2026, Scienceline Publication
World's Veterinary Journal
World Vet J, 16(2): 678-692.
ISSN 2322-4568

DOI: https://dx.doi.org/10.54203/scil.2026.wvj65
PII: S232245682600065-16

Traditional Medicinal Plants as Sources of Broad-Spectrum Antiviral Agents Against Poultry Viral Infections: A Review

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REVIEW ARTICLE
Received: March 07, 2026
Revised: April 11, 2026
Accepted: May 10, 2026
Published: June 30, 2026

ABSTRACT

Across Asia, poultry farming plays a critical role in ensuring food security and supporting rural communities, delivering affordable protein to billions of people. Sustainable poultry production in Asia, especially in India, has been consistently affected by viral diseases. Conventional interventions, including vaccination and biosecurity protocols, often remain inadequate against viral infections, require specific storage conditions, elicit suboptimal immune responses, and pose economic challenges and limitations. In poultry, synthetic antiviral medications are often unsuitable due to their high cost, adverse effects, and concerns about residual compounds. Plant-based remedies emerge not as direct replacements but as valuable alternatives to consider for developing broad-spectrum antiviral solutions. The present study aimed to evaluate the antiviral potential of South Asian ethnomedicinal plants against Newcastle disease virus, infectious bursal disease virus, infectious bronchitis virus, and fowl adenovirus. Compounds such as flavonoids, terpenoids, alkaloids, saponins, and lignans were targeted for their multitarget activities, including inhibition of viral entry and polymerases, immunomodulation, and antioxidant properties. Different studies on *Glycyrrhiza glabra*, *Tephrosia purpurea*, *Cyperus rotundus*, *Tribulus terrestris*, *Boerhavia diffusa*, *Azadirachta indica*, *Andrographis paniculata*, and *Ocimum sanctum* reported promising therapeutic potential against poultry viral diseases. Available *in vitro* studies demonstrated strong antiviral activity across multiple phytochemical classes. Nevertheless, *in vivo* validation and implementation at the field level remain substantially limited. The current findings confirmed the strong potential of ethnomedicinal plants as sustainable, multi-target antivirals for poultry health.

Keywords: Flavonoid, Fowl adenovirus, Infectious bronchitis virus, Infectious bursal disease virus, Saponin, Terpenoid

INTRODUCTION

Poultry farming persistently encounters challenges worldwide, particularly due to the viral effects that disrupt production systems (Muñoz-Gómez et al., 2025). Throughout Asia, poultry farming is a crucial source of income for local communities while also providing food for large populations. Millions of people rely on smallholder farmers in countries such as India and Bangladesh, even as industrial-scale farms expand rapidly (Kabir et al., 2021; Kalaria et al., 2021). However, this rapid growth has caused increased losses related to disease, especially from infectious bursal disease virus (IBDV) and infectious bronchitis virus (IBV), which contribute to chick mortality, lower egg production, hinder feed efficiency, and raise veterinary costs (Kalaria et al., 2021; Islam et al., 2022). Frequently overlooked, potential solutions reside within indigenous plant species that have long been utilized in traditional folk remedies. The antiviral potential of traditional medicinal plants is garnering attention, as recent results confirmed measurable activity against pathogens detrimental to poultry health (Muñoz-Gómez et al., 2025). Rather than relying solely on synthetic pharmaceuticals, some poultry farmers consider utilizing natural sources already available in their environment. Progress in the use of natural sources as antiviral agents remains limited, but there is increasing effort to integrate these methods into broader health strategies for sustainable poultry care management (Kabir et al., 2021; Muñoz-Gómez et al., 2025).

Currently, there are no effective curative treatments for viral diseases in poultry (Szotowska and Ledwoń, 2024). Vaccines, although effective, remain a control strategy constrained by multiple limitations (Ravikumar et al., 2022; Toka and Geinoro, 2023). Mutations in poultry respiratory and immunosuppressive viruses, especially IBV and IBDV, lead to vaccine failure against emerging strains (Toka and Geinoro, 2023; Rafique et al., 2024). Mass vaccination campaigns face challenges, including cold-chain storage, interference from maternal antibodies, high production costs, and

To cite this paper: Dutta R and Ayyagari VS (2026). Traditional Medicinal Plants as Sources of Broad-Spectrum Antiviral Agents Against Poultry Viral Infections: A Review. *World Vet. J.,* 16(2): 678-692. DOI: https://dx.doi.org/10.54203/scil.2026.wvj65

inadequate coverage in rural areas (Ravikumar et al., 2022; Toka and Geinoro, 2023). Synthetic antiviral medications, including those used in human medicine, were not practical for poultry due to costs, toxicity, the risk of residues in meat and eggs, and the potential development of resistance (Szotowska and Ledwoń, 2024). The combination of incomplete vaccination, impractical antiviral medications, and growing resistance created an urgent need for safer, more cost-effective antiviral alternatives in poultry farming.

Long-standing medicinal plants can serve as broad-spectrum antiviral agents (Adeosun and Loots, 2024). Traditional poultry and livestock healthcare relies on a well-documented ethnopharmacological foundation that includes hundreds of unique herbs (Jamil et al., 2022; Pebam et al., 2022). *Azadirachta indica* (neem), *Allium sativum* (garlic), *Zingiber officinale* (ginger), *Ocimum sanctum* (holy basil), and *Andrographis paniculata* (nilavembu) are deeply embedded in South Asian poultry farming practices (Abd El-Hack et al., 2022; Pebam et al., 2022; Eftekhari Hasan Abad and Ghaniei, 2023; Djamen et al., 2024). In poultry health management and nutrition, plants are frequently utilized as feed additives, water supplements, or prophylactic agents to control viral diseases (Abd El-Hack et al., 2022; Jamil et al., 2022). Plants such as neem, ginger, and garlic are rich in flavonoids, alkaloids, terpenoids, saponins, and sulfur compounds, which are known to inhibit viral entry, interfere with replication enzymes, and stimulate host immunity (Adeosun and Loots, 2024; Tahir and Alsayeqh, 2024).

The worldwide transition to sustainable and residue-free production makes plant-based antivirals a critically important strategy for poultry healthcare (Abd El-Hack et al., 2022; Adeosun and Loots, 2024). In many developing countries, small-scale poultry farmers often lack access to resources, where phytotherapeutics can serve as a transformative solution (Jamil et al., 2022; Pebam et al., 2022). Integration of these phytotherapeutics into modern veterinary virology could lead to new opportunities to develop novel medicines and feed-based prophylactic interventions (Adeosun and Loots, 2024; Tahir and Alsayeqh, 2024). The present study aimed to review the broad-spectrum antiviral potential of traditional medicinal plants against major poultry viral diseases, including Newcastle disease virus (NDV), IBDV, IBV, and Fowl Adenovirus (FAdV), and to synthesize evidence on phytochemical mechanisms and knowledge gaps to support sustainable poultry health management.

