PROSPECTS
IN PHARMACEUTICAL SCIENCES

Prospects in Pharmaceutical Sciences, 21(2), 42-56
https://prospects.wum.edu.pl/

Review

MEDICINAL MUSHROOMS: A COMPREHENSIVE STUDY ON THEIR ANTIVIRAL POTENTIAL

Mustafa Sevindik*[1], Celal Bal[2], Emre Cem Eraslan[3], Imran Uysal[3], Falah Saleh Mohammed[4]

[1] *Department of Biology, Faculty of Science and Literature, Osmaniye Korkut Ata University, 80-000 Osmaniye, Türkiye*

[2] *Oğuzeli Vocational School, Gaziantep University, Gaziantep, 27-000, Türkiye*

[3] *Department of Food Processing, Bahçe Vocational School, Osmaniye Korkut Ata University, Osmaniye, 80-000, Türkiye*

[4] *Department of Biology, Faculty of Science, Zakho University, 42-001 Duhok, Iraq.*

* Correspondence, e-mail: sevindik27@gmail.com

Received: 26.04.2023 / Accepted: 23.05.2023 / Published: 06.06.2023

ABSTRACT

Microbial diseases have become quite common in recent years. The interest in new antimicrobial drugs is increasing due to the possible side effects of synthetic drugs and the emergence of resistant microorganisms due to unconscious antimicrobial drug use. Mushrooms have the potential to be used as a natural resource in the fight against microorganisms. In this context, in this study, the effects of different fungal species against different viral diseases were compiled in the literature. According to the findings, it has been reported in the literature that many different mushroom species are effective against Herpes virus (HSV-1, HSV-2, BoHV-1, HCMV), Influenza (A, B, H1N1, H3N2, H5N1, H9N2) and Parainfluenza, Infectious bursal disease virus (IBDV), Poxvirus, Vaccinia virus, Poliovirus, Vesicular stomatitis viruses (VSV), Adenovirus, Syncytial virus (RSV), Dengue virus (DENV-2), Human immunodeficiency virus (HIV), Hepatitis A, B, C virus, Feline calicivirus (FCV), Enterovirus, Coxsackievirus, Coronavirus, Infectious hematopoietic necrosis virus (IHNV), Newcastle disease virus (NDV) and Tobacco Mosaic virus (TMV). In this context, it is thought that mushrooms can be a very important natural resource against viruses.

KEYWORDS: Antivirals, Complementary medicine, Coronavirus, Medicinal mushroom, Viral diseases.

1. Introduction

In contrast to contemporary medical practices, traditional or complementary medicine, commonly referred to as folk medicine, incorporates the utilisation of natural products that have been employed for the treatment of various ailments since ancient times [1-4]. In the realm of traditional medicine, a variety of naturally occurring substances including fungi, flora, and fauna are employed [5,6]. Mushrooms are a commonly consumed dietary item across various communities owing to their nutritional properties [7]. They have significant nutritional constituents, including vitamins, minerals, and protein [8]. Furthermore, these properties have extensive medicinal applications. Numerous studies have documented the diverse biological activities of mushrooms, including but not limited to antioxidant, anticancer, antimicrobial, antiviral, DNA protective, antiproliferative, anti-inflammatory, and hepatoprotective properties [9-18]. The assessment of the biological properties of fungi holds significant importance in the medical domain.

2. Antiviral Activity

Currently, there is a growing prevalence of illnesses resulting from microorganisms [19]. One of the primary factors contributing to this phenomenon is the development of microbial resistance to existing antibiotics, which can be attributed in large part to the indiscriminate use of these drugs [19,20]. Scholars have resorted to exploring novel antimicrobial medications as a means of addressing microorganisms [21]. Antimicrobial natural products are utilised by individuals owing to the potential adverse effects associated with synthetic drugs and insufficient backing [22,23]. This study aimed to investigate the antiviral effects of mushrooms. The present discourse provides a comprehensive catalogue of fungal species that have been documented in the literature as effective against viral diseases.

Table 1. Mushrooms effective against herpes viruses [27-38].

Virus name	Extract type	Mushroom species	Geographic regions
Herpes virus (BoHV-1, HCMV, HSV-1, HSV-2)	Aqueous, ethanol, methanol	*Agaricus bisporus, Agaricus brasiliensis, Agaricus silvaticus, Amanita muscaria, Armillaria dealbata, Armillaria decembris, Armillaria mellea, Armillaria odora, Armillaria tabescens, Aureoboletus gentilis, Auriporia aurea, Boletus bellinii, Boletus edulis, Boletus erythropus, Boletus fragrans, Boletus subtomentosus, Calocybe gambosa, Cantharellus tubiformis, Chalciporus piperatus, Clitocybe gibba, Clitocybe nebularis, Collybia butyracea, Collybia distorta, Collybia fusipes, Collybia maculata, Coprinus comatus, Cortinarius alboviolaceus, Cortinarius bolaris, Cortinarius cinnamomeus, Cortinarius elatior, Cortinarius infractus, Cortinarius largus, Cortinarius orellanoides, Cortinarius phoeniceus, Cortinarius sanguineus, Cortinarius semisanguineus, Cortinarius torvus, Cortinarius uliginosus, Cortinarius vibratilis, Cortinarius violaceus, Entoloma lividum, Entoloma nidorosum, Entoloma rhodopolium, Fistulina hepatica, Flammulina velutipes, Fomes fomentarius, Ganoderma lipsiense, Ganoderma lucidum, Ganoderma pfeifferi, Grifola frondosa, Heterobasidion annosum, Hydnellum concrescens, Hydnum repandum, Hygrocybe coccinea, Hygrophorus nemoreus, Hypholoma fasciculare, Inocybe piriodora, Laccaria amethystea, Laccaria laccata, Lactarius blennius, Lactarius chrysorrheus, Lactarius deliciosus, Lactarius lilacinus, Lactarius necator, Lactarius quietus, Lactarius tabidus, Lactarius torminosus, Lactarius trivialis, Lactarius vellereus, Laetiporus sulphureus, Langermannia gigantea, Lentinula edodes, Lepista inversa, Lepista nuda, Leucopaxillus candidus, Leucopaxillus paradoxus, Lycoperdon perlatum, Lyophyllum shimeji, Macrolepiota procera, Marasmius oreades, Megacollybia platyphylla, Morchella conica, Morchella esculenta, Mycena pura, Oudemansiella mucida, Oudemansiella radicata, Panellus stipticus, Paxillus involutus, Phallus impudicus, Phellinus igniarius, Phellinus pini, Phellinus sp., Pholiota alnicola, Piptoptorus betulinus, Pleurotus columbinus, Pleurotus eryngii, Pleurotus ostreatus, Pleurotus sajor-caju, Pleurotus sp., Pluteus cervinus, Polyporus alveolari, Porodaedalea pini, Psathyrella piluliformis, Pyrofomes demidoffii, Ramaria stricta, Rozites caperata, Russula aeruginea, Russula cyanoxantha, Russula drimeia, Russula emetica, Russula fageticola, Russula fellea, Russula krombholzii, Russula nigricans, Russula ochroleuca, Russula sanguinaria, Russula turci, Schizophyllum commune, Scleroderma verrucosum, Suillus granulatus, Suillus variegatus, Terfezia boudieri, Trametes elegans, Trametes gibbosa, Trametes rubescens, Trametes versicolor, Tricholoma acerbum, Tricholoma album, Tricholoma anatolicum, Tricholoma colombetta, Tricholoma fulvum, Tricholoma portentosum, Tricholoma saponaceum, Tricholoma sejunctum, Tricholoma sulfureum, Tricholoma ustale, Tricholoma ustaloides, Tricholoma virgatum, Xerocomus badius, Xerocomus chrysenteron, Xerocomus rubellus, Xerocomus subtomentosus*	Brazil, France, Germany, South Korea, India Spain, Tunisia, Türkiye, Ukraine

2.1. Herpes virus (BoHV-1, HCMV, HSV-1, HSV-2) (Genus: Simplexvirus)

Herpes simplex virus type 1 (HSV-1) is responsible for infections in the facial and nasal regions, while herpes simplex virus type 2 (HSV-2) is known to cause infections in the genital area [24]. BoHV-1 has been identified as the causative agent for a variety of ailments in cattle, including rhinotracheitis, vaginitis, balanoposthitis, abortion, conjunctivitis, and enteritis [25]. Human herpesvirus 5 (HHV-5), commonly known as CMV strain, is a pathogenic microorganism that can cause infection in humans. The transmission of herpes viruses occurs through either direct contact or the sharing of objects. The transmission of the aforementioned disease is facilitated through the dispersion of salivary fluids and droplets. Moreover, it is transmitted via sexual intercourse. The manifestation of this condition is observable as a cutaneous eruption. The virus invades the mucosal linings of the oral cavity, nasal passages, and genitalia. The hallmark attribute of this phenomenon is the curative mechanism facilitated by the formation of a crust. Nonetheless, these viruses have the capability to enter a phase known as latency. By manipulating the immune system, it is possible to induce its activation during periods of immunosuppression [26].

Our study compiles fungi that have been reported in the literature to be effective against HSV-1, HSV-2, BoHV-1 and HCMV viruses within this particular context. Table 1 displays the results that were obtained. In a study conducted in France, the effect of ethanol and aqueous extract obtained from 121 fungal species on HSV-1 and HSV-2 was investigated. As a result of the study, it was determined that *Trametes gibbosa, Tricholoma virgatum, Tricholoma portentosum, Cortinarius orellanoides, Cortinarius sanguineus* and *Lactarius torminosus* species exhibited the best values against HSV-1 at 0.5-4.5 mg/mL concentrations. It was also reported that *Trametes gibbosa*, *Tricholoma virgatum, Tricholoma portentosum, Tricholoma acerbum, Collybia maculata, Rozites caperata, Cortinarius sanguineus, Hypholoma fasciculare, Hypholoma sublateritium* and *Lactarius torminosus* exhibited the best values against HSV-2 at concentrations of 0.25-3.0 mg/mL [27]. In a study conducted in Germany, the effect of triterpenes obtained from *Ganoderma pfeifferi* species on HSV-1 was investigated. As a result of the examination, the ED50 value of the used species was reported to be 0.068 mmol/L [28]. In a study conducted in South Korea, the effect of ethanol extract obtained from *Phellinus pini* sample on HSV-1 was investigated. As a result of the research, it has been reported that it has an effect of 91-93% at 5 µg/mL [29]. In a study conducted in Brazil, it was reported that the extract obtained from the *Agaricus brasiliensis* species inhibited BoHV-1 by 63.8-83.2% [30]. In another study conducted in Brazil, it was reported that the selective index of ethanol and aqueous extract obtained from *Lentinula edodes* species was 12.11 and 9.02, respectively [31]. In a study conducted in Spain, it was reported that the IC50 values of water and methanol extract obtained from the mushroom *Pleurotus ostreatus* and the polysaccharide obtained from this mushroom species on HSV-1 were 0.20 and 4.80 µg/mL [32]. In a study conducted in Ukraine, the effect of distilled water extract obtained from 10 mushroom species on HSV-2 was investigated. Among the species used in the study, the best selectivity index result was reported to be 161.29 for *Auriporia aurea* and 324.67 for *Trametes versicolor* [33]. In a study conducted in India, the effect of aqueous extract from *Tramates versicolor* and *Tramates elegans* species on BoHV-1 was evaluated. As a result of the study, it was reported that *Trametes versicolor* showed antiviral activity at 10^{-6} dilution with the best results among the extracts obtained from the mushroom samples used [34]. In a study conducted in Turkey, the effect of methanol and aqueous extracts obtained from 10 fungal species on HSV-1 was investigated. As a result of the study, it was reported that *Fomes fomentarius* (EC50 = 11.22 mg/mL; SI > 4.46), *Phellinus igniarius* (EC50 = 9.71 mg/mL; SI > 5.15) and *Porodaedalea pini* (EC50 = 7.16 mg/mL; SI > 6.98) had the best antiviral effect according to the EC50 and the selectivity index SI for the cytopathic effect among the species used [35]. In a study conducted in India, the effect of crude extract obtained from 4 mushroom species against CMV was investigated. As a result of the research, it has been reported that *Polyporus alveolari, Phellinus* sp., *Pleurotus ostreatus* and *Lentinus squarrosulus* have an effect between 160-180 µg/mL [36]. In a study conducted in Egypt, the effect of aqueous extract obtained from *Pleurotus columbinus*, *Pleurotus sajor-caju* and *Agaricus bisporus* species on HSV-2 was investigated. As a result of the study, it was reported that *Agaricus bisporus* had the strongest selective index of 3.7 [37]. In a study conducted in Tunisia, the effect of methanol extract obtained from *Boletus bellinii* and *Boletus subtomentosus* species on HSV-2 was investigated. As a result of the study, it was reported that the species used had an effect of 3.60 and 5.67 µg/mL, respectively [38]. To summarize studies discussed in this chapter, it has been reported that different fungal species are effective against HSV-1, HSV-2, BoHV-1 and CMV. As a result, it is thought that the fungi used can be a natural source against these viruses.

