variation (Maulana *et al.*, 2022).

In order to enable the development of more effective reproductive techniques, a more thorough understanding of repeat breeding is essential given the substantial biological and economic implications. This review article aimed to present a scientific overview of the basic concepts of repeat breeding, related reproductive physiology, etiology and risk factors, pathophysiological mechanisms, diagnostic approaches, prevention and control strategies, and current research developments that can support increased reproductive efficiency in livestock. It is envisaged that by comprehending the connections between the many elements involved, a more focused and long-lasting reproductive strategy to deal with the issue of repetitive breeding can be created.

Normal reproductive physiology and fertility mechanism

The endocrine system, reproductive organs, uterine environment, and cellular systems cooperate in a coordinated manner to achieve conception and sustain pregnancy (Halloran and Stenhouse, 2025). The continuation of several biological stages, beginning with the initiation of the reproductive cycle, gamete maturation, fertilization, embryonic development, and the establishment of physiological communication between the embryo and the mother, determines the success of reproduction in livestock (Zhang *et al.*, 2013). Any of these phases can be disrupted, which lowers reproductive efficiency and raises the possibility of repeated conception failure (Szelényi *et al.*, 2023).

The hypothalamic-pituitary-ovarian axis, which regulates hormonal changes throughout the reproductive cycle, is the first organ involved in reproductive regulation (Shimizu, 2016). Gonadotropin-releasing hormone (GnRH), which is produced by the brain, causes the anterior pituitary to release luteinizing hormone (LH) and follicle-stimulating hormone (FSH) (Hassanein *et al.*, 2024). Through a feedback loop involving ovarian steroid hormones, namely progesterone and estrogen, these two hormones control follicle development, oocyte maturation, and ovulation (Zhang *et al.*, 2021). Ovarian activity and the reproductive tract's preparedness for conception can coincide thanks to this hormonal synergy (Mapletoft *et al.*, 2018).

Ovarian follicles grow and are selected during the follicular phase until a dominant follicle emerges that produces more and more estrogen (Noseir, 2003). Through modifications in cervical mucus, reproductive tract motility, and uterine secretory activity, this hormone contributes to the initiation of estrus behavior and the preparation of the reproductive environment (Bernardi *et al.*, 2016). When an oocyte reaches maturity, a spike in LH causes ovulation, which releases the oocyte into the oviduct, which is the main site of fertilization (Khalil *et al.*, 2025).

A competent egg and a spermatozoon with adequate fertilization capacity must meet for fertilization to be successful (Mikkola *et al.*, 2024). The spermatozoon experiences several physiological changes following deposition in the reproductive canal, which enable capacitation and contact with the oocyte (Kaya *et al.*, 2026). A zygote is created following fertilization, and as it migrates to the uterus, it gradually divides its cells (Georgadaki *et al.*, 2016). The quality of the gametes and the reproductive tract's microenvironmental settings have a significant impact on the early stages of embryonic development (Denicol and Siqueira, 2023).

The embryo continues to develop after entering the uterus and starts to communicate biologically with the tissues of the mother (Sánchez *et al.*, 2019). In addition to serving as a place for development, the uterus actively contributes to the survival of the embryo during this stage by producing growth hormones, immunological mediators, and nutrient secretions (Bazer and Johnson, 2024). The synchronization of endometrial readiness and embryo age has a significant impact on successful embryo growth (Moraes *et al.*, 2018).

Maternal identification of pregnancy, a process by which the embryo communicates with the mother to preserve corpus luteum function and avoid luteolysis, is the next stage that determines the continuation

of pregnancy (Bazer, 2013). By ensuring that progesterone production continues, this procedure keeps the uterus in a state that is favorable for the growth of the embryo (Lonergan *et al.*, 2016). Even if fertilization has gone well, early embryo loss may result from a breakdown in embryo-maternal communication during this stage (Teja *et al.*, 2024).

Hormonal modulation, gamete competency, reproductive tract function, and uterine environmental adaption are all physiologically coordinated throughout the entire reproductive process (Athar *et al.*, 2024). When every stage continues in unison without any physiological or pathological disruptions, reproductive efficiency is attained (Mansur *et al.*, 2024). Therefore, in order to explain the biological alterations behind repetitive breeding and to assist the development of more efficient diagnostic techniques and reproductive control strategies, it is imperative to comprehend normal reproductive mechanisms (Hill, 2016). The coordinated endocrine, ovarian, gamete, uterine, and embryo-maternal processes that support successful conception and pregnancy establishment are summarized in Figure 1.

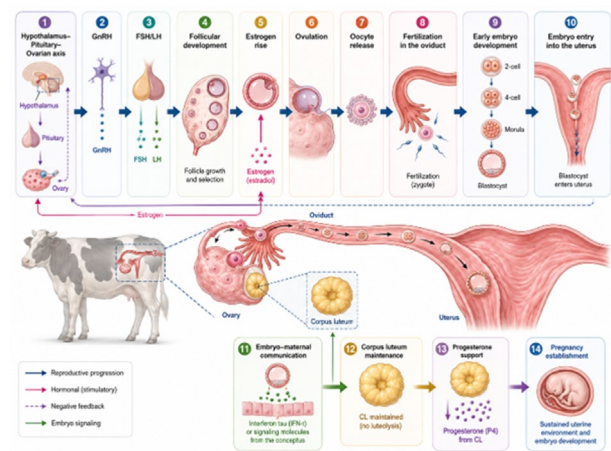


Figure 1. Coordinated reproductive physiology leading to successful pregnancy in livestock.

