



Emergency Vaccination of Cattle with Goatpox Vaccine against Lumpy Skin Disease in India: Evaluation of Efficacy and Potency

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ABSTRACT

Background: Lumpy skin disease (LSD) is a re-emerging transboundary viral disease of cattle and buffaloes, causing significant economic losses and classified as a notifiable disease by the WOAH. Mass vaccination of susceptible animals is the principal strategy for disease control. Live attenuated Goatpox vaccine of Uttarkashi strain is authorized by the government for control of LSD as an emergency measure in India during 2022.

Methods: A vaccination trial was undertaken to determine the optimum dose of Goatpox vaccine for LSD prevention in cattle. Randomly selected heifers were allocated into four groups (A, B, C and D), each containing eight animals. Group A served as the unvaccinated control, while groups B, C and D received 1 mL, 2 mL and 3 mL doses, respectively, of the Goatpox vaccine containing $1 \times 10^{3.0}$ TCID₅₀ per dose.

Result: Group D, vaccinated with three times the dose used in goats (3 mL), exhibited the highest and most persistent humoral immune responses, which continued through day 35 post-vaccination ($p > 0.05$). Results indicated that an increased dose provided better and sustained protection in cattle across the trial period.

Key words: Goatpox vaccine, Immune response, Lumpy skin disease, Protection, Vaccination.

INTRODUCTION

Lumpy skin disease (LSD) is a contagious viral disease of cattle caused by the *Capripoxvirus*, *Lumpy skin disease virus* (LSDV), belonging to the family *Poxviridae*. Besides cattle, the disease can also affect Asian water buffalo and, occasionally, wild ruminants. Although the infection leads to high morbidity, the death rate usually remains low to moderate (OIE, 2021; Tuppurainen *et al.*, 2018). Biting arthropods such as mosquitoes and flies play a major role in its transmission. In India, LSD was first detected in 2019 (Sudhakar *et al.*, 2020) and since then, recurring outbreaks have been observed nationwide, resulting in the loss of over 1,25,000 cattle and infection of nearly 20 million animals (Kumar and Tripathi, 2022, Gayal *et al.*, 2024).

Effective control of LSD relies on a combination of vaccinating susceptible animals, restricting livestock movement and implementing vector management strategies. Globally, both homologous and heterologous vaccines are in use as preventive measures against LSD outbreaks. Among the homologous vaccines, attenuated preparations such as MEVAC in the Middle East (Bazid *et al.*, 2023), the South African Neethling strain (also known as KSGP O-240 and O-180) and inactivated vaccines have been applied in different regions (Hamdi *et al.*, 2020b). Genetic studies indicate that LSDV exhibits about 95% amino acid identity and strong genome collinearity with other members of the *Poxviridae* family (Tulman *et al.*, 2001). Because of their close antigenic similarity, serological differentiation between these viruses is not possible and the antibodies elicited often provide cross-protection. This explains the widespread use of heterologous vaccines against LSD

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(Hamdi *et al.*, 2020a). Examples include the sheep pox and goat pox vaccines, such as RM65 (Abutarbush and Tuppurainen, 2018), the Gorgan goatpox strain in Ethiopia and Iran (sometimes combined with the RM65 sheep pox vaccine), the GPV (G2-LKW) and Niskhi sheep pox strains in Kazakhstan, the Yugoslavian sheep pox RM65 strain in

Israel and Jordan and the Romanian sheep pox strain in Egypt and Saudi Arabia.

In India, a homologous live attenuated vaccine (Lumpi-ProVacInd) was developed through collaboration between the National Centre for Veterinary Type Cultures, Hisar and the Indian Veterinary Research Institute, Izatnagar. However, during the period of this study, the vaccine was still under clinical trial and had not been released for field application. Consequently, the Government of India approved use of the live attenuated Uttarkashi strain of the goatpox vaccine as an emergency measure for LSD control. The Uttarkashi goatpox vaccine (GTPV/Uttarkashi/1978 strain) has demonstrated long-lasting protective immunity in goats (Bhanuprakash *et al.*, 2022). However, protective efficacy of this vaccine against LSD, remained unverified. A dose of 1 mL containing $10^{3.0}$ TCID₅₀ per animal was recommended, but cases of vaccinated cattle showing clinical signs in outbreak areas indicated incomplete protection. Therefore, this investigation aimed to assess immune responses in calves inoculated with varying doses of the Goatpox vaccine and to determine the optimal dose for effective protection against LSD.

