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Lumpy skin disease in cattle and water buffalo (*Bubalus bubalis*): economic impacts and control strategies in a changing global landscape

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ABSTRACT

Lumpy skin disease (LSD) is an emerging transboundary viral disease affecting cattle and water buffalo (*Bubalus bubalis*), posing a serious threat to global livestock production systems. The disease is characterized by fever, lymphadenopathy and the development of firm cutaneous nodules, leading to substantial economic losses through reduced milk yield, poor meat quality, reproductive disorders and irreversible damage to hides. Although cattle are the principal hosts, water buffalo may also be susceptible and could contribute to disease dynamics, particularly in mixed production systems. Transmission occurs mainly through hematophagous arthropod vectors, including mosquitoes, biting flies and ticks, facilitating rapid geographical spread. In recent years, LSD has expanded beyond its endemic regions in Africa to the Middle East, Asia and parts of Europe, raising major concerns for animal health and international trade. Diagnosis is primarily based on clinical signs and confirmed by laboratory techniques such as polymerase chain reaction and virus isolation. In the absence of specific antiviral therapy, control strategies rely on mass vaccination, vector control, movement restrictions and strict biosecurity measures, while clinical management is largely supportive. This review provides a concise overview of the epidemiology, pathogenesis and economic impact of LSD on milk, meat and leather production in cattle and buffalo. It further highlights current control strategies and emerging challenges associated with its global spread, emphasizing the need for integrated and sustainable disease management approaches.

Keywords: Lumpy skin disease, *Capripoxvirus*, Cattle, Water buffalo, Economic impact

1. Introduction

Lumpy skin disease (LSD) is a viral disease of major economic importance affecting cattle and, to a lesser extent, water buffalo (*Bubalus bubalis*). It is characterized by the development of firm, well-circumscribed cutaneous nodules that may extend to mucosal surfaces of the respiratory and urogenital tracts and, in severe cases, to internal organs. Secondary bacterial infections frequently complicate the condition, prolonging recovery and increasing production losses. The causative agent, lumpy skin disease virus (LSDV), belongs to the family *Poxviridae* and genus *Capripoxvirus* (Quinn *et al.*, 2016) [1].

Originally restricted to Africa, LSD has expanded rapidly over the past decade to the Middle East, Asia and Eastern Europe, and is now recognized as a transboundary animal disease of global significance (Azeem *et al.*, 2022; Jyoti *et al.*, 2022; Moudgil *et al.*, 2024) [2, 3, 4]. Recent widespread outbreaks in India have severely impacted dairy, meat and leather sectors, particularly affecting smallholder production systems and rural livelihoods (Mulatu *et al.*, 2018; Moudgil *et al.*, 2024) [5, 4]. This rapid geographical expansion highlights the increasing importance of LSD in the context of global livestock health and trade.

Transmission of LSDV occurs predominantly through mechanical means via hematophagous arthropod vectors such as biting flies, mosquitoes and ticks (Lubinga *et al.*, 2014; Tuppurainen *et al.*, 2011) [6]. The clinical presentation varies from mild to severe and typically includes fever, lacrimation, nasal discharge, hypersalivation and characteristic nodular lesions distributed over the neck, back, limbs, perineum and genital regions. In advanced cases, systemic involvement may occur due to dissemination of lesions to internal organs. Affected animals often exhibit lameness, reduced feed intake, emaciation and a marked decline in milk production. Enlargement of superficial lymph nodes and brisket edema are common, and respiratory complications such as pneumonia may develop.

The epidemiology of LSD is influenced by host immunity, vector abundance and environmental conditions. Morbidity and mortality rates vary widely, with higher susceptibility observed in exotic and crossbred cattle, particularly Holstein Friesian, compared to indigenous zebu breeds (Gari *et al.*, 2010; Babiuk *et al.*, 2008) [8].

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⁷¹. Although cattle are the primary hosts, increasing evidence suggests that water buffalo may also be susceptible, potentially playing a role in disease persistence in mixed farming systems.

LSD leads to substantial economic losses due to decreased milk yield, reduced growth and meat quality, infertility, abortion and permanent damage to hides affecting leather production. Diagnosis is based on clinical observations and confirmed through laboratory techniques such as polymerase chain reaction (PCR), virus isolation and histopathology. In the absence of specific antiviral treatment, control strategies rely mainly on mass vaccination, supported by vector control, movement restrictions and strict biosecurity measures.