Definition and classification of repeat breeding

Even when the animal continues to display seemingly normal reproductive cycle activity, repeat breeding is a reproductive disease marked by the inability to conceive following many reproductive services (Pérez-Marín and Quintela, 2023). Because it is closely linked to lower output, higher reproductive costs, and longer intervals between pregnancies, this condition is prevalent in contemporary livestock systems and is a crucial indicator in assessing reproductive efficiency (Hermadi *et al.*, 2025). Repeated breeding indicates a disruption in one or more reproductive phases that prevents effective conception or the continuation of the original pregnancy, even though clinically the animal frequently exhibits no visible abnormalities (Maulana *et al.*, 2022).

When a female does not conceive after three or more natural matings or artificial inseminations carried out within a typical estrous cycle and utilizing the proper reproductive techniques, it is generally referred to as repeat breeding (Sheikh *et al.*, 2025). In addition to taking into account the quantity of reproductive services, this definition also stipulates that there must be no visible anatomical anomalies related to reproduction or systemic diseases that could be the direct cause of reproductive failure (Rofiqi *et al.*, 2023). Therefore, rather than being a single etiological diagnosis, repeat breeding is better regarded as a clinical expression of diminished fertility (Satrio *et al.*, 2025).

From a biological perspective, this condition denotes the persistence of fundamental reproductive processes, such as ovarian activity, the start of estrus, and the potential for ovulation (Sitko *et al.*, 2024). However, variations in the fertilization process, gamete quality, reproductive environment, embryonic development, or the sow's capacity to sustain preg-

nancy all impair reproductive success (Tummaruk *et al.*, 2001). Repeat breeding is regarded as a multifaceted disorder with a complex etiology since the underlying mechanisms may involve multiple physiological systems (Villar *et al.*, 2025a).

In general, repeat breeding can be divided into two categories: apparent repeat breeding and actual repeat breeding, depending on the features of the underlying reason (Eshete *et al.*, 2023). This classification is used to determine if biological abnormalities within the individual are the primary cause of conception failure or if extrinsic factors connected to reproductive management have a greater influence (Salman *et al.*, 2021).

A condition known as true repeat breeding occurs when animals repeatedly fail to conceive, mostly as a result of internal reproductive system problems (Gustafsson and Emanuelson, 2002). In this group, most reproductive procedures are carried out correctly, but because of physiological or pathological alterations that frequently take place subclinically, conception is nonetheless unsuccessful (Pongkapadang *et al.*, 2025). Impaired follicular development, hormonal imbalance, reduced oocyte quality, uterine dysfunction, poor embryo-maternal communication, or early embryonic mortality are some of the possible contributing factors (Miętkiewska *et al.*, 2022). Identifying actual repeat breeding frequently necessitates a more thorough reproductive assessment because the causes are not always readily apparent (Waqas *et al.*, 2025).

On the other hand, apparent repeat breeding describes a situation in which animals have a comparatively normal capability for reproduction but fail to conceive because of outside conditions that prevent successful reproduction (Budruk, 2023). Inaccurate estrus detection, improper insemination timing, poor semen quality, improper insemination methods, and other management limitations are a few examples of these problems (Amanuel and Tekalign, 2020). Without the need for intricate therapeutic interventions, advancements in reproductive practices and husbandry systems frequently lead to higher conception rates in this group (Yusuf *et al.*, 2012).

Reproductive failure does not always indicate a serious disease of the reproductive organs, as shown by the division of recurrent breeding into these two categories (Carbonari *et al.*, 2024). This classification has significant diagnostic utility in field practice because it facilitates the choice of suitable intervention strategies, directs more effective examination techniques, and aids in determining evaluation priorities (Ranganath *et al.*, 2022). Thus, a thorough comprehension of the definition and categorization of repetitive breeding serves as the foundation for determining

the underlying causes and creating more efficient and long-lasting reproductive management initiatives (Ulansari *et al.*, 2026).

Etiology and risk factors of repeat breeding

A complex interplay of biological, pathological, environmental, and management factors leads to the development of repeat breeding, a multifactorial reproductive syndrome (Satrio *et al.*, 2025). Repeat breeding is typically the consequence of a series of alterations that impact reproductive effectiveness at one or more stages, from gamete maturation and fertilization to early embryonic development and pregnancy maintenance, in contrast to reproductive diseases, which have a single, particular cause (Bonneville-Hébert *et al.*, 2011). Because of this complexity, determining the cause is frequently difficult because afflicted animals may have seemingly normal estrous cycles without overt reproductive problems (Pérez-Marín and Quintela, 2023). Table 1 summarizes the main etiological and risk factors contributing to repeat breeding.

The synchronization of endocrine function, gamete quality, reproductive tract conditions, and the uterine environment's ability to support embryo development are all physiologically necessary for successful reproduction (Mansour, 2025). An imbalance in any one of these factors can raise the risk of repeated reproductive failure and decrease the possibility of pregnancy (Wahyuningrum *et al.*, 2024). Additionally, the risk variables that affect recurrent breeding frequently interact rather than functioning individually, which increases their effect on fertility (Caro *et al.*, 2026).

Reproductive ability is mostly determined by factors that come from individual animals (Saraswat and Purohit, 2016). Oocyte quality, hormonal reactivity, and the capacity to sustain pregnancy can all be impacted by age, parity, genetic background, physical state, and physiological state (Cimadomo *et al.*, 2018). While inadequate metabolic conditions can interfere with hormone regulation and lower overall reproductive competence, increasing reproductive age is frequently linked to decreasing ovarian function efficiency and changes in gamete quality (Puttabyatappa and Padmanabhan, 2018).