MATERIALS AND METHODS

Determining the immunogenicity of Goatpox vaccine

A field-based vaccine trial was carried out in Andhra Pradesh, India, with prior consent from local farmers during 2023. Farms without any history of lumpy skin disease (LSD) outbreaks were specifically chosen for the study. Thirty-two healthy, mixed-breed heifers aged between 6 and 12 months were enrolled. None of the animals had previously received Capripox virus vaccination and all were confirmed seronegative for LSDV-specific antibodies prior to inclusion.

Before vaccination, the heifers were dewormed, with fenbendazole @7.5 mg/ Kg body weight orally, administered one to two weeks prior and farmers were instructed to apply acaricide ivermectin pour-on at 0.2 mg/ Kg body weight in the sheds, along with ensuring a balanced diet and *ad libitum* access to clean water. Each animal was ear-tagged and then randomly assigned to one of four groups (A, B, C, D), with eight animals per group. Group A served as the unvaccinated control. Groups B, C and D received subcutaneous inoculation with the live attenuated goatpox vaccine (Uttarkashi strain) at three different dose levels: 1.0 mL ($1.0 \times 10^{3.0}$ TCID₅₀), 2.0 mL ($2.0 \times 10^{3.0}$ TCID₅₀) and 3.0 mL ($3.0 \times 10^{3.0}$ TCID₅₀), respectively, as per the manufacturer's guidelines.

Following vaccination, animals were closely observed for changes in rectal temperature, vital parameters and any clinical signs suggestive of local or systemic vaccine reactions. Cases of fever were managed with appropriate antipyretic and anti-inflammatory medication. To evaluate immune responses, blood samples were collected from all experimental groups (vaccinated and control) before immunization and subsequently on days 7, 14 and 35 post-vaccination using serum vacutainer tubes (BD®). All

samples were immediately transported to the department of veterinary microbiology, NTR college of veterinary science, Gannavaram andhra Pradesh on ice and stored at -80°C until further processing.

Vaccine

The study employed a live attenuated goatpox vaccine (Uttarkashi strain; GenBank accession KF495215.1), propagated in Vero cell lines and supplied by the Veterinary Biological Research Institute, Hyderabad, Telangana, India. The vaccine had a titer of $1.0 \times 10^{3.0}$ TCID₅₀/mL and was packaged to deliver 10^5 TCID₅₀ per 100 doses.

Virus

For the serum neutralization assay (SNT), a lumpy skin disease virus (LSDV) field isolate, designated LSDV/Cattle/VJA-PNGR/SVVU/2022, was used. This strain originated from a 1.5-year-old female Punganur calf sampled during an active LSD outbreak in Vijayawada andhra Pradesh, in 2022.

Serum neutralization test

Vero cells were seeded in 96-well tissue culture plates and grown until approximately 90% confluence. Pre- and post-vaccination sera were subjected to two-fold serial dilution in serum-free MEM using 96-well deep well storage plates (Tarsons® #510068), prepared in triplicate. For each sample, 100 µL of serum was mixed with 300 µL of MEM to obtain a 1:4 starting dilution, followed by serial two-fold dilutions (1:4 to 1:128) by transferring 200 µL across successive wells containing 200 µL MEM. To each serum dilution, 200 iL of LSDV (100 TCID₅₀ 100 µL of LSDV/Cattle/VJA-PNGR/SVVU/2022) was added and incubated at 37°C for 1 hour. After removing the growth medium, 100 µL of each virus-serum mixture was inoculated into triplicate wells of Vero cell monolayers. Cell controls received 100 µL of 1% maintenance medium, while virus controls received 100 iL of 100 TCID₅₀ inoculum. The plates were sealed with cellophane tape and incubated at 37°C, with daily examination for cytopathic effects (CPE). Final readings were recorded at 72 hours post-inoculation (hpi). Serum collected from a naturally infected, PCR confirmed LSDV case (28 days post infection) was used as the positive control. Antibody free fetal bovine serum (FBS) served as the negative control.

Antibody titers were defined as the reciprocal of the highest serum dilution showing complete inhibition of CPE. The SN₅₀ values were calculated following the Reed and Muench method (Reed and Muench, 1938).

