Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(2): 1161-1171
Received: 01-01-2018
Accepted: 04-02-2018

Uzma Azeem
Department of Botany, Punjabi University, Patiala, Punjab, India

Gurpaul Singh Dhingra
Department of Botany, Punjabi University, Patiala, Punjab, India

Richa Shri
Department of Pharmaceutical Sciences and Drug Research, Punjabi University, Patiala, Punjab, India

Correspondence
Uzma Azeem
Department of Botany, Punjabi University, Patiala, Punjab, India

Pharmacological potential of wood inhabiting fungi of genus *Phellinus* Quél.: An overview

Uzma Azeem, Gurpaul Singh Dhingra and Richa Shri

Abstract
Mushrooms have been in use as human diet and folk medicine against several dieases since antiquity. These properties are credited to the diverse bioactive compounds present in these mushrooms. *Phellinus* Quél. (*Hymenochaetaceae*) is amongst the medicinally important mushrooms and is cosmopolitan in distribution. Species under this genus are wood inhabiting causing white rot in various angiosperms and gymnosperms. However, hymenophores and/or mycelial biomass of many *Phellinus* species are of therapeutic significance. These are used as folk medicine for the management of different disorders since ages and need scientific evaluation. The information regarding the bioactivities and mycochemical components has been collected from Medline, PubMed, Scince Direct and Scopus. The present review accentuates the pharmacological potential of *Phellinus* bthat is attributed to an array of bioactive constituents reported from different species this genus. The information provided in this review may prove beneficial to evaluate *Phellinus* species scientifically and extend their folk medicinal use to drug preparation for clinical use in future.

Keywords: Bioactive constituents, Bioactivities, *Phellinus*

Introduction
Synthetic drugs are costly and various side effects and are not safe for use during gestation period. As an alternative to synthetic drugs, medicines preparaed from natural sources are in great demand these days. Medicines procured from mushrooms are widely used against several disorders throughout the world. Of these medicinal mushrooms, *Phellinus* species are an incredible drug source. Species belonging to this genus are wood inhabitants and cause white rot in a wide variety of angiosperms as well as gymnosperms responsible for great economic losses to forest flora [1–4]. However, several species of *Phellinus* are used traditionally for the treatment of different diseases across the world. These health boosting properties are due to various bioactivities of these species such as antioxidant, antidiabetic, anti inflammatory, antimicrobial, antiallergic, hepatoprotective etc. The pharmacological significance is credited to bioactive constituents like polysaccharides, phenols, flavonoids etc. Based on current knowledge, the present review highlights the pharmacological significance of medicinally important *Phellinus* species and will prove a useful guide for future research on these mushrooms.

Methodology
Literature pertaining to the bioactivities and bioactive constituents of *Phellinus* was assessed by searching the electronic databases like Google Scholar PubMed, Science Direct and Scopus. All English-language articles published regarding *Phellinus* species up to 2018. The subject related references given in the relevant articles were also considered to include all reports and reviews.

Taxonomy
Phellinus Quél. (Family: *Hymenochaetaceae*) is characterized by resupinate to pileate, annual to perennial, single or imbricate hymenophores with a wide color range from yellowish to rusty brown to grey to black. Abhymenium may be tomentose to glabrous to scrupose to crustose to rimose. Hymenium is brown with round to angular to daedaloid pores (Fig. 1). Microscopically, it is identified by dimitic hyphal system with simple septate, branched, thin- to thick-walled, subhyaline to pale yellow generative hyphae and aseptate, thick-walled, occasionally branched, golden yellow to golden brown skeletal hyphae. Setae/setal hyphae may be present or absent. Basidia are four spored and spores are broadly ellipsoid to subglobose to globose with smooth, thin-tothick-wall, hyaline to golden yellow to golden brown, dextrinoid to inamyloid, weakly cyanophilous to acyanophilous basidiospores (Fig. 2).

Distribution

There are 180 taxa listed under genus *Phellinus* all over the world [5]. Mycobank data numbered 361 taxa of this genus strewed to different ecogeographic zones [6]. Indian mycologists reported 97 *Phellinus* species scattered to a wide range of altitudes and latitudes [7–9]. This genus has been mainly described from Himalaya, Himachal Pradesh, Bhutan, Uttarakhand and Maharashtra.

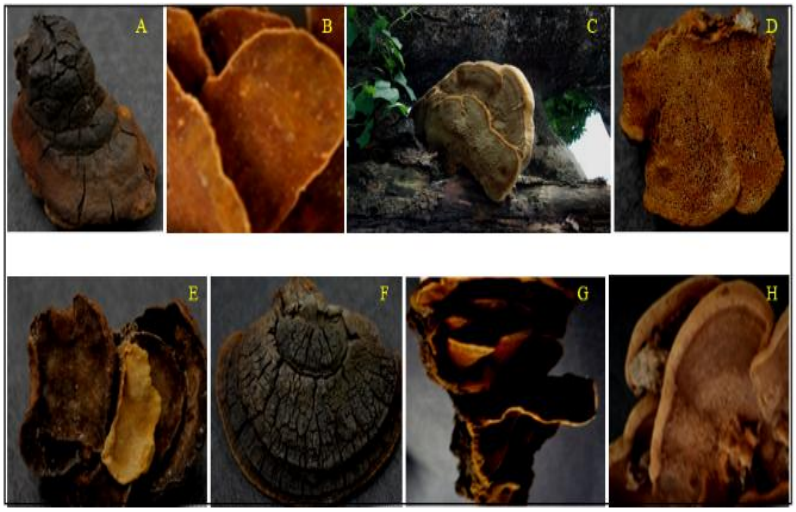

Fig 1: Hymenophores of some *Phellinus* species: A. *P. badius*; B. *P. gilvus*; C. *P. pachyphloeus*; D. *P. pini;* E. *P. pullus*; F. *P. rimosus*; G. *P. sanfordii*; H. *P. torulosus*

