Solid Dose Vaccines:
Transforming Veterinary Medicine Through Innovation

Vaccination is central to animal health, yet its delivery remains rooted in needle-based, cold-chain-dependent systems. Solid Dose Vaccine (SDV) technology offers an innovative alternative, designed for today's challenges of disease control, sustainability and access & cost.

While conventional liquid vaccines have served the veterinary sector well, they bring persistent inefficiencies. Vaccine wastage resulting from cold chain failure, needlestick injuries to personnel, carcass damage caused by broken needles, labour-intensive administration and limited reach in low- and middle-income countries (LMICs) all constrain the effectiveness of vaccination programmes. SDV technology offers a fundamentally different approach by addressing these limitations through stable, needle-free delivery formats (Box 1).

Key Advantages of Solid Dose Vaccine (SDV) Technology

Logistics and Delivery

- Thermostable formulations remove cold chain storage and transport requirements.
- Compact, lightweight doses reduce shipping volume, packaging and waste.
- No reconstitution, mixing, or multidose vial management.
- Suitable for stockpiling and rapid deployment during outbreaks.

Medical and Immunological Benefits

- Antigen sparing enables effective immunity with lower antigen quantities.
- Adjuvant sparing reduces reactogenicity while maintaining immunogenicity.
- Timed-release capability allows single-administration multi-dose schedules.

Safety and Animal Welfare

- Needle-free delivery eliminates needlestick injuries and sharps disposal.
- Faster administration with reduced handling and restraint.
- No risk of broken needles or retained metal fragments in carcasses.
- Reduced injection-site trauma and stress responses.

Economic and Environmental Impact

- Reduced antigen wastage from syringe 'dead space,' cold chain failure and open-vial discard.
- Reduced labour and handling costs in large-scale systems.
- Reduced energy use and greenhouse gas emissions by eliminating refrigeration across the entire distribution, storage and handling processes.
- Eliminates glass waste coupled with less plastic and metal waste across the vaccine lifecycle.
- Reduced overall cost-per delivered dose and improved cost-effectiveness of vaccination campaigns.

Global Access and Disease Control

- Enables vaccination in remote and resource-limited settings.
- Supports high-coverage campaigns for endemic and transboundary diseases.
- Facilitates rapid response to emerging and zoonotic disease threats.

Understanding SDV Technology

SDVs are fully self-contained and include adjuvants (where required) and a single dose of antigen, in contrast to liquid solutions used for conventional vaccines. The resulting SDV takes the form of a small, solid dose (micro-tablet) – that is delivered using a multi-dose needle-free delivery pen. The multi-dose delivery pen employs a spring based mechanism to insert the SDV into the subcutaneous layer where it fully disperses within minutes. Safety features in the delivery pen ensure that the SDV is delivered only when the device is pressed against the skin.

The solid dose formulations are highly thermally stable.

The Hidden Costs of Liquid Vaccines

Liquid vaccine wastage – defined as doses discarded, lost, damaged, or destroyed without administration – is a significant problem. While rarely causing outright program failure, it introduces inefficiency, raises costs and reduces optimal use of vaccines. SDV technology eliminates these inefficiencies.

One of the most consistent sources of wastage is the residual vaccine left in syringes and vials. During human COVID-19 campaigns, such losses ranged from 6% to 35% per dose depending on syringe design.[1] Standard high-dead-space syringes can waste up to 0.3 mL per 1 mL dose, while optimized versions reduce this to approximately 0.03 mL. Veterinary-specific data is limited, but high-dead-space syringes remain common in field settings, particularly in resource-constrained environments.

The problem is compounded by multidose vials, which are frequently used in livestock vaccination, especially in lower-middle-income countries (LMICs). Research in human medicine shows that multidose vials cause five to ten times more wastage than single-dose formats,[2] due to contamination risk, stopper puncture limits and end-of-day discard policies.

Cold Chain Failure

It is also important to consider the impact of cold chain storage. Cold chain failure is one of the main causes of liquid vaccine wastage. Vaccines contain a wide range of antigen types which may be de-natured or destroyed by elevated temperatures. For protein based vaccines exposure to elevated temperatures can cause these proteins to unfold, aggregate and degrade,[3] whereas freezing temperatures can result in the formation of ice crystals,[4] disrupting the protein structure and leading to irreversible denaturation. Live or attenuated based vaccines are also highly susceptible to damage caused by temperature excursions, impacting their effectiveness.

