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Turkey tail mushroom (*Trametes versicolor)*: an edible macrofungi with immense medicinal properties

Olaide Olawunmi Ajibola[1], Cirilo Nolasco-Hipolito[2], Octavio Carvajal-Zarrabal[3], Shanti F Salleh[4], Gbadebo C Adeyinka[5], Stephen A Adefegha[6], Mirja K Ahmmed[7], Kazi Sumaiya[7] and Raymond Thomas[1,*]

Macrofungi, commonly known as mushrooms, are not only considered functional foods for supplying essential nutritional ingredients but also a good source of physiologically beneficial medicines. *Trametes versicolor*, referred to as turkey tail's Mushroom or *Yun Zhi in China,* is an edible mushroom that has extensive historical usage in conventional and traditional Chinese medicine. This mushroom contains an abundance of physiologically bioactive compounds, most notably β-glucan polysaccharides, which are responsible for antioxidant, neuroprotection, hypolipidemic effects, immune-modulating effects, and anticancer effects. *Trametes versicolor* has also been revealed to have wound healing, antidiabetic, antimicrobial, antifibrotic, neurotrophic, and anti-inflammatory effects among other therapeutic efficacies. This review paper has overviewed the recent advances in the research and study on *Trametes versicolor* and discussed the potential health-promoting properties of this exotic macrofungi, with the recognition of bioactive and polysaccharide constituents responsible for these medicinal agents.

Addresses
[1] Department of Biology, Western University, 2025E, 1151 Richmond Street, London N6A 5B7, Canada
[2] Institute of Biotechnology, Universidad del Papaloapan, Circuito Central 200, Col. Parque Industrial, San Juan Bautista Tuxtepec 68301, Mexico
[3] Biochemistry and Nutrition Chemistry Area, University of Veracruz, Juan Pablo II s/n, Boca del Rio 94294, Mexico
[4] Institute of Sustainable and Renewable Energy (ISuRE), University Malaysia Sarawak, Kota Samarahan 94300, Malaysia
[5] Department of Chemical Engineering, Mangosuthu University of Technology, Durban, South Africa
[6] Department of Biochemistry, Federal University of Technology, P.M.B. 704, Akure 340001, Nigeria
[7] Department of Fishing and Post-harvest Technology, Faculty of Fisheries, Chittagong Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh

Corresponding authors: Ajibola, Olaide Olawuni (oajibol3@uwo.ca, olaideajibola@gmail.com)
* Twitter account: rthoma2@uwo.ca

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Introduction

There has been a remarkable resurgence of interest in recent times in the use of herbal remedies globally to improve personal, population, and community health [1]. Many studies suggest that orthodox products or natural products (or alternative therapies) are promising candidate agents for the development of novel therapeutics [2]. Natural products (NPs) are chemical metabolites or constituents derived from various species found in nature that mostly have biological and pharmacological bioactivities leading to their applications in the design and discovery of biopharmaceutical drugs. Many of these metabolites have shown potential applications in the treatment of life-threatening illnesses [3]. Moreover, NP-based medicines are mostly thought to have less detrimental effects [4] on human health outcome than synthetic drugs. Edible macrofungi as a source of natural ingredients are well recognized for their ability to supply both nutritional and therapeutic benefits. Several species belonging to the genera *Marasmius*, *Pleurotus*, *Lentius*, *Herium*, *Agarius*, *Ganoderma*, *Grifola*, *Morchella*, *Cordceps*, *Cantharellus*, *Trametes*, *Russula*, *Cyclocybe*, *Lactarius*, *Craterellus*, *Boletus*, *Amanita*, and *Hydnum* have been extensively investigated for their hepatoprotective, antimicrobial, hypotensive antidiabetic, neuroprotective, anticancer, antiproliferative, and other therapeutic promoting roles [5–7].

Trametes versicolor, commonly referred to as turkey's tail or *Coriolus versicolor*, is an edible fungus that possesses significant medicinal value. This macrofungus belongs to the phylum: Basdiomycota, class: Agaricomycetes and genera: *Trametes*. This species is commonly found across temperate regions of Europe, Asia, and North America, and has a long historical usage in conventional healing [8]. In addition to its healing properties, it is an abundant source of sterols, polysaccharides, proteins, bioactive peptides, triterpenoids, and sphingolipids [9]. Many reports have extensively documented the potential medicinal properties and therapeutic effects of this species, including but not limited to antifragility, antimelanoma, anti-*Toxoplasma gondii*, neuroprotective, and protection against neuronal illness [8–11]. However, most of the therapeutic properties of turkey tail are widely published but fragmented in the literature. We conducted an extensive search across the library catalog to references available in the Web of Science, PubMed, Scopus, and Scholarly databases. This review provides a summary of the health-beneficial properties of turkey tail mushroom and their side effects. We expanded our review beyond specific results, aiming to offer an up-to-date overview of readily available substances. Our focus encompasses a wide range of products, primarily available over the counter, serving as both brain enhancer supplements and therapeutic agents. There have been few studies on the therapeutic polysaccharides of turkey, so we tried to describe the effects of components on the health system.

