A Review on the Role of Dromedary Bulls on Infertility of Camel Herds

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Abstract
Reproduction is the first of the camels' adaptations to a hostile environment, this performance in camels is generally considered low, the reason for the reproductive disorders rates could be blamed to the both the female and the male dromedaries reproductive tracts health, the rates fluctuate between 10% and more than 70%. The goal of this review is to establish the causes of reproductive failures, that could be directly (venereal diseases) or indirectly (poor semen), particularly transmission of venereal diseases by potentially asymptomatic bulls. Unfortunately, research regarding venereal diseases in male dromedaries is very limited. Venereal diseases whose transmission has been verified are: Chlamydiosis, Trichomonosis Brucellosis and Bluetongue in camel, the reproductive diseases that affect the target organs are: Trypanosomosis, Toxoplamosis, Bovine viral diarrhea (BVD), Tuberculosis, Filariasis, Campylobacteriosis, Leptospirosis, and Pseudomonosis. As result, it is essential that all dromedary bulls before rutting season begins, must thorough examination proper to gratifying their reproductive potential, and the implementation of the strategies to prevent the occurrence of the herd infertility.
Keywords: Camel, diseases, infertility, reproductive tract, venereal

Introduction
In camels, the breeding is considered poor, resulting to the late onset of puberty, lengthy pregnancy duration, high rates of newborn deaths, infertility and seasonality, (Zema et al., 2022). Birthing rates rarely exceed 40% in nomadic herds and 70% in more managed herds (Tibary et al., 2006; Selim et al., 2023). Besides the low birth rates, camel populations experience significant reproductive losses, which can sometimes reach epidemic levels (Tibary et al., 2006). Camels typically do not display noticeable signs of infection, but any health issues can be identified through symptoms in the female camels they have mated with (Al-Qarawi 2005; Houssou, 2024).The female occupies first place in all studies that deal with reproduction, performance, pathologies and breeding. Whereas, in males, studies are occasional and may be the limiting factor in development of reproduction, mainly, the genital tract infections may lead to temporary or permanent infertility in the male, depending on the type of infectious agent (virus, fungi, bacteria, and parasitic) and the lesions produced on reproductive tract (Houssou et al., 2018; Houssou et al., 2021). Therefore, the selection of dromedary bull is a strategic moment to achieve genetic improvement, venereal diseases are those that are transmitted during rutting, or even during artificial insemination (Djeddou-Benabid et al., 2025). Rules for semen collection impose that, cattle bulls must be screened for Infectious Bovine Rhinotracheitis, Brucellosis, Bovine viral diarrhea, Bluetongue, Campylobacteriosis, and Trichomonosis (OIE, 2021). There isn't a list of tests for dromedary

bulls to be done before collecting semen.Several authors reported that agents responsible for reproductive tract diseases in male.

Diseases revealed their transmission through semen: 1. Chlamydiosis (Derar et al., 2017; Pourfattahi et al., 2024), 2. Brucellosis (Al-Busadah et al., 2017; Wario and Sultan, 2023), 3. Trichomonosis (Tibary et al., 2006, Wernery et al., 2020), 4. Bluetongue (BT) (OIE 2021; Zema et al., 2022).

Diseases whose affect the reproductive tract has been studied but not their transmission : 1. Trypanosomosis (Zaitoun et al., 2017 ; Aqeel et al., 2024). 2. Campylobacteriosis (Tibary et al., 2006 ;Elshazly et al., 2020), 3. Toxoplasmosis (Derar et al., 2017 ;Selim et al. 2023), 4. Filariasis (Abdel-Rady 2021;Khalphallah et al. 2024), 5. Bovine viral diarrhea (Al-Busadah et al. 2017), 6. Tuberculosis (Wernery and Kinne 2012; Ahmad et al. 2019), 7. Leptospirosis (Tibary et al., 2006; Al- Busadah et al., 2017), 8.Pseudomonosis (Tibary et al., 2006; Elshazly et al., 2020).

The goal of this paper is to analysis the current information concerning the main contagious agents affecting the reproductive tract in dromedary bulls and their venereal potential. The microorganisms must be screened to avoid reproductive failures that distress animal breeding either by causing infertility temporally or by sterility.