Because the reproductive system depends so largely on exact hormonal coordination, endocrine and hormonal diseases also play a major role in repetitive breeding (Pérez-Marín and Quintela, 2023). Early in pregnancy, changes in the hypothalamic-pituitary-ovarian axis can affect follicle development, ovulation timing, corpus luteum production, and uterine environment maintenance (Mlyczyńska *et al.*, 2022). Hormonal

Table 1. Main etiological components and risk factors associated with repeat breeding.

Etiological factor	Main components	Mechanism affecting reproduction	Potential consequences	References
Animal-related factors	Age, parity, genetic background, body condition, physiological status	Influence oocyte quality, hormonal responsiveness, ovarian function, and the ability to maintain pregnancy	Reduced fertility and increased risk of conception failure	Saraswat and Purohit (2016); Cimadomo <i>et al.</i> (2018); Puttabyatappa and Padmanabhan (2018)
Endocrine and hormonal disorders	Dysregulation of the hypothalamic-pituitary-ovarian axis, ovulatory dysfunction, corpus luteum disorders	Cause disruption of follicular development, ovulation timing, and maintenance of the uterine environment	Low conception rate and increased early embryonic loss	Pérez-Marín and Quintela (2023); Mlyczyńska <i>et al.</i> (2022); Turesheva <i>et al.</i> (2023)
Reproductive tract disorders	Disorders affecting the uterus, cervix, and oviduct	Impair gamete transport, reduce endometrial receptivity, and interfere with embryo development	Fertilization failure and reduced establishment of early pregnancy	Akhtar <i>et al.</i> (2025); Zhang <i>et al.</i> (2013); Villar <i>et al.</i> (2025a)
Nutritional factors	Imbalance of energy, protein, vitamins, and minerals	Alter metabolic status, hormonal activity, and gamete quality, and induce oxidative stress	Reduced reproductive cell viability and impaired embryonic development	Noetzold and Zuidhof (2025); Silvestris <i>et al.</i> (2019); Mauchart <i>et al.</i> (2023)
Infectious factors	Local or systemic infections affecting the reproductive system	Induce inflammation, alter endometrial function, and disrupt embryo-maternal communication and hormonal balance	Reduced conception rate and impaired pregnancy maintenance	Gilbert (2019); Kasimanickam <i>et al.</i> (2025); Taru <i>et al.</i> (2024)
Management factors	Estrus detection, insemination timing, semen quality, reproductive management practices, record keeping	Determine synchronization accuracy between reproductive interventions and the physiological condition of the animal	Repeated conception failure despite apparent reproductive normality	Félix-Santiago <i>et al.</i> (2026); Zahrorona <i>et al.</i> (2025); Satrio <i>et al.</i> (2025)
Environmental factors	Temperature, humidity, stocking density, environmental stress	Disturb hormonal balance and metabolic adaptation mechanisms	Reduced reproductive efficiency and increased risk of repeat breeding	Purba <i>et al.</i> (2025); Khan <i>et al.</i> (2023); Maulana <i>et al.</i> (2022)

imbalances can lower conception rates and raise the risk of early embryo loss even though they frequently do not show clear clinical symptoms (Turesheva *et al.*, 2023).

The state of the reproductive tract has a direct impact on the success of conception in addition to hormonal modulation (Akhtar *et al.*, 2025). Changes in the reproductive environment that impede gamete transit, decrease endometrial receptivity, or interfere with embryo development can result from disorders of the uterus, cervix, or oviduct (Zhang *et al.*, 2013). These alterations are frequently asymptomatic and challenging to identify without a more thorough reproductive assessment (Villar *et al.*, 2025a).

Because reproduction is a process that necessitates substantial metabolic support, nutritional status plays a crucial role in influencing reproductive effectiveness (Noetzold and Zuidhof, 2025). Hormonal activity, gamete quality, and the uterus's capacity to sustain embryonic development can all be impacted by imbalances in energy, protein, minerals, and vitamins (Silvestris *et al.*, 2019). Moreover, alterations in metabolic state can lead to oxidative stress, which affects the stability of early embryonic development and the viability of reproductive cells (Mauchart *et al.*, 2023).

Through systemic impacts on the body's physiological balance and local alterations in the reproductive organs, infectious illnesses also lead to decreased fertility (Gilbert, 2019). Inflammation, altered endometrial function, disruption of embryo-maternal communication, and disruption of the hormonal balance required during pregnancy are all consequences of infectious pathogens (Kasimanickam *et al.*, 2025). Since many infections are subclinical, it is sometimes only after repeated conception failures that their effects on reproduction become apparent (Taru *et al.*, 2024).

Reproductive success is greatly impacted by management, an external determinant in addition to biological reasons (Félix-Santiago *et al.*, 2026). Conception rates are influenced by a number of factors, including accurate estrus detection, timing of insemination, semen quality, reproductive care methods, husbandry systems, and the caliber of reproductive records (Zahrerona *et al.*, 2025). In animals that are physically fertile, mistakes in reproductive control might result in recurring miscarriages (Satrio *et al.*, 2025).

Additionally, since rearing conditions affect an animal's physiological reactions and metabolic adaptations, environmental effects cannot be disregarded (Purba *et al.*, 2025). Reproductive efficiency can be lowered and hormonal balance altered by exposure to stressors like as temperature, humidity, cage crowding, and environmental changes (Khan *et al.*, 2023). Over time, these circumstances may raise the likelihood of repeated reproduction, particularly in species with low potential for adaptation (Maulana *et al.*, 2022).