This means that most veterinary vaccines require continuous storage at 2–8 °C. Maintaining these temperatures across the supply chain, from manufacturer to warehouse, transport, and finally to the veterinary clinic or field, is costly, logistically complex, vulnerable to interruption and has a significant negative environmental impact.

The cold chain now accounts for 38% of the pharmaceutical market costs, with logistics costs estimated at $21.3 billion in 2024.[5] According to the WHO and EIC, up to 50% of vaccines are wasted globally due to cold chain failures, while a 2018 University of Bristol study found that none of the UK dairy farms assessed monitored medicine storage temperatures.[6]

With no visual indicators of damage, many degraded vaccines may still be used, potentially resulting in failed immunization, disease outbreaks and financial loss. SDVs are thermostable, removing the need for cold chain storage, simplifying delivery and improving both economic and animal health outcomes.

Antigen Sparing

Another key advantage of SDV technology is its potential for antigen sparing – the ability to achieve equivalent or enhanced immune responses using a reduced amount of antigen compared with conventional liquid vaccines.

Recombinant protein vaccines are well suited to dose-sparing strategies due to their precision, stability and compatibility with advanced delivery technologies. Unlike live attenuated vaccines, which rely on replication of the organism to amplify antigenic exposure, protein-based vaccines can stimulate protective immunity even at low antigen doses, provided antigen presentation and immune activation are efficient.

This effect has been demonstrated in preclinical studies. In a rabbit model using a recombinant influenza H7 antigen, a solid dose formulation (aVaxziPen) induced significantly stronger immune responses than its liquid comparator.[7] Following a second booster immunization, antibody titers in animals receiving the SDV were up to ten-fold higher than those in the liquid vaccine group (Figure 1). Additionally, onset of the immune response was more rapid after the primary dose, indicating more efficient early immune activation.

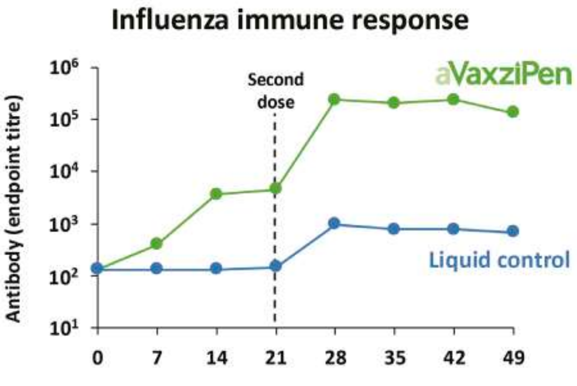


Figure 1. Antibody titers following primary and booster vaccination in a study using recombinant influenza H7 antigen in rabbits. The SDV achieved a more rapid antibody induction after the first dose and a larger boost after the second dose.

Importantly, equivalent immune responses were achieved using approximately 20-fold less antigen in the solid dose formulation compared with the liquid vaccine (Figure 2). These findings illustrate the dose-sparing potential of SDVs. As antigen is typically the most resource-intensive component of vaccine manufacturing, reductions of this magnitude offer a direct, scalable route to cost savings, particularly in high-throughput livestock systems, where many millions of doses may be administered annually.

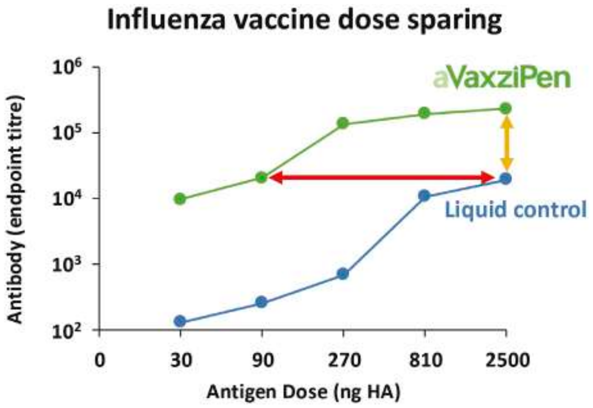


Figure 2. Antibody titers at different antigen doses illustrating the dose-sparing potential of a solid dose formulation. The SDV achieved an equivalent immune response using 20 times less vaccine (red arrow) and ten times greater antibody titers after the second dose (yellow arrow).

