# MEDICINAL HERBS AGAINST EMERGING VIRAL DISEASES: A COMPREHENSIVE REVIEW

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**ABSTRACT:**
Emerging and re-emerging viral diseases continue to pose significant threats to global public health due to their rapid transmission, high mutation rates, and limited therapeutic options. Recent outbreaks of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), dengue virus, Zika virus, chikungunya virus, Ebola virus, Nipah virus, and monkeypox virus have highlighted the urgent need for safe, effective, and broad-spectrum antiviral agents. Medicinal herbs have gained considerable attention as valuable sources of bioactive compounds with antiviral potential. Traditional medical systems, including Ayurveda, Traditional Chinese Medicine, African traditional medicine, and Unani medicine, have long utilized herbal remedies for the prevention and treatment of infectious diseases. Numerous phytochemicals such as polyphenols, flavonoids, alkaloids, terpenoids, saponins, tannins, and essential oils have demonstrated antiviral activities through diverse mechanisms, including inhibition of viral attachment, entry, replication, protein synthesis, and modulation of host immune responses. This review provides a comprehensive overview of emerging viral diseases, medicinal herbs with reported antiviral activities, major antiviral phytochemical classes, and their mechanisms of action. Furthermore, the review highlights experimental evidence supporting the antiviral efficacy of medicinal plants against COVID-19, dengue, Zika, chikungunya, Ebola, Nipah, and monkeypox infections. Recent advances in phytochemistry, molecular docking, metabolomics, and systems biology are also discussed in the context of antiviral drug discovery. The findings underscore the immense potential of medicinal herbs as promising sources of novel antiviral therapeutics and emphasize the need for further preclinical and clinical investigations to facilitate their translation into evidence-based healthcare applications.

***Keywords:***
Medicinal herbs, Emerging viral diseases, Antiviral phytochemicals, SARS-CoV-2, Dengue virus, Zika virus, Chikungunya virus, Ebola virus, Nipah virus , Monkeypox virus, Natural products, Antiviral agents, Phytotherapy , Drug discovery

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## INTRODUCTION:

Emerging and re-emerging viral diseases continue to represent one of the most significant challenges to global public health in the twenty-first century.[1] The increasing frequency of viral outbreaks, including severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), coronavirus disease 2019 (COVID-19), Ebola virus disease, Zika virus infection,[2,3] Chikungunya, Dengue fever, and Nipah virus infection, has highlighted the vulnerability of healthcare systems worldwide. Rapid urbanization, globalization, climate change, ecological disturbances, and increased human-animal interactions have facilitated the emergence and transmission of novel viral pathogens across geographical boundaries. These outbreaks not only result in substantial morbidity and mortality but also impose severe socioeconomic burdens through healthcare expenditures, productivity losses, and disruptions to global trade and travel.[4-8]

Despite remarkable advances in modern medicine, the therapeutic management of viral infections remains challenging. Currently available antiviral drugs are effective only against a limited number of viral pathogens and often exhibit restricted therapeutic windows. Furthermore, many antiviral agents are associated with adverse effects, high treatment costs, poor bioavailability, and limited accessibility in low-resource settings. The lengthy and expensive process of antiviral drug discovery further constrains the rapid development of effective therapeutics against newly emerging viral diseases. Consequently, there is an urgent need to identify novel, safe, and broad-spectrum antiviral agents capable of combating existing and future viral threats.[9-11]

Another major challenge in antiviral therapy is the continuous evolution of viruses through genetic mutations and recombination events. RNA viruses, in particular, possess high mutation rates due to the absence of efficient proofreading mechanisms during genome replication. These mutations can alter viral proteins, resulting in increased pathogenicity, enhanced transmissibility, immune evasion, and reduced susceptibility to existing antiviral medications.[12] The emergence of drug-resistant viral strains has been documented in several clinically important viruses, including human immunodeficiency virus (HIV), influenza virus, hepatitis viruses, and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The development of antiviral resistance significantly compromises treatment efficacy and necessitates the exploration of alternative therapeutic approaches.[13]

Traditional medicine systems have served as valuable healthcare resources for centuries and continue to play a crucial role in disease prevention and treatment across many regions of the world. Medicinal plants constitute the cornerstone of traditional healthcare practices such as Ayurveda, Traditional Chinese Medicine, Unani medicine, and various indigenous healing systems. Numerous medicinal herbs have been traditionally employed for the management of infectious diseases, including viral illnesses. The extensive ethnopharmacological knowledge accumulated over generations provides an important foundation for the discovery of novel antiviral compounds from natural sources. Recent scientific investigations have increasingly validated the therapeutic potential of traditional medicinal plants through pharmacological, phytochemical, and molecular studies.[14-17]

Medicinal plants are recognized as rich reservoirs of structurally diverse bioactive compounds, including alkaloids, flavonoids, polyphenols, terpenoids, tannins, saponins, and glycosides. These phytoconstituents exhibit antiviral activities through multiple mechanisms, such as inhibition of viral attachment and entry, suppression of viral replication, interference with viral protein synthesis, modulation of host immune responses, and attenuation of virus-induced inflammation. Several plant-derived compounds have demonstrated promising activity against a broad spectrum of DNA and RNA viruses in in vitro, in vivo, and computational studies. Furthermore, natural products have historically contributed significantly to pharmaceutical development, with many modern drugs originating directly or indirectly from plant sources. The exploration of medicinal herbs therefore represents a promising strategy for the identification of new antiviral drug candidates with improved safety and therapeutic efficacy.[18-20]

In recent years, advances in phytochemistry, metabolomics, molecular docking, network pharmacology, and systems biology have enhanced the scientific understanding of plant-derived antiviral agents. These multidisciplinary approaches facilitate the identification of bioactive phytochemicals, elucidation of molecular mechanisms, and evaluation of their therapeutic potential against emerging viral pathogens. Such developments have renewed interest in medicinal herbs as complementary and alternative therapeutic resources for addressing current and future viral health challenges.[21-22]

The present review aims to provide a comprehensive and critical overview of medicinal herbs with demonstrated antiviral potential against emerging and re-emerging viral diseases. The review discusses the global burden of emerging viral infections, limitations of current antiviral therapies, mechanisms of viral resistance, and the role of traditional medicinal systems in antiviral drug discovery. Additionally, it highlights important antiviral phytochemicals, their mechanisms of action, evidence from preclinical and clinical studies, recent advances in omics-based research, and future perspectives for the development of plant-based antiviral therapeutics. By integrating contemporary scientific findings with traditional knowledge, this review seeks to identify promising opportunities and research directions for the development of effective herbal interventions against emerging viral diseases.[23-25]