Statistical analysis

Each serum sample was tested in triplicate and results from the SNT were expressed as mean $\pm$ standard error (SE). Statistical evaluation was carried out using SPSS software (Version 17.0; SPSS Inc., Chicago, USA). Differences in neutralizing antibody titers between and within groups were analyzed by one way ANOVA, followed by post hoc multiple comparison tests (Duncan, LSD and Duhok correction methods). Significance was considered at $p < 0.05$.

RESULTS AND DISCUSSION

Since the emergence of LSD during 2019, these outbreaks have severely impacted livestock-dependent farmers in India, resulting in substantial economic losses and compromised rural livelihoods (Kumar and Tripathi, 2022). In response, the Government of India authorized the use of live attenuated goatpox vaccine due to its antigenic similarity with LSDV. Field observations revealed that administering the vaccine dose conventionally used for goats in cattle resulted in insufficient protective immunity, prompting investigation into the efficacy of escalated dosages to enhance immunogenic outcomes and improve disease control.

Safety of goatpox vaccine in cattle

In this study, none of the vaccinated or control heifers exhibited clinical signs characteristic of Capripoxvirus infection during the 35-day monitoring period. All animals maintained normal body temperatures ($99.4 \pm 0.08^\circ\text{F}$), appetite and behaviour and no local or systemic adverse reactions were recorded post-vaccination. These observations align with recent large-scale field trials in India, where the live attenuated goatpox vaccine (Uttarkashi strain)

demonstrated excellent safety profiles, with no reported injection site reactions or febrile episodes in vaccinated cattle (Bayyappa *et al.*, 2025). Similar findings have been reported in studies from Ethiopia and Iran, confirming the vaccine's good tolerability and absence of clinical side effects (Tuppurainen *et al.*, 2018). The safe clinical profile is particularly important for field deployment, as it supports continued use in endemic regions where homologous LSD vaccines are not yet fully available.

Neutralizing antibody titres following vaccination

Humoral immune responses were quantified using the serum neutralization test and expressed as neutralization indices, with a titer of 1:8 defined as the threshold for protective immunity (Kumar *et al.*, 2023). Prior to vaccination, all heifers were screened for neutralizing antibodies and only seronegative animals were selected for inclusion in the study. After vaccination, all vaccinated groups showed a significant rise in neutralizing antibody titers compared to the control group (Table 1 and Fig 1). Antibodies were initially detectable in vaccinated animals at 7 days post-vaccination, reaching peak levels between 14 and 35 days.

Table 1: Neutralizing antibody responses (neutralization index, NI) and seroconversion rates in heifers vaccinated with different doses of Goatpox vaccine.

Group	Vaccine dose (mL* $10^{3.0}$ TCID ₅₀ /mL)	Day 0	Day 7	Day 14	Day 35
A (Control)	0	0% (NI~0)	0% (a few 1:4; NI~0)	0% (NI~0)	0% (NI~0)
B	1	0% (NI~0)	12.5% (1.87)	37.5% (2.85)	37.5% (4.37)
C	2	0% (NI~0)	25% (3.64)	37.5% (7.07)	62.5% (4.89)
D	3	0% (NI~0)	37.5% (7.33)	75% (15.24)	87.5% (26.24)

*Values indicate percentage of animals with protective neutralizing antibody titers ($\geq 1:8$), followed by group mean neutralization index (NI).