2.2. Influenza (A, B, H1N1, H3N2, H5N1, H9N2) and Parainfluenza (Genus: Alphainfluenzavirus and Genus: Betainfluenzavirus)

Influenza viruses are pathogenic microorganisms that exhibit a broad spectrum of disease severity. Common symptoms of the condition include elevated body temperature, nasal discharge, inflamed throat, muscular and cephalic discomfort, coughing, and debilitation. The duration of symptoms persists for a period of 2 to 7 days [39]. There exist four distinct classifications of influenza viruses, namely types A, B, C, and D. Groups A, B, and C can be pathogenic for humans. Moreover, it is noteworthy that group A has a prevalent occurrence in both pigs and mammals, whereas group D is predominantly found in cattle and pigs [40]. The H1N1 virus, which is classified as a subtype of Influenza A, is responsible for the onset of swine flu [41]. The H3N2 viruses represent a distinct subspecies of Influenza A that are capable of infecting both avian and mammalian hosts. The H5N1 virus is a distinct subspecies of Influenza A that specifically targets avian influenza. Furthermore, the H9N2 virus is classified as a subgroup of the group A influenza virus and has the potential to induce infections in both avian and human populations [42]. Parainfluenza viruses (HPIV) have the ability to infect both the upper and lower respiratory tract in humans. Whilst infections may be observed in tropical regions throughout the year, in temperate regions, the incidence of cases typically increases during the winter season. Natural products are employed for mitigating the impact of infections [43].

Table 2 presents the findings of our study on the antiviral effects of fungi against influenza viruses, as reported in the literature. In a study conducted in Germany, the effect of crude extract obtained from *Ganoderma pfeifferi* species on Influenza A virus was investigated. As a result of the examination, the ED50 value of the species used was reported to be 0.19-0.22 mmol/L [28]. In a study conducted in Russia, the effect of aqueous extracts obtained from 11 fungal species against Influenza A virus was investigated. As a result of the research, it was reported that the best effect was 0.167 mg/mL in *Ischnoderma benzoinum* and *Daedaleopsis confragosa* species [44]. In a study conducted in South Korea, the effect of aqueous extract obtained from *Phellinus igniarius* sample on H1N1, H3N2 and H9N2 was investigated. As a result of the study, it was reported that the LC50 value was 0.18-1.14 mg/mL [45].

Table 2. Mushrooms effective against Influenza (A, B, H1N1, H3N2, H5N1, H9N2) and Parainfluenza [28,33, 44-48].

Virus name	Extract type	Mushroom species	Geographic regions
Influenza (A, B, H1N1, H3N2, H5N1, H9N2) and Parainfluenza	Aqueous, ethanol	*Auriporia aurea, Cryptoporus volvatus, Daedaleopsis confragosa, Datronia mollis, Flammulina velutipes, Fomes fomentarius, Ganoderma lucidum, Ganoderma pfeifferi, Ganoderma valesiacum, Irpex lacteus, Ischnoderma benzoinum, Laricifomes officinalis, Lentinus edodes, Lenzites betulina, Lyophyllum shimeji, Phellinus conchatus, Phellinus igniarius, Piptoporus betulinus, Pleurotus eryngii, Pleurotus ostreatus, Pleurotus pulmonarius, Schizophyllum commune, Trametes gibbosa, Trametes versicolor*	Japan, Russia, South Korea, Ukraine, USA

In a study conducted in the United States, the effect of water extract obtained from *Cryptoporus volvatus* sample on H1N1 was investigated. As a result of the study, it was reported that there was a significant reduction in viral lesions in the lungs of mice [46]. In a study conducted in Ukraine, the effect of water extract obtained from 10 fungal species against Influenza A virus was investigated. The species used in the study: *Auriporia aurea*, *Flammulina velutipes, Fomes fomentarius, Ganoderma lucidum, Lentinus edodes, Lyophyllum shimeji, Pleurotus eryngii, Pleurotus ostreatus, Schizophyllum commune* and *Trametes versicolor* have been reported to have a maximum tolerance concentration range of 0.2-25 mg/mL [33]. In a study conducted in Japan, it was reported that the extract obtained from the *Lentinula edodes* sample was administered orally and was effective against Influenza A in mice [47]. In another study conducted in Russia, the effect of water and ethanol extract obtained from *Pleurotus pulmonarius* species against H1N1 was investigated. As a result of the study, it was reported that the EC50 value of the effective dose was in the range of 1.8-3 mg/mL [48]. According to the data in the literature, it has been observed that different fungal species have significant effects against Influenza viruses. Thus, it has been seen that mushrooms can be a natural source against influenza viruses.

2.3. Infectious bursal disease virus (IBDV, Genus: Avibirnavirus), Poxvirus (Family: Poxviridae), Vaccinia virüs (Genus: Orthopoxvirus), Poliovirus (Genus: Enterovirus)

IBDV, also referred to as Gumboro disease, is a viral pathogen that is responsible for inducing significant mortality rates in avian populations. The contagiousness of the disease in young chickens and turkeys is considerably high [49]. The poxvirus is known to infect both vertebrates and arthropods, and is the causative agent of smallpox. Four distinct genera have been identified to cause infections in humans, namely Orthopoxvirus, Parapoxvirus, Yatapoxvirus, and Molluscipoxvirus [50]. The etiological agent responsible for smallpox is the Vaccinia virus. Typically, the condition is characterised by a mild presentation, and even individuals who are considered to be in good health may not exhibit any discernible symptoms. Individuals with compromised immune systems often exhibit symptoms of erythema and pyrexia. The efficacy of the vaccines utilised against this particular virus is noteworthy [51]. The poliovirus is responsible for the onset of poliomyelitis, a severe ailment characterised by muscular spasms and the degeneration of neural tissue. The symptoms of the condition comprise elevated body temperature of up to 40°C, intense cephalalgia and

Table 3. Mushrooms effective against IBDV, Poxvirus, Vaccinia virus, Poliovirus [27, 31, 53-55].

Virus name	Extract type	Mushroom species	Geographic regions
Poxvirus	Methanol	*Cantharellus isabellinus, Cantharellus platyphyllus, Pleurotus citrinopileatus, Pleurotus djamour, Pleurotus sajor-caju*	Tanzania
Infectious bursal disease virus (IBDV)	Methanol	*Cantharellus isabellinus, Cantharellus platyphyllus, Pleurotus citrinopileatus, Pleurotus djamour, Pleurotus sajor-caju*	Tanzania
Vaccinia virus	Aqueous	*Amanita citrina, Amanita fulva, Amanita muscaria, Amanita pantherina, Amanita phalloides, Amanita rubescens, Amanita spissa, Amanita vaginata, Armillariella mellea, Boletus edulis, Cantharellus cibarius, Clitocybe cerussata, Clitocybe discolor, Clitocybe flaccida, Clitocybe gibba, Clitocybe nebularis, Clitocybe odora, Clitocybe tuba, Clitocybe vibecina, Collybia butyracea, Collybia distorta, Collybia dryophila, Collybia peronata, Craterellus cornucopioides, Cystoderma amianthinum, Cystoderma carcharias, Gymnopilus penetrans, Hygrophorus eburneus, Lactarius mitissimus, Lactarius necator, Lactarius piperatus, Lactarius volemus, Leccinum aurantiacum, Leccinum griseum, Lepista gilva, Lepista inversa, Lepista nuda, Lycoperdon perlatum, Macrolepiota procera, Marasmius oreades, Mycena pura, Mycena zephirus, Naematoloma capnoides, Naematoloma fasciculare, Paxillus involutus, Pholiota lenta, Ramaria apiculata, Russula cyanoxantha, Russula fellea, Russula vesca, Scleroderma citrinum, Sparassis crispa, Suillus granulatus, Suillus granulatus, Tricholoma portentosum, Tricholomopsis rutilans, Xerocomus chrysenteron*	Poland
Poliovirus	Ethanol, aqueous	*Agaricus brasiliensis, Agaricus silvaticus, Amanita muscaria, Armillaria dealbata, Armillaria decembris, Armillaria mellea, Armillaria odora, Armillaria tabescens, Aureoboletus gentilis, Boletus edulis, Boletus erythropus, Boletus fragrans, Calocybe gambosa, Cantharellus tubiformis, Chalciporus piperatus, Clitocybe gibba, Clitocybe nebularis, Collybia butyracea, Collybia distorta, Collybia fusipes, Collybia maculata, Coprinus comatus, Cortinarius alboviolaceus, Cortinarius bolaris, Cortinarius cinnamomeus, Cortinarius elatior, Cortinarius infractus, Cortinarius largus, Cortinarius orellanoides, Cortinarius phoeniceus, Cortinarius sanguineus, Cortinarius semisanguineus, Cortinarius torvus, Cortinarius uliginosus, Cortinarius vibratilis, Cortinarius violaceus, Entoloma lividum, Entoloma nidorosum, Entoloma rhodopolium, Fistulina hepatica, Ganoderma lipsiense, Ganoderma lucidum, Grifola frondosa, Heterobasidion annosum, Hydnellum concrescens, Hydnum repandum, Hygrocybe coccinea, Hygrophorus nemoreus, Hypholoma fasciculare, Inocybe piriodora, Laccaria amethystea, Laccaria laccata, Lactarius blennius, Lactarius chrysorrheus, Lactarius deliciosus, Lactarius lilacinus, Lactarius necator, Lactarius quietus, Lactarius tabidus, Lactarius torminosus, Lactarius trivialis, Lactarius vellereus, Laetiporus sulfureus, Langermannia gigantea, Lentinula edodes, Lepista*	France, Brazil

	inversa, Lepista nuda, Leucopaxillus candidus, Leucopaxillus paradoxus, Lycoperdon perlatum, Macrolepiota procera, Marasmius oreades, Megacollybia platyphylla, Mycena pura, Oudemansiella mucida, Oudemansiella radicata, Panellus stipticus, Paxillus involutus, Phallus impudicus, Pholiota alnicola, Piptoptorus betulinus, Pleurotus ostreatus, Pluteus cervinus, Psathyrella piluliformis, Ramaria stricta, Rozites caperata, Russula aeruginea, Russula cyanoxantha, Russula drimeia, Russula emetica, Russula fageticola, Russula fellea, Russula krombholzii, Russula nigricans, Russula ochroleuca, Russula sanguinaria, Russula turci, Scleroderma verrucosum, Suillus granulatus, Suillus variegatus, Trametes gibbosa, Trametes rubescens, Trametes versicolor, Tricholoma acerbum, Tricholoma album, Tricholoma colombetta, Tricholoma fulvum, Tricholoma portentosum, Tricholoma saponaceum, Tricholoma sejunctum, Tricholoma sulfureum, Tricholoma ustale, Tricholoma ustaloides, Tricholoma virgatum, Xerocomus badius, Xerocomus chrysenteron, Xerocomus rubellus, Xerocomus subtomentosus