This review aims to provide a comprehensive yet concise overview of LSD in cattle and buffalo, focusing on its epidemiology, economic impact on milk, meat and leather production and current control strategies. It also highlights recent global trends and identifies key research gaps to support improved disease management and sustainable livestock production systems.

2. Etiology

Lumpy skin disease is caused by lumpy skin disease virus (LSDV), a member of the genus *Capripoxvirus* within the family *Poxviridae*, which also includes sheeppox virus (SPPV) and goatpox virus (GTPV). These viruses are genetically and antigenically closely related, although LSDV is the specific etiological agent affecting cattle and, to a lesser extent, water buffalo (*Bubalus bubalis*) (Quinn *et al.*, 2016) [1]. LSDV is a large, enveloped, double-stranded DNA virus with a brick-shaped morphology measuring approximately 230–260 nm. Its genome (~150 kbp) encodes proteins involved in viral replication, virulence and immune evasion (Babiuk *et al.*, 2008) [7]. Replication occurs entirely in the cytoplasm of infected cells, leading to the formation of cytoplasmic inclusion bodies and release of virions through cell lysis or budding (Tulman *et al.*, 2001) [9]. The virus demonstrates notable environmental stability, particularly in skin nodules, scabs and crusts, where it may remain viable for extended periods. It resists desiccation but is inactivated by common disinfectants, heat and extreme pH (OIE, 2021). Although cattle are the primary hosts, water buffalo may also be infected, generally showing mild or subclinical disease. Their epidemiological role remains unclear.

Antigenic similarity among *Capripoxviruses* enables cross-protection, forming the basis for heterologous vaccination strategies. Despite genetic stability, recent reports of recombinant strains raise concerns regarding virulence and vaccine efficacy.

3. Epidemiology

Lumpy skin disease is a transboundary viral disease with expanding global distribution and significant impact on livestock production (Moudgil *et al.*, 2024) [4]. Initially confined to sub-Saharan Africa, it has spread since the early 21st century to the Middle East, southeastern Europe and Asia, indicating a major epidemiological shift (Beard, 2016; Tuppurainen *et al.*, 2015). Recent outbreaks have been reported across South and East Asia, including India, Bangladesh, China and Nepal. In India, the disease has become a major livestock health concern, causing substantial economic losses (Kumar *et al.*, 2021). The epidemiology of LSD is strongly influenced by arthropod vectors, with higher incidence during warm and humid conditions. Mechanical transmission by mosquitoes, biting flies (*Stomoxys* spp.) and ticks plays a central role in disease spread (Chihota *et al.*, 2001; Lubinga *et al.*, 2013; Tuppurainen *et al.*, 2011) [10, 6]. Wind-assisted dispersal of infected vectors may contribute to long-distance transmission. Animal movement is another key driver, as transport of infected or subclinical animals facilitates rapid geographical spread. Indirect transmission through contaminated fomites may occur but is considered secondary. Host factors such as breed, immunity and management influence disease severity. Exotic and crossbred cattle (e.g., Holstein Friesian) are more susceptible than indigenous zebu breeds (Gari *et al.*, 2010; Babiuk *et al.*, 2008) [8, 7]. Morbidity ranges from 5–45%, while mortality is generally low but may increase in naïve populations (Tuppurainen *et al.*, 2017) [11]. The role of water buffalo (*Bubalus bubalis*) remains unclear. Although infections are often mild or subclinical, buffalo may contribute to virus persistence in mixed farming systems. Environmental and climatic factors, particularly temperature and humidity, significantly influence vector dynamics and disease spread. Consequently, LSD is now regarded as an emerging global disease requiring coordinated surveillance and integrated control strategies.