**Table 1. Major Emerging Viral Diseases and Their Global Health Significance**

| **Viral Disease** | **Causative Virus** | **Year of Major Outbreak** | **Mode of Transmission** | **Global Significance** |
|---|---|---|---|---|
| COVID-19 | SARS-CoV-2 | 2019 | Respiratory droplets and aerosols | Global pandemic with significant mortality and economic impact |
| SARS | SARS-CoV | 2002 | Respiratory transmission | First major coronavirus outbreak |
| MERS | MERS-CoV | 2012 | Zoonotic and | High case |

| | | | | |
|---|---|---|---|---|
| | | | respiratory transmission | fatality rate |
| Dengue Fever | Dengue virus | Recurrent outbreaks | Mosquito-borne | Major tropical public health concern |
| Chikungunya | Chikungunya virus | 2004 onwards | Mosquito-borne | Causes debilitating arthralgia |
| Zika Virus Disease | Zika virus | 2015–2016 | Mosquito-borne and vertical transmission | Associated with congenital abnormalities |
| Ebola Virus Disease | Ebola virus | 2014–2016 | Direct contact with infected fluids | Severe hemorrhagic fever with high mortality |
| Nipah Virus Infection | Nipah virus | 1998 onwards | Bat-to-human and human-to-human transmission | Emerging zoonotic threat |
| Mpox (Monkeypox) | Monkeypox virus | 2022 global outbreak | Direct contact and respiratory exposure | Re-emerging global viral disease |
| Influenza | Influenza A and B viruses | Seasonal and pandemic outbreaks | Respiratory transmission | Continuous public health burden |

**Emerging and Re-emerging Viral Diseases[26-35]**

Emerging and re-emerging viral diseases have become a major concern for global public health due to their increasing incidence, widespread geographical distribution, and substantial impact on human health. Emerging viral infections are caused by newly identified pathogens or previously recognized viruses that have recently expanded their host range, transmission capacity, or geographical prevalence. In contrast, re-emerging viral infections are diseases that were previously controlled but have resurfaced due to changes in environmental conditions, viral evolution, declining immunity, or inadequate public health measures.

The emergence of viral diseases is driven by a complex interaction of ecological, environmental, and socio-economic factors. Rapid urbanization, globalization, international travel, climate change, deforestation, and increased human encroachment into wildlife habitats have significantly enhanced opportunities for zoonotic spillover and viral dissemination. In addition, the high mutation rates of many RNA viruses facilitate genetic adaptation, allowing viruses to evade host immune responses, develop drug resistance, and establish infections in new hosts. These factors collectively contribute to the continuous emergence of viral pathogens with epidemic and pandemic potential. Based on their epidemiological characteristics and modes of transmission, emerging viral diseases can be broadly categorized into respiratory viruses, arboviruses, hemorrhagic fever viruses, zoonotic viruses, and other clinically significant viral pathogens. These viral groups continue to pose serious challenges to healthcare systems worldwide and underscore the urgent need for effective preventive and therapeutic interventions.

**Respiratory Viruses**

Respiratory viruses represent one of the most significant causes of infectious disease outbreaks globally. These viruses primarily infect the respiratory tract and are transmitted through respiratory droplets, aerosols, and direct contact with contaminated surfaces. Their high transmissibility and ability to rapidly spread among populations make them major public health threats.

**SARS-CoV-2**

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the causative agent of Coronavirus Disease 2019 (COVID-19), belongs to the family Coronaviridae. It is an enveloped, positive-sense single-stranded RNA virus characterized by the presence of spike glycoproteins on its surface. The virus primarily enters host cells through interaction with angiotensin-converting enzyme 2 (ACE2) receptors. COVID-19 manifests with a wide spectrum of clinical symptoms ranging from asymptomatic infection to severe respiratory distress, pneumonia, multi-organ failure, and death. Fever, cough, fatigue, dyspnea, loss of smell and taste, and gastrointestinal disturbances are among the most common symptoms. Current therapeutic approaches include antiviral agents such as remdesivir and nirmatrelvir/ritonavir, immunomodulatory therapies, supportive care, and extensive vaccination programs.

**Influenza Viruses**

Influenza viruses are enveloped negative-sense RNA viruses belonging to the Orthomyxoviridae family. Influenza A and Influenza B viruses are primarily responsible for seasonal epidemics and occasional pandemics. The viruses spread mainly through respiratory droplets and aerosol transmission. Clinical manifestations include fever, headache, myalgia, sore throat, cough, fatigue, and respiratory complications. Severe infections may result in viral pneumonia and secondary bacterial infections. Antiviral drugs such as oseltamivir, zanamivir, and baloxavir marboxil are commonly used, while annual vaccination remains the most effective preventive strategy.

**Respiratory Syncytial Virus (RSV)**

Respiratory Syncytial Virus is an enveloped RNA virus belonging to the family Pneumoviridae. RSV is a leading cause of lower respiratory tract infections in infants, young children, immunocompromised individuals, and older adults. The virus is transmitted through respiratory secretions and close contact with infected individuals. Clinical manifestations include bronchiolitis, wheezing, cough, pneumonia, and respiratory distress. Current management primarily involves supportive care, although recent advances have led to the development of monoclonal antibodies and vaccines for high-risk populations.

**Arboviruses**

Arboviruses are arthropod-borne viruses transmitted predominantly by mosquitoes and ticks. Their incidence has increased considerably over recent decades due to climate change, urbanization, and the expansion of vector habitats.

**Dengue Virus**

Dengue virus belongs to the family Flaviviridae and comprises four antigenically distinct serotypes. It is transmitted primarily by Aedes aegypti and Aedes albopictus mosquitoes. Clinical manifestations range from mild febrile illness to severe dengue hemorrhagic fever and dengue shock syndrome. Currently, no specific antiviral therapy is available, and treatment is largely supportive.

**Zika Virus**

Zika virus is a mosquito-borne flavivirus transmitted mainly through Aedes mosquito species. Although most infections are asymptomatic or mild, severe complications such as congenital Zika syndrome, microcephaly, and neurological disorders have been reported. Management is limited to supportive care and preventive vector-control measures.