METHODOLOGY

The present study was conducted through a comprehensive literature review to identify studies related to the antiviral potential of traditional medicinal plants in the context of poultry viral diseases. The investigation was conducted using the electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search terms, used individually and in combination, included traditional medicinal plants, antiviral, phytochemicals, poultry, NDV, IBDV, IBV, FAdV, flavonoids, antiviral mechanisms, terpenoids, immunomodulation, saponins, poultry health, phytogenic feed additives, and ethnomedicinal plants in South Asia.

The inclusion criteria for selecting articles were peer-reviewed original articles, review papers, and relevant case studies, published in English between 2009 and 2025, that demonstrated direct relevance to the phytochemical characterization, antiviral mechanisms, or immunomodulatory effects of traditional medicinal plants against poultry-relevant viral pathogens.

In vitro, *in silico*, and *in vivo* studies reporting antiviral activity of plant-derived compounds were all considered eligible. Studies involving closely related mammalian model viruses were also incorporated, where their findings provided translational relevance to poultry virology. Exclusion criteria included non-peer-reviewed grey literature, conference abstracts without full data, studies on non-relevant species lacking translational value, and publications lacking original phytochemical or antiviral findings. Finally, 72 articles were included for final assessment and synthesis. The collected literature was critically synthesized to evaluate the broad-spectrum antiviral potential of key phytochemical classes, including flavonoids, terpenoids, alkaloids, saponins, and lignans, and to support the multitarget mechanistic framework presented in the present study. Five plants, *Glycyrrhiza glabra* (*G. glabra*), *Tephrosia purpurea (T. purpurea)*, *Cyperus rotundus* (*C. rotundus*), *Tribulus terrestris* (*T. terrestris*), and *Boerhavia diffusa* (*B. diffusa*), were selected for a detailed case study assessment based on the following criteria.

Initially, each plant was documented for its availability and traditional application in South Asian poultry and livestock healthcare. Secondly, phytochemical evidence from scientific studies confirmed the presence of at least one class of bioactive compounds with known antiviral, immunomodulatory, or hepatoprotective properties. Thirdly, preliminary data, whether derived from *in vitro*, *in silico*, or *in vivo* investigations, were available for each plant in the context of poultry or closely related animal models. These plants were subsequently assessed for their therapeutic relevance, practicality as phytogenic feed additives, and potential integration. Into sustainable poultry health management systems in South Asia.

PHYTOCHEMICAL RESERVOIRS OF ANTIVIRAL COMPOUNDS

Based on the existing literature, many traditional medicinal plants contain bioactive secondary metabolites with broad-spectrum antiviral potential (Phillips et al., 2023; da Fonseca et al., 2025). These phytochemical compounds, unlike synthetic antiviral agents, are designed to target specific viral enzymes or pathways and exert multiple effects by modulating viral entry, replication, host immunity, and oxidative stress responses (Phillips et al., 2023; da Fonseca et al., 2025). This multitarget characteristic of phytochemical compounds has demonstrated potential against poultry viruses (Sarwar et al., 2022).

Flavonoids

The structural diversity and extensive bioactivity of flavonoids have established them as one of the most comprehensively studied categories of plant-derived antivirals agents (da Fonseca et al., 2025). Flavonoids are structurally diverse, encompassing flavonols (quercetin, kaempferol), flavones (apigenin, luteolin), flavanones (naringenin), and catechins (epigallocatechin gallate [EGCG]; da Fonseca et al., 2025). These compounds exhibited both direct and indirect antiviral effects (Wang et al., 2021a; da Fonseca et al., 2025). Quercetin has been reported to inhibit viral polymerases and proteases, interfere with viral entry by blocking hemagglutinin-like interactions, and enhance host interferon responses (Wang et al., 2021a; da Fonseca et al., 2025).

In Ross 308 broiler chickens, supplementing the diet with 200-800 ppm of quercetin, primarily sourced from flavonol-rich plants such as *Allium cepa* and *Camellia sinensis*, enhanced growth performance, improved gut microbiota, and increased antioxidant enzyme gene expression. However, no significant increase in humoral antibody titers against the avian influenza H5N1 vaccine was observed by day 35 post-supplementation. These findings suggested that the immunoadjuvant properties of quercetin warrant further focused investigation (Abdel-Latif et al., 2021). Epigallocatechin-3-gallate, the principal catechin derived from *Camellia sinensis* (green tea), has demonstrated significant activity against coronaviruses and paramyxoviruses *in vitro*, mainly through binding to viral surface proteins and inhibiting attachment (Pham, 2021; Wang et al., 2021a). Although poultry-specific data remain limited, similar mechanisms may apply to IBV and other enveloped RNA viruses, in which surface glycoproteins are vulnerable to flavonoid interference, which is significant (Wang et al., 2021a; Saadh, 2022).

Terpenoids and steroids

Terpenoids, derived from isoprene units, encompass monoterpenes, diterpenes, triterpenes, and steroids (Obianwuna et al., 2024). Terpenoids are abundant in *Andrographis paniculata* (*A. paniculate*; andrographolide) and *Ocimum sanctum* (ursolic acid; Yasmin et al., 2020; Obianwuna et al., 2024). Terpenoids exert antiviral effects by disrupting viral membranes, inhibiting viral fusion proteins, and suppressing viral transcription (Yasmin et al., 2020; Obianwuna et al., 2024). Andrographolide from *A. paniculata* interferes with NDV replication and reduces the release of inflammatory cytokines, providing dual antiviral and host-protective effects (Nagajothi et al., 2020; 2023). Neem-derived limonoids, such as nimbolide, have generally exhibited virucidal effects against paramyxoviruses by directly destabilizing the viral envelope (Wylie and Merrell, 2022; Rajendran et al., 2024). Plant steroids, particularly phytosterols, can modulate host immune responses, thereby enhancing poultry resistance to viral infections (Yasmin et al., 2020; Obianwuna et al., 2024). Beta-sitosterol, found in many medicinal plants, has been associated with improved lymphocyte proliferation and macrophage activity (Obianwuna et al., 2024; Rajendran et al., 2024).

Alkaloids

Nitrogen-rich compounds known as alkaloids exhibit diverse antiviral effects (Kang et al., 2025). These compounds include piperine, which is found in black pepper, berberine, derived from *Tinospora cordifolia*, and solasodine, present in specific Solanum species (Kang et al., 2025). Alkaloids primarily exert antiviral effects by disrupting viral genome replication, inhibiting viral protein synthesis, and preventing viral attachment to host cell receptors (Kang et al., 2025). Piperine has been associated with enhanced immune responses post-vaccination and reduced disease incidence in poultry raised for commercial purposes (Mohite et al., 2024). Berberine acts against multiple RNA-based pathogens, including influenza, hepatitis C, respiratory syncytial virus (RSV), chikungunya, and NDV, by interfering with viral enzymes and cellular signaling pathways, such as the MAPK pathway. However, the role of berberine in controlling poultry viruses remains uncertain without further laboratory investigation (Kang et al., 2025).

Lignans and coumarins

Lignans and coumarins have yet to attract significant attention; however, interest in their potential antiviral properties is increasing (Lawal et al., 2021; Wang et al., 2023). Podophyllotoxin-based lignans inhibit DNA polymerase activity. In contrast, certain coumarins, such as umbelliferone and scopoletin, tend to disrupt viral replication and affect oxidative processes (Lawal et al., 2021; Wang et al., 2023). The conserved nature of RNA-dependent RNA polymerases (RdRp) across RNA virus families suggested that further investigations into the effectiveness of lignans and coumarins against avian viruses could yield important clinical insights (Lawal et al., 2021; Wang et al., 2023).