Venereal diseases

Trichomonosis

Tritrichomonas foetus is a protozoan parasite that has been traditionally identified as a cause of reproductive tract disease in cattle, human, birds and cats, Kunstler described the parasite for the first time in France in 1888 (Al-Hasnawy and Rabee, 2023). The disease can cause economic losses in herds due to low pregnancy rates, infertility, endometritis, and abortions in pregnant cows (Al-Hasnawy and Rabee, 2023).

Infection can spread through sexual activity or by checking cows with dirty tools during exams. It can also happen through artificial insemination, since the semen from sick bulls might be unknowingly tainted with *T. foetus* found in the areas around their reproductive organs (Wernery et al., 2020; Ali et al., 2021). Literature on trichomonosis in camels is rare and there is only few reports on this disease, that a flagellate was isolated from a dromedary bulls (Wernery et al., 2020).

Brucellosis

Brucellosis is an endemic disease (Tibary et al., 2006; Wernery 2014; Aliyi et al., 2024). The three varieties of Brucella that lead to brucellosis in camels (B. abortus, B. melitensis, B. ovis) have the potential to infect any location, with rates ranging from 1 % to 40 % (Wernery 2014). Females are more disposed to brucellosis than male (Salisu et al., 2018). According to Salisu et al. (2018), male animals are less disposed to Brucella infections because they lack the sugar erythritol, which is present in the uterus. Additionally, female camels typically remain in herds for breeding purposes for a longer time than their males (Salisu et al., 2018). Brucella bacteria can enter animals' bodies through breathing, eating, or via damaged skin and mucous membranes. In camels, brucellosis is marked by instances of abortion mastitis, placentitis, infertility, orchitis and epididimits (Al-Qarawi 2005; Narnaware et al., 2017; 21Ali et al., 2021 ;Djeddi et al., 2024). Al-Busadah et al. (2017) detected the agents of brucellosis in semen obtained from unproductive males, and have a venereal transmission (Al-Qarawi 2005; Wario and Sultan 2023)

Chlamydiosis

Chlamydophila spp. are known to affect a wide range of hosts including mammals, reptiles, invertebrates and fish, especially ruminants, which is caused by different species of

Chlamydia genus (Pourfattahi et al., 2024).

In dromedary camel, the researchs focused essentially on seroprevalence of *C. abortus* (Ali et al., 2012). The seroprevalence ranged between 12% and 30% (Elzlitne and Elhafi, 2016; Al-Rubaye et al. 2018). The incidence of chlamydiosis is higher in female (Elzlitne and Elhafi, 2016). Many studies reported that Chlamydiosis cause several diseases like enteritis, encephalitis, polyarthritis, and conjunctivitis (Al-Rubaye et al., 2018), mastitis (Djeddi et al. 2024), and cause also abortion, cervical adhesion, ovarian hydrobursitis, testicular degeneration and preputial lesions (Derar et al., 2017; Pourfattahi et al., 2024), According Derar et al. (2017), these contagions increase reproductive losses and may result in sexual transmission among females. Nevertheless, certain animals that showed seropositivity for Chlamydophila abortus did not exhibit any symptoms (Pourfattahi et al., 2024).

Bluetongue

Bluetongue (BT) is a viral disease but not contagious, spread by arthropods affecting both wild and domesticated ruminants. This infection is caused by the Bluetongue virus (BTV), which falls under the Orbivirus genus and the Reoviridae family. The primary means of transmission is through blood-feeding insect vectors from the Culicoides genus, where the virus can replicate (Ranjan et al., 2017). There are 27 identified serotypes of BTV. The virus has been found in the blood of dromedaries that were experimentally infected, but these animals do not show any clinical symptoms. For serotypes 1 and 8, it has been confirmed that the virus can be present in the bloodstream, along with seroconversion and the generation of neutralizing antibodies. (Zema et al., 2022). BTV infection effects in significant financial damages because of elevated rates of illness, death, stillbirths, miscarriages, lower birth weights in offspring, decreased milk production and reproductive rates, weight reduction, premature culling, along with losses in meat and wool production. Additionally, secondary losses arise from limitations on the movement of ruminant animals, their genetic material, and animal products, as well as costs associated with vaccination, diagnosis, controlling vectors, and treating clinically affected animals. (Gethmann et al. 2020). BTV usually affects ruminants (Ranjan et al., 2017).