Pathophysiology of repeat breeding

Despite the animal's seemingly normal reproductive activity, the pathophysiology of recurrent breeding is a complicated process involving disturbances at many phases of reproduction, leading to failure to obtain or maintain pregnancy (Pérez-Marín and Quintela, 2023). Repeat breeding indicates a decline in reproductive efficiency brought on by flawed interactions between the endocrine system, gamete quality, reproductive tract function, uterine environment, and embryonic development, in contrast to absolute infertility, which is defined by the loss of reproductive function (Taru *et al.*, 2024). Animals can experience estrus on a regular basis and receive repeated reproductive services without becoming pregnant due to the complexity of these systems (Arashiro *et al.*, 2017).

Reduced oocyte quality and poor follicular development can initiate the pathophysiological process of recurrent breeding prior to fertilization (Nehra *et al.*, 2012). Incomplete maturation reduces the ability of oocytes to fertilize and limits the growth of embryos following conception (Lee *et al.*, 2011). Changes in hormone regulation, metabolic disorders, or phys-

iological stress that impact the ovarian microenvironment are frequently linked to this illness (Kasimanickam *et al.*, 2026). Moreover, improper ovulation timing may result in less synchronization between the release of oocytes and the availability of viable sperm in the reproductive system (Nakao *et al.*, 2023).

Changes in the reproductive environment can prevent gametes from meeting and interacting during the fertilization stage (Deneke *et al.*, 2024). Sperm's capacity to reach the fertilization site or the effectiveness of the oocyte capacitation and penetration processes can be compromised by disruptions in cervical mucus, reproductive tract motility, or oviduct biochemistry (Ikawa *et al.*, 2010). Consequently, conception does not always happen even with regular insemination and the use of semen of sufficient quality (Eshete *et al.*, 2023).

The ability of the embryo to develop during the early stages of life determines the success of subsequent reproduction if fertilization takes place (Nowicki, 2021). Because the embryo still depends on the inherent quality of the fertilized product and the nurturing maternal environment, the early stages of embryonic development are especially fragile (Besenfelder and Havlicek, 2023). Delays in embryonic development, poor cell differentiation, or early embryonic mortality might result from metabolic abnormalities, subclinical inflammation, hormonal imbalances, or changes in uterine secretory activity (Várhidi *et al.*, 2024). Animals under these circumstances typically resume their estrus cycles without exhibiting any obvious symptoms of pregnancy loss (De Rensis *et al.*, 2024).

As the major location of interaction between the embryo and the mother, the uterine environment is crucial to the pathophysiology of repeat breeding (Funeshima *et al.*, 2021). In order to facilitate embryo implantation and development, the endometrium must be responsive (Oishi *et al.*, 2026). Growth factors, immunological mediators, and chemicals involved in embryo-maternal communication can all be secreted differently when endometrial structure and function are altered (Yaginuma *et al.*, 2019). Even if there are no overt clinical signs, persistent, mild inflammation might change the uterine milieu and lower the likelihood of a healthy pregnancy (Segabinazzi *et al.*, 2021).

Repeated breeding is also greatly influenced by endocrine variables (Ahammed *et al.*, 2018). Reduced progesterone production, poor corpus luteum formation, and reduced follicle development can all result from imbalances in the production of reproductive hormones (Thasmi *et al.*, 2025). In order to sustain uterine circumstances that promote embryo growth, progesterone is essential (Nowicki, 2021). The uterus' capacity to give the embryo a stable environment is diminished when levels of this hormone are low, raising the possibility of embryo loss in the early stages of pregnancy (Dochi *et al.*, 2008).

Apart from hormonal processes, the reproductive immune system also contributes to the equilibrium between protection against external agents and embryo tolerance (Wu *et al.*, 2022). The uterus can produce an immunological milieu that facilitates implantation without causing an overwhelming inflammatory response under normal physiological parameters (Benkhalifa *et al.*, 2022). However, altered immune modulation may result in elevated local inflammatory activity that prevents the development of the embryo or obstructs the sow's ability to detect pregnancy (Wang *et al.*, 2025). The chance of repeated breeding failure is significantly increased by this immune response imbalance (Hermadi *et al.*, 2026).

The relationship between the reproductive system and the body's metabolic condition also affects the pathophysiology of repetitive breeding (Villar *et al.*, 2025a). Inadequate energy levels can impact the release of reproductive hormones, lower the quality of oocytes, and hinder the development of the embryo (Serbetci *et al.*, 2024). Additionally, oxidative mediators that harm reproductive cell integrity and impede physiological processes required to sustain pregnancy can be produced more frequently as a result of metabolic stress (Ojo *et al.*, 2023). The major biological disruptions involved in repeat breeding, from impaired gamete competence to early embryonic loss, are illustrated in Figure 2.