Saponins

Saponins, mainly found in plants such as *T. terrestris* and *Quillaja saponaria*, are glycosides with mixed solubility. Despite their structural complexity, these compounds exhibit measurable antiviral activity and enhance immune function (Wang, 2021b; Saeed et al., 2024). While often derived from legumes, saponins are notable for their surfactant properties, which disrupt viral membranes. Saponin-mediated membrane disruption occurs alongside broader immunological changes, including increased antibody levels. Saponins derived from *Quillaja saponaria* are frequently incorporated into poultry vaccines to enhance protective immune responses against IBV (Wang, 2021b; Saddoris-Clemons et al., 2024; Morais et al., 2025).

Protection increases as circulating antibodies and cellular defences respond more effectively (Wang, 2021b; Saddoris-Clemons et al., 2024; Morais et al., 2025). Supplementation with *T. terrestris* extract has enhanced macrophage activation and elevated serum antibody concentrations in experimental models (Al-Garadi et al., 2022; Saeed et al., 2024). Such findings suggested dual roles, including preventive health support and enhanced vaccine effectiveness (Al-Garadi et al., 2022; Saeed et al., 2024).

Synergistic and multifactorial mechanisms

The antiviral effectiveness of phytochemical compounds rarely results from a single compound alone (Jasim et al., 2024; Fouad et al., 2025). Most medicinal plants contain complex mixtures of flavonoids, terpenoids, alkaloids, and saponins that act synergistically (Jasim et al., 2024; Fouad et al., 2025). For instance, garlic (*Allium sativum*) contains allicin, ajoene, and multiple organosulfur compounds that combine virucidal, antioxidant, and immunostimulatory properties (Doostmohammadian et al., 2020; Adjei-Mensah et al., 2023). Similarly, turmeric (*Curcuma longa*) yields curcuminoids along with volatile oils, demonstrating both anti-inflammatory and direct antiviral effects (Aderemi and Alabi, 2023; Fouad et al., 2025). This multifactorial activity is especially important in poultry virology, where viral diversity and coinfections often occur on commercial poultry farms, creating persistent challenges for disease management and vaccine effectiveness (Jasim et al., 2024; Fouad et al., 2025).

MECHANISMS OF ANTIVIRAL ACTION

The antiviral effectiveness of traditional medicinal plants stems from diverse bioactive compounds that interfere with multiple stages of the viral life cycle while also boosting host defenses (Adeosun and Loots, 2024; da Fonseca et al., 2025). Unlike synthetic medications designed for narrow-spectrum targets, phytochemicals typically act synergistically via multiple pathways (Adeosun and Loots, 2024; da Fonseca et al., 2025). In poultry virology, this multifaceted action is especially important due to the antigenic variability of viruses such as NDV and IBV, as well as the significant immunosuppression caused by IBDV (Ravikumar et al., 2022; Tahir and Alsayeqh, 2024).

Inhibition of viral entry and attachment

Viral entry initiates with viral surface glycoproteins attaching to host cell receptors, which then leads to membrane fusion or endocytosis (Adeosun and Loots, 2024; da Fonseca et al., 2025). Inhibiting these steps is an effective strategy for infection prevention (da Fonseca et al., 2025). Flavonoids, including quercetin and EGCG, interact with viral hemagglutinin-like proteins and receptor-binding domains, thereby inhibiting adsorption (Figure 1; Pham, 2021; Wang et al., 2021a; da Fonseca et al., 2025). In poultry studies, quercetin analogues typically inhibited syncytium formation in NDV-infected cell cultures (Hasan and Ahad, 2024; Mochamad et al., 2024).

Terpenoids, such as andrographolide derived from *Andrographis paniculata*, destabilize viral envelopes and actively interfere with fusion proteins, thereby diminishing viral entry efficiency (Figure 2; Nagajothi et al., 2020; 2023). Aqueous extracts of *Azadirachta indica* (neem) bark and leaf at concentrations ranging from 50% to 100% were confirmed to reduce NDV infectivity following pre-incubation with virions (8 HA units) for 30 minutes at 27.3°C. This reduction was assessed using a haemagglutination assay in nine-day-old embryonated chicken eggs. Notably, neem bark extract achieved complete viral inactivation at the undiluted concentration (Hasan and Ahad, 2024).

Saponins disrupt lipid bilayers due to their detergent-like amphipathic structure, rendering enveloped viruses, such as IBV, non-infectious before cell entry (Sarwar et al., 2022; Hasan and Ahad, 2024; Mochamad et al., 2024).