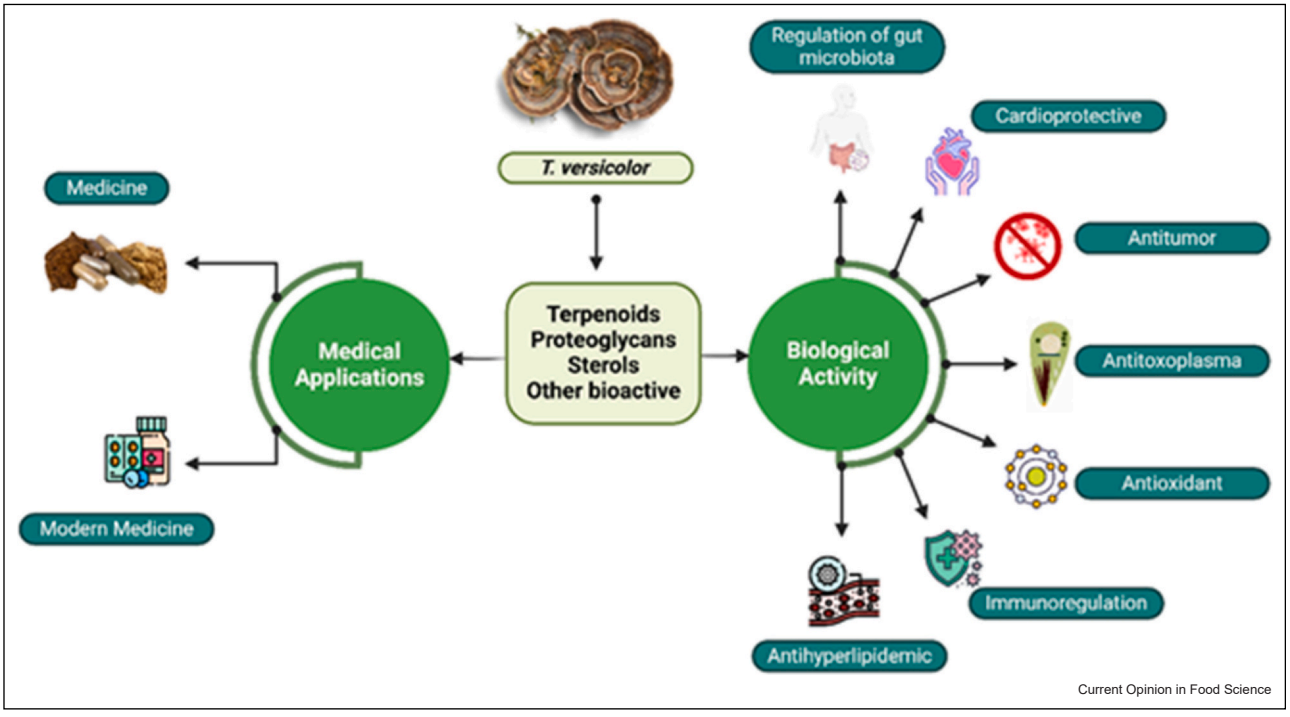
Medicinal efficacies of *T.versicolor*

In oriental countries, *T. versicolor* mushroom has been utilized for centuries as a preventive measure against a wide range of traditional ailments, including phlegm, pulmonary disorders, and gastrointestinal disorders. It is commonly consumed in the form of tea or decoction with the goal of promoting overall wellness, enhancing vitality, and supporting longevity. In Western medicine practices, turkey tail mushroom is also recognized for its potential to address conditions such as hyperlipidemia, cancer, and inflammation (Figure 1). The most recent biological findings pertaining to the effectiveness of *T. versicolor* medicine and related therapies are outlined below.

Bioactive components of *T.versicolor*

Different biologically active polysaccharides are the primary effective constituents of macrofungi, which are responsible for their medicinal effects (Table 1). The majority of the medicinal actions of *T. versicolor* described above are best known by the potential of its polysaccharide fraction. Like other medicinal or edible mushrooms, the majority of the therapeutic polysaccharides derived from *T. versicolor* are beta-glucan [12].

Figure 1



Overview of medical applications and biological activity of *T. versicolor*.

Table 1

The health-promotive bioactive metabolites of *T. versicolor*.

Source	Compounds	Method of determination	Molecular weight (Da)	Beneficial bioactivities	Ref
Fruit body	B-Glucan (polysaccharide), with a (l→4)-β-/(1→3)-β-D- glucopyranosyl group as a branch-linked backbone at the O- 6 site)	HPGPC NMR and UV-Vis, FT -IR, HPLC	High molecular weight	Antioxidant, antitumor, immunoregulation, hepatoprotective, antibacterial, liver protection	[13]
Fruit body	HR (a hetero-polysaccharide with a (l→4)-β-/(1→3)-β-D- glucopyranosyl group as a branch-linked backbone at the O- 6 site) Other polysaccharides: (galacturonic acid, glucuronic acid, D-glucose polymer)	FT-IR, GC/MS, HPLC	2553.19 Da	cardioprotective potential, antimicrobial, antioxidant- Broad spectrum therapeutic beneficial agents	[14] [14]
Fruit body	CVPaF (a homopolysaccharides, with a backbone structure of →4,6)-β-D-Glcp-(1 → 4)-β-D -Glcp-(1 → 3,6)-β-D-Glcp-(1 → 3)-β-D-Glcp-(1→)	HPGPC, GC-MS, IR NMR	50.8 kDa	- Anticancerous, immunomodulatory	[15]
Mycelium	*T. verisoclor* (bioactive molecules)	NA	NA	- Antimalignant melanoma	[8]
Whole specimen	Lipid metabolites: ergosterol, ethyl palmitate, ethyl linoleate, ethyl stearate, palmitic, pentadecanoic acid (mixture); Phospholipids, sphingolipids, fatty acids, ergostadienol, ethyl ester, linolenic, stearic acid, Phytosterols, ergostanes, glyceryl linoleate, fatty acid	NA	NA	-Broad spectrum therapeutic beneficial agents	[9]
Fruit body	Polysaccharide peptide (PSP) and polysaccharide K (PSK) Lipid fractions (triterpenoid sterol ergosta-7,22,dien-3β-ol as well as fungisterol and β-sitosterol	NA	100 kDa	Antioxidant	[5]
Mycelium Culture broth	HR polysaccharide with glucose as the main building monosaccharide and minor amounts of mannose, xylose, galactose, fucose and glucuronic acid	HPLC, FT-IR	2.45 x104 Da	Anti-inflammatory	[16]
Mycelium culture broth	Intracellular (IPTV) and extracellular (EPTV) polysaccharide (α-pyran polysaccharide [mainly composed of mannose, glucose and galactose]	FT-IR, HPGPC, GC-MS, Circular dichroism spectrum analysis	IPTV (127 kDa): EPTV (68.4 kDa)	Antihyperlipidemic	[6]
Fruit body	HM polysaccharide with a backbone of (1 → 3)-linked α-D-Glcp residues and (1 → 3,6)-linked α-D-Glcp residues that branched at O-6.	HPGPC, FT-IR,GC-MS,1D and 2D NMR	1.03 x 106 Da	Antitumor; immunomodulatory	[17]
Fermented mycelium powder	An inhomogenous polysaccharide with a backbone consisted of →1)-β-D-Man-(6,4→1)-α-D-Gal-(3→1)-α-D-Man-(4→1)-α-D-Gal-(6→, with branches of →1)-α-D-Glc-(6→1)-α-D-Man-(4,3→1)-β-D-Xyl-(2→1)-β-D-Glc on the O-6 position of →1)-β-D-Man-(6,4→ of the main chain	Methylation, GC-MS, FT-IR	17,478 Da	Facilitate the prevention of high-fat diet-induced nonalcoholic fatty liver disease	[18]
Fruit body	HM (a homogeneous polysaccharide with a back bone structure of →6)-α-D-Glcp-(1 → 6)-α-D-Galp-(1 → 3)-β-D-Galp-(1 → 6)-β-D-Glcp-(1 → 4)-α-D-Galp-(1 → 4)-α-D-Galp-(1 → 4)-α-D-Glcp-(1→)	FT-IR, Methylation and GC-MS NMR, SEM, and TEM	13884 Da	Anticancer (inhibiting cell migration and inducing cell apoptosis	[19]