Transmission caused by contaminated needles, vertical transfer (specifically for serotype 8), and transfer via semen have been revealed (OIE, 2021; Zema et al., 2022).

Diseases that affect the bull reproductive tract

Parasitic diseases

Trypanosomosis

Trypanosomosis in camelids (Surra) known for the first time in 1880 (India) (Osman et al., 2023). *Trypanosoma evansi* is most commonly found in camels when compared to other animal hosts including buffaloes, cows, dogs, horses, and smaller ruminants. (Aregawi et al., 2019). The affected countries, the seroprevalence between 49.5% and 73.2% (Benaissa et al., 2020; Osman et al., 2023), In 2009, the World Organization for Animal Health (OIE) classified surra as a notifiable multispecies animal disease (OIE 2021). This disease is more pronounced in camelids, it evolves in weaker with staring hair, loss of appetite and weight, neurological symptoms, ovarian hydrobursitis, abortion (Ali et al., 2012), oedema (ventral parts, udder or scrotum, and sheath), anaemia, and petechial or ecchymotic haemorrhages (Zaitoun et al., 2017; Aqeel et al., 2024). A specific odor of the urine is efficient for diagnosing the disease (Aqeel et al., 2024). The testicular degeneration associated with sessions of fever that compromise Sertoli cell function (Amin et al. 2020). Zema et al (2022) have reported that trypanosomosis affect the pituitary function and may contribute to poor

semen quality. The relationship between the testicular lesions, the quality of semen and the reproductive losses in the females remains the possibility of sexual transmission in dromedary.

Toxoplasmosis

Toxoplasmosis is a cosmopolitan parasitic disease in various species of animals (Lass et al., 2019). The prevalence of T. gondii antibodies in camels, rates ranging from 3 % to more than 90%. (Selim et al., 2023). Dass et al. (2011) reported that T. gondii could transmit sexually in rats and *T. gondii* cysts were detected in the semen and epididymitis of male rats that were infected eight weeks after exposure. Additionally, these cysts were found in the vaginal wash of female rats 12 hours following mating with the infected males, causing infection in the females.. Lopes et al. (2011) reported that after Toxoplasmosis, the reproductive system histological changes (Testis, epididymitis, seminal vesicles, and prostate) in small male ruminants. Research revealed that infection with *T. gondii* affect female reproductive tract, and cause reproductive damage in male dromedary (Ali et al., 2021).The camel did not respond to anti-toxoplasmic treatment with sulphonamides (Djeddou-Benabid et al., 2025).

Filariasis

Filariasis is a cosmopolitan parasitic diseases in camel, caused by nematodes (Abdel-Rady, 2021). Haemoparasitic like dipetalonemiasis negatively affect the health, efficiency, and labor capabilities of camels (Khalphallah et al., 2024). Infection rates of Dipetalonema evansi were affected by seasonal changes, with the peak rate occurring in the summer (Abdel-Rady, 2021). Female camels exhibited a higher infection prevalence for camel filariasis compared to males (Khalphallah et al., 2024). The group of camels aged 4 to 5 years showed the highest occurrence of Dipetalonema evansi infections. (Borji et al., 2009). The testicular lesions (orchitis and epididymitis) due to filariasis have been stated in dromedary males, with a rate between regions from 2.56 to 10% (Abdel-Rady et al., 2021). Animlas that were naturally infected with microfilaria exhibited reduced appetite, significant weight loss, light-colored mucous membranes, stiffness in their movements, a wide stance, and elevated body temperature ranging from 39.4 to 39.8 °C. The organs impacted by the parasites include the testes and prepuce (Abdel-Rady, 2021; Khalphallah et al., 2024). Also, an analysis of testicular histopathology identified the presence of adult filaria in all cases of camel filariasis linked to balanoposthitis. (Khalphallah et al., 2024). The same author reported that males have difficult sperm collection, poor reproductive performance and later sexual behaviour. There is no history of Filariasis venereal disease in dromedary bull

Bacterial diseases

Campylobacteriosis

There exist germs that seemingly do not impact the fertility of bulls; however, they can be passed on to females, resulting in reproductive difficulties (Givens, 2018). *Campylobacter fetus subsp. venerealis* leads to a bacterial illness in bulls typically thought to show no symptoms, which can be transmitted to females, manifesting as irregular estrus along with early embryonic and fetal loss (Michi et al., 2016). The infected dromedaries with *Campylobacter fetus* exhibited infertility without any observable clinical symptoms or abnormalities in their spermiograms, yet this might contribute to reduced reproductive success in male dromedaries (Derar et al., 2017; Ali et al., 2021). Nonetheless, the available epidemiological information regarding the occurrence and transmission of these pathogens among male camels is quite limited and unclear..