dorsalgia, and feelings of nausea. The condition manifests as minor outbreaks, particularly during the summer and autumn seasons, and results in enduring muscular impairment. The employment of vaccines in the battle against polio has yielded considerable success [52]. Table 3 displays the fungal species documented in literature as having activity against IBDV, Poxvirus, Vaccinia virus, and Poliovirus in this particular study. In a study conducted in Tanzania, methanol extracts obtained from *Cantharellus platyphyllus, Cantharellus isabellinus, Pleurotus djamour, Pleurotus sajor-caju* and *Pleurotus citrinopileatus* were reported to be effective against IBDV and Poxvirus [53]. In a study conducted in Poland, the effect of water extract obtained from 56 fungal species on Vaccinia virus was investigated. As a result of the study, it was reported that the toxic zone range of the species used was between 12-37 mm [54]. In a study conducted in France, the effect of ethanol and aqueous extract obtained from 121 fungal species on Poliovirus was investigated. As a result of the study, it was reported that *Clitocybe nebularis*, one of the species used, showed high activity with 1.0-5.0 mg/mL, *Lepista inversa* with 1.0-4.5 mg/mL, *Mycena pura* with 1.25-1.75 mg/mL and *Lactarius torminosus* with 0.5-2.5 mg/mL [27]. In a study conducted in Brazil, the effect of ethanol extract of *Agaricus brasiliensis* species on Poliovirus was investigated. As a result of the study, it has been reported that it has 50-88% inhibition effect [55]. In another study conducted in Brazil, the selective index of ethanol and aqueous extracts obtained from *Lentinula edodes* species against Poliovirus was reported as 19.85 and 5.82, respectively [31]. In this context, the effects of different fungal species against IBDV, Poxvirus, Vaccinia virus and Poliovirus have been reported. According to these results, it is thought that fungi may be a natural source against these viruses.

2.4. Vesicular stomatitis virus (VSV, Genus: Vesiculovirus), Adenovirus (Family: Adenoviridae), Syncytial virus (RSV, Genus: Orthopneumovirus), Dengue virus (DENV-2, Genus: Flavivirus)

VSV is commonly referred to as Indiana vesiculovirus. The arthropod has the potential to cause infection in bovine, equine, and porcine species. The predicament faced by farmers is particularly challenging, particularly in diverse global regions [56]. Adenoviruses are known to induce infections in both human and animal populations. The pathogen in question elicits acute respiratory disease, acute follicular conjunctivitis, epidemic keratoconjunctivitis, cystitis, and in some cases, gastroenteritis and pneumonia in human hosts [57]. The virus commonly referred to as RSV is alternatively known as a human respiratory syncytial virus or human orthopneumovirus. Respiratory syncytial virus (RSV) is a prevalent and communicable virus that induces respiratory infections [58]. The etiological agent responsible for the manifestation of dengue fever is the Dengue virus. The incidence of Dengue virus has exhibited a noteworthy escalation over the preceding two decades. Mosquitoes are responsible for approximately 390 million infections annually, with a higher incidence in tropical regions [59].

The present investigation aimed to explore the mushrooms species that have been documented in the literature as efficacious against VSV, adenovirus, RSV, and DENV-2. Table 4 displays the results that were obtained. In a study conducted in France, the effect of ethanol and aqueous extract obtained from 121 fungal species on VSV was investigated. Among the species used in the study, the VSV value was 1.0-5.0 mg/mL in *Clitocybe nebularis*, 1.5-4.5 mg/mL in *Lepista inversa*, 1.0-3.0 mg/mL in *Collybia maculata*, 1.5-2.0 mg/mL in *Mycena pura* and *Lactarius torminosus* at 0.5-2.0 mg/mL [27]. In a study conducted in Japan, the effect of crude extract obtained from the mushroom *Lentinus edodes* on VSV was evaluated. The result of the study was reported to be 2.0×10^2 - 9.4×10^1 PFU/mL after 48 hours [60]. In a study conducted in Egypt, the effect of aqueous extract obtained from *Pleurotus columbinus*, *Pleurotus sajor-caju* and *Agaricus bisporus* species on Adenovirus was investigated. As a result of the study, it was reported that *Pleurotus columbinus* had the strongest selective index of 4.2 [37]. In a study conducted in China, the effect of some sesquiterpenes obtained from the *Agrocybe salicacola* species on RSV was examined. As a result of the study, it was reported that the LC50 value of the species used was 100 μM [61]. In a study conducted in Malaysia, it was reported that the LC50 value range of *Lignosus rhinocerotis, Pleurotus giganteus, Hericium erinaceus, Schizophyllum commune* and *Ganoderma* lucidium against DENV-2 was 226.3-2080.2 μg/mL [62]. In *another* study conducted in Malaysia, the state of the aqueous extract of the fungus *Ganoderma lucidium* on DENV-2 was analyzed. As a result of the study, it was reported that the inhibition value was 84.6% [63]. In a study conducted in the Czech Republic, it was reported that ganodermanontriol, lucidumol A, ganoderic acid C2 and ganosporeric acid A obtained from *Ganoderma lucidium* extract had an effect on DENV-2 [64]. In this context, according to the data reported in the literature, it has been seen that fungi have the potential to be a natural source against VSV, adenovirus, RSV, DENV-2.

Table 4. Mushrooms effective against VSV, Adenovirus, RSV, DENV-2 [27,37, 60-64].

Virus name	Extract type	Mushroom species	Geographic regions
Vesicular stomatitis virus (VSV)	Aqueous, ethanol	*Agaricus silvaticus, Amanita muscaria, Armillaria dealbata, Armillaria decembris, Armillaria mellea, Armillaria odora, Armillaria tabescens, Aureoboletus gentilis, Boletus edulis, Boletus erythropus, Boletus fragrans, Calocybe gambosa, Cantharellus tubiformis, Chalciporus piperatus, Clitocybe gibba, Clitocybe nebularis, Collybia butyracea, Collybia distorta, Collybia fusipes, Collybia maculata, Coprinus comatus, Cortinarius alboviolaceus, Cortinarius bolaris, Cortinarius cinnamomeus, Cortinarius elatior, Cortinarius infractus, Cortinarius largus, Cortinarius orellanoides, Cortinarius phoeniceus, Cortinarius sanguineus, Cortinarius semisanguineus, Cortinarius torvus, Cortinarius uliginosus, Cortinarius vibratilis, Cortinarius violaceus, Entoloma lividum, Entoloma nidorosum, Entoloma rhodopolium, Fistulina hepatica, Ganoderma lipsiense, Ganoderma lucidum, Grifola frondosa, Heterobasidion annosum, Hydnellum concrescens, Hydnum repandum, Hygrocybe coccinea, Hygrophorus nemoreus, Hypholoma fasciculare, Inocybe piriodora, Laccaria amethystea, Laccaria laccata, Lactarius blennius, Lactarius chrysorrheus, Lactarius deliciosus, Lactarius lilacinus, Lactarius necator, Lactarius quietus, Lactarius tabidus, Lactarius torminosus, Lactarius trivialis, Lactarius vellereus, Laetiporus sulfureus, Langermannia gigantea, Lentinus edodes, Lepista inversa, Lepista nuda, Leucopaxillus candidus, Leucopaxillus paradoxus, Lycoperdon perlatum, Macrolepiota procera, Marasmius oreades, Megacollybia platyphylla, Mycena pura, Oudemansiella mucida, Oudemansiella radicata, Panellus stipticus, Paxillus involutus, Phallus impudicus, Pholiota alnicola, Piptoptorus betulinus, Pleurotus ostreatus, Pluteus cervinus, Psathyrella piluliformis, Ramaria stricta, Rozites caperata, Russula aeruginea, Russula cyanoxantha, Russula drimeia, Russula emetica, Russula fageticola, Russula fellea, Russula krombholzii, Russula nigricans, Russula ochroleuca, Russula sanguinaria, Russula turci, Scleroderma verrucosum, Suillus granulatus, Suillus variegatus, Trametes gibbosa, Trametes rubescens, Trametes versicolor, Tricholoma acerbum, Tricholoma album, Tricholoma colombetta, Tricholoma fulvum, Tricholoma portentosum, Tricholoma saponaceum, Tricholoma sejunctum, Tricholoma sulfureum, Tricholoma ustale, Tricholoma ustaloides, Tricholoma virgatum, Xerocomus badius, Xerocomus chrysenteron, Xerocomus rubellus, Xerocomus subtomentosus*	France, Japan
Syncytial virus (RSV)	Terpen	*Agrocybe salicacola*	China
Adenovirus	Aqueous	*Agaricus bisporus, Pleurotus columbinus, Pleurotus sajor-caju*	Egypt
Dengue virus (DENV-2)	Aqueous, ethanol, ethyl acetate, hexane	*Ganoderma lucidium, Hericium erinaceus, Lignosus rhinocerotis, Pleurotus giganteus, Schizophyllum commune*	Czech Republic, Malaysia

2.5. Human immunodeficiency virus (HIV) (Genus: Lentivirus)

The Human Immunodeficiency Virus (HIV) is a pathogenic virus that is responsible for the onset of acquired immunodeficiency syndrome (AIDS). The duration of the incubation period is relatively extended. As the infection disseminates throughout the organism, the immune system experiences a compromise [65]. Consequently, individuals become more vulnerable to a range of illnesses. This is indicative of excessive weight loss. Vertical transmission of the condition is possible through perinatal routes such as transplacental transfer during pregnancy, perinatal exposure during childbirth, or postnatal transmission via breastfeeding [66]. Furthermore, it is noteworthy that the transmission of the aforementioned disease can occur via blood transfusions, sexual intercourse, needles, or exposure to the blood of individuals who are infected. However, the likelihood of transmission through bodily fluids such as saliva, sweat, or tears is exceedingly low [67].

Since its first identification, HIV has caused the demise of approximately 40 million individuals. The development of a treatment or vaccine is currently in the research phase. Furthermore, the utilisation of anti-retroviral medications is advantageous in maintaining the equilibrium of the disease. The utilisation of natural products for combating HIV primarily involves fortifying the immune system. Furthermore, it confers advantages in retarding the impact of HIV [68]. This study aimed to compile the reported effectiveness of fungi against HIV as documented in the literature. Table 5 displays the results that were obtained.

Table 5. Mushrooms effective against HIV [69-77].