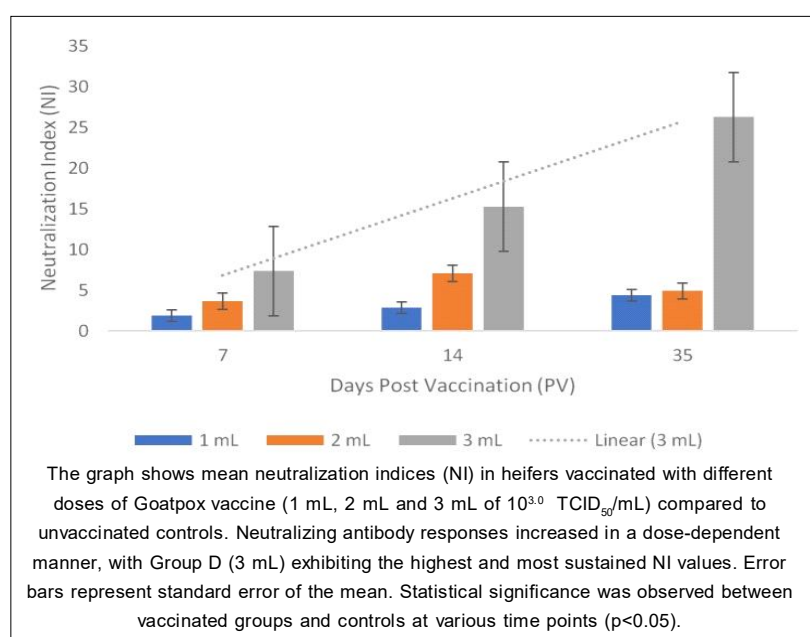


Fig 1: Neutralizing antibody dynamics in vaccinated heifers over 35 days post-vaccination.

Group A

The control group remained seronegative for the duration of the experiment. A few heifers in this group exhibited neutralizing antibody titers of 1:4 during the trial. No significant changes were observed in antibody titers on days 0, 7, 14 and 35 post-vaccination within this group.

Group B

A group of eight heifers was vaccinated with 1 mL of $10^{3.0}$ TCID₅₀/mL. No significant increase in antibody titers was observed from day 0 to 7 post-vaccination (PV). However, seroconversion was detected in one heifer at day 7 PV, with a neutralization index (NI) of 1.87. By day 14 PV, three heifers showed protective antibody titers ($\geq 1:8$), raising the group's NI to 2.85. At day 35 PV, the NI further increased to 4.37, although the percentage of seroconverted animals remained constant at 37.5%. A significant rise in antibody titers was noted between days 0, 14 and 35 PV, while no significant difference was observed between days 7 and 14 PV.

Group C

A group of eight heifers was vaccinated with 2 mL of $10^{3.0}$ TCID₅₀/mL. At 7 days post-vaccination (PV), neutralizing antibodies were detected in seven heifers; however, only two animals (25%) exhibited protective antibody levels, with a neutralization index (NI) of 3.64. By day 14 PV, protective antibody levels were present in three heifers and the NI increased to 7.07. At day 35 PV, five animals showed protective antibody levels, but the NI decreased to 4.89 due to a decline in antibody levels in three of the animals.

Group D

This group received the highest dose of the Goatpox vaccine, 3 mL of $10^{3.0}$ TCID₅₀/mL. At 7 days post-vaccination (PV), protective antibody levels were detected in three heifers (37.5%), with a neutralization index (NI) of 7.33. A

significant increase in antibody titers was observed between day 0 and day 14 PV. By day 14 PV, 75% of the animals showed protective antibody levels, with the NI rising to 15.24. By day 35, seven heifers (87.5%) exhibited protective antibody levels, with the NI further increasing to 26.24.

Sero-conversion between the groups

Serum antibody levels in vaccinated heifers increased in proportion to the vaccine dose administered, with neutralization indices of Groups B, C and D being significantly higher than those of the control Group A throughout the study (Fig 2). Control animals remained seronegative during the trial. No significant differences were observed among groups at day 0. By 7 days post-vaccination (PV), Groups C and D showed significantly higher neutralization indices compared to Group A, whereas Group B did not differ significantly from the control ($p < 0.05$). At 14 days PV, Group B exhibited significantly lower neutralization indices than Groups C and D ($p < 0.05$). At 35 days PV, a significant difference was evident only between Group D and the control Group A ($p < 0.05$). Superior antibody responses were detected in the maximum number of animals within Group D and these seropositive animals maintained protective antibody titres throughout the observation period. In contrast, a few animals in Group C failed to sustain protective antibody levels up to 35 days PV.