Methylation, GC-MS: Gas chromatography-mass spectrometry, NMR: nuclear magnetic resonance, FI-IR: Fourier transform infrared spectroscopy, HPGPC: high performance gel permeation chromatography, HPLC: high performance liquid chromatography, IR: Infrared spectroscopy, UV-Vis: UV–visible spectrophotometer, SEM: Scanning electron microscope, TEM: transmission electron microscopy, NA: not available.

Jing et al. [13] identified the antitumor as well as the immunomodulatory compound of *T. versicolor* as a high molecular weight polysaccharide with a (l→4)-β-/(1→3)-β-D-glucopyranosyl group as a branch-linked backbone at the O-6 site. Similarly, Nikolic et al. [14] isolated a new heteropolysaccharide (HR) from the fruiting bodies of *T. versicolor* composed of glucose (Glu), rhamnose, xylose, and galactose. A new homopolysaccharide, CVPaF, was isolated by Zhang et al. [15] from the fruit bodies of *C. versicolor*, which had a backbone structure consisting of β-D-Glcp units connected as follows: → 4,6)-β-D-Glcp-(1 → 4)-β-D-Glcp-(1 → 3,6)-β-D-Glcp→ 3)- β-D-Glcp-(1→.

Recently, Lowenthal and co-workers confirmed the existence of 16 candidate compounds in the mycelium extract of *T. versicolor*, which were not found in fruiting body extract [8]. The compounds isolated were sterols family: pentylfuran, orcinyl di-angelate, nonadecatriene, monoethyl succinate, methylene- butyrolactone, methylcyclohexanol, inositol, ethyl tetracosanate, ethyl myristate, ethyl heptadecanoate, ethyl docosanoate, dioctyl isophthalate, ethyl myristate, ethyl heptadecanoate, ethyl docosanoate, dioctyl isophthalate, dimethoxybenzyl alcohol, diethyl tartrate, and dehydroergosterol. Furthermore, they also isolated 25 components from ethanol fruiting body extract. These components include vanillacetic acid, trimethyl dodecane, tridecene, tetradecene, vanillacetic acid, stearic acid, squalene, octacosanol, nonanal, nonadecyl trifluoroacetate, nonadecene, methyloctane, methyl benzaldehyde, long chain hydrocarbon, linolenic acid, hexadecane sulfonyl chloride, hexadecane, heptadecene, glyceryl linoleate, fumaric acid ethyl ester, fluroacetate family, ethyl succinate, ethyl glucopyranoside, ergostadienol, docosenamide, and dimethyl hexanediol. Furthermore, vitamins (bioactive compounds), lipids (phospholipids and sphingolipids), phenolic acids, triterpenoids, fatty acids, peptides, lanostane, ergostanes, and phytosterols have been isolated from the methanol extract of *T. verisoclor* and identified as an effective anti-*Toxoplasma gondii* activity by Sharma et al. [9].

Antioxidant effect

Oxidative imbalance is implicated in a broad spectrum of age-related disorders, ranging from neurodegenerative to cardiovascular disease (CVD) [20–22]. Traditional medicines or nutraceutical supplements containing antiradical agents play a crucial role in combating oxidative stress. Rašeta et al. [5] have investigated the *in vitro* antiradical efficacy, and free radical scavenging activities of ethanol and water extract of *T. versicolor*, along with other edible and medicinal macrofungi. Findings from their study revealed that the ethanol extracts exhibited superior scavenging activity against superoxide (SO), hydroxyl (OH), and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals (IC50 = 5.0 μg/mL, IC50 = 0.6 μg/mL, and IC50 = 5.6 μg/mL, respectively) compared to the water extract of *T. versicolor* (IC50 = 25.4 μg/mL, IC50 = 0.6 μg/mL, and IC50 = 11.9 μg/mL, respectively. This enhancement may be attributed to the structure and second hydroxyl group in the ortho or para position, which is known to increase antioxidative activity [5].

Krsmanović et al. [23] made a significant discovery regarding the mycelium filtrate of turkey tail and other edible and medicinal macrofungi. They found that these filtrates contain high levels of phenolic compounds with significant antioxidant activities. Notably, p-hydroxybenzoic acid, identified as one of the most abundant compounds in *Trametes versicolor* filtrate, exhibited significant antioxidant activity. *Trametes versicolor* filtrate, after 14 days of incubation, demonstrated a scavenging activity of 71.29 ± 0.54% in the Superoxide Anion assay, while *F. velutipes* filtrate, after 21 days, exhibited a scavenging activity of 73.5 ± 1.81%. Although specific quantitative data on the mitigation of UV irradiation damage are not provided, the findings suggest a potential role for p-hydroxybenzoic acid in combating oxidative stress induced by UV exposure [23]. Furthermore, their investigation revealed that turkey tail extract, following 4 weeks of irradiation, exhibited substantially higher levels of the bioflavonoid amentoflavone (1934.5 μg/g d.w.), in contrast to non-irradiated ethanol-based extracts (7.79 μg/g d.w.). This increase is likely attributed to greater extracellular production of polyphenolic compounds after 3 weeks [23].

In addition, the extract of *C. versicolor* demonstrated remarkable antioxidant potency against neurodegenerative processes induced by chronic traumatic brain injury in experimental mice [24]. In that research, the preassessment of macrofungi extract significantly attenuated neuroinflammation spread and oxidative stress in the brains of mice [24]. Furthermore, the antioxidant efficacy of the biomass from *T. versicolor* mycelium has also been studied previously [16]. These findings collectively highlight the potential therapeutic applications of macrofungi in combating oxidative stress–related conditions and neuroinflammation.