Virus name	Extract type	Mushroom species	Geographic regions
Human immunodeficiency virus (HIV)	Aqueous, Ethanol	*Agaricus brasiliensis, Cantharellus cibarius, Cantharellus cornucopioides, Cantharellus isabellinus, Cordyceps militaris, Cordyceps sinensis, Fomes fomentarius, Ganoderma applanatum, Ganoderma colossum, Ganoderma lucidum, Ganoderma pfeifferi, Ganoderma sinense, Ganoderma sp., Grifola frondosa, Hohenbuehelia serotina, Lentinus edodes, Lentinus sp., Phellinus igniarus, Phellinus linteus, Russula paludosa, Schizophyllum commune, Trametes versicolor*	China, Colombia, Germany, Ghana, Japan, Tanzania, Vietnam,

In a study conducted in Tanzania, it was reported that *Ganoderma lucidum, Ganoderma applanatum, Ganoderma pfeifferi, Trametes versicolor, Cantharellus cibarius, Cantharellus cornucopioides, Cantharellus isabellinus, Schizophyllum commune, Phellinus igniarus, Fomes fomentarius* and *Phellinus linteus* were effective on HIV [69]. In a study conducted in China, the effect of a peptide isolated from the extract obtained from *Russula paludosa* species on HIV was investigated. As a result of the study, it was reported that the peptide used was 41.8-99.2% effective at 1, 0.2 and 0.04 mg/mL concentrations [70]. In a study conducted in Vietnam, the effect of extract obtained from *Ganoderma colossum* mushroom against HIV was investigated. As a result of the study, it was reported that the LC50 effect value was 5-39 µg/mL [71]. In a study conducted in Germany, the effect of the extract obtained from the fungus *Epicoccum nigrum* on HIV was examined. As a result of the study, it was reported that the EC50 value was 13.5 µM [72]. In a study conducted in Japan, the effect of the extract obtained from the *Ganoderma sinense* species on HIV was examined. As a result of the study, it was reported that the LC50 value was between 20-40 µM [73]. In another study conducted in China, the effect of the extract obtained from the *Cordyceps militaris* mushroom on HIV was examined. The effect range of the species used in the study was reported to be 0.78-65.27% [74]. In a study conducted in Ghana, it was reported that *Lentinus edodes, Grifola frondosa, Ganoderma lucidum, Trametes versicolor, Cordyceps sinensis* and *Agaricus brasiliensis* significantly increased CD4+ and T-lymphocyte counts in HIV patients after 60 days [75]. In a study conducted in China, the effect of the extract obtained from the *Hohenbuehelia serotina* sample on HIV was examined. As a result of the study, it was reported that the LC50 value was 25-50 µM [76]. In a study conducted in Colombia, the effect of extracts obtained from *Ganoderma* sp. and Lentinus sp. species on HIV was investigated. As a result of the study, it was reported that the extract obtained in the species used inhibited HIV replication between 80% and 90% and decreased the early and late transcript production between 55.5-91.3% and 82.1-93.6%, respectively. The best selectivity index of *Lentinus* sp. was SI = 8.3 [77]. In this context, it has been observed that the reported mushrooms have efficacy against HIV. As a result, fungi are thought to have a potential anti-HIV effect.

2.6. Hepatovirus A, B, C (Genus: Hepatovirus)

Hepatitis is an inflammation of specific liver tissue resulting in a yellow color in the skin and whites of the eyes. Anorexia, vomiting, abdominal pain, weakness and gastrointestinal disturbances may occur [78]. If the disease resolves within 6 months, it is defined as acute hepatitis, and if it lasts longer than 6 months, it is defined as chronic hepatitis [79]. Acute hepatitis may go away on its own, but chronic hepatitis can cause cirrhosis, liver cancer, and liver failure. Causes are usually drugs, alcohol consumption, toxins and autoimmune diseases [80]. There are types A, B, C, D and E. Types A and E can be transmitted through contaminated food and water, type B sexually, during pregnancy or by contact with contaminated blood, and type C through blood. Type D can be transmitted to people infected with type B. A, B and D type vaccination and C type antiviral drugs are used [81]. In this study, mushroom effective against hepatitis were compiled in the literature. The obtained results are shown in Table 6.

In a study conducted in Egypt, the effect of ethyl acetate and water extract obtained from the fungus *Hericium erinaceus* on HAV was investigated. As a result of the examination, it was reported that the CC50 value was 26 and 111 µg/mL for ethyl acetate and water extract, respectively [82]. In a study conducted in China, the effect of the extract obtained from the mushroom *Agaricus blazei* on HBV was examined. As a result of the study, it was reported that spartate aminotransferase and alanine aminotransferase levels decreased from 246.0 to 61.3 IU/L and from 151.0 to 46.1 IU/L. In this context, it has been observed that Agaricus blazei extracts have significant potentials in normalizing the liver functions of HBV patients [83]. In another study conducted in China, the effect of the extract obtained from *Grifola frondosa*

Table 6. Mushrooms effective against Hepatovirus A, B, C [82-90].

Virus name	Extract type	Mushroom species	Geographic regions
Hepatovirus A (HAV)	Aqueous, ethyl acetate	*Hericium erinaceus*	Egypt
Hepatovirus B (HBV)	Aqueous, chloroform, ethanol	*Agaricus blazei, Ganoderma lucidum, Grifola frondosa*	China
Hepatovirus C (HCV)	Aqueous, ethyl acetate, dichloromethane, n-hexane	*Agaricus bisporus, Pleurotus ostreatus, Rhodotus palmatus*	Egypt, Germany, Spain

on HBV was investigated and it was reported that there was 50% inhibition as a result of the study [84]. In a study conducted in China, it was reported that the extract obtained from *Ganoderma lucidum* sample had an inhibitory effect on HBsAg and HBeAg secretion [85]. In another study conducted in China, it was reported that ganoderic acid obtained from a sample of *Ganoderma lucidum* inhibited HBV at 8 μg/mL [86]. In a study conducted in Spain, the effect of ethyl acetate, dichloromethane and n-hexane extracts of *Agaricus bisporus* species on HCV was investigated. As a result of the research, it was reported that the inhibition percentage of *Agaricus bisporus* was 64.85-75.56% [87]. In a study conducted in Egypt, it was reported that laccase obtained from the fungus *Pleurotus ostreatus* inhibited HCV at 2.0 and 2.5 mg/mL [88]. In a study conducted in Spain, water extract of the fungus *Agaricus bisporus* was reported to be effective on HCV [89]. In a study conducted in Germany, it was reported that rhodatin (a meroterpenoid) and rhodocoranes A–E (sesquiterpenoids) obtained from the fungus *Rhodotus palmatus* have effects on HCV [90]. In this context, it has been seen that mushrooms have a significant potential against hepatitis types according to literature data.

2.7. Feline calicivirus (FCV, Genus: Vesivirus), Enterovirus (Genus: Enterovirus), Coxsackievirus (Genus: Enterovirus)

FCV causes respiratory infections in cats. There is no specific treatment for FCV. However, supportive treatments can be applied according to symptoms [91]. Enterovirus causes infections of many humans and mammals worldwide each year. Generally, children younger than 5 years old constitute the majority of the diseased [92]. Coxsackie viruses are widespread throughout the world. They are mostly transmitted by fecal and oral route. Meningitis-like disease may occur [93]. In this study, mushrooms reported in the literature against FCV, enterovirus and Coxsackie viruses were compiled. The obtained results are shown in Table 7.

Table 7. Mushrooms effective against FCV, Enterovirus, Coxsackievirus [29, 38, 76, 94-97].

Virus name	Extract type	Mushroom species	Geographic regions
Feline calicivirus (FCV)	Aqueous, ethanol, hexane	*Cordyceps sinensis, Ganoderma lucidum, Inonotus obliquus, Morchella esculenta, Phellinus igniarius*	China, Thailand
Enterovirus	Aqueous ethanol, aqueous	*Ganoderma lucidum, Ganoderma neo-japonicum, Grifola frondosa*	China, Malaysia
Coxsackievirus	Aqueous, ethanol, methanol	*Boletus bellinii, Boletus subtomentosus, Ganoderma neo-japonicum, Phellinus pini*	Malaysia, South Korea, Tunisia

In a study conducted in China, the effect of polysaccharides obtained from the mushroom *Inonotus obliquus* on FCV was investigated. As a result of the study, it has been reported that polysaccharides directly act as an inhibitor on virus particles by blocking viral binding/absorption in an in vitro experiment [94]. In a study conducted in Thailand, the effects of hexane, ethanol and water extracts obtained from *Inonotus obliquus*, *Phellinus igniarius*, *Cordyceps sinensis*, *Ganoderma lucidum* and *Morchella esculenta* samples on FCV were investigated. As a result of the study, it was reported that the best LC50 value of *Inonotus obliquus* was 0.80±0.16 μg/mL [95]. In a study conducted in China, the effect of heteropolysaccharin obtained from *Grifola frondosa* extracts on Enterovirus was investigated. As a result of the study, it was reported that viral replication was suppressed [96]. In another study conducted in China, the effects of triterpenoids obtained from *Ganoderma lucidum* mushroom extract on Enterovirus were investigated. It has been reported that Lanosta-7,9(11),24-trien-3-one,15;26-dihydroxy (GLTA) and Ganoderic acid Y (GLTB) obtained as a result of the investigation are effective [76]. In a study conducted in Malaysia, it was reported that the extracts obtained from the *Ganoderma neo-japonicum* sample showed 100% efficacy at 1.25 mg/mL against Enterovirus [97]. In a study conducted in Tunisia, the effect of methanol extract obtained from *Boletus bellinii* and *Boletus subtomentosus* species on Coxsackievirus was investigated. As a result of the study, it was reported that the species used had an effect of 5.70 and 56.88 μg/mL, respectively [38]. In a study conducted in South Korea, the effect of ethanol extract obtained from *Phellinus pini* sample on Coxsackievirus was investigated. As a result of the research, it has been reported that it has 84% effect at 1 mg/mL [29]. In a study conducted in Malaysia, it was reported that extracts obtained from *Ganoderma neo-japonicum* sample showed 60-70% effect at 1.25 mg/mL [97]. In this context, it has been reported in the literature that fungi are effective against FCV, enterovirus and Coxsackie viruses. As a result, it is thought that fungi can be a natural source against these viruses.

2.8. Coronavirus (Family: Coronaviridae)

Coronavirus variants are present in avian and mammalian species. MERS-CoV, SARS-CoV and COVID-19 (SARS-CoV-2) types cause respiratory infections that can be fatal in humans [98]. The last type of coronavirus seen in 2019, called SARS-CoV-2 or Covid-19, was quite deadly. High fever, dry cough, weakness, shortness of breath, and loss of taste are some of the symptoms. After the first contact, the symptoms last between 1-14 days on average. Usually, the symptoms are mild. However, it can cause serious respiratory tract infections in people with weakened immunity or chronic diseases. It can also cause blood clots and organ failure. Transmission is usually by contact or by being in the same environment with an infected person [99]. Mushrooms reported to be effective against SARS-CoV-2 in the literature are reported in Table 8.