**Chikungunya Virus**

Chikungunya virus is a positive-sense RNA virus belonging to the family Togaviridae. It is transmitted by Aedes mosquitoes and is characterized by acute fever, severe polyarthralgia, rash, and prolonged joint pain. Treatment remains symptomatic, focusing on pain management and supportive care.

**Hemorrhagic Fever Viruses**

Hemorrhagic fever viruses are associated with severe systemic infections characterized by vascular damage, coagulation abnormalities, and high mortality rates.

**Ebola Virus**

Ebola virus is an enveloped filamentous RNA virus belonging to the Filoviridae family. Human infection occurs through direct contact with infected bodily fluids and contaminated materials. Clinical manifestations include fever, vomiting, diarrhea, hemorrhage, shock, and multi-organ failure. Recent advances have led to the development of monoclonal antibody therapies and effective vaccines.

**Marburg Virus**

Marburg virus is closely related to Ebola virus and is also classified within the Filoviridae family. The virus causes severe hemorrhagic fever with symptoms including high fever, bleeding, shock, and organ dysfunction. Current treatment is mainly supportive, although several therapeutic candidates are undergoing clinical evaluation.

**Zoonotic Viruses**

Zoonotic viruses are transmitted from animal reservoirs to humans and represent a major source of emerging infectious diseases worldwide.

**Nipah Virus**

Nipah virus is a highly pathogenic member of the Paramyxoviridae family. Fruit bats serve as the primary reservoir host. Human infection may occur through contaminated food, infected animals, or direct person-to-person transmission. Clinical manifestations include encephalitis, respiratory distress, seizures, and high mortality rates. No approved antiviral therapy currently exists, and treatment remains supportive.

**Hantavirus**

Hantaviruses are enveloped RNA viruses transmitted through inhalation of aerosolized rodent excreta. Human infection can result in hantavirus pulmonary syndrome or hemorrhagic fever with renal syndrome. These diseases are associated with severe respiratory and renal complications. Management relies primarily on intensive supportive care.

Other Emerging Viral Diseases

**Monkeypox (Mpox) Virus**

Monkeypox virus is a large double-stranded DNA virus belonging to the Poxviridae family. Human transmission occurs through direct contact with infected individuals, contaminated materials, or infected animals. Clinical manifestations include fever, lymphadenopathy, and characteristic vesiculopustular skin lesions. Tecovirimat and supportive care are currently used for disease management.

**Hepatitis Viruses**

Hepatitis viruses comprise a diverse group of hepatotropic viruses including hepatitis A, B, C, D, and E viruses. These viruses differ in their genomic structures and modes of transmission but collectively contribute to a substantial global burden of liver disease. Clinical outcomes range from acute hepatitis to chronic liver disease, cirrhosis, and hepatocellular carcinoma. Current therapeutic approaches include antiviral drugs, vaccination, and supportive medical management depending on the viral type.

**Table 2. Characteristics of Major Emerging and Re-emerging Viral Diseases**

| Viral Disease | Viral Family | Genome Type | Transmission Route | Major Clinical Manifestations | Available Therapeutic Approaches |
|---|---|---|---|---|---|
| COVID-19 | Coronaviridae | ssRNA (+) | Respiratory droplets | Fever, pneumonia, ARDS | Antivirals, vaccines |
| Influenza | Orthomyxoviridae | ssRNA (-) | Respiratory droplets | Fever, cough, pneumonia | Oseltamivir, vaccines |
| RSV Infection | Pneumoviridae | ssRNA (-) | Respiratory secretions | Bronchiolitis, pneumonia | Supportive care, monoclonal antibodies |
| Dengue Fever | Flaviviridae | ssRNA (+) | Mosquito-borne | Hemorrhagic fever | Supportive care |
| Zika Virus Disease | Flaviviridae | ssRNA (+) | Mosquito-borne | Congenital abnormalities | Supportive care |
| Chikungunya | Togaviridae | ssRNA (+) | Mosquito-borne | Severe arthralgia | Symptomatic treatment |
| Ebola Virus Disease | Filoviridae | ssRNA (-) | Body fluids | Hemorrhagic fever | Monoclonal antibodies |
| Marburg Virus Disease | Filoviridae | ssRNA (-) | Bat-associated transmission | Hemorrhagic fever | Supportive care |
| Nipah Virus Infection | Paramyxoviridae | ssRNA (-) | Bat-to-human transmission | Encephalitis | Supportive care |
| Hantavirus Infection | Hantaviridae | Segmented RNA | Rodent exposure | Pulmonary syndrome | Intensive care |
| Mpox | Poxviridae | dsDNA | Direct contact | Skin lesions | Tecovirimat |
| Viral Hepatitis | Various Families | RNA/DNA | Blood, food, sexual transmission | Hepatitis, cirrhosis | Antivirals, vaccines |

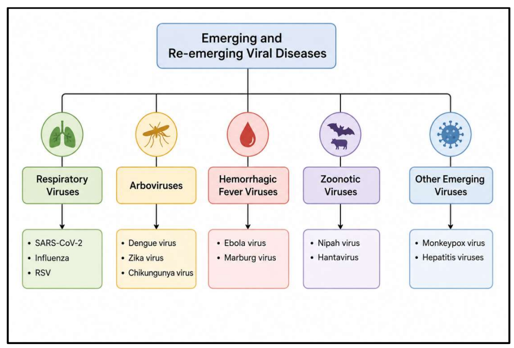


**Figure 1. Classification of Emerging and Re-emerging Viral Diseases and Their Global Health Impact**

**Medicinal Herbs as Sources of Antiviral Agents[36-52]**

Medicinal plants have been utilized for centuries as valuable therapeutic resources for the prevention and treatment of various infectious diseases. Long before the advent of modern pharmaceuticals, traditional healthcare systems relied extensively on herbal remedies to manage viral, bacterial, and parasitic infections. The rich diversity of bioactive compounds present in medicinal plants has attracted considerable scientific interest in recent decades, particularly in response to the increasing prevalence of emerging viral diseases and the limitations of conventional antiviral therapies. Numerous plant-derived metabolites have demonstrated antiviral activities against a broad spectrum of human pathogens, highlighting the significant potential of medicinal herbs as sources of novel therapeutic agents.

**Historical Perspective of Medicinal Herbs in Viral Disease Management**

The use of medicinal plants for treating infectious diseases is deeply rooted in human civilization. Traditional medical systems developed across different regions of the world have accumulated extensive knowledge regarding the therapeutic properties of herbs. These systems continue to provide valuable information for the identification of potential antiviral compounds and have served as an important foundation for contemporary drug discovery research.