Cardiovascular complications protecting properties

T. versicolor demonstrates remarkable positive effects in combating cardiovascular complications. Macrofungi have a rich historical record of being utilized as a nutraceutical to combat the dysregulation of fat metabolism linked to CVDs [24]. The activities of extracellular (EPTV) and intracellular polysaccharide (IPTV) of *T. versicolor* were reported by Huang et al. [6] in high-fat diet-induced hyperlipidemic mice [6]. Their findings revealed that EPTV exhibited superior hypolipidemic effects compared to IPTV, likely attributed to its lower molecular mass (68.4 vs 127 kDa) as well as higher fraction of mannose (36.87% vs 25.98%). The EPTV and IPTV

improved liver index, serum lipid profiles, and body weight in high-fat dietary-induced hyperlipidemic mice. The supplementation of *T. versicolor* heteropolysaccharides (TVH) effectively restored elevated levels of low-density lipoprotein, triglycerides, and total cholesterol (TC), especially when administered at medium as well as highest doses. However, neither dose regimen was able to achieve the levels of high-density lipoprotein observed in the serum of healthy untreated rats. This may be attributed to the potential limitation of TC to transfer from peripheral tissues to the liver via reverse cholesterol transport pathways [14]. Inhibitors of diabetic-induced cardiomyopathy (DCM) serve as therapeutics in many vascular illnesses, including cardiac inflammation and fibrosis leading to cardiac dysfunction. Wang et al. [25] reported that aqueous extracts of *T. versicolor* inhibited DCM induced by cardiac fibrosis. In their study, they discovered that *T. versicolor* extract exhibited anti-inflammatory as well as antifibrotic properties in rats with diabetes mellitus, thus, making *T. versicolor* an effective therapeutic agent in DCM management. Nikolic et al. [14] conducted a study to investigate the cardioprotective potential of TVH *in vivo* and *ex vivo* in a rat model of metabolic syndrome (MetS). The treatment exhibited notable effects in reducing blood pressure and improving heart function while also demonstrating hypoglycemic and oxidative stress–reducing properties. These findings suggest a promising role for *T. verisolor* macrofungi in the management of MetS-related diseases. Meng et al. [26] also conducted a study to investigate the therapeutic effect of *C. versicolor* fruiting body (CVFB) on streptozotocin-induced diabetic mice. The findings revealed that administration of CVFB to diabetic mice resulted in significant control or reduction of blood sugar levels. Moreover, CVFB treatment exhibited notable effects in accelerating the rate of glucose metabolism, regulating lipid metabolic disorder, reducing oxidative stress damage, providing protection to the pancreas, and facilitating the repair and regulation of pancreatic function to achieve blood sugar balance [26].

Neuroprotective effects

Neurotrophic factors are important for the organization as well as the maintenance of neuron functionality. D' Amico et al. [24] examined the effect of *T. versicolor* extract on reducing neuroinflammation, which was observed to extend beyond the cortex to other brain regions. They also studied its potential in preventing neurodegenerative processes linked to severe traumatic brain injury [24]. Table 2 provides a comprehensive overview of therapeutic interventions and outcomes observed in various disease models utilizing mushroom extracts. These interventions involve a range of conditions, from peripheral multiorgan dysfunction induced by sepsis to specific diseases such as Parkinson's disease and traumatic brain injury. The table delineates the model systems employed, dosage regimens, trial durations, and the resulting outcomes, offering valuable insights into the therapeutic potential of mushroom extracts across different health conditions. *T. versicolor* has been suggested as a potential treatment or preventive measure for neuroinflammation and cognitive dysfunction in rats [27]. *T. versicolor* administration elevated the survival rates and reduced tissue injury induced by CLP (cecal ligation and perforation) during the acute phase of sepsis. Hossen et al. [28] demonstrated the clinical effects of *T. versicolor* on depression, locomotive activity, immobility time, and sleep quality. The authors proposed that the intake *T. versicolor* could potentially alleviate depression and anxiety in mice. In an *in vitro* investigation, it was found that *T. versicolor* induced high levels of Lipoxin A4 in the hippocampus and cortex of the brain in experimental rats. This suggests that *T. versicolor* supplementation could be administered as a response to counteract intracellular pro-oxidant status in patients with Meniere's disorder [29]. Li et al. [30] conducted a study investigating the therapeutic potential of extracts derived from the fruiting bodies of *T. versicolor* in treating cerebral ischemia-reperfusion injury (CIRI) in rats through oral administration. Their findings revealed a notable improvement in the neurological dysfunction of rats after 6 hours of CIRI.

Anticancer & immune-modulating agents

Over the past decade, studies have consistently reported the anticancer properties of *T. versicolor* polysaccharide against cancer cell lines such as MCF-7 and lung carcinoma [17,31,32]. Immuno-modulation is one of the mechanisms underlying the anticancer properties of *T. versicolor* [18,33]. Yang et al. [34] investigated the immuno-modulation and antitumor actions small peptide (SM) derived from a *C. versicolor* (CV) in various cancer cell lines such as breast adenocarcinoma (MDA-MB-231), lung carcinoma (A549), and glioblastoma T98G cells. The result revealed that SMCV suppressed the production of tumor necrosis factor (TNF)-α induced by (LPS) lipopolysaccharide while improving the levels of IFN-β induced by polyinosinic: polycytidylic in human primary blood macrophages. Additionally, SMCV and its bioactive metabolite (9-KODE methyl ester) were found to exhibit indirect antitumor effects by inhibiting TNF-α-induced matrix metalloproteinases-3 production in T98G cells and direct anticancer effects by reducing the invasive potential of malignant cells such as MDA-MB-231, A549, and T98G. Pawlikowska et al. [35] also reported on the anticancer and immunity-regulating effect of protein-bound polysaccharides of CV in SKMel-188 amelanotic melanoma and MCF-7 breast cancer cells by reactive oxygen species (ROS)-mediated necroptosis. However, since RIPK3 is not universally expressed in several cancer cells [36], mixed lineage kinase domain-like protein, as the final executioner of necroptosis signaling pathways, could be a potential target in these types of cancer cells. Furthermore, SK-MEL-5 human

Table 2

Therapeutic interventions and outcomes in various disease models using mushroom extracts.