In a study conducted in Egypt, it was reported that kaempferol, chlorogenic acid and ascorbic acid, catechin, superoxide dismutase and quercetin from *Pleurotus ostreatus, Lentinula edodes* and *Agaricus bisporus* samples effectively bind to Mpro of SARS-CoV-2 [100]. In a study conducted in Russia, the effect of water extract obtained from the mushroom *Inonotus obliquus* on SARS-CoV-2 was investigated. As a result of the study, it was reported that water extracts have 50% inhibition of replication of SARS-CoV-2 (nCoV/Victoria/1/2020 strain) in Vero E6 and Vero cell cultures in the concentration range of 0.75 to 11.6 μg/mL [101]. In a study conducted in India, the effect of the extract obtained from the *Polyozellus multiplex* sample on SARS-CoV-2 was investigated. As a result of the study, it was reported that the agents Kynapcin-12 (M_78), Kynapcin-28 (M_82), Kynapcin-24 (M_83) and Neonambiterphenyls-A (M_366) obtained from the sample were effective [102]. In another study conducted in Egypt, the effect of the extract obtained from the mushroom *Inonotus obliquus* on SARS-CoV-2 was investigated. As a result of the study, it was reported that betulinic acid and inonotusane C obtained from the sample can bind to the spike protein near the host cell recognition site of angiotensin converting enzyme 2 [103]. In a study conducted in Thailand, the effect of some compounds obtained from *Ganoderma* sp. on SARS-CoV-2 was investigated. As a result of the study, it was reported that the ursolic acid, 20(21)-dehydrolucidenic acid N, agrocybin, betulinic acid, colossolactone (A, E,G,V, VII, VIII), ellagic acid, ergosterol, gallic acid, ganoderic acid (α, Β, β, C1, GS- 2, H), Ganoderiol (A, B, F), ganodermanondiol, ganodermanontriol, ganolucidic acid A, ganomycin (B, I), heliantriol F, linoleic acid, lucidumol B, methyl gallate, oleanolic acid, semicochliodinol (A, B) and velutin obtained from *Ganoderma* sp. had an effect between 1.02-757.15 μM and 18.58-865.36 nM [104]. In a study conducted in Iraq, the effect of the extract obtained from the *Ganoderma lucidum* mushroom on COVID-19 was investigated. As a result of the study, it was reported that the hemoglobin value decreased from 14.0 to 13.6 Hb g/dL, the packed cell volume decreased from 46 to 45%, the red blood cells decreased from 6.5 to 5.75 cell/mm^3, and the platelets decreased from 300.0 to 159.0 cell/mm^3 [105]. In a study conducted in China, the status of the L-fucose compound obtained from *Ganoderma lucidum* extract on SARS-CoV-2 was examined. It has been reported that the compound obtained as a result of the study is effective at 2 μg/mL [106]. In a study conducted in Malaysia, the effects of the extract obtained from *Ganoderma lucidum, Grifola frondosa, Agrocybe* species, *Auricularia auricula, Hericium erinaceus*, *Hypsizygus marmoreus*, *Pleurotus cystidiosus*, *Pleurotus eryngii*, *Pleurotus flabellatus, Pleurotus florida, Pleurotus sajor-cajuju*, *Schizophyllum commune* and *Volvariella volvaceae* on SARS-CoV-2 were investigated and it was reported that the obtained triterpenes had effects on ACE proteins [107]. In a study conducted in Taiwan, the effect of extract obtained from *Antrodia cinnamomea* and *Antrodia salmonea* mushroom samples on SARS-CoV-2 was investigated. It has been reported that the samples used in the study result inhibit ACE2 thanks to the antcins compounds [108]. In this context, it has been seen that mushroom, which are reported to be effective against SARS-CoV-2 in the literature, can be used as a natural resource.

Table 8. Mushrooms effective against Coronavirus [44, 100-108].

Virus name	Extract type	Mushroom species	Geographic regions
SARS-CoV-2	Aqueous	*Agaricus bisporus, Agrocybe sp., Antrodia cinnamomea, Antrodia salmonea, Auricularia auricula, Ganoderma lucidum, Ganoderma sp., Grifola frondosa, Hericium erinaceus, Hypsizygus marmoreus, Inonotus obliquus, Lentinula edodes, Pleurotus cystidiosus, Pleurotus eryngii, Pleurotus flabellatus, Pleurotus florida, Pleurotus ostreatus, Pleurotus sajor-caju, Polyozellus multiplex, Schizophyllum commune, Tricholoma giganteum, Volvariella volvaceae*	China, Egypt, India, Iraq, Malaysia, Russia, Taiwan, Thailand

2.9. Infectious hematopoietic necrosis virus (IHNV, Genus: Novirhabdovirus), Newcastle disease virus (NDV, Genus: Orthoavulavirus), Tobacco Mosaic virus (TMV, Genus: Tobamovirus)

IHNV virus causes the disease known as infectious hematopoietic necrosis in fish such as trout and salmon [109]. NDV causes a contagious avian disease. It can infect different animals, including poultry and rodents [110]. TMV infects plants such as tobacco and members of the Solanaceae family. Mosaic-like mottling and discoloration are characteristic signs [111]. In this study, the activities of fungi against IHNV, NDV and TMV were compiled based on literature data. The obtained results are shown in Table 9.

Table 9. Mushrooms effective against IHNV, NDV, TMV [112-117].

Virus name	Extract type	Mushroom species	Geographic regions
Infectious hematopoietic necrosis virus (IHNV)	Aqueous	*Lentinus edodes*	China
Newcastle disease virus (NDV)	Aqueous, ethyl acetate, methanol, n-butanol	*Cordyceps militaris, Ganoderma lucidum, Hydnellum concrescens*	China, Nigeria, South Korea
Tobacco Mosaic Virus (TMV)	Methanol	*Fomes fomentarius, Omphalia lapidescens, Schizophyllum commune*	China, Japan

In a study conducted in China, the effect of extract from the mushroom *Lentinus edodes* on IHNV was examined. As a result of the study, it was reported that a new lentinan isolated from the extract was effective between 39.60-82.38% [112]. In a study conducted in South Korea, the effect of methanol extract obtained from the *Hydnellum concrescens* mushroom sample on NDV was investigated. As a result of the study, it was reported that the LC50 value of the extract obtained from the mushroom sample used in baby hamster kidney (BHK) cells was 15 µg/mL [113]. In a study conducted in Nigeria, the effect of methanol, ethylacetate and n-butanol extracts of *Ganoderma lucidum* on NDV was investigated. As a result of the study, it was reported that 1% of red blood cells inhibited the elution of NDV neuraminidase [114]. In a study conducted in China, the effect of water and ethanol extract from *Cordyceps militaris* on NDV was evaluated. As a result of the research, it was reported that Fractional CMP40 and CMP50 polysaccharides obtained from the extracts had an effect on chicken peripheral lymphocyte proliferation [115]. In a study conducted in China, the effect of methanol extract of *Omphalia lapidescens* mushroom sample on TMV was investigated. As a result of the study, it was reported that the leiwansterols A and B compounds obtained from the extract had an effect [116]. In a study conducted in Japan, the effect of extract obtained from *Fomes fomentarius* and *Schizophyllum commune* samples on TMV was investigated. As a result of the study, it was reported that the best results were obtained in BAS-F, Xanthi-nc 2 µg/mL, a polysaccharide produced by *Fomes fomentarius* [117]. In this context, it has been observed that fungi have efficacy against IHNV, NDV and TMV.

3. Conclusions

In recent years, viral diseases have become quite common. A lot of natural products are used in the fight against viral infections. In this study, the potential of fungi against viruses was compiled. The types of mushrooms used, their effects, where they were collected and how they were used were determined. As a result of the researches, it is thought that fungi can be used as a natural source against viruses.

Author Contributions: Conceptualization, M.S., I.U. and F.S.M; methodology, M.S., I.U., E.C.E., C.B. and F.S.M; validation, M.S., I.U., E.C.E., C.B. and F.S.M; investigation, M.S., I.U., E.C.E., C.B. and F.S.M; resources, M.S., I.U., E.C.E., C.B. and F.S.M; data curation, M.S., I.U., E.C.E., C.B. and F.S.M; writing—original draft prep-aration, M.S., I.U., E.C.E., C.B. and F.S.M; writing—review and editing, M.S., I.U., E.C.E., C.B. and F.S.M; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bal, C.; Akgul, H.; Sevindik, M.; Akata, I.; Yumrutas, O. Determination of the anti-oxidative activities of six mushrooms. *Fresenius Environ. Bull.,* **2017**, *26(10),* 6246-6252.
2. Sevindik, M. The novel biological tests on various extracts of *Cerioporus varius*. *Fresenius Environ. Bull.,* **2019**, *28(5),* 3713-3717.
3. Sevindik, M.; Akgul, H.; Bal, C.; Selamoglu, Z. Phenolic contents, oxidant/antioxidant potential and heavy metal levels in *Cyclocybe cylindracea*. *Indian J. Pharm. Educ. Res.,* **2018,** *52(3),* 437-441. https://doi.org/10.5530/ijper.52.3.50
4. Bal, C.; Sevindik, M.; Akgul, H.; Selamoglu, Z. Oxidative stress index and antioxidant capacity of *Lepista nuda* collected from Gaziantep/ Turkey. *Sigma J. Engin. Nat. Sci.,* **2019**, *37*(*1*), 1-5.
5. Korkmaz, A. I.; Akgul, H.; Sevindik, M.; Selamoglu, Z. Study on determination of bioactive potentials of certain lichens. *Acta Aliment.,* **2018**, *47(1),* 80-87. http://dx.doi.org/10.1556/066.2018.47.1.10
6. Sevindik, M.; Akgül, H.; Dogan, M.; Akata, I.; Selamoglu, Z. Determination of antioxidant, antimicrobial, DNA protective activity and heavy metals content of *Laetiporus sulphureus*. *Fresenius Environ. Bull.,* **2018**, *27(3),* 1946-1952.
7. Selamoglu, Z.; Sevindik, M.; Bal, C.; Ozaltun, B.; Sen, İ.; Pasdaran, A. Antioxidant, antimicrobial and DNA protection activities of phenolic content of *Tricholoma virgatum* (Fr.) P. Kumm. *Biointerface Res. Appl. Chem.,* **2020**, *10*(*3*), 5500-5506. http://dx.doi.org/10.33263/BRIAC103.500506
8. Sevindik, M.; Akgul, H.; Selamoglu, Z.; Braidy, N. Antioxidant and antigenotoxic potential of *Infundibulicybe geotropa* mushroom collected from Northwestern Turkey. *Oxid. Med. Cell. Longev.,* **2020**, https://doi.org/10.1155/2020/5620484
9. Mushtaq, W.; Baba, H.; Akata, I.; Sevindik, M. Antioxidant potential and element contents of wild edible mushroom *Suillus granulatus*. *KSU J. Agric. Nat.,* **2020**, *23(3),* 592-595. http://dx.doi.org/10.18016/ksutarimdoga.vi.653241
10. Sevindik, M.; Akata, I. Antioxidant, oxidant potentials and element content of edible wild mushroom *Helvella leucopus*. *Indian J. Nat. Prod. Resour.,* **2020**, *10*(4), 266-271.
11. Saridogan, B. G. O.; Islek, C.; Baba, H.; Akata, I.; Sevindik, M. Antioxidant antimicrobial oxidant and elements contents of *Xylaria polymorpha* and *X. hypoxylon* (Xylariaceae). *Fresenius Environ. Bull.,* **2021**, *30*(5), 5400-5404.
12. Sevindik, M.; Anticancer, antimicrobial, antioxidant and DNA protective potential of mushroom *Leucopaxillus gentianeus* (Quél.) Kotl. *Indian J. Exp. Biol., **2021**, 59*(05), 310-315.
13. Eraslan, E. C.; Altuntas, D.; Baba, H.; Bal, C.; Akgül, H.; Akata, I.; Sevindik, M. Some biological activities and element contents of ethanol extract of wild edible mushroom *Morchella esculenta*. *Sigma J. Engin. Nat. Sci.,* **2021**, *39*(*1*), 24-28.
14. Islek, C.; Saridogan, B. G. O.; Sevindik, M.; Akata, I. Biological activities and heavy metal contents of some *Pholiota* species. *Fresenius Environ. Bull.,* **2021**, *30*(*6*), 6109-6114.

15. Sevindik, M.; Bal, C. Antioxidant, antimicrobial, and antiproliferative activities of wild mushroom, *Laeticutis cristata (*Agaricomycetes*)*, from Turkey. *Int. J. Med. Mushrooms*, **2021**, *23*(11), 85-90. https://doi.org/10.1615/intjmedmushrooms.2021040415

16. Sevindik, M. Antioxidant and antimicrobial capacity of *Lactifluus rugatus* and its antiproliferative activity on A549 cells. *Indian J. Tradit. Knowl.,* **2020***, 19*(2), 423-427.