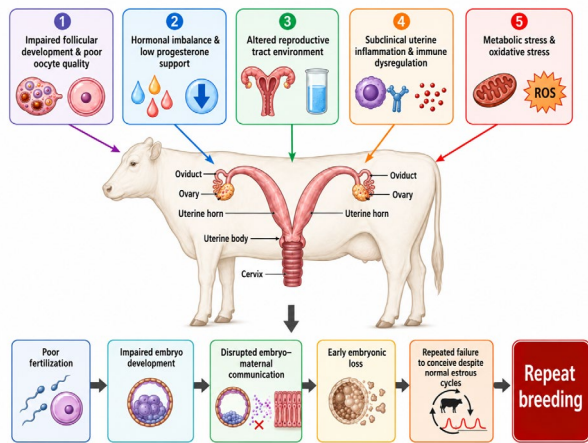


Figure 2. Multifactorial pathophysiological cascade of repeat breeding in livestock

Diagnosis

Because repeat breeding cannot be diagnosed based only on the number of unsuccessful conceptions, a thorough approach is needed to consider the interaction of multiple factors that affect reproductive success (Eshete *et al.*, 2023). The diagnostic method seeks to pinpoint the site of disruption in the reproductive chain and rule out the potential of illness or other disorders that could cause infertility because recurrent breeding is a complex condition with frequently ambiguous clinical signs (Pongkapadang *et al.*, 2025). To determine if subclinical reproductive illnesses, management-related external factors, or inherent animal factors are the main causes of reproductive failure, a methodical diagnostic approach is necessary (Maulana *et al.*, 2022). Table 2 summarizes the main components of a stepwise and integrated approach to the diagnosis of repeat breeding.

A comprehensive assessment of the reproductive history is the first step in the diagnosing process (Hermadi *et al.*, 2026). To get a picture of the characteristics of the unsuccessful conception, data on age, breed, parity, postpartum interval, number and timing of prior reproductive services, pregnancy history, estrus patterns, and reproductive problems should be examined (Salman *et al.*, 2021). Good reproductive records

make it possible to spot trends that can point to suspected reasons such as insemination mistakes, early embryo loss, or unsuccessful fertilization (Ooi *et al.*, 2023).

The next step in evaluating the structure and functionality of the reproductive organs is a clinical reproductive examination (Ferreira *et al.*, 2008). Evaluation is done to find uterine involution issues, organ size changes, structural anomalies, or indications of inflammation that may impact fertility (Taru *et al.*, 2024). Additionally, the examination seeks to evaluate uterine health in relation to reproductive readiness, ovarian activity, and the existence of follicles or the corpus luteum (Dolinko *et al.*, 2024). The clinical examination is still the foundation for deciding the course of additional testing, even if many cases of recurrent breeding do not exhibit clear structural abnormalities (Yusuf *et al.*, 2010).

The ability to visualize ovarian and uterine abnormalities in greater depth makes reproductive ultrasonography examination a valuable diagnostic tool (Medan and El-Aty, 2010). This method makes it possible to assess follicular dynamics, corpus luteum activity, endometrial structural alterations, intrauterine fluid accumulation, and signs of subclinical reproductive diseases more precisely (Fricke, 2002). Ultrasound aids in monitoring reproductive cycle synchronization and evaluating the potential for early embryo loss in addition to identifying anomalies (Sahu *et al.*, 2025).

An essential component of comprehending reproductive function that cannot be seen through physical examination is hormonal evaluation (Carbonari *et al.*, 2024). Evaluation of reproductive hormone profiles reveals details on luteal function, ovarian activity, and estrous cycle coordination (Barui *et al.*, 2015). Hormonal changes could be a sign of endocrine imbalances, corpus luteum insufficiency, or ovulatory abnormalities that lead to infertility (Selvaraju *et al.*, 2020). This method is essential for examining cases of repeat breeding since many hormonal abnormalities manifest subclinically (Abraham, 2017).

To identify abnormalities that are not clinically noticeable, laboratory tests of reproductive health are also required (Sheikh *et al.*, 2025). In order to detect subclinical reproductive problems, uterine conditions can be evaluated using cytology, microbiology, and inflammatory biomarker studies (Janowski *et al.*, 2013). These tests aid in determining whether alterations in the uterine environment that prevent fertilization or embryo

Table 2. Diagnostic approaches for identification of repeat breeding and determination of underlying causes.

Diagnostic component	Main evaluation	Diagnostic objective	Potential findings	References
Reproductive history assessment	Age, breed, parity, postpartum interval, number and timing of reproductive services, pregnancy history, estrus patterns, and history of reproductive disorders	Identify patterns of conception failure and determine predisposing factors contributing to repeat breeding	Suspected fertilization failure, early embryonic loss, or inappropriate reproductive management	Hermadi <i>et al.</i> (2026); Salman <i>et al.</i> (2021); Ooi <i>et al.</i> (2023)
Clinical reproductive examination	Evaluation of reproductive organ anatomy and function, uterine involution, signs of inflammation, and ovarian activity	Assess overall reproductive status and detect structural or functional abnormalities	Uterine abnormalities, ovarian changes, impaired uterine involution, or absence of obvious clinical alterations	Ferreira <i>et al.</i> (2008); Taru <i>et al.</i> (2024); Dolinko <i>et al.</i> (2024); Yusuf <i>et al.</i> (2010)
Reproductive ultrasonography	Visualization of ovarian structures, follicular dynamics, corpus luteum, endometrial morphology, and uterine condition	Evaluate reproductive dynamics and detect subclinical reproductive disturbances	Abnormal follicular development, endometrial alterations, intrauterine fluid accumulation, or indications of early embryonic loss	Medan and El-Aty (2010); Fricke (2002); Sahu <i>et al.</i> (2025)
Hormonal evaluation	Assessment of reproductive hormone profiles and ovarian function	Evaluate endocrine coordination and synchronization of the reproductive cycle	Ovulatory disorders, corpus luteum insufficiency, or hormonal imbalance	Carbonari <i>et al.</i> (2024); Barui <i>et al.</i> (2015); Selvaraju <i>et al.</i> (2020); Abraham (2017)
Laboratory examination	Cytology, microbiological analysis, and reproductive inflammatory biomarkers	Identify subclinical alterations in the reproductive environment	Uterine inflammation, disruption of the uterine environment, or indications of impaired fertility	Sheikh <i>et al.</i> (2025); Janowski <i>et al.</i> (2013); Pothmann <i>et al.</i> (2015)
Molecular and biomarker-based approaches	Molecular, genetic, immunological, and metabolic analyses	Improve detection sensitivity for physiological changes that are not clinically observable	Altered reproductive biomarkers and indications of dysfunction at the molecular level	Ayantoye <i>et al.</i> (2025); Marrella and Biase (2023); Gustafsson and Emanuelson (2002)
Management and environmental evaluation	Estrus detection systems, semen quality, insemination techniques, nutritional management, housing conditions, and reproductive record assessment	Determine the contribution of external factors to conception failure	Inappropriate insemination timing, suboptimal reproductive performance, or management incompatibility	Saraswat and Purohit (2016); Maulana <i>et al.</i> (2022); Eshete <i>et al.</i> (2023)