Table 1. Transboundary spread of lumpy skin disease virus

Year / Period	Region / Country	Key Epidemiological Event	Reference
1929	Zambia	First recorded emergence of LSD	Tuppurainen and Oura, 2012
1940s–1980s	Africa	Spread across Africa except Libya, Algeria, Morocco, Tunisia	Tuppurainen and Oura, 2012
1988	Egypt	First outbreak due to cattle movement from Africa	Ali <i>et al.</i> , 1990
2006	Egypt	Re-emergence due to unrestricted cattle movement	Fayez and Ahmed, 2011
1989	Israel	First outbreak outside Africa; vector-borne spread	Yeruham <i>et al.</i> , 1995
2012–2013	Syria, Jordan, Lebanon	First appearance; Cross-border-transmission spread	Abutarbush <i>et al.</i> , 2015
2013	Turkey, Iraq	Disease spread to neighboring countries	BY-ND, 2016
2014	Iran	Continued regional spread	BY-ND, 2016
2019	Israel	Re-emergence due to reduced vaccination	
July–Sept 2019	Bangladesh	First outbreak; 66 cases out of 360 animals	Kayesh <i>et al.</i> , 2020
Aug 2019	China	First outbreak; 65 animals affected near Kazakhstan border	OIE-WAHIS, 2019
Aug 2019	India (Odisha)	First outbreak during monsoon season	Sudhakar <i>et al.</i> , 2020
Aug 2019	India (Mayurbhanj, Bhadrak districts)	Multiple outbreaks; 7.1% morbidity, no mortality	Sudhakar <i>et al.</i> , 2020
2019	Turkey, Russia	Re-emergence in southern and eastern provinces	Sudhakar <i>et al.</i> , 2020

4. Transmission

Transmission of lumpy skin disease virus (LSDV) occurs predominantly through mechanical means, with hematophagous arthropods acting as the primary vectors. Direct contact between infected and susceptible animals plays a limited role, as the virus is mainly trans-

ferred by blood-feeding insects during interrupted feeding (Chihota *et al.*, 2001).

A variety of vectors are involved, including biting flies such as *Stomoxys calcitrans*, mosquitoes (*Aedes* and *Culex* spp.), and ticks of the genera *Rhipicephalus* and *Amblyomma* (Lubinga *et al.*, 2015; Tuppurainen *et al.*, 2011) [12, 6]. These vectors function mainly as me

chanical carriers, with short-term virus persistence. Among them, stable flies (*Stomoxys* spp.) are particularly efficient due to their frequent feeding behavior (Tuppurainen *et al.*, 2017) [11].

Ticks may contribute through mechanical and possible biological transmission, as LSDV can persist within ticks and may be transmitted transstadially or transovarially; however, their epidemiological significance remains unclear (Tuppurainen *et al.*, 2013) [13].

Indirect transmission via contaminated fomites such as equipment, vehicles, feed, water troughs and personnel may occur, especially under poor biosecurity conditions. The virus is also present in secretions including saliva, nasal discharge, milk and semen, although these routes are of minor importance; the presence in semen raises concerns for artificial insemination (Irons *et al.*, 2005) [14].

LSDV shows high environmental stability and can persist in skin nodules, scabs and crusts, serving as a source of infection for vectors and facilitating indirect spread under favorable conditions.

Although cattle are the primary hosts, water buffalo (*Bubalus bubalis*) may also become infected. While disease expression is usually mild, their role in virus maintenance in mixed production systems cannot be excluded.

Overall, LSD transmission is multifactorial, involving interactions among vectors, hosts and environmental factors, necessitating integrated control strategies including vector control, movement restriction and biosecurity measures.

Table 2. Host range and susceptibility of lumpy skin disease virus

Host Category	Species / Group	Susceptibility / Remarks	Reference
Domestic cattle	<i>Bos indicus</i>	Susceptible; relatively more resistant than exotic breeds	Al-Salihi, 2014
Domestic cattle	<i>Bos taurus</i>	Highly susceptible compared to indigenous breeds	Al-Salihi, 2014
Buffalo	<i>Bubalus bubalis</i>	Susceptible host	Al-Salihi, 2014
Calves	Cattle calves	More susceptible; lesions may develop within 24–48 h	Al-Salihi, 2014
Wildlife (natural conditions)	Various species	Generally resistant; negligible role in transmission	Davies, 1991; Padilla <i>et al.</i> , 2005
Wildlife (experimental infection)	Giraffe (<i>Giraffa camelopardalis</i>)	Clinical lesions observed experimentally	Davies, 1991
	Impala (<i>Aepyceros melampus</i>)	Experimental susceptibility	Davies, 1991
	Arabian oryx (<i>Oryx leucoryx</i>)	Experimental susceptibility	Padilla <i>et al.</i> , 2005
	Springbok (<i>Antidorcas marsupialis</i>)	Experimental susceptibility	Padilla <i>et al.</i> , 2005
	Oryx (<i>Oryx gazella</i>)	Experimental susceptibility	Padilla <i>et al.</i> , 2005
	Thomson's gazelle	Experimental susceptibility	Padilla <i>et al.</i> , 2005