**Ayurveda**

Ayurveda, one of the oldest holistic healthcare systems originating in India more than 5,000 years ago, extensively utilizes medicinal plants for disease prevention and treatment. Ayurvedic literature describes numerous herbal formulations used to strengthen immunity and combat infectious diseases. Herbs such as *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulsi), *Tinospora cordifolia* (Guduchi), *Withania somnifera* (Ashwagandha), and *Curcuma longa* (Turmeric) have traditionally been employed for their immunomodulatory, anti-inflammatory, and antimicrobial properties. Recent pharmacological investigations have validated the antiviral potential of many Ayurvedic herbs against influenza viruses, dengue virus, hepatitis viruses, and SARS-CoV-2. The holistic approach of Ayurveda, which emphasizes host immunity and disease prevention, remains highly relevant in the management of emerging viral infections.

**Traditional Chinese Medicine**

Traditional Chinese Medicine (TCM) represents one of the most extensively documented herbal medical systems in the world. For thousands of years, TCM practitioners have utilized medicinal plants to manage respiratory infections, febrile illnesses, and epidemic diseases. Common antiviral herbs used in TCM include *Andrographis paniculata*, *Glycyrrhiza glabra* (Licorice), *Lonicera japonica* (Honeysuckle), *Scutellaria baicalensis*, and *Camellia sinensis* (Green tea). During recent outbreaks of SARS, influenza, and COVID-19, several TCM formulations were investigated for their therapeutic benefits and demonstrated promising antiviral, anti-inflammatory, and immune-regulating activities. The integration of traditional knowledge with modern pharmacological research has contributed significantly to the identification of bioactive compounds with antiviral potential.

**African Traditional Medicine**

African traditional medicine encompasses a diverse range of indigenous healthcare practices that rely heavily on medicinal plants for treating infectious diseases. Various African communities have traditionally employed herbs such as *Artemisia afra*, *Sutherlandia frutescens*, *Vernonia amygdalina*, and *Hypoxis hemerocallidea* for the management of respiratory and febrile illnesses. Many of these plants contain phytochemicals with demonstrated antiviral, antioxidant, and immunostimulatory properties. The rich biodiversity of the African continent offers a vast but relatively underexplored source of bioactive compounds that may contribute to the development of future antiviral therapeutics.

**Unani Medicine**

Unani medicine, which originated from ancient Greek medical traditions and later flourished in the Middle East and South Asia, employs a holistic approach to disease management. Herbal preparations play a central role in Unani therapeutics, particularly in the treatment of infectious diseases. Medicinal plants such as *Nigella sativa* (Black seed), *Glycyrrhiza glabra*, *Allium sativum* (Garlic), and *Zingiber officinale* (Ginger) are widely utilized for their anti-inflammatory, antimicrobial, and immune-enhancing properties. Contemporary scientific studies have confirmed the antiviral activities of several Unani medicinal plants against influenza viruses, hepatitis viruses, and coronaviruses, supporting their potential role in antiviral drug development.

**Importance of Medicinal Herbs in Modern Drug Discovery**

The increasing emergence of viral pathogens and the growing limitations of conventional antiviral therapies have intensified interest in natural products as alternative sources of therapeutic agents. Medicinal plants continue to play a pivotal role in pharmaceutical research owing to their immense chemical diversity and broad spectrum of biological activities.

**Natural Products as Drug Leads**

Natural products have historically served as an important source of pharmaceutical agents. Many clinically approved drugs have been derived directly from natural sources or developed based on natural product scaffolds. Plant-derived compounds possess unique structural characteristics that often differ significantly from synthetic chemical libraries, thereby providing valuable templates for drug development. The success of natural products in oncology, infectious disease treatment, and immunotherapy has encouraged researchers to investigate medicinal plants for novel antiviral compounds. Advances in computational biology, molecular docking, high-throughput screening, and artificial intelligence have further accelerated the identification of plant-derived molecules with potential antiviral activity.

**Phytochemical Diversity and Antiviral Potential**

Medicinal plants synthesize a remarkable array of secondary metabolites that contribute to their therapeutic properties. These phytochemicals include alkaloids, flavonoids, polyphenols, terpenoids, tannins, saponins, glycosides, lignans, coumarins, and essential oils. Such compounds exhibit antiviral activities through multiple mechanisms, including inhibition of viral attachment and entry, suppression of viral replication, interference with viral protein synthesis, modulation of host immune responses, and attenuation of inflammatory pathways.

Unlike conventional antiviral agents that often target a single viral protein, plant-derived phytochemicals frequently exert multitarget effects, reducing the likelihood of resistance development. Additionally, many phytochemicals possess antioxidant and immunomodulatory properties that may enhance host defense mechanisms against viral infections. This chemical diversity provides an extensive reservoir of bioactive molecules for the discovery and development of next-generation antiviral therapeutics. The convergence of traditional medicinal knowledge, modern phytochemical research, and advanced molecular technologies has significantly expanded the scientific understanding of medicinal herbs as antiviral agents. Consequently, medicinal plants continue to represent one of the most promising and sustainable resources for addressing current and future challenges posed by emerging viral diseases.

**Table 3. Traditional Medical Systems and Representative Medicinal Herbs with Reported Antiviral Potential**

| **Traditional System** | **Representative Medicinal Herbs** | **Major Bioactive Constituents** | **Reported Antiviral Applications** |
|---|---|---|---|
| Ayurveda | *Azadirachta indica*, *Ocimum sanctum*, *Tinospora cordifolia*, *Curcuma longa* | Limonoids, eugenol, curcuminoids, diterpenoids | Dengue, influenza, SARS-CoV-2 |
| Traditional Chinese Medicine | *Andrographis paniculata*, *Glycyrrhiza glabra*, *Scutellaria baicalensis*, *Camellia sinensis* | Andrographolide, glycyrrhizin, baicalin, EGCG | SARS-CoV-2, influenza, hepatitis |
| African Traditional Medicine | *Artemisia afra*, *Sutherlandia frutescens*, *Vernonia amygdalina* | Terpenoids, flavonoids, phenolic compounds | Respiratory viral infections, influenza |
| Unani Medicine | *Nigella sativa*, *Allium sativum*, *Zingiber officinale*, *Glycyrrhiza glabra* | Thymoquinone, allicin, gingerols, glycyrrhizin | Influenza, hepatitis, coronavirus infections |

These two sections are among the most important parts of your review because they provide the scientific basis for the antiviral efficacy of medicinal herbs. For a high-impact review, avoid describing every phytochemical individually in excessive detail. Instead, discuss phytochemical classes first, then provide representative examples and summarize them in comprehensive tables.