Tuberculosis

Tuberculosis is a lasting disease that affects animals and is characterized by granulomatous inflammation, initiated by a specific set of bacteria known collectively as the Mycobacterium tuberculosis complex (MTBC). In camels, the disease mainly propagates when an infected member is added to the herd or through close interactions with infected animals from various species (Hussein, 2021). The disease is primarily spread horizontally through aerosols emitted by animals suffering from pulmonary tuberculosis. Additionally, oral transmission may take place if contaminated food or water is consumed (Hussein, 2021), and it might also occur through exposure to wounds or urine.and faeces (Wernery and Kinne, 2012). Ahmad et al. (2019) founded a testicles tuberculosis of dromedary in Nigeria. Vertical congenital transmission, transmission by semen and vaginal secretions is possible (Wernery and Kinne, 2012; Ahmad et al. 2019).

Pseudomonosis

Pseudomonas aeruginosa is a primary contributor to illnesses including ear infections, inflammation of the mammary glands, uterine infections, severe lung infections with bleeding, and infections of the urinary tract in both farm animals and pets. (Elshazly et al. 2020; Djeddi et al. 2024). Waheed et al. (2022) reported that the infertile camels had colonies of Pseudomonas aeruginosa in preputial swabs. A few studies is available about P. aeruginosa in camel. Pseudomonas aeruginosa, has been isolated from infertile camels (Tibary et al. 2006; Waheed et al., 2022) and may be associated with venereal transmission (Tibary et al. 2006).

Leptospirosis

The possibility of vennereal transmission among cattle has been frequently proposed, happening from males to females and the other way around (Loureiro, and Lilenbaum, 2020; Givens, 2018), given that pathogenic leptospires have been identified in the reproductive systems of both genders (Aymée et al., 2024). Al-Busadah et al. (2017) reported the infertile camels had colonies of leptospires in semen. While leptospirosis is not commonly found in nomadic herds, it could become significant intensive dairy herds (Tibary et al**.,** 2006).

Viral diseases

Bovine viral diarrhea (BVD)

Bovine viral diarrhea virus (BVDV) is a pathogen classified under the Pestivirus group in the Flaviviridae family, responsible for the illness known as bovine viral diarrhea (BVD). BVDV affects both cattle and camels (Selim et al., 2024). The rate of BVD occurrence in camels differs across countries, ranging from 3.4% to 6.7% (Selim et al., 2024). While BVD is prevalent among cattle, it is increasingly recognized in camels, which can become infected by grazing alongside cattle (Wernery, 2012). In males, BVD infections lead to decreased sperm concentration and movement, as well as an increase in sperm defects (El-Mohamady et al., 2020). The virus can be passed on by males, including through methods like artificial insemination (Givens, 2018). Additionally, the illness manifests in camels with symptoms such as diarrhea, reproductive issues, and respiratory problems. (Saidi et al., 2018;Tesfaye et al., 2021). Low fertility, in which males suffering from Bovine viral diarrhea disease could transmit these etiological agents to females (Al-Busadah et al. 2017; El-Mohamady et al., 2020).

Others microorganisms

The preputial sac can act as a reservoir of organisms and it thus responsible for ascending uro-genital infection (Agartan et al., 2005). The source of camel preputial contamination is usually soil, faeces and female genital tract (Waheed et al., 2022). The prevalent organisms in the dromedary semen: species of Staphylococcus, Bacillus and Streptococcus (Ghoneim et al., 2014; Waheed et al., 2022), Mycoplasma spp., (Tibary et al., 2006; Al-Busadah et al., 2017), Paratubercolosis (Selim et al., 2024). Waheed et al. (2022) reported that the infertile camels had colonies species of Corynebacterium, E. coli, Actinomyces, Fusobacterium, Clostridium perfringens and fungi in camels' prepuce in preputial swabs. Candida is a common mycoflora presentin the genitalia of healthy female camels (Shokri et al., 2010). Insufficient information exists regarding the specific functions of BoHV-4 and BoHV-5 in the infertility of dromedary bulls or how they are passed to females through either natural or artificial insemination..