This finding is well supported by Zhugunissov *et al.*, (2020), who found that animals vaccinated with ten times the dose of Goatpox vaccine, developed neutralizing antibody titres by day 7 PV, increased by day 14 PV and peaked by day 21 PV (end of the trial) and concluded that Goatpox vaccine induced better immunogenicity compared to Sheep pox vaccine. A similar finding was also recorded by Varshovi *et al.* (2017) and Gari *et al.* (2015) who also observed that neutralising antibody titers started at day 7

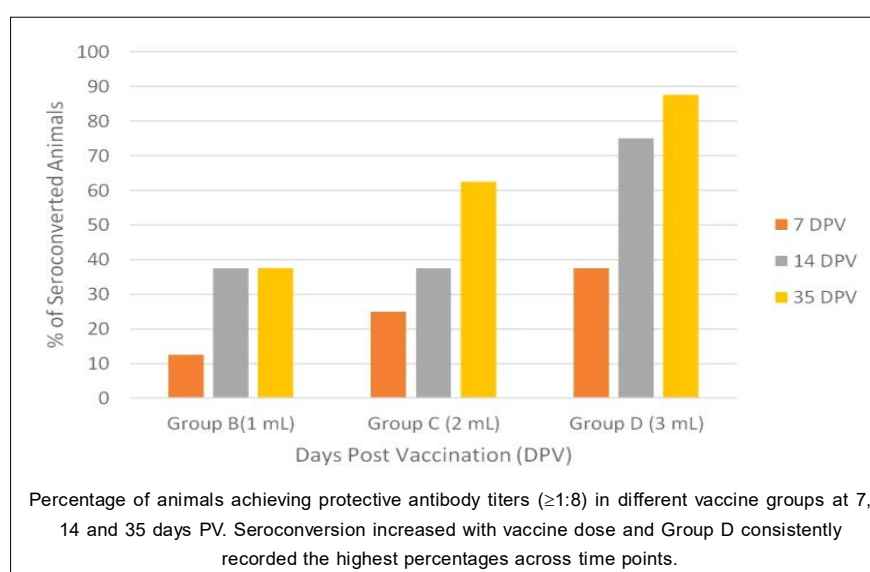


Fig 2: Proportion of seroconverted heifers following vaccination.

PV, reached to protective level by day 21 PV and persisted till day 35 PV. Similarly, Norian detected neutralising antibodies in calves vaccinated with Gorgan GPV by one week PV and the titre rose to peak at 3-5 weeks PV (Norian *et al.*, 2019). Titers maintained at the protective level till the end of their experiment *i.e.*, for a period of 5 months and GPV vaccinated calves showed higher level of antibodies than in SPV vaccinated calves.

Even homologous LSDV vaccines are efficacious, though field outcomes remain variable. Live attenuated homologous vaccines provide superior protection in cattle when adequate coverage is achieved (Hakobyan *et al.*, 2023). Although such vaccines may not elicit immediate detectable antibodies, post-challenge studies have shown earlier antibody responses in homologous compared to heterologous vaccine groups (Gari *et al.*, 2015). In India, following the 2019 incursion of LSD, NCVTC, Hisar and IVRI, Izatnagar jointly developed a homologous live attenuated vaccine (Lumpi-ProVacInd), which, despite not being released for widespread use, demonstrated high safety with negligible Neethling response (0.018%) and induced seroconversion in 85.18% of vaccinated animals by day 30 post-vaccination (Kumar *et al.*, 2023).

However, limitations of homologous vaccines have been emphasized, including the risk of recombination between vaccine and field strains (Kononov *et al.*, 2019; Sprygin *et al.*, 2018), possible reversion to virulence (Tuppurainen *et al.*, 2018), transient post-vaccination reactions (Neethling response) and virus shedding in milk, blood and nasal secretions (Bedeković *et al.*, 2018). Taken together, these findings highlight that while homologous vaccines remain pivotal to LSD control, their deployment should be critically guided by post-vaccination monitoring and rigorous risk-benefit assessment to ensure broad efficacy without compromising biosafety.

The immune protection elicited in vaccinated animals represents a synergistic interplay between humoral and cellular arms of immunity; thus, comprehensive evaluation of both components is indispensable for accurate determination of vaccine efficacy. Kitching (2003) highlighted this principle by asserting that the mere absence of measurable antibodies cannot automatically be equated with lack of protection. In line with this, Kumar *et al.* (2023) demonstrated that animals mounting robust antibody responses did not consistently exhibit pronounced cellular immunity and vice versa, underscoring the distinct yet complementary nature of humoral and cell-mediated immunity (CMI). CMI assessment through delayed-type hypersensitivity and IFN-gamma quantification, mediated by CD4+ and CD8+ T cells, is central to protective immunity against LSDV. Contemporary evidence further substantiates that both virus-neutralizing antibodies and CMI are indispensable determinants of infection control and clinical outcome (Fay *et al.*, 2022; Kumar *et al.*, 2023).