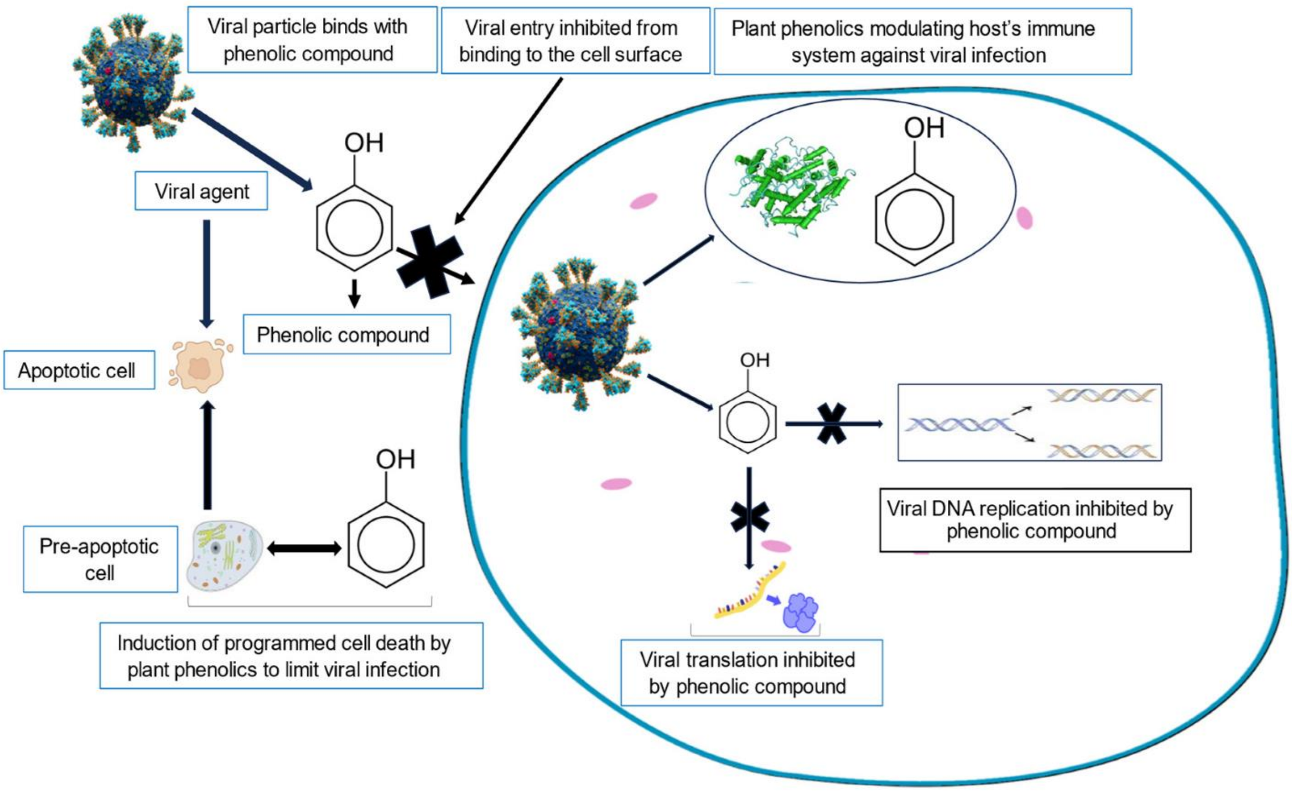

Figure 1. The mechanisms of action of the antiviral properties of phenolic compounds. Source of the image: Adeosun and Loots (2024)

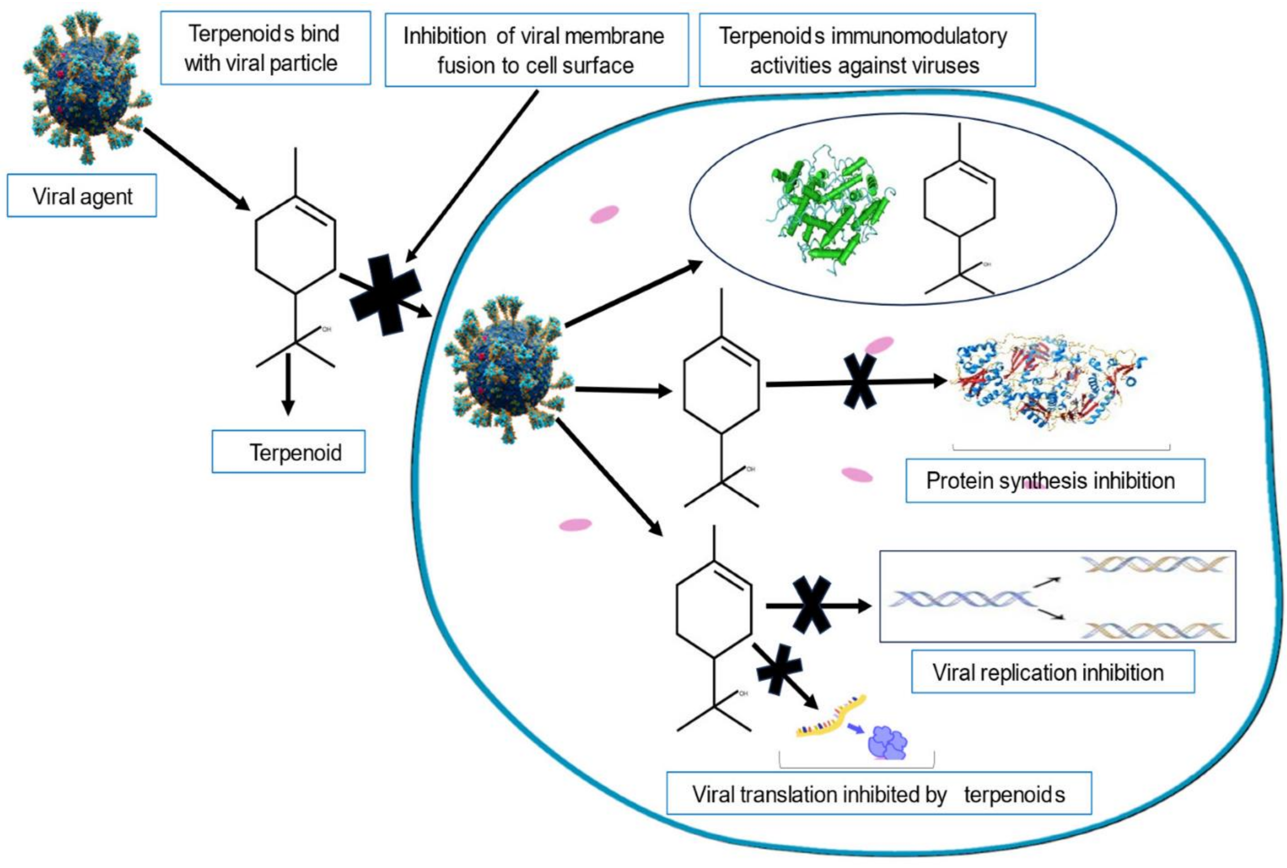

Figure 2. The mechanism of the antiviral activities of terpenoids. Source of the image: Adeosun and Loots (2024)

Suppression of viral polymerases and proteases

The replication of poultry RNA viruses primarily depends on RdRp and viral components (Phillips et al., 2023; da Fonseca et al., 2025). Inhibiting these enzymes directly prevents genome replication and protein maturation (Phillips et al., 2023; da Fonseca et al., 2025). *In silico* studies have demonstrated that flavonoids exhibit favorable docking interactions with essential NDV replication proteins, including the V protein. Quercetin and luteolin derivatives have been identified as potential inhibitors through molecular docking and molecular dynamics simulation (Sarwar et al., 2022). Piper longum extracts exhibited considerable immunomodulatory activity against NDV, enhancing HI antibody titers in broiler chickens (Karande et al., 2024).

Alkaloids such as berberine and piperine essentially interfere with nucleic acid synthesis and protease activity (Figure 3; Mohite et al., 2024; Kang et al., 2025). The ethanolic extract of Piper longum, administered orally at a dosage of 10-15 mg/kg body weight to commercial broiler chickens (strain 430-Y) from day 7 to 21, significantly enhanced HI antibody titers against NDV compared to the unvaccinated control group. This finding indicated the immunomodulatory activity of Piper longum (Sarwar et al., 2022; Karande et al., 2024). *In silico* studies showing that coumarin derivatives strongly bind to IBDV RdRp offered a plausible explanation for how coumarins inhibit viral proteases and polymerases (Sarwar et al., 2022; Karande et al., 2024). These findings indicated that phytochemical compounds can act as natural inhibitors of RdRp, similar to ribavirin but potentially with lower toxicity (Szotowska and Ledwoń, 2024; da Fonseca et al., 2025).