Diseases	Model system	Dosage	Trial duration	Outcome	Ref.
Peripheral multiorgan dysfunction and hippocampal neuroinflammation induced by sepsis	Male Wistar rats (250–280 g, 6–8 weeks old)	200 mg/kg in saline	28 days	– Increased survival and reduced acute tissue injury. - - Reduced the release of pro-inflammatory cytokines in the bloodstream, leading to reduced chronic inflammation. – In the hippocampus, restored tight junction expressions, reduce cytokines accumulation and glia activation. – Reduced toll-like receptor 4 (TLR4) and neuronal nitric oxide synthase (nNOS) and the NLR family pyrin domain containing 3 (NLRP3) inflammasome components expression. – Showed antioxidant activities, restoring glutathione (GSH) levels and catalase and superoxide dismutase (SOD) activities and reducing lipid peroxidation, nitrite and ROS levels.	[27]
Rotenone-induced Parkinson's disease (PD)	Male mice weighing approximately 25–30 g	*Hericium erinaceus, Coriolus versicolor* or a combination of the two (200 mg/kg, orally)	28 days	– Act on neuroinflammation through the nuclear factor-kB pathway and on oxidative stress through the Nrf2 pathway. – Prevented dopaminergic neurons from undergoing apoptosis and prevented the alteration of typical PD markers and α-synuclein accumulation.	[15]
Traumatic brain injury	Male CD1 mice (25–30 g)	200 mg/kg in saline	30 days	– Significant tissue alteration in the perilesional area of the cortex – Reduced the degree of brain injury, effects of the combined treatment have a more significant effect than the single substances. – Reduction in cytoplasmic vacuolization and cell loss in the midbrain – prevent both the neuroinflammatory and oxidative processes typical of PD	[24]
Depression	Either sex of Swiss albino mice at the age of 4–5 weeks old (20–25 g)	Methanol extract of *Trametes versicolor* (METV): 400 mg/kg aqueous extract of *Trametes versicolor* (AETV): 200 mg/kg	Open field test: 3 min Hole cross test: 3 min Forced swimming test: 6 min Forced swimming test: 6 min Thiopental sodium induced sleeping test: 20 min Hole board test: 5 min Rotarod test: 30, 60, and 90 min at a speed of 12 rpm.	– A significant decrease in immobility time in forced swimming test and increased prolongation of sleep in thiopental sodium-induced sleeping time test.	[28]

Table 2 (*continued*)

Diseases	Model system	Dosage	Trial duration	Outcome	Ref.
Ischemic cerebrovascular disease	216 healthy male Sprague Dawley rats (280 ± 30 g)	150 mg/kg/d	6, 12, 24, and 48 h	– Decreased the expression of p38MAPK and Caspase-3 by regulating – the p38MAPK signaling pathway. – Alleviated the cerebral ischemia-reperfusion injury (CIRI)-induced inflammatory response. – Ultimately reduced the apoptosis of nerve cells, which had a therapeutic effect on CIRI rats.	[29]
Meniere's disease (MD)	40 patients (22 males and 18 females) with MD.	Orally in tablets of 500 mg (3 tablets every 12 h, morning and evening)	2 consecutive months	– Notable improvement in total mood disturbance, including anger, confusion, depression, and tension (measured by POMS) in treatment group but not in control group. – Significant improvement in tinnitus severity (measured by THI) in treatment group compared to control group, and significant improvements in frequency range, average loss in dB, and intellection threshold related to auditory function from baseline in the treatment group, but not control group.	[30]

melanoma cell lines demonstrated antimelanoma activity, such as reduced migration, proliferation, and invasion following treatment with mycelium extracts from turkey tail. The authors proposed that the anticancer effect could be attributed to the inhibition of the migration that increased the major histocompatibility complex-II presentation, induction of the cleavage of pro-apoptotic poly (ADP-ribose) polymerase, and upregulating the expression of autophagy marker LC3-II [8].

Jędrzejewski et al. [37] reported that the crude hot water extract from this macrofungi significantly enhanced the production of interleukin (IL) 6, IL-8, and metalloproteinase (MMP) in human umbilical vein endothelial (HUVEC) and MCF-7 breast cancer cells and MCF-7 breast cancer cells when stimulated with lipopolysaccharide (LPS). This enhancement was achieved by reducing the expression of Toll-like receptor (TLR) 4 in both LPS-stimulated HUVEC cells and MCF-7 human breast cancer cells, along with preventing the phosphorylation of IκB in these cells.

He et al. [38] utilized a protein extract (musarin [3 ug/mL: 245 nM]) derived from *C. versicolor* to suppress the proliferation of colorectal cancer cells after 4 days of treatment. The relative proliferation suppressive rates induced by the extract varied among the colorectal epithelial cell lines. The HCT15 cells exhibited the highest sensitivity (87% of growth inhibition), while HT29 cells (73%) and T84 cells (61%) showed a moderate sensitivity response to muscarine-induced inhibition. This extract inhibits the colonic carcinoma cells' growth and epithelial-to-mesenchymal transition via altering the selectivity of epidermal growth factor receptor phosphorylation and differential expression of other related signaling molecules.

Moreover, the extract of *T. versicolor* induced RIPK1/RIPK3/MLKL-dependent necroptosis in the depigmented melanoma cells [39]. The extract also demonstrated that the suppression of tyrosinase activity in pigmented melanoma cells influences melanoma-mononuclear cell crosstalk leading to remarkable amplification of proinflammatory cytokines expression in co-cultured human peripheral blood mononuclear cells. However, despite its remarkable effect on suppressing melanogenesis in melanoma cell responses, the extract of *T. versicolor* exhibited contrasting effects.