Hence, a holistic vaccine efficacy appraisal should obligatorily encompass measurement of antibody titres, DTH reactivity and cytokine profiling.

CONCLUSION

In conclusion, our study demonstrates that the Goatpox vaccine strain (Uttarkashi) is safe, non-virulent, eliciting strong immunogenicity in cattle when given at three times the dosage recommended for the target species, goats. While this study focused on assessing antibody levels for up to 35 days after vaccination, prolonging the investigation to six months would offer important information regarding the duration of protective immunity and the possible requirement for booster doses. Additional studies involving challenge trials with pathogenic field strains are essential for a thorough evaluation of vaccine effectiveness. Therefore, this current research should be viewed as a preliminary study, necessitating more extensive investigations that include different cattle groups across a range of ages, health statuses and locations to enhance vaccine application and LSD management approaches.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the official views or policies of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided but accept no liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

- Abutarbush, S.M. and Tuppurainen, E.S. (2018). Serological and clinical evaluation of the Yugoslavian RM 65 sheep pox strain vaccine use in cattle against lumpy skin disease. *Transboundary and Emerging Diseases*. **65**(6): 1657-1663.
- Bayyappa, M.R.G., Pabbineedi, S.M., Nagaraj, S., Bijalwan, S., Tadakod, S., Uma, C.R., Pawar, S., Khan, P.Y., Teotia, V.K. and Gulati, B.R. (2025). Spatiotemporal epidemiology of lumpy skin disease and evaluation of the heterologous goatpox vaccine: Insights into immunogenicity and impact. *Vaccines*. **13**(6): 641-655.