5. Pathogenesis

The pathogenesis of lumpy skin disease involves complex interactions between lumpy skin disease virus (LSDV) and the host immune system, resulting in both systemic and cutaneous manifestations. Infection typically occurs via arthropod vectors, followed by local viral replication at the inoculation site and spread to regional lymph nodes, leading to primary viremia (Babiuk *et al.*, 2008) [7]. During secondary viremia, the virus disseminates to the skin, mucous membranes, lungs and gastrointestinal tract. LSDV shows tropism for endothelial cells, macrophages and fibroblasts, resulting in vasculitis, thrombosis and tissue necrosis. These pathological changes lead to the formation of characteristic firm nodular skin lesions, which may ulcerate and become complicated by secondary bacterial infections. Lymphadenopathy is a consistent feature, while vascular damage contributes to edema, particularly in the limbs and brisket. Host immune responses, including innate and adaptive mechanisms, are critical for viral clearance. Inadequate immunity or immunosuppression may result in severe disease and prolonged viremia. In water buffalo (*Bubalus bubalis*), infections are generally mild or subclinical, suggesting differences in host susceptibility or immune response, although the underlying mechanisms remain unclear.

6. Clinical signs

Clinical manifestations of LSD vary widely depending on viral virulence, host immunity, breed and environmental conditions. Following an incubation period of 4–14 days, affected animals initially show fever (40–41 °C), depression, anorexia and a marked decline in milk production (OIE, 2021). Lacrimation, nasal discharge and hypersalivation are also common. Enlargement of superficial lymph nodes,

particularly prescapular and prefemoral nodes, is an early and consistent finding (Babiuk *et al.*, 2008) [7]. The most characteristic feature is the development of multiple firm, well-circumscribed nodules (0.5–5 cm) distributed over the neck, back, limbs, perineum and genital regions. In severe cases, lesions may become generalized. As the disease progresses, nodules may undergo necrosis, forming scabs that slough off, leaving deep ulcers. Secondary bacterial infections are common and delay healing (Gari *et al.*, 2010) [8]. Mucosal involvement may lead to respiratory complications, including pneumonia, while ocular lesions such as conjunctivitis and keratitis may also occur. Lameness is frequently observed due to limb lesions and inflammation of joints and tendons. Edema of the limbs and brisket is common due to vascular and lymphatic damage. Reproductive disorders, including infertility in males and abortion in females, have also been reported (Irons *et al.*, 2005) [14]. Disease severity ranges from mild or subclinical to severe generalized infection with occasional mortality. Exotic and crossbred cattle are generally more severely affected than indigenous breeds (Gari *et al.*, 2010) [8]. In water buffalo, clinical signs are usually milder and often subclinical, which may lead to underdiagnosis.

7. Diagnosis

Accurate diagnosis of LSD is essential for effective control and prevention. While clinical signs provide a strong presumptive diagnosis, laboratory confirmation is required due to similarities with other dermatological diseases (OIE, 2021). Differential diagnoses include pseudo-lumpy skin disease, dermatophilosis, insect bite hypersensitivity and cutaneous tuberculosis (Babiuk *et al.*, 2008) [7]. Polymerase chain reaction (PCR) is the gold standard for detection of LSDV, offering high sensitivity and specificity. It can detect viral DNA from

skin nodules, scabs, blood, lymph nodes and secretions. Real-time PCR further improves diagnostic accuracy and is widely used in surveillance (Alexander *et al.*, 2019; Tuppurainen *et al.*, 2017; Heine *et al.*, 1999) [15, 11, 16]. Virus isolation in cell culture provides confirmatory evidence but is time-consuming and requires specialized facilities. Serological tests such as ELISA and virus neutralization tests are useful for assessing herd immunity but have limited value in early infection due to delayed antibody response and cross-reactivity (OIE, 2021). Histopathology supports diagnosis by revealing epidermal hyperplasia, intracytoplasmic inclusion bodies, vasculitis and necrosis. In buffalo, diagnosis may be more challenging due to mild or subclinical presentation, making laboratory confirmation particularly important.