development are linked to reproductive failure (Pothmann *et al.*, 2015).

The use of genetic techniques and reproductive biomarkers to boost detection sensitivity is also made possible by advances in diagnostic technology (Ayantoye *et al.*, 2025). The identification of physiological alterations linked to reproductive quality at the genetic, immunological, and metabolic levels is made possible by molecular analysis (Marrella and Biase, 2023). Since most instances of recurrent breeding do not always result in morphological alterations that can be identified by traditional methods, this strategy is becoming more and more important (Gustafsson and Emanuelson, 2002).

The diagnosis of repetitive breeding necessitates taking management and environmental variables that may impact reproductive efficiency into account in addition to individual assessments (Saraswat and Purohit, 2016). Finding the root reasons of conception failure requires evaluating the estrus detection system, semen quality, insemination methods, dietary plans, husbandry circumstances, and the caliber of reproductive records (Maulana *et al.*, 2022). This assessment is required because reproductive incompatibility, rather than animal biological diseases, is often the cause of repetitive breeding (Eshete *et al.*, 2023).

Prevention and control strategies

Because this condition is not produced by a single mechanism but rather arises from the interplay of physiological, pathological, dietary, environmental, and reproductive management elements, preventing and regulating repeat breeding necessitates a multidimensional strategy (Satrio *et al.*, 2025). Therefore, intervention measures should address predisposing factors that affect total reproductive success in addition to raising conception rates (Coman *et al.*, 2024). Reducing the frequency of repeated conception failure and permanently improving reproductive efficiency require an integrated approach (Walsh *et al.*, 2011).

Optimizing reproductive control is a crucial part of reducing repetitive breeding (Satrio *et al.*, 2025). The timing of reproductive services that correspond with ovulation dynamics depends critically on the accurate detection of estrus (Hermadi *et al.*, 2026). A lack of synchronization between sperm availability and oocyte release might result from inaccurate estrus identification, which lowers the likelihood of conception (Dodicho *et al.*, 2026). Therefore, the introduction of regular reproductive protocols, consistent reproductive documentation, and systematic monitoring of reproductive behavior are essential stages in increasing conception efficiency (Nishi *et al.*, 2018).

Another essential component of the control method is proper insemination (Canu *et al.*, 2010). In addition to using high-quality semen, insemination timing, operator expertise, and semen handling all have a role in reproductive success (Mengistu *et al.*, 2026). The likelihood of fertilization can be increased and the frequency of reproductive failure due to technical issues can be decreased by performing reproductive procedures consistently and in accordance with the animal's physiological condition (Coman *et al.*, 2024).

One preventative strategy that has a wide-ranging effect on reproductive function is improving nutritional condition (Hasan *et al.*, 2021). Ovarian activity, follicle development, oocyte quality, and the uterus's capacity to support embryo development all depend on a balance between physiological requirements and food availability (Butler, 2003). Maintaining hormonal stability and reducing the negative effects of metabolic stress on reproduction can be achieved by creating a dietary plan that considers the animal's bodily condition, production phase, and metabolic requirements (Ibtisham *et al.*, 2018).

Reducing the prevalence of repeat breeding also heavily depends on managing reproductive health issues (Pongkapadang *et al.*, 2025). Frequent monitoring of reproductive health enables early identification of potential fertility-impairing alterations before they become chronic problems (Kasimanickam *et al.*, 2026). Risk factors that may contribute to conception failure can be identified by evaluating the uterine condition,

ovarian activity, and reproductive status following parturition (Nasution *et al.*, 2021). A more favorable reproductive environment is also created by putting in place a health program that promotes the preservation of reproductive tract integrity (Eshete *et al.*, 2023).

Maintaining reproductive performance also involves controlling environmental conditions (Malik *et al.*, 2019). Maintaining physiological stability and lowering stress levels that can interfere with hormone regulation are two benefits of keeping animals in comfortable circumstances (Fernandez-Novoa *et al.*, 2020). A approach that promotes long-term reproductive success includes managing pen density, ventilation quality, environmental sanitation, and consistent husbandry techniques (Waqas *et al.*, 2025).

Based on the findings of diagnostic assessments, treatments targeted at enhancing endocrine function and reproductive synchronization may be taken into consideration in situations pertaining to physiological reproductive problems (Sun *et al.*, 2024). By enhancing the synchronization of follicular growth, ovulation, and uterine preparedness, this strategy seeks to raise the likelihood of conception (Yaginuma *et al.*, 2019). However, precisely determining the root reason of repetitive breeding is crucial to the effectiveness of therapies (Islam *et al.*, 2017).