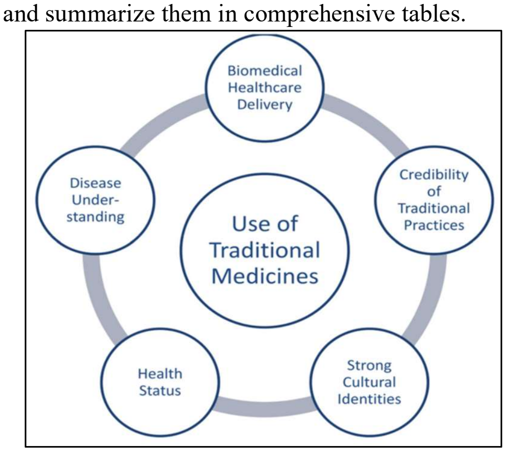


**Figure 2. Use of traditional medicines**

**Phytochemical Classes with Antiviral Activity[53-65]**

Medicinal plants synthesize a vast array of secondary metabolites that contribute to their therapeutic properties and ecological adaptation. These phytochemicals possess diverse chemical structures and exhibit broad-spectrum antiviral activities against both DNA and RNA viruses. Recent pharmacological and molecular studies have demonstrated that plant-derived bioactive compounds can interfere with multiple stages of the viral life cycle, including viral attachment, entry, replication, assembly, and release. Furthermore, many phytochemicals possess immunomodulatory, antioxidant, and anti-inflammatory properties that enhance host defense mechanisms and mitigate virus-induced tissue damage.

**Polyphenols**

Polyphenols constitute one of the largest groups of plant secondary metabolites and are characterized by the presence of multiple phenolic hydroxyl groups. These compounds are widely distributed in fruits, vegetables, medicinal herbs, and beverages such as tea. Polyphenols exhibit potent antiviral activity through inhibition of viral entry, suppression of viral replication, modulation of cellular signaling pathways, and enhancement of host immune responses.

Among the most extensively studied polyphenols, quercetin has demonstrated antiviral activity against influenza viruses, dengue virus, hepatitis viruses, and SARS-CoV-2. Catechins, particularly epigallocatechin gallate (EGCG) from green tea, have been shown to interfere with viral attachment and replication. Curcumin, a polyphenolic compound derived from Curcuma longa, exhibits broad-spectrum antiviral activity through modulation of inflammatory pathways and inhibition of viral protein expression. Resveratrol, commonly found in grapes and berries, has demonstrated inhibitory effects against respiratory viruses, herpes viruses, and coronaviruses through regulation of cellular antiviral signaling mechanisms.

**Flavonoids**

Flavonoids represent a diverse subclass of polyphenolic compounds characterized by a C6-C3-C6 carbon skeleton. They are widely recognized for their antiviral, antioxidant, and anti-inflammatory activities. Flavonoids have attracted considerable attention as potential antiviral agents because of their ability to target multiple viral and host cellular pathways simultaneously.

Luteolin has demonstrated inhibitory activity against influenza viruses, dengue virus, and coronaviruses through suppression of viral replication and interference with viral proteases. Apigenin exhibits antiviral activity by regulating viral gene expression and modulating host immune responses. Kaempferol has shown efficacy against influenza virus, hepatitis B virus, and SARS-CoV-2 by inhibiting viral replication and reducing inflammatory responses associated with infection.

**Alkaloids**

Alkaloids are nitrogen-containing organic compounds that possess significant pharmacological activities. Numerous plant-derived alkaloids have demonstrated broad-spectrum antiviral effects against a variety of clinically important viral pathogens. Their antiviral mechanisms frequently involve inhibition of viral nucleic acid synthesis, disruption of protein translation, and interference with viral replication machinery.

Berberine, an isoquinoline alkaloid found in Berberis species, exhibits antiviral activity against influenza viruses, hepatitis viruses, and coronaviruses. Lycorine, isolated from Amaryllidaceae plants, has demonstrated potent inhibitory activity against SARS-CoV, SARS-CoV-2, Zika virus, and enteroviruses through suppression of viral replication and protein synthesis.

**Terpenoids**

Terpenoids constitute one of the most structurally diverse groups of natural products and are synthesized from isoprene units. These compounds are widely distributed in medicinal plants and exhibit a broad range of biological activities, including antiviral, anti-inflammatory, and immunomodulatory effects.

Glycyrrhizin, a triterpenoid saponin isolated from Glycyrrhiza glabra, has demonstrated antiviral activity against SARS-CoV, SARS-CoV-2, hepatitis viruses, and HIV through inhibition of viral entry and replication. Artemisinin and its derivatives, obtained from Artemisia annua, have shown promising antiviral activity against several RNA viruses through modulation of host immune responses and inhibition of viral proliferation.

**Saponins**

Saponins are amphiphilic glycosides characterized by a hydrophobic aglycone linked to hydrophilic sugar moieties. Their surfactant properties enable interactions with viral envelopes and host cell membranes. Saponins have been reported to inhibit viral attachment, disrupt viral membranes, and stimulate both innate and adaptive immune responses. Several saponin-rich medicinal plants have demonstrated activity against influenza viruses, herpes simplex viruses, and coronaviruses.

**Tannins**

Tannins are high-molecular-weight polyphenolic compounds capable of forming complexes with proteins and other macromolecules. Antiviral tannins exert their effects through direct interactions with viral proteins, inhibition of viral adsorption, and suppression of viral replication. Numerous hydrolyzable and condensed tannins have demonstrated activity against influenza viruses, HIV, herpes simplex virus, and hepatitis viruses.

**Essential Oils**

Essential oils are volatile aromatic compounds primarily composed of monoterpenes, sesquiterpenes, and their oxygenated derivatives. These compounds possess significant antimicrobial and antiviral properties. Essential oils can inhibit viral infectivity by disrupting viral envelopes, preventing viral attachment, and modulating host immune responses. Essential oils derived from eucalyptus, thyme, oregano, tea tree, and ginger have shown promising antiviral activities against respiratory and enveloped viruses. The remarkable chemical diversity of plant-derived secondary metabolites provides an extensive reservoir of bioactive molecules with potential applications in antiviral drug discovery. Their multitarget mechanisms of action and favorable safety profiles make them attractive candidates for the development of novel therapeutic interventions against emerging viral diseases.