Mitigating Reactogenicity

Lower antigen doses may also mitigate vaccine reactogenicity – that is, the local and systemic inflammatory response to immunization. While some innate immune activation is essential to trigger protective immunity,[8] excessive reactogenicity can lead to adverse outcomes that have both animal welfare and commercial implications.

Local reactions, particularly at intramuscular injection sites, are well-documented in livestock. These may include inflammation, swelling, or lesion formation and in meat-producing animals, such effects have direct commercial consequences. A study conducted at Colorado State University demonstrated that approximately 9.7% of beef round cuts contained visible lesions at the injection site, requiring an average of 212 grams of meat to be trimmed and discarded.[9] Moreover, meat from the tissue surrounding the lesion exhibited reduced tenderness due to increased collagen deposition and localised fibrosis. The study concluded that intramuscular injection-site lesions caused significant muscle damage, affecting both yield and meat quality.

Adjuvant Sparing

Closely related to antigen sparing is the concept of adjuvant sparing – achieving robust immune responses with lower quantities of adjuvant. Vaccine adjuvants are chemicals, microbial components or proteins that enhance the immune response to an antigen.[10]

However, adjuvants account for much of the reactogenicity associated with vaccination – the local inflammation, injection-site reactions and systemic side effects that may be seen. As already discussed, in production animals local reactions can have implications for welfare and carcass quality. Furthermore in cats, chronic inflammation at the site of vaccination has been linked to the development of feline injection-site sarcomas (FISS). While the precise role of adjuvants in FISS pathogenesis is unknown, vaccines containing adjuvants tend to induce more local inflammation than non-adjuvanted formulations and chronic inflammation is a known risk factor for FISS development.[11,12]

In horses, intradermal testing has shown that some animals with a history of vaccine hypersensitivity react specifically to adjuvant components.[13] This suggests that adjuvants may act as sensitising agents, priming the immune system for exaggerated responses to future exposures. Reducing adjuvant exposure may therefore help to lower cumulative exaggerated immune burden.

Adjuvant Sparing Potential

The adjuvant sparing properties of SDVs are highlighted in a preclinical study using an influenza vaccine and the aVaxziPen SDV platform.[7] Solid dose formulations containing just 0.2 µg of QS-21 elicited a strong antibody response, despite using a 25-fold lower adjuvant dose compared to another SDV group (Figure 3).

These findings highlight the potential of SDVs to achieve effective immune responses while substantially reducing adjuvant content. Reducing adjuvant content in vaccine formulations can offer significant safety and tolerability benefits, particularly in veterinary settings where animals may receive repeated vaccinations over their lifetime and where field conditions may complicate post-vaccination monitoring.

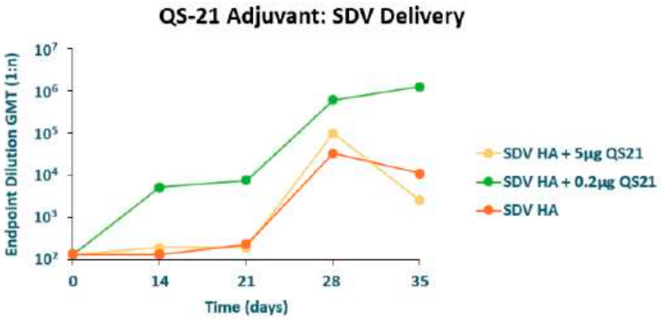


Figure 3. The adjuvant sparing potential of an influenza SDV. A strong antibody response was achieved with a 25-fold lower dose of QS-21.

Needlestick Safety

While often overshadowed by other vaccine-related concerns, needlestick injuries represent a significant occupational hazard. Needlestick injuries are particularly common in livestock settings, where animal movement, time pressure and volume all increase the chance of accidental contact. As well as local trauma to the handler, these injuries can lead to exposure to biological agents or vaccine components, as well as lost working time, compensation costs and litigation risk for commercial operators.

The Veterinary Medicines Directorate (VMD) holds many reports of people suffering from prolonged pain, inflammation and restrictions to mobility because of a veterinary needlestick injury.[14] The demographic of people at risk is wide-ranging, from staff in clinical veterinary facilities, to farmers administering routine medication to large numbers of livestock.

SDV delivery devices contain no sharps, require no needle handling or recapping, and can be safely discarded in ordinary waste streams after use. For large-scale vaccination campaigns, this safety advantage scales significantly.