Other therapeutic activities

Recently, the efficacy of *T. verisoclor* (fermented mycelium) therapy in treating nonalcoholic fatty liver disease has been reported by Tang et al. [18]. Furthermore, Lo et al. [40] investigated the effects of extracellular polysaccharopeptides (ePSP) derived from *T. versicolor* on type 2 diabetes mellitus (T2DM)-induced damage in male Wistar rats, revealing a robust protective effect

against T2DM-associated damage. Sharma et al. [9] reported that methanol extract of *T. versicolor* showed inhibitory activity against *T. gondii in vitro*. The heteropolysaccharide fractions of *T. versicolor* showed potent cardioprotective action *in vivo* [14]. While Ahmadpour Torki et al. [41] reported antimicrobial properties of *T. versicolor* aqueous extract as against *Staphylococcus aureus*, *Escherichia coli*, and *Fusarium thapsinum*, Huang et al. [6] studied the hyperlipidemic property of CV. This suggests that the sample could potentially serve as an antihyperlipidemic agent as well. They produced intracellular (IP) and extracellular (EP) polysaccharide extracts from the submerged culture of CV. The research found that mice fed with IP and EP extracts of CV exhibited improvements in serum lipids, body weight, as well as liver index in high-fat diet-induced hyperlipidemic mice.

Conclusion

T. versicolor is recognized as both an edible medicinal fungus and a delicacy for food supplements, earning significant attention for its potential pharmaceutical benefits. This mushroom is predominantly consumed in East Asian countries, and most of the research studies have been conducted in Korea, China, and Japan. However, there is a need for broader global research, cultivation, and consumption. Regular consumption of this mushroom may keep people away from several life-threatening disorders. Despite its potential, scientific studies on *T. versicolor* at a global scale are currently limited. Thus, further research, particularly clinical trials, is recommended to fully understand and establish the therapeutic potentials of *T. versicolor* in both healthy individuals and those with specific medical conditions.

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CRediT authorship contribution statement

Olaide O Ajibola: Conception of idea, Drafting-original draft preparation, Project administration, Design of review outline, Writing – original draft, Writing – review & editing, Visualization, Conceptualization, Supervision. **Cirilo Nolasco-Hipolito:** Design of review outline. **Carvajal Zarrabal-Octavio:** Design of review outline. **Shanti F Salleh:** Writing – original draft. **Gbadebo C Adeyinka:** Conceptualization, Writing – review & editing. **Stephen A Adefegha:** Writing – review & editing, Visualization. **Mirja K Ahmmed:** Conceptualization, Writing – review & editing. **Kazi Sumaiya:** Writing – original draft. **Raymond Thomas:** Conception of idea, Drafting-original draft preparation, Project administration, Supervision.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Qadir SU, Raja V, Bhat RA, Hakeem KR, Dervash MA: **Chapter 5 – Herbal medicine: Old practice and Modern Perspectives, in Phytomedicine**. Academic Press; 2021:149-180, https://doi.org/10.1016/B978-0-12-824109-7.00001-7

2. Ajibola OO: **Master's thesis. Faculty of Resource Science and Technology, University Malaysia Sarawak; Kota Samarahan, Malaysia**. *Potential Use of Lactococcus lactis Subsp. Lactis IO- 1 in Fermented Coconut Juice*; 2020. Available online: ⟨https://ir.unimas.my/id/eprint/31400⟩ [Accessed on 20 April 2022].

3. Choudhary S, Zehra A, Mukarram M, Wani KI, Naeem M, Hakeem KR, Aftab T: **Potential uses of bioactive compounds ofmedicinal plants and their mode of action in several human diseases**. In *Medicinal and Aromatic Plants: Healthcare and Industrial Applications*. Edited by Aftab T, Hakeem KR. 2021:143-158, https://doi.org/10.1007/978-3-030-58975-2_5

4. •• Zhang L, Song J, Kong L, Yuan T, Li W, Zhang W, Hou B, Lu Y, Du G: **The strategies and techniques of drug discovery from natural products**. *Pharmacol Ther* 2020, **216**:107686, https://doi.org/10.1016/j.pharmthera.2020.107686.
The article discusses the crucial role of natural products in drug discovery, highlighting various strategies and technologies involved. Its impact stems from its comprehensive overview of how traditional medicine, ancient wisdom, and modern scientific methods converge in the discovery and development of drugs from natural sources.

5. Rašeta M, Popović M, Knežević P, Šibul F, Kaišarević S, Karaman M: **Bioactive phenolic compounds of two medicinal mushroom species *Trametes versicolor* and *Stereum subtomentosum* as antioxidant and antiproliferative agents**. *Chem Biodivers* 2020, **17**:e2000683, https://doi.org/10.1002/cbdv.202000683

6. Huang Z, Zhang M, Wang Y, Zhang S, Jiang X: **Extracellular and intracellular polysaccharide extracts of *Trametes versicolor* improve lipid profiles via serum regulation of lipid-regulating enzymes in hyperlipidemic mice**. *Curr Microbiol* 2020, **77**:3526-3537, https://doi.org/10.1007/s00284-020-02156-3

7. Cör Andrejč D, Knez Ž, Knez Marevci M: **Antioxidant, antibacterial, antitumor, antifungal, antiviral, anti-inflammatory, and nevro-protective activity of *Ganoderma lucidum*: an overview**. *Front Pharmacol* 2022, **13**:934982, https://doi.org/10.3389/fphar.2022.934982

8. • Lowenthal R, Taylor M, Gidden JA, Heflin B, Lay JO Jr, Avaritt N, Tackett AJ, Urbaniak A: **The mycelium of the *Trametes versicolor***

synn. *Coriolus versicolor* (turkey tail mushroom) exhibit anti-melanoma activity in vitro. *Biomed Pharmacother* 2023, **161**:114424, https://doi.org/10.1016/j.biopha.2023.114424.
The article investigates the potential therapeutic effects of *Trametes versicolor* (turkey tail mushroom) extracts on melanoma, highlighting their cytotoxic activity against human melanoma cell lines, induction of apoptotic cell death, upregulation of immune-related markers, and inhibition of cell migration.

9. •• Sharma HN, Catrett J, Nwokeocha OD, Boersma M, Miller ME, Napier A, Robertson BK, Abugri DA: **Anti-*Toxoplasma gondii* activity of *Trametes versicolor* (turkey tail) mushroom extract**. *Sci Rep* 2023, **13**:8667, https://doi.org/10.1038/s41598-023-35676-6.
The study explores the anti-*Toxoplasma gondii* activity of *Trametes versicolor* (turkey tail) mushroom extract. The research demonstrates that the extract inhibits the growth of *T. gondii* tachyzoites *in vitro* in a dose-dependent manner without causing cytotoxic effects on host cells. These findings suggest that turkey tail mushroom extract could be a promising source for the development of new anti-*Toxoplasma gondii* drugs.