8. Treatment

No specific antiviral treatment is available for LSD, and management is primarily supportive. Non-steroidal *anti*-inflammatory drugs are used to control fever and inflammation, while broad-spectrum antibiotics help prevent secondary bacterial infections (Babiuk *et al.*, 2008) [7]. Supportive care may include fluid therapy, electrolyte supplementation and nutritional support to improve recovery. Topical antiseptics and proper wound management are recommended to promote healing and reduce hide damage. Vector control using insecticides and repellents plays an important supportive role during outbreaks by reducing transmission. Isolation of infected animals is also essential. In water buffalo, treatment approaches are similar, although clinical intervention is often minimal due to milder disease. Overall, supportive management reduces morbidity and economic losses, but vaccination remains the most effective control measure.

9. Preventive measures

Prevention of LSD relies on integrated strategies combining vaccination, vector control, movement restriction and biosecurity. Vaccination is the cornerstone of control programs. Both homologous (LSDV-based) and heterologous (sheepox/goatpox-based) vaccines provide effective protection due to antigenic similarity among *Capripoxviruses*. Annual vaccination is recommended in endemic areas, while emergency vaccination is used during outbreaks (Tuppurainen *et al.*, 2017) [11]. Vector control is essential and includes the use of insecticides, repellents and environmental management to reduce breeding sites. Proper manure disposal and elimination of stagnant water significantly reduce vector populations. Movement restrictions and quarantine are critical to prevent disease spread. Newly introduced animals should be isolated and monitored before herd integration. Strict biosecurity practices, including disinfection of equipment and personnel hygiene, are essential to limit transmission. Surveillance and early detection enable rapid response and containment. In mixed farming systems, control measures should include both cattle and water buffalo, as buffalo may contribute to virus circulation despite mild clinical signs.

10. Socio-economic impact

Lumpy skin disease has significant socio-economic consequences, particularly in livestock-dependent regions (Banata *et al.*, 2024) [17]. It affects milk production, meat yield, hide quality, reproduction and draught power, resulting in substantial economic losses. Mortality is generally low (1–5%), but morbidity may exceed 50%, making production losses the primary burden (Mat *et al.*, 2021; Gumbe, 2018) [19, 18].

10.1 Animal health

Losses are mainly associated with morbidity, leading to emaciation, reduced draught power, infertility and abortions (Tuppurainen *et al.*, 2011; Zewdie, 2021) [6, 20].

10.2 Milk production

Milk yield declines significantly due to fever, anorexia and mastitis. In India, economic losses exceed USD 2.4 billion, largely driven by reduced milk production (Mulatu *et al.*, 2018; Jyoti *et al.*, 2022) [5, 3].

10.3 Meat production

Weight loss and poor body condition reduce carcass yield and quality, leading to economic losses in both subsistence and commercial systems (Mat *et al.*, 2021) [19].

10.4 Leather production

Skin lesions result in permanent hide damage, reducing leather quality and market value (Babiuk *et al.*, 2008) [7].

10.5 Wider economic consequences

Indirect losses include reduced draught power, increased labor costs and treatment expenses. In India, total losses exceed USD 2.4 billion (Sharma and Kumar, 2025; Moudgil *et al.*, 2024) [4].

11. Integrated control strategies

Effective control requires a combination of vaccination, vector control, movement restriction and biosecurity measures.

11.1 Therapeutic management

Supportive treatment with antibiotics, NSAIDs and nutritional supplementation reduces morbidity and improves recovery but does not eliminate infection (Abutarbush, 2017) [21].

11.2 Movement restrictions

Isolation and quarantine of infected animals are essential to limit disease spread (Tuppurainen *et al.*, 2013; Abutarbush, 2017) [13, 21].

11.3 Vector control measures

Mechanical transmission by biting flies and ticks is the primary route of LSDV spread; therefore, integrated vector control using insecticides, repellents and environmental management is essential, as wind-assisted dispersal may further facilitate transmission (EFSA, 2015; Sprygin *et al.*, 2019) [22, 23].