**Mechanisms of Antiviral Action of Medicinal Herbs[66-71]**

The antiviral efficacy of medicinal herbs is attributed to their ability to interfere with multiple stages of the viral life cycle while simultaneously modulating host defense mechanisms. Unlike conventional antiviral drugs that often target a single viral protein, phytochemicals generally exhibit multitarget actions that reduce the likelihood of resistance development and enhance therapeutic effectiveness.

**Prevention of Viral Attachment**

The initial stage of viral infection involves the attachment of viral surface proteins to specific receptors on host cells. Several phytochemicals prevent this interaction by binding either to viral glycoproteins or host cell receptors, thereby blocking viral adsorption and reducing infectivity.

**Inhibition of Viral Entry**

Following attachment, viruses enter host cells through membrane fusion or endocytosis. Numerous herbal compounds interfere with these processes by altering membrane dynamics, inhibiting receptor-mediated internalization, or preventing fusion of viral and cellular membranes.

**Inhibition of Viral Replication**

Viral replication represents one of the most important targets for antiviral intervention. Several phytochemicals inhibit viral genome replication by suppressing viral enzymes, interfering with nucleic acid synthesis, or disrupting intracellular signaling pathways essential for viral proliferation.

**Protease Inhibition**

Many viruses require proteolytic processing of viral polyproteins for maturation and infectivity. Certain flavonoids, polyphenols, and terpenoids inhibit viral proteases, thereby preventing the production of functional viral proteins and reducing viral propagation.

**Inhibition of Viral RNA Polymerase**

RNA-dependent RNA polymerase plays a critical role in the replication of RNA viruses. Numerous plant-derived compounds have demonstrated the ability to inhibit viral polymerase activity, thereby suppressing viral genome synthesis and replication.

**Immunomodulatory Activity**

Many medicinal herbs enhance innate and adaptive immune responses through stimulation of macrophages, natural killer cells, dendritic cells, and lymphocytes. Immunomodulatory phytochemicals also promote cytokine production and improve antiviral defense mechanisms.

**Anti-inflammatory Activity**

Excessive inflammatory responses contribute significantly to viral pathogenesis and tissue damage. Herbal compounds such as curcumin, quercetin, and glycyrrhizin suppress pro-inflammatory cytokines and regulate signaling pathways including NF-κB, MAPK, and JAK-STAT pathways.

**Antioxidant Activity**

Oxidative stress is a common feature of viral infections and contributes to cellular damage and disease progression. Antioxidant phytochemicals neutralize reactive oxygen species, protect cellular components from oxidative injury, and enhance overall cellular resilience during viral infections. Collectively, these mechanisms highlight the multifaceted nature of plant-derived antiviral compounds and their potential as complementary or alternative therapeutic agents for combating emerging viral diseases.

**Table 4. Major Antiviral Phytochemicals and Their Mechanisms of Action**

| Phytochemical Class | Representative Compound | Source Plant | Target Viruses | Major Mechanism of Action |
|---|---|---|---|---|
| Polyphenol | Quercetin | Onion, Apple, Tea | Influenza, Dengue, SARS-CoV-2 | Inhibits viral replication and entry |
| Polyphenol | EGCG | Green Tea | Influenza, HIV, SARS-CoV-2 | Blocks viral attachment |
| Polyphenol | Curcumin | Turmeric | Influenza, SARS-CoV-2 | Anti-inflammatory, replication inhibition |
| Polyphenol | Resveratrol | Grapes | RSV, Influenza, SARS-CoV-2 | Antioxidant and antiviral signaling |
| Flavonoid | Luteolin | Celery, Chamomile | Dengue, Influenza | Protease inhibition |
| Flavonoid | Apigenin | Parsley, Chamomile | Influenza, HSV | Replication inhibition |
| Flavonoid | Kaempferol | Tea, Broccoli | HBV, SARS-CoV-2 | Viral enzyme inhibition |
| Alkaloid | Berberine | Berberis species | Influenza, HBV | Viral replication suppression |
| Alkaloid | Lycorine | Lycoris radiata | SARS-CoV-2, Zika | Protein synthesis inhibition |
| Terpenoid | Glycyrrhizin | Licorice | SARS-CoV- | Viral entry |

| | | | | |
|---|---|---|---|---|
| | | | 2, HIV, HBV | inhibition |
| Terpenoid | Artemisinin | Artemisia annua | SARS-CoV-2, Dengue | Immunemodulation |
| Saponin | Glycyrrhizin derivatives | Licorice | Influenza, Coronavirus | Membrane disruption |
| Tannin | Tannic Acid | Various medicinal plants | HSV, HIV | Viral adsorption inhibition |
| Essential Oil | Eugenol | Ocimum sanctum, Clove | Influenza, HSV | Viral envelope disruption |

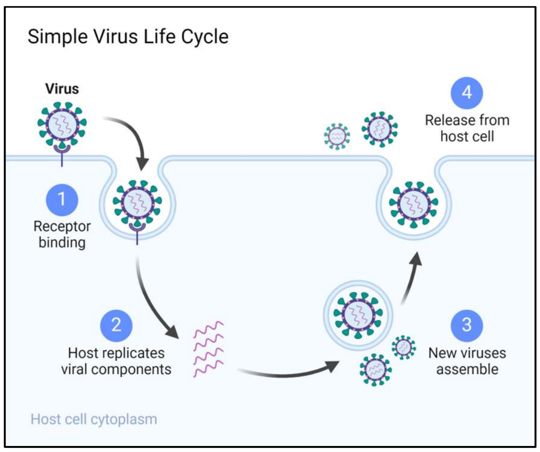


**Figure 3. Virus life cycle**

**Important Medicinal Herbs against Emerging Viral Diseases**[72-81]

Medicinal plants have gained considerable attention as potential sources of antiviral agents due to their rich phytochemical composition and broad-spectrum biological activities. Numerous herbs traditionally used in various medical systems have demonstrated significant antiviral effects against emerging and re-emerging viral pathogens. These antiviral activities are primarily attributed to bioactive constituents capable of targeting multiple stages of the viral life cycle while simultaneously modulating host immune responses. Recent advances in phytochemical analysis, molecular docking, in vitro studies, and animal models have further validated the therapeutic potential of these medicinal herbs against clinically important viral infections.