- Bazid, A.H., Wasfy, M., Fawzy, M., Nayel, M., Abdelmegeid, M., Thabet, R.Y., Yong, H.S., El-Sayed, M.M., Magouz, A. and Badr, Y. (2023). Emergency vaccination of cattle against lumpy skin disease: Evaluation of safety, efficacy and potency of MEVAC® LSD vaccine containing Neethling strain. *Veterinary Research Communications*. **47(2)**: 767-777.
- Bedeković, T., Šimić, I., Krešić, N. and Lojkić, I. (2018). Detection of lumpy skin disease virus in skin lesions, blood, nasal swabs and milk following preventive vaccination. *Transboundary and Emerging Diseases*. **65(2)**: 491-496.
- Bhanuprakash, V., Hosamani, M., Venkatesan, G. and Singh, R.K. (2022). Long-term protective immunity to goatpox in goats after a single immunization with a live attenuated goatpox vaccine. *Archives of Virology*. **167(10)**: 2035-2040.
- Fay, P.C., Wijesiriwardana, N., Munyanduki, H., Sanz-Bernardo, B., Lewis, J., Haga, I.R., Moffat, K., van Vliet, A., Hope, J.C., Graham, S.P. and Beard, P.M. (2022). The immune response to lumpy skin disease virus in cattle is influenced by inoculation route. *Frontiers in Immunology*. **13**: 857432.
- Gari, G., Abie, G., Gizaw, D., Wubete, A., Kidane, M., Asgedom, H., Bayissa, B., Ayelet, G., Oura, C.A., Roger, F. and Tuppurainen, E.S. (2015). Evaluation of the safety, immunogenicity and efficacy of three capripoxvirus vaccine strains against lumpy skin disease virus. *Vaccine*. **33(28)**: 3256-3261.
- Gayal, S.D., Sakhare, M.P., Suman, P., Shafi, T.A., Siddiqui, M.F.M.F. and Yeotikar, P.V. (2024). Molecular detection and seroprevalence of Lumpy skin disease in cattle. *Indian Journal of Animal Research*. **58(10)**: 1786- 1792. doi: 10.18805/IJAR.B-4933.
- Hakobyan, V., Sargsyan, K., Kharatyan, S., Elbakyan, H., Sargsyan, V., Markosyan, T., Vardanyan, T., Badalyan, M. and Achenbach, J.E. (2023). The serological response in cattle following administration of a heterologous sheep pox virus strain vaccine for protection from lumpy skin disease; Current situation in armenia. *Veterinary Sciences*. **10(2)**: 102.
- Hamdi, J., Bamouh, Z., Jazouli, M., Boumart, Z., Tadiaoui, K.O., Fihri, O.F. and El Harrak, M. (2020a). Experimental evaluation of the cross-protection between Sheeppox and bovine Lumpy skin vaccines. *Scientific Reports*. **10(1)**: 8888.
- Hamdi, J., Boumart, Z., Daouam, S., El Arkam, A., Bamouh, Z., Jazouli, M., Tadiaoui, K.O., Fihri, O.F., Gavrilo, B. and El Harrak, M. (2020b). Development and evaluation of an inactivated lumpy skin disease vaccine for cattle. *Veterinary Microbiology*. **245**: 108689.
- Kitching, R.P. (2003). Vaccines for lumpy skin disease, sheep pox and goat pox. *Developments in Biologicals*. **114**: 161-167.
- Kononov, A., Byadovskaya, O., Kononova, S., Yashin, R., Zinyakov, N., Mischenko, V., Perevozchikov, N. and Sprygin, A. (2019). Detection of vaccine-like strains of lumpy skin disease virus in outbreaks in Russia in 2017. *Archives of Virology*. **164(6)**: 1575-1585.
- Kumar, N. and Tripathi, B.N. (2022). A serious skin virus epidemic sweeping through the Indian subcontinent is a threat to the livelihood of farmers. *Virulence*. **13(1)**: 1943-1944.
- Kumar, N., Barua, S., Kumar, R., Khandelwal, N., Kumar, A., Verma, A., Singh, L., Godara, B., Chander, Y. et al. (2023). Evaluation of the safety, immunogenicity and efficacy of a new live-attenuated lumpy skin disease vaccine in India. *Virulence*. **14(1)**: 2190647.
- Norian, R., Ahangran, N.A., Varshovi, H.R. and Azadmehr, A. (2019). Comparative efficacy of two heterologous capripox vaccines to control lumpy skin disease in cattle. *Bulgarian Journal of Veterinary Medicine*. **22(2)**: 171-179. doi: 10.15547/bjvm. 2067
- OIE. (2021). Office International des epizooties. In: Manual of diagnostic tests and vaccines for terrestrial animals. Chapter 3.4.12. Lumpy Skin Disease.
- Reed, L.J. and Muench, H. (1938). A simple method of estimating 50% end point. *American Journal of Hygiene*. **27**: 493.
- Sprygin, A., Pestova, Y., Prutnikov, P. and Kononov, A. (2018). Detection of vaccine like lumpy skin disease virus in cattle and *Musca domestica* L. flies in an outbreak of lumpy skin disease in Russia in 2017. *Transboundary and Emerging Diseases*. **65(5)**: 1137-1144.
- Sudhakar, S.B., Mishra, N., Kalaiyarasu, S., Jhade, S.K., Hemadri, D., Sood, R., Bal, G.C., Nayak, M.K., Pradhan, S.K. and Singh, V.P. (2020). Lumpy skin disease (LSD) outbreaks in cattle in Odisha state, India in August 2019: Epidemiological features and molecular studies. *Transboundary and Emerging Diseases*. **67(6)**: 2408-2422.
- Tulman, E.R., Afonso, C.L., Lu, Z., Zsak, L., Kutish, G.F. and Rock, D.L. (2001). Genome of lumpy skin disease virus. *Journal of Virology*. **75(15)**: 7122-7130.
- Tuppurainen, E.S., Babiuk, S. and Klement, E. (2018). Epidemiology and Transmission. *Lumpy Skin Disease*. 53-62.
- Varshovi, H.R., Norian, R., Azadmehr, A. and Afzal Ahangaran, N. (2017). Immune response characteristics of Capri pox virus vaccines following emergency vaccination of cattle against lumpy skin disease virus. *Iranian Journal of Veterinary Science and Technology*. **9(2)**: 33-40.
- Zhugunissov, K., Bulatov, Y.E., Orynbayev, M., Kutumbetov, L., Abduraimov, Y.E., Shayakhmetv, Y.E. et al. (2020). Goatpox virus (G20-LKV) vaccine strain elicits a protective response in cattle against lumpy skin disease at challenge with lumpy skin disease virulent field strain in a comparative study. *Veterinary Microbiology*. **245**: 108695.