11.4 Biosecurity and outbreak management

Effective biosecurity measures are essential for controlling LSD outbreaks and limiting virus transmission. Key practices include strict quarantine of affected herds, selective depopulation of infected and exposed animals where necessary, safe carcass disposal, and thorough cleaning and disinfection of contaminated premises. When combined with vector control strategies, these measures play a critical role in interrupting virus circulation during outbreaks (Sprygin *et al.*, 2019; EFSA, 2015) [23, 22].

11.5 Immunoprophylaxis

Vaccination remains the most effective strategy for the prevention and control of LSD. Homologous live attenuated vaccines, particularly those based on the Neethling strain, provide strong and long-lasting immunity. In regions where LSD-specific vaccines are not available, heterologous vaccines derived from sheepox or goatpox viruses offer cross-protection due to antigenic similarity among *Capripoxviruses* (Brenner *et al.*, 2009; Tuppurainen *et al.*, 2015; Coakley and Capstick, 1961) [24, 25]. Effective immunization programs require mass vaccination with high herd coverage. Calves should be vaccinated at 3–4 months of age, followed by annual vaccination of breeding animals to maintain protective immunity (Tuppurainen *et al.*, 2017; Carn *et al.*, 1994) [11, 26].

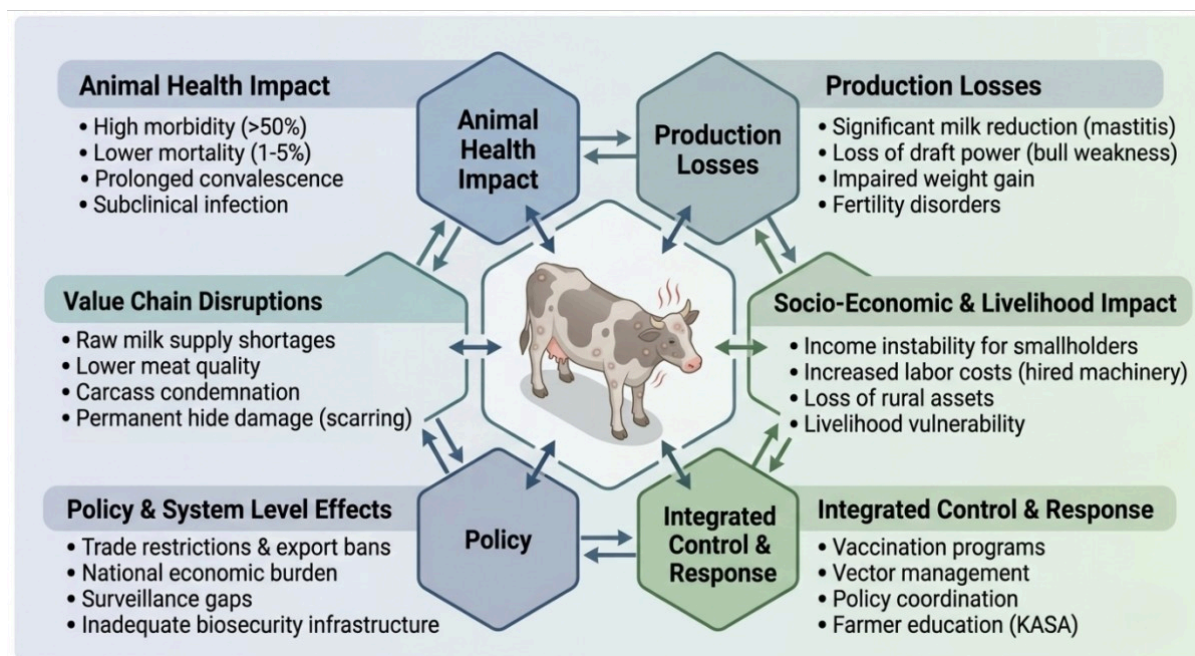


Figure 1. Socio-Economic Impact of LSDV

Table 3. Types of vaccines used for lumpy skin disease control

Vaccine type	Strain / Origin	Reported efficacy	Limitations	Regions commonly used
Live attenuated homologous	Neethling strain	High ($\approx 75\text{--}95\%$)	Mild post-vaccination reactions, cold-chain dependent	Africa, Middle East, Asia, parts of Europe (Sprygin <i>et al.</i> , 2019; Tuppurainen <i>et al.</i> , 2017; Bedeković <i>et al.</i> , 2018)
Live attenuated heterologous (sheepox-based)	Romanian sheepox	Moderate	Lower efficacy, incomplete protection	Europe, Middle East, Asia (Tuppurainen <i>et al.</i> , 2012; EFSA, 2015)
Live attenuated heterologous (goatpox-based)	Gorgan / similar	Moderate–high	Variable efficacy	South Asia, Middle East, endemic regions (Tuppurainen <i>et al.</i> , 2017; Gupta <i>et al.</i> , 2020)
Inactivated LSDV	Chemically inactivated	Safe	Requires boosters, lower immunogenicity	Experimental / research settings (Miranda <i>et al.</i> , 2016; Hamdi <i>et al.</i> , 2020)

12. Future research priorities

Despite significant advances in understanding LSD, several key research areas require further attention to improve disease control and management. Development of next-generation vaccines, including recombinant, DIVA-compatible, and inactivated vaccines, is essential to enhance safety, efficacy, and differentiation between infected and vaccinated animals (Tuppurainen *et al.*, 2017; Tuppurainen *et al.*, 2015) [11]. Genomic surveillance using whole-genome sequencing is crucial for monitoring viral evolution, detecting recombination events, and distinguishing vaccine strains from field isolates (Babiuk *et al.*, 2008; Sudhakar *et al.*, 2020; Moudgil *et al.