Beyond human safety, needle-free delivery also confers important benefits for animals and food safety. Needle breakage during injection is a recognised risk in livestock vaccination, particularly in pigs and cattle, where sudden movement can cause needles to snap and become embedded in muscle tissue. Retained needle fragments may only be detected at slaughter, resulting in carcass trimming, condemnation, or removal of the animal from the food chain entirely. This represents a direct economic loss to producers and a potential food safety concern.

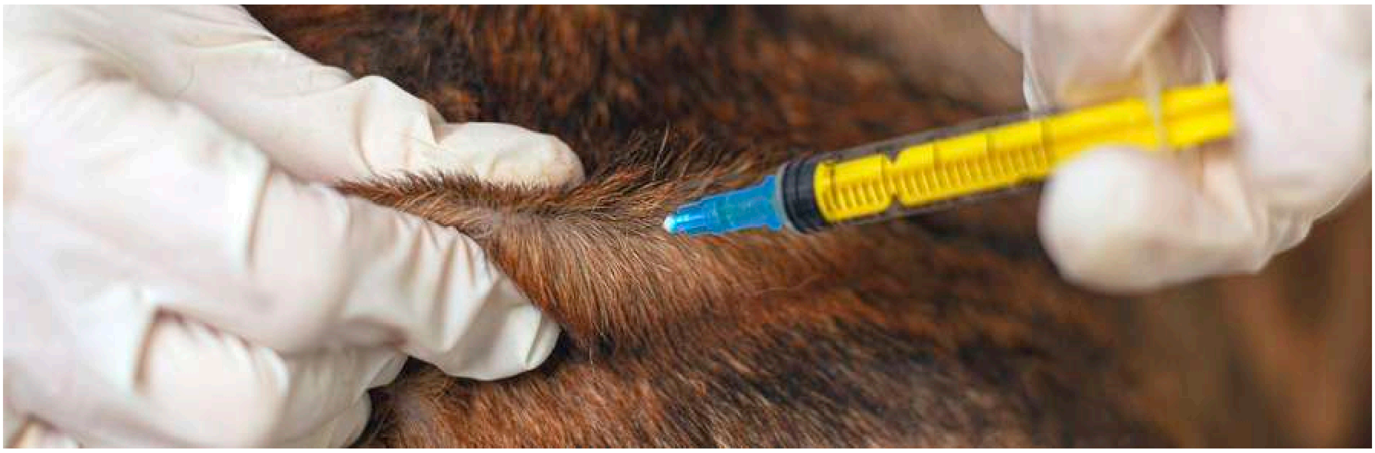
Protection Against PRRS

A key question for any novel delivery format is whether it translates beyond preclinical models into protection in target livestock species. A recent study evaluated a needle-free solid dose delivery of a modified-live PRRSV vaccine in pigs and found it generated neutralising antibody responses and protection comparable to standard needle-and-syringe vaccination.[15] Protection was evidenced by reductions in viremia, virus shedding, and gross lung lesions following challenge. This study marks a significant step forward in the development of SDVs for commercial use.

Expanding Access in Resource-Limited Settings

The potential benefits of SDV technology are apparent in high-throughput livestock systems, such as intensive pig or poultry systems, where millions of doses may be administered annually. They are equally compelling in LMICs, where cost, logistics and infrastructure constraints remain major barriers to effective vaccine deployment.

Many of the infectious diseases where vaccination is central to control - including foot-and-mouth disease (FMD), peste des petits ruminants (PPR) and lumpy skin disease (LSD) – are endemic or recurrent in LMICs. These transboundary diseases not only undermine local livestock productivity and



food security but also pose ongoing risks to regional and global animal health.

In such settings, the ability to deploy vaccines that are thermostable, scalable and easy to administer by livestock workers is critical. SDV technology supports rapid scale-up of vaccine production and distribution during outbreak scenarios, while reducing dependence on cold chain infrastructure and lowering costs per delivered dose of vaccine. This enables wider coverage, more reliable immunization campaigns and greater resilience in disease control programs.

Conclusion

As global agriculture faces increasing pressure to decarbonize, manage emerging disease threats and improve production sustainability, the veterinary sector must evolve. SDV technology addresses the fundamental limitations of liquid vaccines and offers a path toward more efficient, sustainable and accessible animal health interventions. By aligning scientific innovation with practical delivery, SDVs have the potential to strengthen disease control, support animal welfare, environmental goals and global food security, whilst at the same time improving the cost-effectiveness of vaccinations.

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