10. Davis R: **Turkey tail mushrooms and the antifragility of the immune system**. *JAHC* 2020, **12**:31-37. Available in: https://reneeadavis.com/wp-content/uploads/2020/09/Turkey-Tail-and-Antifragility-DAVIS.pdf..

11. Kıvrak I, Kivrak S, Karababa E: **Assessment of bioactive compounds and antioxidant activity of turkey tail medicinal mushroom *Trametes versicolor* (Agaricomycetes)**. *Int Med Mushrooms* 2020, **22**:559-571, https://doi.org/10.1615/IntJMedMushrooms.2020035027

12. Venturella G, Ferraro V, Cirlincione F, Gargano ML: **Medicinal mushrooms: bioactive compounds, use, and clinical trials**. *Int J Mol Sci* 2021, **22**:634, https://doi.org/10.3390/ijms22020634

13. Jing Y, Zhang S, Li M, Ma Y, Zheng Y, Zhang D, Wu L: **Research progress on the extraction, structure, and bioactivities of polysaccharides from *Coriolus versicolor***. *Foods* 2022, **11**:2126, https://doi.org/10.3390/foods11142126

14. •• Nikolic M, Lazarevic N, Novakovic J, Jeremic N, Jakovljevic V, Zivkovic V, Bradic J, Pecarski D, Tel-Çayan G, Glamocija J, Sokovic M: **Characterization, in vitro biological activity and in vivo cardioprotective properties of *Trametes versicolor* (L.:Fr.) Quél. heteropolysaccharides in a rat model of metabolic syndrome**. *Pharmaceuticals* 2023, **16**:787, https://doi.org/10.3390/ph16060787.
The study investigated the cardioprotective potential of TVH in a rat model of MetS. Results showed that TVH treatment significantly reduced oxidative stress, improved glucose homeostasis, and enhanced cardiac function compared to untreated MetS rats, suggesting TVH as a promising agent for cardioprotection in MetS.

15. Zhang X, Cai Z, Mao H, Hu P, Li X: **Isolation and structure elucidation of polysaccharides from fruiting bodies of mushroom *Coriolus versicolor* and evaluation of their immunomodulatory effects**. *Int J Biol Macromol* 2021, **166**:1387-1395, https://doi.org/10.1016/j.ijbiomac.2020.11.018

16. Angelova G, Brazkova M, Mihaylova D, Slavov A, Petkova N, Blazheva D, Deseva I, Gotova I, Dimitrov Z, Krastanov A: **Bioactivity of biomass and crude exopolysaccharides obtained by controlled submerged cultivation of medicinal mushroom *Trametes versicolor***. *J Fungi* 2022, **8**:738https://doi.org/10.Ahmadpour 3390/jof8070738.

17. Bi S, Jing Y, Cui X, Gong Y, Zhang J, Feng X, Shi Z, Zheng Q, Li D: **A novel polysaccharide isolated from *Coriolus versicolor* polarizes M2 macrophages into an M1 phenotype and reversesits immunosuppressive effect on tumor microenvironment**. *Int J Biol Macromol* 2024, **259**:129352, https://doi.org/10.1016/j.ijbiomac.2024.129352

18. Tang H, Zha Z, Tan Y, Li Y, Jiao Y, Yang B, Xiong Q, Yin H, Wang H: **Extraction and characterization of polysaccharide from fermented mycelia of *Coriolus versicolor* and its efficacy for treating nonalcoholic fatty liver disease**. *Int J Biol Macromol* 2023, **248**:125951, https://doi.org/10.1016/j.ijbiomac.2023.125951

19. Wang J, Nie J, Wang D, Liu H, Liu M, Yang Y, Zhong S: **The structural characterization and anticancer activity of a polysaccharide from *Coriolus versicolor***. *New J Chem* 2022, **46**:9830-9840, https://doi.org/10.1039/d2nj00897a

20. Ajibola OO, Lihan S, Hussaini A, Hipolito CN, Octavio CZ, Sarbini SR, Mohamad SAS: **Cell viability physicochemical and sensory characteristics of probiotic coconut juice during cold storage**. *J Sustain Sci Manag* 2021, **16**:1-13, https://doi.org/10.46754/jssm.2021.12.001

21. Salleh SF, Ajibola OO, Nolasco-Hipolito C, Husaini A, Zarrabal-Octavio C, Lihan S, Adeyinka GC, Rosli FR, Ahmed IA, Zayed MZ, Saat R: **Fatty acid profile and antioxidant capacity of Dabai (*Canarium odontophyllum* L.): effect of origin and fruit component**. *Molecules* 2022, **27**:3840, https://doi.org/10.3390/molecules27123840

22. Ajibola OO, Lihan S, Husaini A, Saat R, Sinang FM, Ahmed IA, Abideen WA: **Use of the *Lactococcus lactis* IO-1 for developing a novel functional beverage from coconut water**. *Ann Unive Dunarea Jos Galati* 2020, **44**:118-131, https://doi.org/10.35219/foodtechnology.2020.1.07

23. Krsmanović N, Rašeta M, Mišković J, Bekvalac K, Bogavac M, Karaman M, Isikhuemhen OS: **Effects of UV stress in promoting antioxidant activities in fungal species *Trametes versicolor* (L.) Lloyd and *Flammulina velutipes* (Curtis) Singer**. *Antioxidants* 2023, **12**:302, https://doi.org/10.3390/antiox12020302

24. D'Amico R, Trovato Salinaro A, Fusco R, Cordaro M, Impellizzeri D, Scuto M, Ontario ML, Lo Dico G, Cuzzocrea S, Di Paola R, Siracusa R: ***Hericium erinaceus* and *Coriolus versicolor* modulate molecular and biochemical changes after traumatic brain injury**. *Antioxidants* 2021, **10**:898, https://doi.org/10.3390/antiox10060898

25. Wang Y, Li H, Li Y, Zhao Y, Xiong F, Liu Y, Xue H, Yang Z, Ni S, Sahil A, Che H, Wang L: ***Coriolus versicolor* alleviates diabetic cardiomyopathy by inhibiting cardiac fibrosis and NLRP3 inflammasome activation**. *Phytother Res* 2019, **33**:2737-2748, https://doi.org/10.1002/ptr.6448