Through the use of more accurate reproductive monitoring systems, advances in reproductive technology also provide chances to control repetitive breeding (Mikkola *et al.*, 2024). Early detection of reproductive alterations and improved decision-making are made possible by the integration of reproductive recording, individual performance evaluation, and diagnostic technologies (Pérez-Marín and Quintela, 2023). This data-driven strategy presents a chance to lower conception failure brought on by a delay in identifying reproductive issues (Gustafsson and Emanuelson, 2002).

Emerging approaches and future perspectives

A paradigm shift in the knowledge and management of recurrent breeding has been brought about by advances in reproductive science and animal husbandry technology (Eshete *et al.*, 2023). Previously, the approach was centered on recognizing clinical signs, but it is now more precise, predictive, and biologically based (Canu *et al.*, 2010). The intricacy of the etiology of repeat breeding implies that traditional reproductive assessment is frequently unable to completely explain the reasons behind repeated conception failure (Maulana *et al.*, 2022). As a result, numerous novel techniques are being created to enhance the precision of diagnoses, improve intervention tactics, and facilitate more efficient reproductive control (Coman *et al.*, 2024).

The use of reproductive biomarkers to identify physiological alterations before to clinical symptoms is one advancement that is receiving more and more attention (Sultana *et al.*, 2022). Early and more precise reproductive evaluation is made possible by the identification of biomarkers associated with ovarian function, endometrial state, embryo quality, and inflammatory responses (Volovsky and Seifer, 2024). This method may be able to distinguish between infertility, poor embryo development, and the inability to sustain pregnancy, enabling therapeutic plans to be customized to the underlying processes in each situation (Villar *et al.*, 2025b).

New avenues for repeat breeding studies are also being made possible by developments in omics technologies (Marrella and Biase, 2023). The investigation of biological alterations at the molecular level that were previously challenging to detect using traditional techniques is made possible by genomic, transcriptomic, proteomic, and metabolomic methodologies (Xie *et al.*, 2025). Gene regulation, metabolic pathways, protein activity, and physiological alterations related to fertility are all better understood thanks to this investigation (Aranciaga *et al.*, 2023). It is anticipated that combining different omics techniques would result in a more thorough biological model that explains the variability of repeat breeding cases (Wadood *et al.*, 2025).

Research on the function of the reproductive microbiome is likewise becoming more and more promising (Gupta *et al.*, 2024). The reproductive tract is now seen as a biological ecosystem impacted by interactions between microbes and reproductive tissues rather than as a sterile environment (Félix-Santiago *et al.*, 2026). It is thought that local immunological and metabolic factors that are important for healthy conception and embryo development are influenced by changes in the microbial community's makeup (Kitagawa *et al.*, 2025). New methods for managing and preventing repetitive breeding may be made possible by a deeper comprehension of the connection between the microbiota and reproduction (Eshete *et al.*, 2023).

Precision reproductive technology advancements are starting to be used in conjunction with biological research to increase monitoring and decision-making effectiveness (Mikkola *et al.*, 2024). Compared to manual observation, sensor-based monitoring systems allow for more objective identification of changes in physiological activity, estrus dynamics, and reproductive behavior (Sharifuzzaman *et al.*, 2024). Identification of animals at risk of reproductive diseases prior to repeated conception failure is made possible by the incorporation of real-time reproductive data (Villar *et al.*, 2025a).

The sector of animal reproduction is also seeing an increase in the application of data analytics and artificial intelligence (Adenuga and Adenuga, 2025). Predictive algorithms that integrate environmental, health, productivity, and reproduction data make it possible to find trends that are challenging to find through traditional assessment (Abdelrahman *et al.*, 2026). Predicting the likelihood of repeat breeding, scheduling reproductive services optimally, and assisting in the creation of more customized and flexible reproductive programs are all possible with this method (Tanimura *et al.*, 2022). An integrated diagnostic and precision-management framework for identifying repeat breeders and guiding targeted interventions is presented in Figure 3.

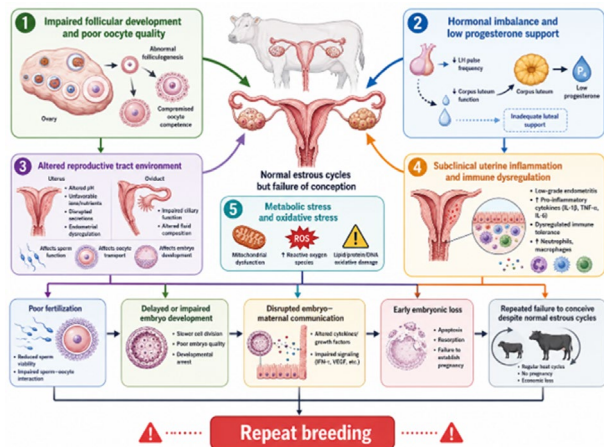


Figure 3. Integrated diagnostic and future precision management approach for repeat breeding.

Enhancing knowledge of the connections between immunology, metabolism, and reproduction is also an important field of study (Gupta *et al.*, 2023). It is now recognized that the process of reproduction depends not only on the function of the reproductive organs but also on the body's general physiological state (Chastant and Saint-Dizier, 2019). It is anticipated that future studies will focus more on integrating biological systems to comprehend how immune and metabolic alterations affect reproductive success (Burgos-Paz *et al.*, 2025).