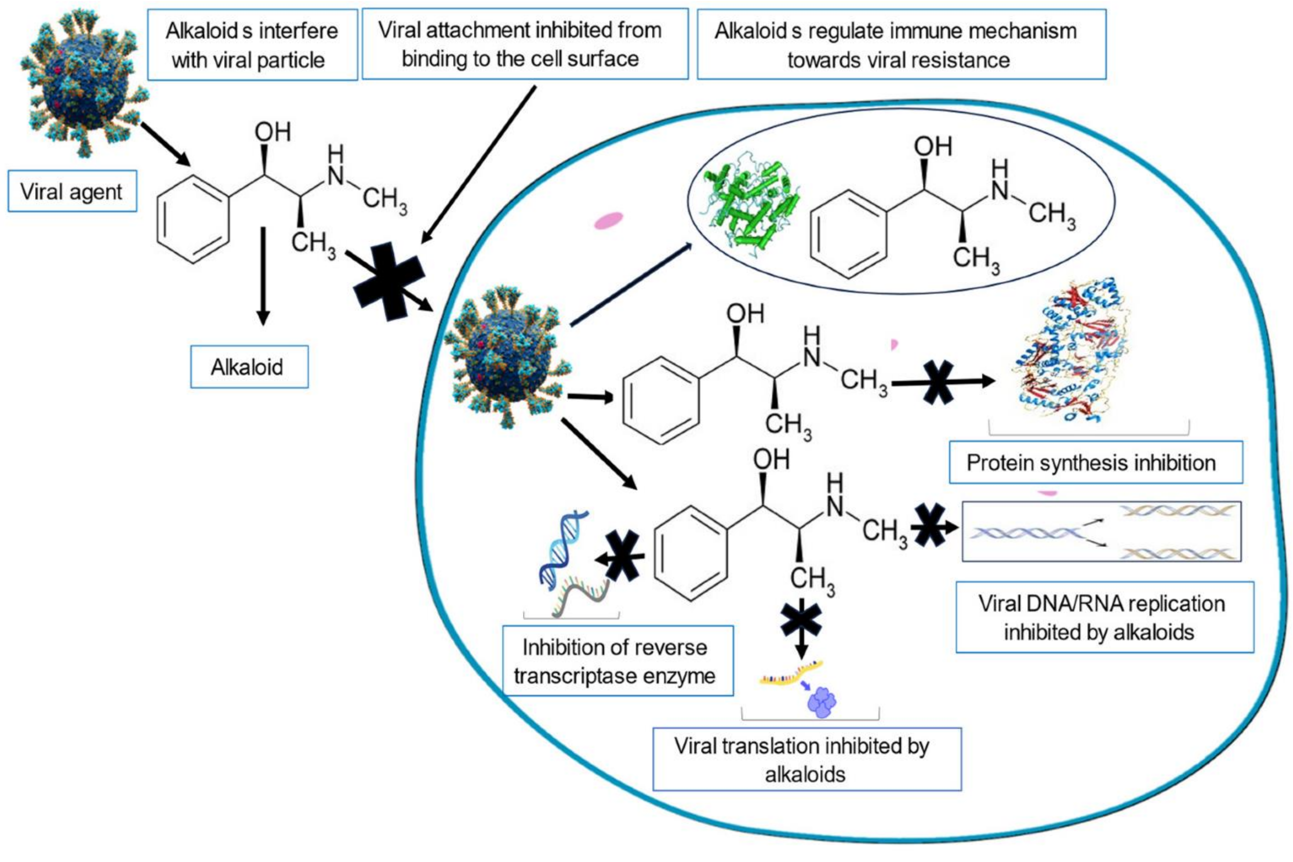

Figure 3. The mechanism of the antiviral activities of alkaloids. Source of the image: Adeosun and Loots (2024)

Modulation of host immune responses

A distinguishing characteristic of plant-based antivirals is their ability to enhance host immunity, often complementing or synergizing with vaccine-induced protection (Phillips et al., 2023; Adeosun and Loots, 2024; Tahir and Alsayeqh, 2024). Cytokine modulation by flavonoids and terpenoids mostly regulates interferon (IFN) pathways and pro-inflammatory cytokines (Intharuksa et al., 2022; da Fonseca et al., 2025). For instance, andrographolide reduces IL-6 and TNF-α production in infected tissues, mitigating immunopathology while preserving antiviral IFN-γ activity (Abd El-Ghany, 2024; El-Saadony et al., 2024; Shan et al., 2025). Adjuvant effects of saponins derived from *T. terrestris* and *Quillaja saponaria* are well-established as vaccine adjuvants in poultry, enhancing different mucosal Immunoglobulin A (IgA) and systemic Immunoglobulin G (IgG) responses against NDV and IBV (Abd El-Ghany, 2024; El-Saadony et al., 2024; Shan et al., 2025). Thus, phytochemical compounds not only inhibit viral replication but also boost both adaptive and innate immunity, which are vital for flock-level health resilience.

TRADITIONAL MEDICINAL PLANTS

Glycyrrhiza glabra (Licorice)

Licorice root has actually been used in Ayurveda, Unani, and Chinese medicine for centuries (Wu et al., 2021; 2022). The primary active constituent, glycyrrhizin, has been extensively studied for its antiviral activity (Wu et al., 2021; 2022). Glycyrrhizin interferes with viral gene expression and replication, modulates host cytokine responses, and exhibits antioxidant properties (Wu et al., 2021; Abdel-Haleem et al., 2024). In mammalian systems, glycyrrhizin has demonstrated effectiveness against the hepatitis B virus and coronaviruses (Wu et al., 2021; 2022). In poultry, *in vitro* studies indicated the potential of *G. glabra* compounds to control viral diseases, particularly paramyxovirus infections (Wu et al., 2021; 2022). Glycyrrhizin has been reported to suppress paramyxovirus replication (Wu et al., 2021; 2022). *In vivo* investigations in broiler chickens have demonstrated that licorice polysaccharides enhanced macrophage phagocytic activity and specifically stimulate antibody production, thereby substantiating their application as an immunostimulant in poultry feed (Abo-Samaha et al., 2022; Abdel-Haleem et al., 2024). Given the well-established safety and traditional herbal use of *G. glabra*, it is a promising candidate for further investigation into antiviral applications in poultry (Abo-Samaha et al., 2022; Abdel-Haleem et al., 2024).

Tephrosia purpurea (Wild indigo)

Tephrosia purpurea is widely used in Indian ethnomedicine, especially for its hepatoprotective, anti-inflammatory, and antioxidant properties (Athirstalaxmi et al., 2015; Choudhary et al., 2021). The phytochemical profile of *T. purpurea* root extract confirmed the presence of flavonoids, including tephrosin and rotenoid derivatives, as well as chalcones (Athirstalaxmi et al., 2015; Choudhary et al., 2021). Preliminary *in silico* studies strongly indicated that several *T. purpurea* phytochemicals, including tephrosin, rotenoid derivatives, and chalcones, have the potential to inhibit viral proteases (Youssef et al., 2023; Youssef et al., 2024). Despite a notable absence of direct poultry-virus data, particularly for IBV, the antioxidant and immunomodulatory activities observed in *T. purpurea* suggested its potential utility in studies aimed at inhibiting viral polymerases, boosting vaccine efficacy, and attenuating disease severity (Choudhary et al., 2021; Youssef et al., 2023).