Screening and strategies to reduce diseases

Clinical analysis

Clinically, it is difficult because the diseases such as (Chlamydiosis, Campylobacteriosis, toxoplasmosis…etc.) are most often asymptomatic, and even when it is expressed clinically, the anatomo-clinical picture is polymorphous. This explains the difficulty of clinical diagnosis. However, must always be taken into account in the event of collective abortions in flocks (especially in ewes) (Tibary et al., 2006; Derar et al., 2017; Al-Rubaye et al., 2018 ; Elshazly et al., 2020 ; Ali et al., 2021; Pourfattahi et al., 2024; Khalphallah et al., 2024).

Laboratory analysis

Microscopical diagnosis

Giemsa-stained thin blood smears (GSBS) under light microscopy is used to diagnosis of protozoa infection in the field and acute cases, but this method is not suitable for detection in carrier animals (Toaleb, and Shaapan, 2024).

Cytological analysis of the endometrium in females is performed to investigate infertility issues, particularly to identify venereal infections and acute or chronic endometritis (Houssou et al. 2021). Limited research exists on reproductive cytology in camels, and treatments for infections are derived from information related to other domesticated species like cattle and horses. Research focusing on the cytology and bacteriology of the reproductive systems in camels is essential for comprehending the cytological processes in these animals, which would aid in recognizing venereal diseases..

Serological tests

The enzyme-linked immunosorbent assay (ELISA: indirect or blocking).With the ELISAs, antibodies can be detected in serum or plasma samples and hormonal analysis.

CFT: complement fixation test, FPA: using fluorescence polarization, RBT: test with Rose Bengal dye, SAT: test for serum clumping.

Molecular Diagnosis

The DNA was subjected to PCR amplification for micro-organisms using the specific primer sequence and reaction procedure (Narnaware et al., 2017).

PCR protocols have been developed to monitor semen of domestic animals for various infectious agent (Al-Busadah et al., 2017).

Necropsy and Histopathologic

Testicular biopsy, fine-needle aspiration, tissue samples from the testicles collected in 10 % formal saline for histopathology. The laboratory diagnostic methodologies depending on the type of infection, are described in details in: (Al-Qarawi, 2005; Narnaware et al.,2017, 10Al-Busadah et al., 2017, Ahmad et al., 2019; Amin et al., 2020; Elshazly et al., 2020; Wernery et al., 2020;; Selim et al., 2023; Wario and Sultan, 2023, Aliyi et al., 2024; Pourfattahi et al.,2024,). The Figure 1 outlines a flowchart to examine the bull that may be contributing to herd reproductive failures..