Even though a number of technologies have demonstrated encouraging potential, there are still obstacles to their application in livestock systems, including expense, the need for infrastructure, and inconsistent field conditions (Roche *et al.*, 2017). Therefore, in order to attain widespread application and practical benefits, reproductive technology development must be followed by validation under real-world production circumstances (Hossein-Zadeh, 2024).

Challenges and research gaps

Even while recurrent breeding has long been acknowledged as a significant issue in animal reproduction, there are still many practical and scientific obstacles in the way of comprehending the underlying mechanisms (Maulana *et al.*, 2022). It is challenging to explain recurrent breeding with a single, cohesive pathophysiology model due to the large degree of interindividual variation in features, variations in husbandry techniques, and the participation of multiple biological and nonbiological factors (Eshete *et al.*, 2023). As a result, effective diagnosis and treatment frequently provide uneven outcomes among populations and industrial settings (Pérez-Marín and Quintela, 2023).

The absence of completely consistent diagnostic criteria is one of the primary obstacles in repeat breeding studies (Pongkapadang *et al.*, 2025). The number of reproductive services utilized as a diagnostic threshold, fertility assessment techniques, and exclusion criteria for other reproductive illnesses are among the operational definitions that differ between research (Tobolski *et al.*, 2025). This diversity makes it more difficult to compare studies and restricts the capacity to make broadly applicable conclusions (Weigel, 2001).

Understanding the biochemical mechanisms causing this illness is further hampered by the etiology's intricacy (Pongkapadang *et al.*, 2025). The majority of study concentrates on individual aspects, such as nutrition, infections, or hormonal imbalances, whereas the interactions between these elements are frequently understudied (Satrio *et al.*, 2025). However, under field conditions, a combination of concurrent physiological changes is more likely to result in recurrent breeding (Ulansari *et al.*, 2026). The causal linkages between reproductive factors are still not fully understood due to the constraints of a multidisciplinary approach (Eshete *et al.*, 2023).

Finding subclinical alterations that are hard to find with traditional techniques presents another difficulty (Villar *et al.*, 2025c). A diagnosis is frequently made following recurrent reproductive failures because many repeat breeders retain normal estrous cycles and do not show clear anatomical abnormalities (Satrio *et al.*, 2025). This implies that molecular, cellular, or physiological alterations may have taken place prior to the onset of clinical symptoms but have not yet been properly detected (Carbonari *et al.*, 2024).

There are additional issues with oocyte quality and early embryo competency research (Nowicki, 2021). The significance of intrinsic embryonic variables to successful conception is still poorly known, and the majority of reproductive evaluations concentrate mostly on maternal circumstances and the reproductive environment (Asaduzzaman *et al.*, 2017). Research on the mechanisms relating gamete quality to the embryo's capacity to sustain early development is still needed (Carbonari *et al.*, 2024).

Furthermore, research on the significance of the reproductive environment is still in its early stages, especially with regard to the interactions between the endometrium, the immune system, and the embryo (Taru *et al.*, 2024). The failure of some animals to sustain pregnancy after proper fertilization cannot be entirely explained by a knowledge of embryo-maternal communication (Nowicki, 2021). More research is still needed to understand the dynamics of endometrial secretory factors, local immunological control, and uterine physiological changes throughout the early stages of pregnancy (Canisso *et al.*, 2020).

There are significant gaps in our understanding of how metabolic state and reproductive function are integrated (Ayantoye *et al.*, 2025). Although there has been much written on the connection between energy balance, oxidative stress, endocrine regulation, and successful reproduction, the molecular processes that connect metabolic alterations to recurrent breeding are still unclear (Eshete *et al.*, 2023). This emphasizes the necessity of conducting research that concurrently combines methods from systemic physiology, metabolism, and reproduction (Akhtar *et al.*, 2025).

Translating study findings to various livestock systems still has limits when it comes to practical application (Pongkapadang *et al.*, 2025). Since many precision reproduction techniques and diagnostic technologies are created in controlled experimental settings, it is not always possible to replicate their efficacy in commercial or smallholder agricultural settings (Shalloo *et al.*, 2021). The actual application of research findings is influenced by variations in management, resources, and environmental variables (Aseged *et al.*, 2023).

In order to produce a more thorough understanding of disease causes, repeat breeding research going ahead must concentrate on an integrative strategy that incorporates reproductive data, metabolic profiles, immunological indicators, genetic traits, and environmental information (Prihatno *et al.*, 2012). It is anticipated that the creation of more sensitive biomarkers, data-driven predictive models, and field validation of reproductive technologies would enhance diagnostic precision and provide more successful preventative and control measures (Palmer and Barnhart, 2013).

Conclusion

Repeated failure to conceive despite seemingly normal estrous cycles is the hallmark of repeat breeding, a multifactorial reproductive condition. Individual factors, hormonal imbalances, anomalies of the reproductive system, dietary status, viral infections, environmental conditions, and reproductive management methods all combine intricately to cause this syndrome. The underlying mechanisms may include early embryonic development, poor fertilization, or inability to sustain pregnancy.

In order to more precisely determine the underlying causes of repeat breeding, a thorough evaluation incorporating reproductive tests, health evaluations, metabolic problems, and management considerations is necessary. An integrated approach that incorporates monitoring reproductive health, enhancing nutrition, optimizing reproductive management, and putting in place suitable diagnostic tools is necessary to achieve prevention and control.

In order to increase the effectiveness and sustainability of livestock production, advances in reproductive research are anticipated to enhance knowledge of the biological mechanisms underlying repeat breeding and facilitate the creation of more accurate methods for reproductive diagnosis and control.

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Conflict of interest

The authors declare that there is no conflict of interest.

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