Cyperus rotundus (nut grass)

Cyperus rotundus is a perennial sedge used in Ayurvedic medicine to treat gastrointestinal disorders and inflammation (Samra et al., 2020; Kumar et al., 2021). Phytochemical profiling of *C. rotundus* essential oils revealed the presence of flavonoids, sesquiterpenes, polyphenols, and other bioactive compounds with antimicrobial and immunomodulatory effects (Samra et al., 2020; Ali et al., 2023). *In vitro* studies indicated that the ethanolic extract of *C. rotundus* exhibited weak to moderate antiviral activity against herpes simplex virus and SARS-CoV-2 (Kumar et al., 2021). Green-synthesized silver nanoparticles derived from *C. rotundus* extract exhibited antiviral efficacy against IBV (Abo-El-Yazid et al., 2022). Although there are few direct challenge trials against enteric poultry viruses (rotavirus, reovirus), the immunostimulatory properties and safety observed in growth studies make *C. rotundus* a promising candidate for further antiviral investigations in poultry (Abo-El-Yazid et al., 2022; Wigraiboon et al., 2024).

Tribulus terrestris (Puncture vine)

Tribulus terrestris, used in Ayurvedic and Unani traditional medicine as an aphrodisiac and tonic, is notably rich in steroidal saponins, such as protodioscin and protogracillin, as well as different phytochemical compounds (Fekri Yazdi et al., 2014; Parham et al., 2020). The antiviral activity of *T. terrestris* crude extracts has been documented in non-poultry systems (Parham et al., 2020), and *in vivo* studies highlighted its effectiveness against the NDV (Malik et al., 2023). In poultry, limited studies have demonstrated that supplementation with *T. terrestris* powder significantly increases antibody titers against the NDV (Fekri Yazdi et al., 2014). The dual immunostimulatory and antiviral properties of *T. terrestris* make it a promising candidate for feed-based applications (Al-Garadi et al., 2022; Malik et al., 2023). The safety profile of *T. terrestris* requires careful evaluation, as some studies indicated that although certain doses are usually tolerated, high saponin levels may affect performance or cause histological changes (Fekri Yazdi et al., 2014; Al-Garadi et al., 2022).

Boerhavia diffusa (Punarnava)

Boerhavia diffusa (Punarnava) is a widely recognized ethnomedicinal plant in India, valued for its hepatoprotective, anti-inflammatory, antioxidant, and immunostimulant properties (Manu and Kuttan, 2009; Wudali and Nagella, 2020). Phytochemical studies have confirmed that *B. diffusa* contains rotenoid compounds (boeravinones), flavonoids, lignans, and alkaloids, which are recognized in broad antiviral screens in non-poultry systems (Wudali and Nagella, 2020; Ashrafi et al., 2022). Compounds such as punarnavine (an alkaloid) have been shown to increase antibody titers, enhance splenocyte proliferation, and lower pro-inflammatory cytokines in mice (Manu and Kuttan, 2009). In broiler chickens, adding *B. diffusa* ethanol extract at 1-10% (w/v) to drinking water, along with Costus afer, for 4 weeks enhanced hematological parameters (Nwokocha et al., 2013). The favorable safety profile and significant immunomodulatory activity of *B. diffusa* make it a promising candidate for future studies as a poultry feed supplement or vaccine adjuvant against viral diseases (Ashrafi et al., 2022; Wang et al., 2023). The phytochemical profiles, target viruses, antiviral mechanisms, and poultry health relevance of all five selected plants are collectively summarized in Table 1.

Table 1. Phytochemical composition, antiviral mechanisms, and poultry health relevance of five selected South Asian ethnomedicinal plants against poultry viral pathogens

Plant	Major compounds	Target viruses	Antiviral mechanism	Poultry relevance	Key references
Glycyrrhiza glabra	Glycyrrhizin	RNA viruses, NDV (potential)	Inhibits replication, modulates cytokines	Immunostimulant, candidate feed additive	Wu et al. (2021; 2022); Abo-Samaha et al. (2022); Abdel-Haleem et al. (2024)
Tephrosia purpurea	Flavonoids (tephrosin)	Polymerase-dependent viruses	Inhibits RNA polymerase	Potential NDV/IBV inhibitor	Athirstalaxmi et al. (2015); Choudhary et al. (2021); Youssef et al. (2023; 2024)
Cyperus rotundus	Flavonoids, terpenes	Enteric viruses	Immunomodulatory, antiviral	May protect against poultry enteric viruses	Samra et al. (2020); Abo-El-Yazid et al. (2022); Ali et al. (2023); Wigraiboon et al. (2024)
Tribulus terrestris	Steroidal saponins	Enveloped viruses, NDV, IBDV	Envelope disruption, immune adjuvant	Vaccine enhancer, prophylactic	Fekri Yazdi et al. (2014); Parham et al. (2020); Al-Garadi et al. (2022); Malik et al. (2023)
Boerhavia diffusa	Boeravinones	RNA viruses (HIV, model)	Integrase inhibition, immunostimulant	Poultry immune booster	Manu and Kuttan (2009); Nwokocha et al. (2013); Wudali and Nagella (2020); Ashrafi et al. (2022)

NDV: Newcastle disease virus, IBDV: Infectious bursal disease virus, IBV: Infectious bronchitis virus, FAdV: Fowl adenovirus, HIV: Human immunodeficiency virus, RNA: Ribonucleic acid, RdRp: RNA-dependent RNA polymerase

RELEVANCE TO POULTRY PRODUCTION AND VIRAL DISEASES

Infectious bursal disease virus

Infectious bursal disease virus targets the bursa of Fabricius, resulting in immune suppression that predisposes layers and broiler chickens to secondary infections (Kalaria et al., 2021; Toka and Geinoro, 2023). Antioxidant and immunostimulant phytochemical compounds, such as flavonoids from *Moringa oleifera* and curcuminoids from turmeric, protect lymphoid tissues by reducing oxidative stress and promoting lymphocyte recovery (Aderemi and Alabi, 2023; Morais et al., 2025). Saponins have exhibited considerable immunomodulatory potential in poultry concerning viral pathogens. Dietary supplementation with *T. terrestris* powder at 1 g/kg and 5 g/kg of feed has led to notably elevated antibody titers against NDV and avian influenza virus in broiler chickens (Fekri Yazdi et al., 2014). The crude extract of *T. terrestris*, containing 286.6 ± 3.16 µg/g of total saponins, demonstrated significant anti-NDV activity *in vitro* at 80 µg/mL. Haemagglutination assays conducted in embryonated chicken eggs revealed that pre-infection treatment decreased haemagglutinin titers from 320.0 ± 128.0 HAU (untreated controls) to 2.5 ± 1.0 HAU (Malik et al., 2018). Several studies confirmed that saponins not only enhanced IgA cell and iIEL numbers in the duodenum, jejunum, and ileum but also reduced bursal lesions in chickens challenged with IBDV, thereby supporting the observed protective effects (Saeed et al., 2024; Tahir and Alsayeqh, 2024).