*, 2024) [7, 27, 4]. Standardized economic models are needed to accurately quantify both direct and indirect losses associated with LSD. For example, outbreaks in India affecting millions of cattle have resulted in losses exceeding USD 60 million (Sharma and Kumar, 2025; Jyoti *et al.*, 2022) [3]. Integrated disease management strategies should combine vaccination, vector control, movement restrictions, and farmer awareness programs to ensure effective and sustainable control (Kayesh *et al.*, 2020; Gupta *et al.*, 2020) [29, 28]. Region-specific control strategies must account for variations in vector ecology, climatic conditions, and livestock management practices (Moudgil *et al.*, 2024) [4]. Strengthening veterinary infrastructure, surveillance systems, and rapid reporting mechanisms is essential for early detection and response to outbreaks (Smaraki *et al.*, 2024) [30]. Adopting a One

Health approach that integrates animal health, vector ecology, and socio-economic factors will further enhance long-term disease management (Tuppurainen *et al.*, 2011; Azeem *et al.*, 2022) [6, 2].

13. Conclusion

Lumpy skin disease has emerged as a significant transboundary viral disease with substantial implications for global livestock production. Its rapid spread beyond Africa into the Middle East, Europe, and Asia highlights its growing importance as a major animal health concern. The disease imposes considerable economic losses through reduced milk production, decreased meat quality, and damage to hides, thereby affecting the sustainability of livestock industries. The epidemiology of LSD is complex, driven primarily by arthropod vectors and influenced by environmental and management factors, which complicates control efforts. Although advances have been made in understanding its virology, transmission dynamics, and clinical presentation, important gaps remain in knowledge related to host–virus interactions, vector competence, and long-term immunity. While cattle are the primary hosts, emerging evidence suggests that water buffalo (*Bubalus bubalis*) may contribute to disease epidemiology, particularly in mixed production systems. However, their precise role in virus maintenance and transmission requires further investigation. Vaccination remains the cornerstone of LSD control, supported by vector management, movement restrictions, and improved biosecurity measures. Nevertheless, challenges such as vaccine coverage, field

implementation, and the emergence of new viral strains necessitate continuous monitoring and refinement of control strategies. In the context of climate variability, increasing livestock movement, and intensification of animal production systems, the risk of further disease spread remains high. Therefore, coordinated efforts involving surveillance, research, policy development, and farmer awareness are essential. In conclusion, LSD represents a persistent and evolving threat to livestock health and productivity. Strengthening integrated control strategies, advancing research—particularly on buffalo involvement—and enhancing international collaboration will be critical for reducing the economic burden of the disease and ensuring sustainable livestock production in the future.

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