**Andrographis paniculata**

Andrographis paniculata, commonly known as the "King of Bitters," is widely used in Ayurvedic and Traditional Chinese Medicine. The major bioactive constituent, andrographolide, exhibits broad-spectrum antiviral activity against respiratory viruses, including SARS-CoV-2 and influenza viruses. Experimental studies suggest that andrographolide inhibits viral replication, suppresses inflammatory cytokine production, and enhances antiviral immune responses. Molecular docking investigations have demonstrated strong interactions with SARS-CoV-2 main protease and spike proteins, supporting its potential role in COVID-19 management.

**Glycyrrhiza glabra**

Glycyrrhiza glabra (Licorice) is an important medicinal plant extensively employed in traditional medicine systems. Glycyrrhizin, the principal triterpenoid saponin, possesses antiviral, anti-inflammatory, and immunomodulatory properties. Studies have demonstrated activity against SARS-CoV, SARS-CoV-2, hepatitis viruses, HIV, and influenza viruses. Glycyrrhizin interferes with viral attachment, inhibits viral replication, and modulates host immune responses through regulation of cytokine production.

**Curcuma longa**

Curcuma longa (Turmeric) contains curcumin as its major bioactive polyphenol. Curcumin exhibits antiviral activity against influenza viruses, hepatitis viruses, dengue virus, and SARS-CoV-2. Its antiviral effects are associated with inhibition of viral replication, suppression of viral protein expression, antioxidant activity, and regulation of inflammatory signaling pathways including NF-κB and MAPK pathways.

**Azadirachta indica**

Azadirachta indica (Neem) has been widely used in Ayurvedic medicine for treating infectious diseases. Limonoids, nimbin, azadirachtin, and quercetin contribute to its antiviral activities. Experimental studies have reported inhibitory effects against dengue virus, herpes simplex virus, hepatitis viruses, and influenza viruses. Neem-derived compounds interfere with viral entry, replication, and host-pathogen interactions.

**Ocimum sanctum**

Ocimum sanctum (Holy Basil or Tulsi) is regarded as an important adaptogenic and immunomodulatory herb. The major active constituents include eugenol, ursolic acid, and rosmarinic acid. Tulsi has demonstrated antiviral activity against influenza viruses, herpes viruses, and respiratory pathogens. Its therapeutic effects are largely attributed to immune enhancement, antioxidant activity, and suppression of inflammatory mediators.

**Allium sativum**

Allium sativum (Garlic) contains sulfur-containing compounds such as allicin, ajoene, and diallyl sulfides. Garlic extracts have shown antiviral activity against influenza viruses, coronaviruses, rhinoviruses, and herpes viruses. These compounds inhibit viral replication, stimulate immune responses, and reduce oxidative stress associated with viral infections.

**Zingiber officinale**

Zingiber officinale (Ginger) contains bioactive compounds including gingerols, shogaols, and zingerone. Several studies have demonstrated antiviral activity against respiratory syncytial virus, influenza virus, and human coronaviruses. Ginger inhibits viral attachment to host cells, modulates immune responses, and exerts significant anti-inflammatory effects.

**Camellia sinensis**

Camellia sinensis (Green Tea) is rich in catechins, particularly epigallocatechin gallate (EGCG). Green tea polyphenols exhibit antiviral activity against HIV, influenza viruses, hepatitis viruses, and SARS-CoV-2. EGCG interferes with viral attachment, inhibits viral replication, and modulates cellular antiviral pathways.

**Artemisia annua**

Artemisia annua is best known for producing artemisinin and its derivatives. In addition to their antimalarial activity, these compounds have demonstrated antiviral potential against SARS-CoV-2, hepatitis viruses, and several arboviruses. Artemisinin derivatives inhibit viral replication and modulate inflammatory responses associated with viral infections.

**Sambucus nigra**

Sambucus nigra (Elderberry) contains anthocyanins, flavonoids, and phenolic acids. Elderberry extracts have demonstrated antiviral activity against influenza viruses and respiratory pathogens. The herb promotes immune stimulation, reduces viral load, and alleviates symptoms associated with respiratory viral infections.

**Table 5. Important Medicinal Herbs with Reported Antiviral Activity Against Emerging Viral Diseases**

| Medicinal Herb | Major Active Constituents | Target Viruses | Major Antiviral Mechanisms |
|---|---|---|---|
| Andrographis paniculata | Andrographolide | SARS-CoV-2, Influenza | Viral replication inhibition |
| Glycyrrhiza glabra | Glycyrrhizin | SARS-CoV-2, HBV, HCV, HIV | Viral entry and replication inhibition |
| Curcuma longa | Curcumin | Influenza, Dengue, SARS-CoV-2 | Anti-inflammatory and antiviral activity |
| Azadirachta indica | Limonoids, Azadirachtin | Dengue, HSV, Influenza | Viral inhibition and immune modulation |
| Ocimum sanctum | Eugenol, Ursolic acid | Influenza, HSV | Immunomodulatory activity |
| Allium sativum | Allicin, Ajoene | Influenza, Corona virus | Viral replication inhibition |
| Zingiber officinale | Gingerols, Shogaols | RSV, Influenza | Viral attachment inhibition |
| Camellia sinensis | EGCG | HIV, Influenza, SARS-CoV-2 | Viral replication suppression |
| Artemisia annua | Artemisinin | SARS-CoV-2, Dengue | Antiviral and immunomodulatory activity |
| Sambucus nigra | Anthocyanins | Influenza | Immune stimulation and antiviral activity |

**Medicinal Herbs against Specific Viral Diseases[82-93]**

**Medicinal Herbs against COVID-19**

COVID-19 is caused by SARS-CoV-2, an enveloped positive-sense RNA virus that primarily targets the respiratory system through ACE2 receptor-mediated entry. Although antiviral drugs and vaccines have significantly reduced disease severity, therapeutic challenges remain due to viral mutations and emerging variants. Several medicinal herbs have demonstrated promising anti-SARS-CoV-2 activity. Andrographis paniculata, Glycyrrhiza glabra, Curcuma longa, Camellia sinensis, and Artemisia annua have shown inhibitory effects against viral replication, viral entry, and inflammatory pathways. Experimental evidence from molecular docking, cell culture studies, and animal models supports their therapeutic potential.