Infectious bronchitis virus

The control of IBV is complicated by the emergence of variant strains and the limitations of vaccine cross-protection (Toka and Geinoro, 2023; Rafique et al., 2024). Essential oils and flavonoids with envelope-disrupting and polymerase-inhibiting activities, such as catechins and ursolic acid, may generally offer broad-spectrum antiviral protection (Yasmin et al., 2020; Tahir and Alsayeqh, 2024). Herbal feed additives such as neem (*Azadirachta indica*) and garlic (*Allium sativum*) have been reported to possess antiviral properties relevant to poultry respiratory pathogens. Neem extract demonstrated significant antiviral activity against NDV and IBV in embryonated SPF chicken eggs, while garlic extract exhibited a dose-dependent inhibitory effect against influenza-related viruses, suggesting their potential to mitigate respiratory viral infections in poultry (Yasmin et al., 2020; Rafique et al., 2024).

Fowl adenoviruses

Fowl adenoviruses constitute a diverse group of non-enveloped DNA viruses responsible for conditions such as inclusion body hepatitis (IBH), hydropericardium syndrome (HPS), and gizzard erosion in poultry (El-Shall et al., 2022; Rashid et al., 2024). These diseases cause significant economic losses in broiler chickens and layers across Asia, with high mortality reported during outbreaks (El-Shall et al., 2022; Ishag et al., 2022). Unlike IBDV or IBV, FAdV infections often emerge in immunocompromised flocks, complicating control strategies (Ishag et al., 2022; Rashid et al., 2024). Vaccines against FAdV are neither widely accessible nor standardized, and vertical transmission complicates eradication efforts (El-Shall et al., 2022; Rashid et al., 2024). Traditional medicinal plants offer a promising supplementary approach against FAdV, particularly for their ability to improve liver function and modulate immunity (Adeosun and Loots, 2024; Tahir and Alsayeqh, 2024). *Glycyrrhiza glabra*, known for its hepatoprotective effects, might reduce liver damage caused by FAdV, as indicated by increased serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and creatine phosphokinase in FAdV-infected poultry (El-Shall et al., 2022; Abdel-Haleem et al., 2024). *Ocimum sanctum*, which is rich in ursolic acid and has documented antiviral and anti-inflammatory activity, may counteract FAdV-4-driven $CD4^+/CD8^+$ T-cell depletion and cytokine dysregulation (Rashid et al., 2024). Preliminary *in vitro* findings suggested that certain flavonoids and lignans interfere with adenoviral replication. For instance, flavonoids from *B. diffusa* inhibit RdRp activity *in vitro*. Additionally, *C. rotundus* flavonoid nanoparticles reduce IBV replication at an IC of 9.5 µg/mL in Vero cells. Moreover, podophyllotoxin-derived lignans inhibited DNA polymerase enzymes involved in adenoviral replication, but no trials have been conducted specifically with FAdV (Lawal et al., 2021; Abo-El-Yazid et al., 2022; Sarwar et al., 2022). Integrating phytogenic feed additives that target viral replication and support liver health could provide an effective strategy to reduce FAdV levels in poultry systems across South Asia (El-Shall et al., 2022; Rashid et al., 2024).

Practical applications in poultry production

Phytogenic feed additives

A primary application of medicinal plants in poultry health is their use as phytogenic feed additives (Abd El-Hack et al., 2022; Tahir and Alsayeqh, 2024). Incorporating *G. glabra* extract, *T. terrestris* powder, or *B. diffusa* leaf meal into broiler chicken and layer chickens' diets not only improved growth performance but also enhanced resistance to viral infections (Abd El-Hack et al., 2022; Jamil et al., 2022). Feed-based interventions are particularly appropriate for smallholder poultry farms in South Asia, given the irregular distribution of vaccines within the sector (Jamil et al., 2022; Pebam et al., 2022). Unlike injectable antiviral medications, feed additives provide prophylaxis for the entire flock without requiring extra labor (Abd El-Hack et al., 2022; Adeosun and Loots, 2024).

Herbal prophylactics and therapeutics

Polyherbal formulations, particularly mixtures of garlic, ginger, turmeric, onion, and Phyllanthus niruri, are commonly administered during suspected NDV or IBDV outbreaks in backyard poultry systems (Jamil et al., 2022; Pebam et al., 2022). These non-standardized, crude herbal preparations originated in culturally embedded practices but can often be refined into dependable herbal formulations (Jamil et al., 2022; Adeosun and Loots, 2024). Controlled trials have demonstrated that crude herbal preparations improved survival and performance metrics during outbreaks (Adjei-Mensah et al., 2023; Fouad et al., 2025). The immunostimulatory and hepatoprotective properties of *G. glabra* and *B. diffusa* are important for incorporation into these formulations (Abo-Samaha et al., 2022; Wudali and Nagella, 2020).

Vaccine synergy

The immunomodulatory and adjuvant effects of phytochemicals present a fundamentally practical approach to enhancing vaccine efficacy. For instance, saponin-rich extracts were utilized as adjuvants in experimental poultry vaccines, significantly enhancing both systemic and mucosal responses. This interaction is vital in areas where vaccine efficacy is compromised by inadequate cold-chain maintenance or increased pathogen variability.

Economic and sustainability considerations

From an economic perspective, plant-derived phytogenic feed additives, specifically *G. glabra* (licorice), *T. terrestris* (puncture vine), and *B. diffusa* (Punarnava), provide cost-effective interventions in comparison to synthetic medicines or recurrent vaccination campaigns (Abd El-Hack et al., 2022; Adeosun and Loots, 2024). *Glycyrrhiza glabra*, *T. terrestris*, and *B. diffusa* are indeed cultivated or foraged throughout South Asia, making them cost-effective options for poultry farmers (Jamil et al., 2022; Pebam et al., 2022). The use of herbal feed additives aligns with growing consumer demand for green, antibiotic-free poultry products, thereby offering potential market advantages (Abd El-Hack et al., 2022; Tahir and Alsayeqh, 2024). Moreover, unlike synthetic antiviral medicines, plant-based products pose a lower risk of resistance development due to their multitarget mechanisms (Adeosun and Loots, 2024; da Fonseca et al., 2025).

From a sustainability perspective, medicinal plants can indeed be integrated into local agroecosystems (Jamil et al., 2022; Pebam et al., 2022). *Azadirachta indica* and *Moringa oleifera* are multipurpose tree species cultivated for food, fodder, and medicinal applications, thereby reinforcing circular farming systems (Abd El-Hack et al., 2022; Adjei-Mensah et al., 2023). This integration would reduce dependency on imported pharmaceuticals and strengthen local resilience (Pebam et al., 2022; Adeosun and Loots, 2024).

One health perspective

Plant-based antivirals are important not only for poultry health but also within the wider One Health approach (Adeosun and Loots, 2024; Tahir and Alsayeqh, 2024). Reducing viral outbreaks in poultry supports food security and economic stability in South Asia. Additionally, limiting the use of synthetic medicines decreases chemical residues in meat and eggs, reducing their potential entry into the human food chain (Abd El-Hack et al., 2022; Szotowska and Ledwoń, 2024). By mitigating immune suppression and secondary infections, phytochemicals generally reduce reliance on antibiotics, thereby addressing antimicrobial resistance (AMR), a shared global health concern (Adeosun and Loots, 2024; Tahir and Alsayeqh, 2024).