17. Bal, C.; Baba, H.; Akata, I.; Sevindik, M.; Selamoglu, Z.; Akgül, H. Biological Activities of Wild Poisonous Mushroom *Entoloma sinuatum* (Bull.) P. Kumm (Boletales). *KSU J. Agric. Nat.,* **2022**, *25*(1), 83-87. http://dx.doi.org/10.18016/ksutarimdoga.vi.880151

18. Krupodorova, T.; Sevindik, M. Antioxidant potential and some mineral contents of wild edible mushroom *Ramaria stricta. AgroLife Sci. J.,* **2020***, 9(1),* 186-191.

19. Karaltı, İ.; Eraslan, E. C.; Sarıdoğan, B. G. Ö.; Akata, I.; Sevindik, M. Total Antioxidant, Antimicrobial, Antiproliferative Potentials and Element Contents of Wild Mushroom *Candolleomyces candolleanus* (Agaricomycetes) from Turkey. *Int. J. Med. Mushrooms*, **2022**, *24*(12), 69-76. https://doi.org/10.1615/intjmedmushrooms.2022045389

20. Sevindik, M. Mushrooms as natural antiviral sources and supplements foods against coronavirus (COVID-19). *J. Bacteriol. Mycol. Open Access*, **2021**, *9*, 73-76. https://doi.org/10.15406/jbmoa.2021.09.00299

21. Sevindik, M.; Akgul, H.; Akata, I.; Alli, H.; Selamoglu, Z. *Fomitopsis pinicola* in healthful dietary approach and their therapeutic potentials. *Acta Aliment.,* **2017**, *46*(4), 464-469. https://doi.org/10.1556/066.2017.46.4.9

22. Baba, H.; Sevindik, M.; Dogan, M.; Akgül, H.; Antioxidant, antimicrobial activities and heavy metal contents of some Myxomycetes. *Fresenius Environ. Bull.,* **2020**, *29*(09), 7840-7846.

23. Sevindik, M.; Investigation of antioxidant/oxidant status and antimicrobial activities of *Lentinus tigrinus*. Adv. Pharmacol. Sci., **2018**, Art. No. 1718025. https://doi.org/10.1155%2F2018%2F1718025

24. Mohammed, F. S.; Uysal, I.; Sevindik, M. A Review on Antiviral Plants Effective against Different Virus Types. *Prospects Pharm. Sci.*, **2023**, *21*(2), 1-21. https://doi.org/10.56782/pps.128

25. Muylkens, B.; Thiry, J.; Kirten, P.; Schynts, F.; Thiry, E. Bovine herpesvirus 1 infection and infectious bovine rhinotracheitis. *Vet. Res.,* **2007**, *38*(2), 181-209. https://doi.org/10.1051/vetres:2006059

26. Griffiths, P.; Baraniak, I.; Reeves, M. The pathogenesis of human cytomegalovirus. *J. Pathol.*, **2015**; *235*(2), 288-297. https://doi.org/10.1002/path.4437

27. Amoros, M.; Boustie, J.; Py, M. L.; Hervé, V.; Robin, V. Antiviral activity of Homobasidiomycetes: evaluation of 121 Basidiomycetes extracts on four viruses. *Int. J. Pharmacogn.*, **1997**, *35*(4), 255-260. https://doi.org/10.1076/phbi.35.4.255.13308

28. Mothana, R. A. A.; Ali, N. A.; Jansen, R.; Wegner, U.; Mentel, R.; Lindequist, U. Antiviral lanostanoid triterpenes from the fungus *Ganoderma pfeifferi*. *Fitoterapia*, **2003**, *74*(1-2), 177-180. https://doi.org/10.1016/s0367-326x(02)00305-2

29. Lee, S. M.; Kim, S. M.; Lee, Y. H.; Kim, W. J.; Park, J. K.; Park, Y. I.; Synytsya, A. Macromolecules isolated from *Phellinus pini* fruiting body: chemical characterization and antiviral activity. *Macromol. Res.*, **2010**, *18*, 602-609. https://doi.org/10.1007/s13233-010-0615-9

30. Minari, M. C.; Rincão, V. P.; Soares, S. A.; Ricardo, N. M. P. S.; Nozawa, C.; Linhares, R. E. C. Antiviral properties of polysaccharides from *Agaricus brasiliensis* in the replication of bovine herpesvirus 1. *Acta Virol.*, **2011**, *55*(3), 255-259. https://doi.org/10.4149/av_2011_03_255

31. Rincão, V. P.; Yamamoto, K. A.; Silva Ricardo, N. M. P.; Soares, S. A.; Paccola Meirelles, L. D.; Nozawa, C.; Carvalho Linhares, R. E. Polysaccharide and extracts from *Lentinula edodes*: structural features and antiviral activity. *Virol. J.*, **2012**, *9*(1), 1-6. https://doi.org/10.1186%2F1743-422X-9-37

32. Santoyo, S.; Ramírez-Anguiano, A.C.; Aldars-García, L.; Reglero, G.; Soler-Rivas, C. Antiviral activities of *Boletus edulis, Pleurotus ostreatus* and *Lentinus edodes* extracts and polysaccharide fractions against Herpes simplex virus type 1. *J. Food Nutr. Res.*, **2012**, *51*, 225–235.

33. Krupodorova, T.; Rybalko, S.; Barshteyn, V. Antiviral activity of Basidiomycete mycelia against influenza type A (serotype H1N1) and herpes simplex virus type 2 in cell culture. *Virol. Sin.*, **2014**, *29*, 284-290. https://doi.org/10.1007/s12250-014-3486-y

34. Manoj, R.; Earanna, N.; Chandranaik, B. M. Molecular characterization of *Trametes* species and screening their aqueous extracts for antiviral properties. *Biosci. Trends*, **2017**, *10*(40), 8524-8529.

35. Doğan, H. H.; Karagöz, S.; Duman, R. In vitro evaluation of the antiviral activity of some mushrooms from Turkey. *Int. J. Med. Mushrooms*, **2018**, *20*(3), 201-212. https://doi.org/10.1615/intjmedmushrooms.2018025468

36. Roy, D.; Ansari, S.; Chatterjee, A.; Luganini, A.; Ghosh, S. K.; Chakraborty, N. In vitro search for antiviral activity against humancytomegalovirus from medicinal mushrooms Pleurotus sp. and *Lentinus* sp. *J. Antivir. Antiretrovir*, **2020**, *12*(3), 201. DOI: 10.35248/1948-5964.20.12.201

37. Elhusseiny, S. M.; El-Mahdy, T. S.; Awad, M. F.; Elleboudy, N. S.; Farag, M. M.; Aboshanab, K. M.; Yassien, M. A. Antiviral, cytotoxic, and antioxidant activities of three edible agaricomycetes mushrooms: *Pleurotus columbinus, Pleurotus sajor-caju*, and *Agaricus bisporus*. *J. Fungi.*, **2021**, *7*(8), 645. https://doi.org/10.3390/jof7080645

38. Boudagga, S.; Bouslama, L.; Papetti, A.; Colombo, R.; Arous, F.; Jaouani, A. Antiviral activity of Inonotusin A an active compound isolated from *Boletus bellinii* and *Boletus subtomentosus*. *Biologia*, **2022**, *77*(12), 3645–3655. https://doi.org/10.1007%2Fs11756-022-01219-z

39. Tong, S.; Zhu, X.; Li, Y.; Shi, M.; Zhang, J.; Bourgeois, M.; Yang, H.; Chen, X.; Recuenco, S.; Gomez, J.;

Chen, L.; Johnson, A.; Tao, Y.; Dreyfus, C.; Yu, W.; McBride, R.; Carney, P.J.; Gilbert, A.T.; Chang, J.; Guo, Z.; Davis, C.T.; Paulson, J.C.; Stevens, J.; Rupprecht, C.E.; Holmes, E.C.; Wilson, I.A.; Donis, R.O. New world bats harbor diverse influenza A viruses. *PLoS Pathogens*, **2013**, *9*(10), e1003657. https://doi.org/10.1128/genomea.00965-17

40. Dadonaite, B.; Vijayakrishnan, S.; Fodor, E.; Bhella, D.; Hutchinson, E. C. Filamentous influenza viruses. *J. Gen. Virol.*, **2016**, *97*(8), 1755. https://doi.org/10.1099/jgv.0.000535
41. Novel Swine-Origin Influenza A (H1N1) Virus Investigation Team. (Emergence of a novel swine-origin influenza A (H1N1) virus in humans. *N. Engl. J. Med.*, **2009**, *360*(25), 2605-2615. https://doi.org/10.1056/nejmoa0903810
42. Jester, B. J.; Uyeki, T. M.; Jernigan, D. B. Fifty years of influenza A (H3N2) following the pandemic of 1968. *Am. J. Public Health*, **2020**, *110*(5), 669-676. https://doi.org/10.2105%2FAJPH.2019.305557
43. Henrickson, K. J. Parainfluenza viruses. *Clin. Microbiol. Rev.*, **2003**, *16*(2), 242-264. https://doi.org/10.1128/cmr.16.2.242-264.2003
44. Teplyakova, T. V.; Psurtseva, N. V.; Kosogova, T. A.; Mazurkova, N. A.; Khanin, V. A.; Vlasenko, V. A. Antiviral activity of polyporoid mushrooms (higher Basidiomycetes) from Altai Mountains (Russia). *Int. J. Med. Mushrooms*, **2012**, *14*(1), 37-45. https://doi.org/10.1615/intjmedmushr.v14.i1.40
45. Lee, S.; Kim, J. I.; Heo, J.; Lee, I.; Park, S.; Hwang, M. W.; Park, M. S. The anti-influenza virus effect of *Phellinus igniarius* extract. *J. Microbiol.*, **2013**, *51*, 676-681. https://doi.org/10.1007/s12275-013-3384-2
46. Gao, L.; Sun, Y.; Si, J.; Liu, J.; Sun, G.; Sun, X.; Cao, L. *Cryptoporus volvatus* extract inhibits influenza virus replication in vitro and in vivo. *PLoS One*, **2014**, *9*(12), e113604. https://doi.org/10.1371%2Fjournal.pone.0113604
47. Kuroki, T.; Lee, S.; Hirohama, M.; Taku, T.; Kumakura, M.; Haruyama, T.; Kawaguchi, A. Inhibition of influenza virus infection by *Lentinus edodes* mycelia extract through its direct action and immunopotentiating activity. *Front. Microbiol.*, **2018**, *9*, 1164. https://doi.org/10.3389/fmicb.2018.01164
48. Vlasenko, V.A., Ilyicheva, T. N., Teplyakova, T. V., Svyatchenko, S. V., Asbaganov, S. V., Zmitrovich, I. V., Vlasenko, A. V. Antiviral activity of total polysaccharide fraction of water and ethanol extracts of *Pleurotus pulmonarius* against the influenza A virus. *Curr. Res. Environ. Appl. Mycol.*, **2020**, *10*(1), 224-235. https://doi.org/10.5943/cream/10/1/22
49. Becht, H. Infectious bursal disease virus. *Curr. Top. Microbiol. Immunol.*, **1980**, 107-121. https://doi.org/10.1007/978-3-642-67717-5_5
50. Johnston, J. B., & McFadden, G. (2003). Poxvirus immunomodulatory strategies: current perspectives. *J. Virol.*, **2003**, *77*(11), 6093-6100. https://doi.org/10.1128%2FJVI.77.11.6093-6100.2003
51. Kaynarcalidan, O.; Moreno Mascaraque, S.; Drexler, I. Vaccinia virus: from crude smallpox vaccines to elaborate viral vector vaccine design. *Biomedicines*, **2021**, *9*(12), 1780. https://doi.org/10.3390/biomedicines9121780
52. Thompson, K. M.; Kalkowska, D. A. Review of poliovirus modeling performed from 2000 to 2019 to support global polio eradication. *Expert Rev. Vaccines*, **2020**, *19*(7), 661-686. https://doi.org/10.1080%2F14760584.2020.1791093
53. Kidukuli, A. W.; Mbwambo, Z. H.; Malebo, H. M.; Mgina, C. A.; Mihale, M. J. In vivo antiviral activity, protease inhibition and brine shrimp lethality of selected Tanzanian wild edible mushrooms. *J. Appl. Biosci.*, **2010**, *31*(1), 1887-1894.
54. Kandefer-Szerszeń, M.; Kawecki, Z.; Sałata, B.; Witek, M. Mushrooms as a source of substances with antiviral activity. *Acta Mycol.*, **1980**, *16*(2), 215-220. https://doi.org/10.5586/am.1980.014
55. Faccin, L. C.; Benati, F.; Rincão, V. P.; Mantovani, M. S.; Soares, S. A.; Gonzaga, M. L.; Carvalho Linhares, R. E. Antiviral activity of aqueous and ethanol extracts and of an isolated polysaccharide from *Agaricus brasiliensis* against poliovirus type 1. *Lett. Appl. Microbiol.*, **2007**, *45*(1), 24-28. https://doi.org/10.1111/j.1472-765x.2007.02153.x
56. Munis, A. M.; Bentley, E. M.; Takeuchi, Y. A tool with many applications: vesicular stomatitis virus in research and medicine. *Expert. Opin. Biol. Ther.*, **2020**, *20*(10), 1187-1201. https://doi.org/10.1080/14712598.2020.1787981
57. Gallardo, J.; Pérez-Illana, M.; Martín-González, N.; San Martín, C. Adenovirus structure: what is new?. *Int. J. Mol. Sci.*, **2021**, *22*(10), 5240. https://doi.org/10.3390%2Fijms22105240
58. Battles, M. B.; McLellan, J. S. Respiratory syncytial virus entry and how to block it. *Nat. Rev. Microbiol.*, **2019**, *17*(4), 233-245. https://doi.org/10.1038/s41579-019-0149-x
59. Palomar, Q.; Xu, X.; Gondran, C.; Holzinger, M.; Cosnier, S.; Zhang, Z. Voltammetric sensing of recombinant viral dengue virus 2 NS1 based on Au nanoparticle–decorated multiwalled carbon nanotube composites. *Microchimica Acta*, **2020**, *187*, 1-10. https://doi.org/10.1007/s00604-020-04339-y
60. Takehara, M.; Kuida, K.; Mori, K. Antiviral activity of virus-like particles from *Lentinus edodes* (Shiitake). *Arch. Virol.*, **1979**, *59*, 269-274. https://doi.org/10.1007/bf01317423
61. Zhu, Y. C.; Wang, G.; Yang, X. L.; Luo, D. Q.; Zhu, Q. C.; Peng, T.; Liu, J. K. Agrocybone, a novel bis-sesquiterpene with a spirodienone structure from basidiomycete *Agrocybe salicacola*. *Tetrahedron Lett.*, **2010**, *51*(26), 3443-3445. https://doi.org/10.1016/j.tetlet.2010.04.128
62. Ellan, K.; Thayan, R.; Raman, J.; Hidari, K. I.; Ismail, N.; Sabaratnam, V. Anti-viral activity of culinary and medicinal mushroom extracts against dengue virus serotype 2: an in-vitro study. *BMC Complement Altern. Med.*, **2019**, *19*, 1-12. https://doi.org/10.1186/s12906-019-2629-y