**Medicinal Herbs Against Dengue**

Dengue virus is a mosquito-borne flavivirus that causes dengue fever, dengue hemorrhagic fever, and dengue shock syndrome. The disease is characterized by excessive inflammatory responses, thrombocytopenia, and vascular leakage. Medicinal plants such as Azadirachta indica, Carica papaya, Andrographis paniculata, and Curcuma longa have demonstrated potential therapeutic benefits. These herbs possess antiviral, immunomodulatory, and platelet-supportive activities. Experimental studies have reported reduced viral replication and improvement of clinical parameters in dengue infection.

**Medicinal Herbs Against Zika Virus**

Zika virus infection is associated with neurological complications and congenital abnormalities. Currently, no specific antiviral treatment is available. Several plant-derived compounds, including quercetin, EGCG, curcumin, and lycorine, have demonstrated inhibitory effects on Zika virus replication in experimental studies. Herbal extracts rich in polyphenols and flavonoids have shown promise as potential antiviral candidates.

**Medicinal Herbs Against Chikungunya**

Chikungunya virus infection is characterized by severe fever and prolonged joint pain. Current treatment remains largely symptomatic. Medicinal herbs such as Andrographis paniculata, Curcuma longa, Artemisia annua, and Glycyrrhiza glabra possess anti-inflammatory and antiviral properties that may alleviate disease symptoms and reduce viral replication. Several in vitro investigations have reported significant antiviral activity against chikungunya virus.

**Medicinal Herbs Against Ebola Virus**

Ebola virus causes severe hemorrhagic fever with high mortality rates. Despite advances in vaccine development, therapeutic options remain limited. Natural products including flavonoids, terpenoids, and alkaloids derived from medicinal plants have demonstrated inhibitory effects on Ebola viral proteins and replication pathways. Several phytochemicals have shown promising activity in molecular docking and experimental studies.

**Medicinal Herbs Against Nipah Virus**

Nipah virus is a highly pathogenic zoonotic virus associated with encephalitis and respiratory disease. The absence of approved antiviral therapies necessitates the exploration of alternative therapeutic strategies.

Bioactive compounds such as quercetin, luteolin, glycyrrhizin, and berberine have demonstrated potential inhibitory effects against Nipah virus proteins in computational and experimental studies. Their immunomodulatory properties may further contribute to disease management.

**Medicinal Herbs Against Monkeypox Virus**

Monkeypox virus is an emerging orthopoxvirus responsible for recent global outbreaks. The disease is characterized by fever, lymphadenopathy, and cutaneous lesions. Several medicinal plants rich in flavonoids, polyphenols, and terpenoids have demonstrated antiviral activity against poxviruses. Compounds such as quercetin, kaempferol, EGCG, and glycyrrhizin are currently being investigated as potential therapeutic candidates against monkeypox virus infection.

**Table 6. Medicinal Herbs Investigated Against Specific Emerging Viral Diseases**

| **Viral Disease** | **Pathogenesis** | **Current Treatment** | **Herbal Interventions** | **Experimental Evidence** |
|---|---|---|---|---|
| COVID-19 | Respiratory and systemic infection | Antivirals, vaccines | Andrographis, Licorice, Turmeric | In vitro, in vivo, docking studies |
| Dengue | Vascular leakage, thrombocytopenia | Supportive care | Neem, Papaya, Turmeric | Cell culture and animal studies |
| Zika | Neurotropic infection | Supportive care | Green tea, Curcumin, Quercetin | Experimental antiviral studies |
| Chikungunya | Joint inflammation | Symptomatic treatment | Andrographis, Licorice | In vitro evidence |
| Ebola | Hemorrhagic fever | Monoclonal antibodies | Polyphenol-rich herbs | Computational and laboratory studies |
| Nipah | Encephalitis and respiratory disease | Supportive care | Glycyrrhizin, Berberine, Quercetin | In silico and experimental studies |
| Monkeypox | Systemic and cutaneous infection | Tecovirimat | Flavonoid-rich medicinal plants | Emerging experimental evidence |

**CONCLUSION:**

Emerging and re-emerging viral diseases continue to challenge global healthcare systems, necessitating the development of innovative therapeutic strategies beyond conventional antiviral drugs. The increasing prevalence of viral outbreaks, coupled with issues such as viral mutations, drug resistance, limited treatment options, and adverse drug reactions, has renewed scientific interest in medicinal plants as alternative and complementary therapeutic resources. Traditional medicinal systems have provided valuable knowledge regarding the use of herbs for managing infectious diseases, and contemporary research has increasingly validated many of these traditional claims through pharmacological and molecular investigations. Medicinal herbs constitute a rich reservoir of structurally diverse bioactive compounds, including polyphenols, flavonoids, alkaloids, terpenoids, saponins, tannins, and essential oils. These phytochemicals exhibit broad-spectrum antiviral activities by targeting multiple stages of the viral life cycle, including viral attachment, entry, replication, assembly, and release. In addition, their immunomodulatory, antioxidant, and anti-inflammatory properties contribute significantly to host protection against viral infections. Several medicinal plants, including *Andrographis paniculata*, *Glycyrrhiza glabra*, *Curcuma longa*, *Azadirachta indica*, *Ocimum sanctum*, *Allium sativum*, *Zingiber officinale*, *Camellia sinensis*, *Artemisia annua*, and *Sambucus nigra*, have demonstrated promising antiviral activities against major emerging viral pathogens such as SARS-CoV-2, dengue virus, Zika virus, chikungunya virus, Ebola virus, Nipah virus, and monkeypox virus. Recent advances in phytochemistry, metabolomics, molecular docking, network pharmacology, and systems biology have accelerated the identification and characterization of plant-derived antiviral compounds. However, despite encouraging experimental findings, the clinical translation of many herbal antivirals remains limited due to challenges related to standardization, quality control, bioavailability, safety evaluation, and insufficient clinical evidence. Therefore, future research should focus on comprehensive mechanistic studies, large-scale clinical trials, advanced formulation approaches, and integration of multi-omics technologies to fully exploit the therapeutic potential of medicinal herbs. Overall, medicinal plants represent a promising and sustainable source of novel antiviral agents capable of addressing current and future viral health challenges. The integration of traditional medicinal knowledge with modern scientific approaches may facilitate the discovery and development of effective plant-based therapeutics for the prevention and management of emerging viral diseases worldwide.

**CONFLICT OF INTREST:**

The author declares that there is no conflict of interest.

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