26. Meng F, Lin Y, Hu L, Feng W, Su P, Wu L: **The therapeutic effect of *Coriolus versicolor* fruiting body on STZ-induced ICR diabetic mice**. *J Healthc Eng* 2022, **2022**:7282453, https://doi.org/10.1155/2022/7282453

27. D'Amico R, Tomasello M, Impellizzeri D, Cordaro M, Siracusa R, Interdonato L, Abdelhameed AS, Fusco R, Calabrese V, Cuzzocrea S, *et al*.: **Mechanism of action of natural compounds in peripheral multiorgan dysfunction and hippocampal neuroinflammation induced by sepsis**. *Antioxidants* 2023, **12**:635, https://doi.org/10.3390/antiox12030635

28. Hossen SM, Tanim MAH, Hossain MS, Sami SA, Emon NU: **Deciphering the CNS anti- depressant, antioxidant and cytotoxic profiling of methanol and aqueous extracts of *Trametes versicolor* and molecular interactions of its phenolic compounds**. *Saudi J Biol Sci* 2021, **28**:6375-6383, https://doi.org/10.1016/j.sjbs.2021.07.016

29. Scuto M, Di Mauro P, Ontario ML, Amato C, Modafferi S, Ciavardelli D, Trovato Salinaro A, Maiolion L, Calabrese V: **Nutritional mushroom treatment in Meniere's disease with *Coriolus versicolor*: a rationale for therapeutic intervention in neuroinflammation and antineurodegeneration**. *Int J Mol Sci* 2019, **21**:284, https://doi.org/10.3390/ijms21010284

30. Li L, Li Y, Miao C, Liu Y, Liu R: ***Coriolus versicolor* polysaccharides (CVP) regulates neuronal apoptosis in cerebral ischemia-reperfusion injury via the p38MAPK signaling pathway**. *Ann Transl Med* 2020, **8**:1168, https://doi.org/10.21037/atm-20-575933241017

31. He Z, Lin J, He Y, Liu S: **Polysaccharide-Peptide from *Trametes versicolor*: the potential medicine for colorectal cancer treatment**. *Biomedicines* 2022, **10**:2841, https://doi.org/10.3390/biomedicines10112841

32. Nguyen HTK, Lee J, Park Y, Park HJ, Ahn SK, Kim JK, Kang DK, Kim M, Ahn C, Kim C, Choi J: **Comparative analysis of anticancer and antibacterial activities among seven *Trametes* species**. *Mycobiology* 2023, **51**:256-263, https://doi.org/10.1080/12298093.2023.2247218

33. Jędrzejewski T, Wrotek S, Sobocińska J, Pawlikowska M: **DzialukA: dual effect of the extract from the fungus *Coriolus Versicolor* on lipopolysaccharide-induced cytokine production in RAW 264.7 macrophages depending on the**

lipopolysaccharide concentration. *J Inflamm Res* 2022, **15**:3599, https://doi.org/10.2147/JIR.S364945

34. Yang CLH, Chik SCC, Lau ASY, Chan GCF: ***Coriolus versicolor* and its bioactive molecule are potential immunomodulators against cancer cell metastasis via inactivation of MAPK pathway**. *J Ethnopharmacol* 2023, **301**:115790, https://doi.org/10.1016/j.jep.2022.115790

35. Pawlikowska M, Jędrzejewski T, Brożyna AA, Wrotek S: **Protein-bound polysaccharides from *Coriolus Versicolor* induce RIPK1/RIPK3/MLKL-mediated necroptosis in ER-positive breast cancer and amelanotic melanoma cells**. *Cell Physiol Biochem* 2020, **54**:591-604, https://doi.org/10.33594/000000242

36. Chaouhan HS, Vinod C, Mahapatra N, Yu SH, Wang IK, Chen KB, Yu TM, Li CY: **Necroptosis: a pathogenic negotiator in human diseases**. *Int J Mol Sci* 2022, **23**:12714, https://doi.org/10.3390/ijms232112714

37. • Jędrzejewski T, Sobocińska J, Pawlikowska M, Dzialuk A, Wrotek S: **Extract from the *Coriolus versicolor* fungus as an anti-inflammatory agent with cytotoxic properties against endothelial cells and breast cancer cells**. *Int J Mol Sci* 2020, **21**:9063, https://doi.org/10.3390/ijms21239063.
The study investigated the effect of CV extract on HUVEC endothelial cells and MCF-7 breast cancer cells in a proinflammatory microenvironment mimicked by LPS. Results showed that the CV extract inhibited the production of proinflammatory and proangiogenic factors, decreased expression of TLR4 and phosphorylated IκB (p-IκB), and induced cytotoxicity enhanced by LPS, suggesting its potential as an anti-inflammatory and anti-tumorigenic agent.

38. He Y, Liu S, Newburg DS: **Musarin, a novel protein with tyrosine kinase inhibitory activity from *Trametes versicolor*, inhibits colorectal cancer stem cell growth**. *Biomed Pharmacother* 2021, **144**:112339, https://doi.org/10.1016/j.biopha.2021.112339

39. Pawlikowska M, Jędrzejewski T, Slominski AT, Brożyna AA, Wrotek S: **Pigmentation levels affect melanoma responses to *Coriolus versicolor* extract and play a crucial role in melanoma-mononuclear cell crosstalk**. *Int J Mol Sci* 2021, **22**:5735, https://doi.org/10.3390/ijms22115735

40. Lo HC, Hsu TH, Lee CH: **Extracellular polysaccharopeptides from fermented turkey tail medicinal mushroom, *Trametes versicolor* (Agaricomycetes), mitigate oxidative stress, hyperglycemia, and hyperlipidemia in rats with type 2 diabetes mellitus**. *Int J Med Mushrooms* 2020, **22**:417-429, https://doi.org/10.1615/IntJMedMushrooms.2020034560

41. Ahmadpour Torki M, Ranjbar M, Govahi M, Tafrihi M: **Effect of aqueous extract of turkey tail (*Trametes versicolor*) on *Staphylococcus aureus, Escherichia coli* and *Fusarium thapsinum***. *J Gorgan Univ Med Sci* 2022, **24**:93-98 ⟨http://goums.ac.ir/journal/article-1-4082-en.html⟩.