63. Lim, W. Z.; Cheng, P. G.; Abdulrahman, A. Y.; Teoh, T. C. The identification of active compounds in *Ganoderma lucidum* var. *antler* extract inhibiting dengue virus serine protease and its computational studies. *J. Biomol. Struct. Dyn.*, **2020**, *38*(14), 4273-4288. https://doi.org/10.1080/07391102.2019.1678523

64. Bharadwaj, S.; Lee, K. E.; Dwivedi, V. D.; Yadava, U.; Panwar, A.; Lucas, S. J.; Kang, S. G. Discovery of *Ganoderma lucidum* triterpenoids as potential inhibitors against Dengue virus NS2B-NS3 protease. *Sci. Rep.*, **2019**, *9*(1), 19059. https://doi.org/10.1038/s41598-019-55723-5

65. Douek, D. C.; Roederer, M.; Koup, R. A. Emerging concepts in the immunopathogenesis of AIDS. *Annu. Rev. Med.*, **2009**, *60*, 471. https://doi.org/10.1146%2Fannurev.med.60.041807.123549

66. Powell, M. K., Benková, K., Selinger, P., Dogoši, M., Kinkorová Luňáčková, I., Koutníková, H., Laštíková, J.; Roubíčková, A.; Špůrková, Z.; Laclová, L.; Eis, V.; Šach, J.; Heneberg, P. Opportunistic infections in HIV-infected patients differ strongly in frequencies and spectra between patients with low CD4+ cell counts examined postmortem and compensated patients examined antemortem irrespective of the HAART era. *PLoS One*, **2016**, *11*(9), e0162704. https://doi.org/10.1371/journal.pone.0162704

67. Sharp, P. M., & Hahn, B. H.; The evolution of HIV-1 and the origin of AIDS. *Philos. Trans. R. Soc. Lond., B, Biol. Sci.*, **2010**, *365*(1552), 2487-2494. https://doi.org/10.1098%2Frstb.2010.0031

68. Board, N. L.; Moskovljevic, M.; Wu, F.; Siliciano, R. F.; Siliciano, J. D. Engaging innate immunity in HIV-1 cure strategies. *Nat. Rev. Immunol.*, **2022**, *22*(8), 499-512. https://doi.org/10.1038/s41577-021-00649-1

69. Sumba, J. D. GACOCA Formulation of East African wild mushrooms show promise in combating Kaposi's sarcoma and HIV/AIDS. *Int. J. Med. Mushrooms*, **2005**, *7*(3), 473-474. https://doi.org/10.1615/IntJMedMushrooms.v7.i3.1040

70. Wang, J.; Wang, H. X.; Ng, T. B. A peptide with HIV-1 reverse transcriptase inhibitory activity from the medicinal mushroom *Russula paludosa*. *Peptides*, **2007**, *28*(3), 560-565. https://doi.org/10.1016/j.peptides.2006.10.004

71. El Dine, R. S.; El Halawany, A. M.; Ma, C. M.; Hattori, M. Anti-HIV-1 protease activity of lanostane triterpenes from the vietnamese mushroom *Ganoderma colossum*. *J. Nat. Prod.*, **2008**, *71*(6), 1022-1026. https://doi.org/10.1021/np8001139

72. Guo, H.; Sun, B.; Gao, H.; Chen, X.; Liu, S.; Yao, X.; Che, Y. Diketopiperazines from the Cordyceps-colonizing fungus *Epicoccum nigrum*. *J. Nat. Prod.*, **2009**, *72*(12), 2115-2119. https://doi.org/10.1021/np900654a

73. Sato, N.; Zhang, Q.; Ma, C. M.; Hattori, M. Anti-human immunodeficiency virus-1 protease activity of new lanostane-type triterpenoids from *Ganoderma sinense*. *Chem. Pharm. Bull.*, **2009**, *57*(10), 1076-1080. https://doi.org/10.1248/cpb.57.1076

74. Jiang, Y.; Wong, J. H.; Fu, M.; Ng, T. B.; Liu, Z. K.; Wang, C. R.; Liu, F. Isolation of adenosine, iso-sinensetin and dimethylguanosine with antioxidant and HIV-1 protease inhibiting activities from fruiting bodies of *Cordyceps militaris*. *Phytomedicine*, **2011**,*18*(2-3), 189-193. https://doi.org/10.1016/j.phymed.2010.04.010

75. Adotey, G.; Quarcoo, A.; Holliday, J.; Fofie, S.; Saaka, B. Effect of immunomodulating and antiviral agent of medicinal mushrooms (immune assist 24/7 TM) on CD4+ T-lymphocyte counts of HIV-infected patients. *Int. J. Med. Mushrooms*, **2011**, *13*(2), 109-113. https://doi.org/10.1615/intjmedmushr.v13.i2.20

76. Zhang, W.; Tao, J.; Yang, X.; Yang, Z.; Zhang, L.; Liu, H.; Wu, J. Antiviral effects of two *Ganoderma lucidum* triterpenoids against enterovirus 71 infection. *Biochem. Biophys. Res. Commun.*, **2014**, *449*(3), 307-312. https://doi.org/10.1016/j.bbrc.2014.05.019

77. Flórez-Sampedro, L.; Zapata, W.; Orozco, L. P.; Mejía, A. I.; Arboleda, C.; Rugeles, M. T. In vitro anti-HIV-1 activity of the enzymatic extract enriched with laccase produced by the fungi *Ganoderma* sp. and *Lentinus* sp. *Vitae*, **2016**, *23*(2), 109-118. https://doi.org/10.17533/udea.vitae.v23n2a03

78. Lingala, S.; Ghany, M. G. Natural history of hepatitis C. *Gastroenterol. Clin.*, **2015**, *4*(4), 717-734. https://doi.org/10.1016/j.gtc.2015.07.003

79. Thomas, D. L. Global elimination of chronic hepatitis. *N. Engl. J. Med.*, **2019**, *380*(21), 2041-2050. https://doi.org/10.1056/nejmra1810477

80. Basra, S.; Anand, B. S. Definition, epidemiology and magnitude of alcoholic hepatitis. *World J. Hepatol.*, **2011**, *3*(5), 108. https://doi.org/10.4254%2Fwjh.v3.i5.108

81. Terziroli Beretta-Piccoli, B.; Mieli-Vergani, G.; Vergani, D. Autoimmmune hepatitis. *Cell. Mol. Immunol.*, **2022**, *19*(2), 158-176. https://doi.org/10.1038/s41423-021-00768-8

82. Suleiman, W. B.; Shehata, R. M.; Younis, A. M. In vitro assessment of multipotential therapeutic importance of *Hericium erinaceus* mushroom extracts using different solvents. *Bioresour. Bioprocess.*, **2022**, *9*(1), 1-13. https://doi.org/10.1186/s40643-022-00592-6

83. Hsu, C. H.; Hwang, K. C.; Chiang, Y. H.; Chou, P. The mushroom *Agaricus blazei* Murill extract normalizes liver function in patients with chronic hepatitis B. *J. Altern. Complement. Med.*, **2008**, *14*(3), 299-301. https://doi.org/10.1089/acm.2006.6344

84. Gu, C. Q.; Li, J. W.; Chao, F. H. Inhibition of hepatitis B virus by D-fraction from *Grifola frondosa*: Synergistic effect of combination with interferon-α in HepG2 2.2. *Antivir. Res.*, **2006**, *72*(2), 162-165. https://doi.org/10.1016/j.antiviral.2006.05.011

85. Li, Y. Q.; Zhang, K. C. In vitro inhibitory efects on HBsAg and HBeAg secretion of 3 new components produced by *Ganoderma lucidum* in the medium contained *Radix sophorae flavescentis* extract. *Acta Microbiol. Sin.*, **2005**, *45*(4), 643-646.