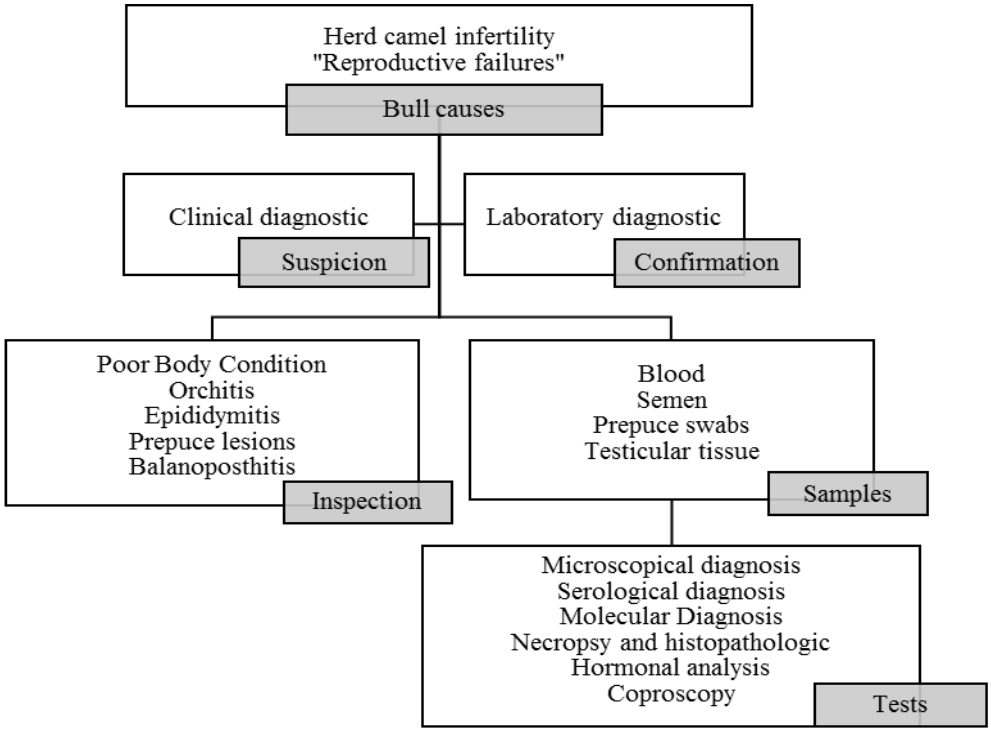

Figure 1. Flowchart to examine the bull that may be contributing to reproductive failures.

Preventing infectious factors that lead to reproductive losses in camels should rely on effective biosecurity protocols designed to stop the entry and dissemination of diseases among groups. Such initiatives can be categorized into external and internal strategies (Tibary et al., 2006). It is crucial to understand that no immunization scheme offers complete protection against diseases. Hence, it is essential to reduce the chances of disease introduction and transmission, especially for infections that can spread rapidly within a group.

Fatnassi et al. (2021) emphasized that the male camels intended for artificial insemination should be raised with a focus on enhancing their living conditions and ensuring their well-being, since these elements are also associated with productivity and reproduction. Furthermore, the establishment of a monitoring plan that aligns with hazard analysis and critical control points (HACCP) principles, along with maintaining all necessary records, is very important and should not be overlooked. (Zema et al., 2022).

The application of Artificial Intelligence in advancing camel health and for facilitating the early prediction of diseases like Trypanosoma evansi using artificial neural networks. Furthermore, Artificial Intelligence contributes to the development of camel-derived diagnostic and therapeutic products, emphasising the utility of Machine Learning in analysing complex datasets for antibodies and nanobodies, and optimization the application of Artificial Intelligence in camel management and welfare (Alsaleem et al., 2024). Table 1 shows the approaches to prevent the incidence of infections

Table 1. Some strategies to prevent the occurrence of diseases.

External Biosecurity		Internal Biosecurity	
Environmental	**Breeding management**	**Infections Agent**	**Host Animal**
Good hygiene Respect Temperature, humidity, ventilation Animal environment (separation, hygienne/ disinfection) Moving/ handling	Respect animal density Avoid the presence of other species (cat, dog, sheep…etc. Nutritional efficiency Access to clean water Optimum body condition score Improve nursing behaviour Screening carrier animals Remove stillbirth, placenta, etc.	Existence of microorganism in environment Perseverance of agent inside host–carrier Size of pathogen load Virulence factors	Full physical examination Application of Artificial Intelligence Quarantine facilities/ procedures Isolation of new animals Failure of passive transfer Improve immune competence: Vaccination

Conclusion

The efficiency of herd reproductive depending on early diagnosis of male infertility, it is best to examine the males before the rutting season begins. It is crucial that any prospective breeding dromedary bulls undergo a comprehensive assessment before being bought to guarantee their ability to attain reproductive success. The assessment requires both clinical observation and laboratory testing, which involves analyzing blood, semen, and testicular tissue. The link between testicular damage, sperm quality, genital lesions, and abortions in females has yet to establish how reproductive bulls may influence or spread venereal diseases. It is advised that cases of abortion within herds not be ignored, and appropriate testing should be conducted to determine the underlying cause. Implementing this and additional strategies should help alleviate the issues related to reproductive health in livestock. Accurate diagnosis must always incorporate various methods, taking into account medical history, the reasons for testing, and the phase of the suspected illness. For a conclusive assessment, it is important to carefully analyze a combination of epidemiological, clinical, and laboratory data..

Competing interests

No conflict of interest.

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