KNOWLEDGE GAPS

Limited *in vivo* studies on phytochemicals against poultry-specific viral pathogens

A significant gap exists due to the limited number of studies directly assessing antiviral activity against poultry-specific pathogens. While some plants, such as *G. glabra*, have demonstrated effectiveness against NDV *in vitro*, there are many fewer studies exploring their effects *in vivo* in poultry (Abo-Samaha et al., 2022; Wu et al., 2022). For viruses such as IBV, investigations remain limited, with most insights derived from studies conducted on non-avian model organisms, including murine and human cell lines.

Lack of standardization in plant preparations

Traditional medicinal plants are often prepared as crude extracts, decoctions, or feed additives, with inconsistent plant parts, solvents, or dosages (Jamil et al., 2022; Pebam et al., 2022). This inconsistency in choosing plant parts, extraction techniques, and dosages led to inconsistent results across studies and made reproduction difficult (Adeosun and Loots, 2024; Muñoz-Gómez et al., 2025). For instance, *G. glabra* extracts can differ significantly in glycyrrhizin content depending on whether roots, rhizomes, or aerial parts are used, with aqueous, ethanolic, or hydroalcoholic extraction yielding markedly different concentrations of bioactive constituents (Abo-Samaha et al., 2022; Wu et al., 2022). Similarly, *T. terrestris* saponin content varies considerably across growing regions, harvest stages, and formulation methods (Fekri Yazdi et al., 2014; Parham et al., 2020). Bioassay-guided fractionation and phytochemical profiling are essential for identifying active components, standardizing concentrations, and ensuring reproducibility across study groups (Adeosun and Loots, 2024; da Fonseca et al., 2025).

In vivo pharmacokinetics

No phytogenic compound can be approved for commercial poultry without first establishing safety and tissue residue data (Szotowska and Ledwoń, 2024). Yet few studies have actually examined the pharmacokinetics, tissue distribution, or excretion of antiviral phytochemicals in poultry (Adeosun and Loots, 2024; Muñoz-Gómez et al., 2025). Without safety and residue data, safe withdrawal periods for meat and eggs cannot be determined. The potential accumulation of bioactive compounds in edible tissues may pose health risks to consumers and generally complicate the export certification process (Szotowska and Ledwoń, 2024; Tahir and Alsayeqh, 2024).

Interactions with vaccines and diagnostics

Phytochemicals act as immunomodulators; however, their interactions with conventional vaccines remain poorly understood (Phillips et al., 2023). While some studies have reported increased antibody titers following phytochemical supplementation, not all compounds produce measurable enhancement of vaccine-associated humoral responses; for example, quercetin supplementation showed no significant increase in antibody titers in broilers (Abdel-Latif et al., 2021). Furthermore, intense immune stimulation can affect diagnostic serology by elevating baseline antibody levels (Wu et al., 2021; Phillips et al., 2023).

Emerging opportunities: Nanotechnology and delivery systems

The bioavailability of phytochemicals is often compromised by rapid metabolism and instability (Phillips et al., 2023; da Fonseca et al., 2025). Nanotechnology-based delivery systems, such as liposomes, nano-emulsions, and polymeric nanoparticles, can improve solubility, stability, and targeted delivery of plant-derived antiviral agents (Chopra et al., 2021; da Fonseca et al., 2025). Curcumin nanoparticles demonstrated a tenfold increase in bioavailability compared to free curcumin. Furthermore, preclinical studies indicated that an 80 mg dose of nanocurcumin was more effective than a 500 mg dose of the free compound (Chopra et al., 2021). Additionally, nanocurcumin significantly decreased AST levels in broiler chickens at a dosage of 200 mg/kg. This finding suggested that nanotechnology-based delivery methods may facilitate the use of lower effective doses while achieving improved antiviral efficacy in poultry systems (Chopra et al., 2021). Adapting these methods for poultry could improve the delivery of phytogenic antivirals, enabling reduced, more uniform dosing with superior efficacy.

Regulatory and commercialization challenges

In many Asian countries, regulations for herbal feed additives and veterinary medicines are still evolving. In India, these herbal feed additives may be classified as Ayurvedic remedies or feed supplements; nevertheless, the regulatory framework lacks a clearly defined process for verifying claims related to viral disease control (Jamil et al., 2022; Pebam et al., 2022). In Bangladesh, there is currently no formal regulatory framework established for approving phytogenic compounds with antiviral claims for use in veterinary or poultry production. Consequently, manufacturers and farmers lacked standardized guidelines for safety, efficacy, and labelling. Without well-defined regulatory pathways for approval and standardization, investment in the commercial development and clinical validation of phytogenic antiviral agents for poultry remains severely limited.

Integrating ethnoveterinary knowledge with modern science

Ethnoveterinary knowledge provides a valuable foundation; however, its full potential can only be realized through integration with modern analytical and clinical methodologies. Future studies should use high-throughput screening and omics tools to test traditional plants against poultry viruses and to understand how these viruses affect host pathways. Molecular docking combined with artificial intelligence modelling should be used to predict plant-virus interactions and help prioritize *in vivo* experiments. Community-based participatory studies conducted in India and Bangladesh would be valuable for validating locally practiced ethnomedicinal interventions under controlled, reproducible conditions. By combining indigenous knowledge with cutting-edge science, a pipeline for novel poultry antivirals can be established.

CONCLUSION

Traditional medicinal plants of South Asia contain a rich diversity of phytochemicals, including flavonoids, terpenoids, alkaloids, saponins, and sulfur compounds, that exert broad-spectrum antiviral activity against major poultry pathogens such as NDV, IBDV, IBV, and fowl adenovirus. These effects are mediated by multiple mechanisms, including inhibition of viral entry, suppression of viral polymerases, immunomodulation, and antioxidant activity. The findings confirm that these medicinal plants can serve as affordable, residue-free feed additives for prevention or treatment, making them especially suitable for small-scale poultry farms with limited access to vaccines. Plant-based antiviral agents, confirmed through both ethnobotanical knowledge and contemporary virological methods, serve as credible options for maintaining poultry health and support the One Health approach sustainability. Future studies should focus on rigorous poultry trials that track how plant compounds move through the body and whether residues remain, while developing standardized formulations that meet safety regulations for real-world farm use. Furthermore, future studies should employ high-throughput screening and omics-based tools to systematically evaluate traditional medicinal plants against poultry viruses and to elucidate how these pathogens modulate host molecular pathways, enabling the rational development of evidence-based, plant-derived antiviral interventions.

DECLARATIONS

Acknowledgements

The authors would like to acknowledge RR Animal Health Care Ltd., Research and Development Department, Hyderabad, Telangana, India, for providing the essential facilities and support.

Authors' contributions

Rimee Dutta conducted the study, performed the data analysis, and contributed to manuscript preparation. Vijaya Sai Ayyagari provided supervision, assisted with data interpretation, and revised the manuscript. All authors have read and approved the final edition of the manuscript before publication in the World's Veterinary Journal.

Availability of data and materials

The data used and analyzed during the present study are available from the corresponding author upon reasonable request.

Competing interests

The authors declared that they have no competing interests.

Ethical considerations

Plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been checked by all authors. The authors also confirmed that no AI-assisted text generation tools were used in preparing this manuscript.

Funding

The current study received no funding.

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