86. Li, Y. Q.; Wang, S. F. Anti-hepatitis B activities of ganoderic acid from *Ganoderma lucidum*. *Biotechnol. Lett.*, **2006**, *28*, 837-841. https://doi.org/10.1007/s10529-006-9007-9

87. del Mar Delgado-Povedano, M.; de Medina, V. S.; Bautista, J.; Priego-Capote, F.; de Castro, M. D. L. Tentative identification of the composition of Agaricus bisporus aqueous enzymatic extracts with antiviral activity against HCV: A study by liquid chromatography–tandem mass spectrometry in high resolution mode. *J. Funct. Foods*, **2016**, *24*, 403-419. https://doi.org/10.1016/j.jff.2016.04.020

88. EL-Fakharany, E.; Haroun, B.; Ng, T.; Redwan, E. R. Oyster mushroom laccase inhibits hepatitis C virus entry into peripheral blood cells and hepatoma cells. *Protein Pept. Lett.*, **2010**, *17*(8), 1031-1039. https://doi.org/10.2174/092986610791498948

89. Gallego, P.; Rojas, Á.; Falcón, G.; Carbonero, P.; García-Lozano, M. R.; Gil, A.; Del Campo, J. A. Water-soluble extracts from edible mushrooms (*Agaricus bisporus*) as inhibitors of hepatitis C viral replication. *Food Funct.*, **2019**, *10*(6), 3758-3767. https://doi.org/10.1039/C9FO00733D

90. Sandargo, B.; Michehl, M.; Praditya, D.; Steinmann, E.; Stadler, M.; Surup, F. Antiviral meroterpenoid rhodatin and sesquiterpenoids rhodocoranes A–E from the Wrinkled Peach Mushroom, *Rhodotus palmatus*. *Org. Lett.*, **2019**, *21*(9), 3286-3289. https://doi.org/10.1021/acs.orglett.9b01017

91. Peñaflor-Téllez, Y.; Chávez-Munguía, B.; Lagunes-Guillén, A.; Salazar-Villatoro, L.; Gutiérrez-Escolano, A. L. The feline calicivirus leader of the capsid protein has the functional characteristics of a viroporin. *Viruses*, **2022**, *14*(3), 635. https://doi.org/10.3390%2Fv14030635

92. Lalani, S.; Poh, C. L. Flavonoids as antiviral agents for Enterovirus A71 (EV-A71). *Viruses*, **2020**, *12*(2), 184. https://doi.org/10.3390/v12020184

93. Daba, T. M.; Zhao, Y.; Pan, Z. Advancement of mechanisms of coxsackie virus B3-induced myocarditis pathogenesis and the potential therapeutic targets. *Curr. Drug Targets*, **2019**, *20*(14), 1461-1473. https://doi.org/10.2174/1389450120666190618124722

94. Tian, J.; Hu, X.; Liu, D.; Wu, H.; Qu, L. Identification of *Inonotus obliquus* polysaccharide with broad-spectrum antiviral activity against multi-feline viruses. *Int. J. Biol. Macromol.*, **2017**, *95*, 160-167. https://doi.org/10.1016/j.ijbiomac.2016.11.054

95. Seetaha, S.; Ratanabunyong, S.; Tabtimmai, L.; Choowongkomon, K.; Rattanasrisomporn, J.; Choengpanya, K. Anti-feline immunodeficiency virus reverse transcriptase properties of some medicinal and edible mushrooms. *Vet. World*, **2020**, *13*(9), 1798. https://doi.org/10.14202%2Fvetworld.2020.1798-1806

96. Zhao, C.; Gao, L.; Wang, C.; Liu, B.; Jin, Y.; Xing, Z. Structural characterization and antiviral activity of a novel heteropolysaccharide isolated from *Grifola frondosa* against enterovirus 71. *Carbohydr. Polym.*, **2016**, *144*, 382-389. https://doi.org/10.1016/j.carbpol.2015.12.005

97. Ang, W. X.; Sarasvathy, S.; Kuppusamy, U. R.; Sabaratnam, V.; Tan, S. H.; Wong, K. T.; Ong, K. C. In vitro antiviral activity of medicinal mushroom *Ganoderma neo-japonicum* Imazeki against enteroviruses that caused hand, foot and mouth disease. *Trop. Biomed.*, **2021**, *38*(3), 239-247. https://doi.org/10.47665/tb.38.3.063

98. Rehman, M. F. U.; Akhter, S.; Batool, A. I.; Selamoglu, Z.; Sevindik, M.; Eman, R.; Aslam, M. Effectiveness of Natural Antioxidants against SARS-CoV-2? Insights from the In-Silico World. *Antibiotics*, **2021**, *10*(8), 1011. https://doi.org/10.3390%2Fantibiotics10081011

99. Hu, B.; Guo, H.; Zhou, P.; Shi, Z. L. Characteristics of SARS-CoV-2 and COVID-19. *Nat. Rev. Microbiol.*, **2021**, *19*(3), 141-154. https://doi.org/10.1038/s41579-020-00459-7

100. Elhusseiny, S. M.; El-Mahdy, T. S.; Elleboudy, N. S.; Yahia, I. S.; Farag, M. M.; Ismail, N. S.; Aboshanab, K. M. In vitro Anti SARS-CoV-2 Activity and Docking Analysis of *Pleurotus ostreatus, Lentinula edodes* and *Agaricus bisporus* Edible Mushrooms. *Infect. Drug Resist.*, **2022**, *15*, 3459-3475. https://doi.org/10.2147/idr.s362823

101. Teplyakova, T. V.; Pyankov, O. V.; Safatov, A. S.; Ovchinnikova, A. S.; Kosogova, T. A.; Skarnovich, M. O.; Poteshkina, A. L. Water Extract of the Chaga Medicinal Mushroom, *Inonotus obliquus* (Agaricomycetes), Inhibits SARS-CoV-2 Replication in Vero E6 and Vero Cell Culture Experiments. *Int. J. Med. Mushrooms*, **2022**, *24*(2), 23-30. https://doi.org/10.1615/IntJMedMushrooms.2021042012

102. Sen, D.; Debnath, B.; Debnath, P.; Debnath, S., Zaki, M. E.; Masand, V. H. Identification of potential edible mushroom as SARS-CoV-2 main protease inhibitor using rational drug designing approach. *Sci. Rep.*, **2022**, *12*(1), 1503. https://doi.org/10.1038/s41598-022-05349-x

103. Basal, W. T.; Elfiky, A.; Eid, J. Chaga medicinal mushroom *Inonotus obliquus* (agaricomycetes) terpenoids may interfere with SARS-CoV-2 spike protein recognition of the host cell: a molecular docking study. *Int. J. Med. Mushrooms*, **2021**, *23*(3), 1-14. https://doi.org/10.1615/intjmedmushrooms.2021037942

104. Rangsinth, P.; Sillapachaiyaporn, C.; Nilkhet, S.; Tencomnao, T.; Ung, A. T.; Chuchawankul, S. Mushroom-derived bioactive compounds potentially serve as the inhibitors of SARS-CoV-2 main protease: An in silico approach. *J. Tradit. Complement. Med.*, **2021**, *11*(2), 158-172. https://doi.org/10.1016/j.jtcme.2020.12.002

105. AL-jumaili, M. M. O.; Al-dulaimi, F. K.; Ajeel, M. A. The role of *Ganoderma lucidum* uptake on some hematological and immunological response in patients with coronavirus (COVID-19). *Sys. Rev. Pharm.*, **2020**, *11*, 537-541.

106. Jan, J. T.; Cheng, T. J. R.; Juang, Y. P.; Ma, H. H.; Wu, Y. T.; Yang, W. B.; Wong, C. H. Identification of existing pharmaceuticals and herbal medicines as inhibitors of SARS-CoV-2 infection. *Proc. Natl. Acad.*

Sci., **2021**, *118*(5), e2021579118. https://doi.org/10.1073/pnas.2021579118

107. Rahman, M. A.; Rahman, M. S.; Bashir, N. M. B.; Mia, R.; Hossain, A.; Saha, S. K.; Sarker, N. C. Rationalization of mushroom-based preventive and therapeutic approaches to COVID-19. *Int. J. Med. Mushrooms*, **2021**, *23*(5), 1-11. https://doi.org/10.1615/intjmedmushrooms.2021038285

108. Senthil Kumar, K. J.; Gokila Vani, M.; Hsieh, H. W.; Lin, C. C.; Wang, S. Y. Antcins from Antrodia cinnamomea and Antrodia salmonea inhibit angiotensin-converting enzyme 2 (ACE2) in epithelial cells: Can be potential candidates for the development of SARS-CoV-2 prophylactic agents. *Plants*, **2021**, *10*(8), 1736. https://doi.org/10.3390/plants10081736

109. Hu, Y.; Chen, W.; Shen, Y.; Zhu, B.; Wang, G. X. Synthesis and antiviral activity of coumarin derivatives against infectious hematopoietic necrosis virus. *Bioorg. Med. Chem.*, **2019**, *29*(14), 1749-1755. https://doi.org/10.1016/j.bmcl.2019.05.019

110. Burman, B.; Pesci, G.; Zamarin, D. Newcastle disease virus at the forefront of cancer immunotherapy. *Cancers*, **2020**, *12*(12), 3552. https://doi.org/10.3390/cancers12123552

111. Lee, K. Z.; Basnayake Pussepitiyalage, V.; Lee, Y. H.; Loesch-Fries, L. S.; Harris, M. T.; Hemmati, S.; Solomon, K. V. Engineering tobacco mosaic virus and its virus-like-particles for synthesis of biotemplated nanomaterials. *Biotechnol. J.*, **2021**, *16*(4), 2000311. https://doi.org/10.1002/biot.202000311

112. Ren, G.; Xu, L.; Lu, T.; Yin, J. Structural characterization and antiviral activity of lentinan from Lentinus edodes mycelia against infectious hematopoietic necrosis virus. *Int. J. Biol. Macromol.*, **2018**, *115*, 1202-1210. https://doi.org/10.1016/j.ijbiomac.2018.04.132

113. Lee, D.; Boo, K. H.; Lee, J. M.; Viet, C. D.; Quyen, N.; Unno, T.; Lee, D. S. Anti-viral activity of Hydnellum concrescens, a medicinal mushroom. *Afri. J. Biotechnol.*, **2012**, *11*(86), 15241-15245.

114. Shamaki, B. U.; Sandabe, U. K.; Ogbe, A. O.; Abdulrahman, F. I.; El-Yuguda, A. D. Methanolic soluble fractions of lingzhi or reishi medicinal mushroom, Ganoderma lucidum (Higher basidiomycetes) Extract inhibit neuraminidase activity in newcastle disease virus (LaSota). *Int. J. Med. Mushrooms,* **2014**, *16*(6), 579-583. https://doi.org/10.1615/intjmedmushrooms.v16.i6.70

115. Wang, M.; Meng, X.; Yang, R.; Qin, T.; Li, Y.; Zhang, L.; Fei, C.; Zhen, W.; Zhang, K.; Wang, X.; Hu, Y.; Xue, F. Cordyceps militaris polysaccharides can improve the immune efficacy of Newcastle disease vaccine in chicken. *Int. J. Biol. Macromol.*, **2013**, *59*, 178-183. https://doi.org/10.1016/j.ijbiomac.2013.04.007

116. Yan, H.; Rong, X.; Chen, P. T.; Zhang, X.; Ma, Z. Q. Two new steroids from sclerotia of the fungus *Omphalia lapidescens*. *J. Asian Nat. Prod. Res.*, **2014**, *16*(3), 265-270. https://doi.org/10.1080/10286020.2013.874346

117. Aoki, M.; Tan, M.; Fukushima, A.; Hieda, T.; Kubo, S.; Takabayashi, M.; Mikami, Y. Antiviral substances with systemic effects produced by Basidiomycetes such as *Fomes fomentarius*. *Biosci. Biotechnol. Biochem.*, **1993**, *57*(2), 278-282. https://doi.org/10.1271/bbb.57.278