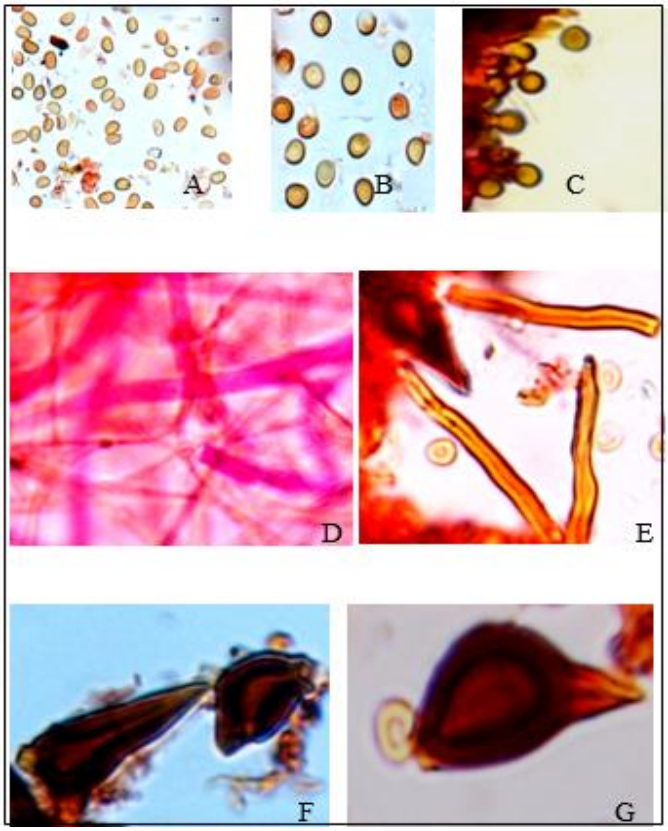

Fig 2: Microscopic structures of *Phellinus* species: A–C (type of spores); D–E (type of hyphae); F–G (Setae)

Traditional uses

Ancient medicinal literature documented the use of *Phellinus* species as folk medicine against various ailments [10]. In Chinese medical books, viz. the world's earliest pharmacopoeia issued by the Tang government "New compendium of Materia Medica" [11], and "Chinese Compendium of Materia Medica" of Shi-Zhen Li in the Ming Dynasty [12]. Literature reports mentioned traditional medicinal uses of many *Phellinus* species such as *P. rimosus, P. conchatus, P. baumii, P. igniarius, P. nigricans* and *P. senex* [13–15]. In India, *Phellinus rimosus* has been used against mumps in Kerala [16].

Phramacological activities

An array of bioactivities has been credited to *Phellinus* species [17–18]. Scientific examinations have shown that *Phellinus* species demonstrate pharmacological activities such as antioxidant, anti inflammatory, antimicrobial, anticancer etc. in various *in-vitro* and *in vivo* experimental models [19]. Their health benefits are due to various bioactivities such as antioxidant, anti inflammatory, antimicrobial, anticancer etc.

Antioxidant

Excessive production of ROS distorts cell structure and deteriorates biomolecules [20] leading to degenerative disorders. To prevent this oxidative destruction elimination of ROS is necessary. *Phellinus* mushrooms exhibit significant antioxidant potency and provide protection against ROS damage [21–24]. *Phellinus linteus*, *P. igniarius* and *P. durissimus* showed significant DPPH scavenging, prevent lipid peroxidation, inhibited thiobarbituric acid reactive substances (TBARS) formation and possessed considerable reducing power [25-28]. This can be attributed to various antioxidant compounds such as caffeic acid, davalliallactone, ellagic acid, hispidin, hypholomine B, inoscavin A, interfungins A, methyldavallialactone, protocatechualdehyde and protocatechuic acid isolated from these mushrooms [29-30].

Antidiabetic

Phellinus mushrooms possess good antidiabetogenic properties. *P. baumii* exopolysaccharides showed antidiabetic effect by decreasing glucose, triglyceride level and enhancing glucose disposal, food efficiency, insulin sensitivity as well as activating the peroxisome proliferator-activated receptor gamma (PPAR-γ) [31]. The compounds such as hispidin, phelligridimer A, davallialactone, methyldavallialactone, hypholomine B, interfungins A, inoscavin A along with protocatechuic acid, protocatechualdehyde, caffeic acid and ellagic acid extracted from *P. linteus* showed antidiabetic potential by inhibiting aldose reductase activity [32]. *P.*

merrillii extract inhibited α-glucosidase and aldose reductase activities contributed by hispidin, hispolon and inotilone [33]. *P. badius* extract lowered glucose, triglycerides, cholesterol, activity of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) along with the increase in food intake, body weight in alloxan induced diabetic rats [34].

Hepatoprotective

Several investigations proved *Phellinus* species as hepatoprotective and antihepatotoxic agents [35–38]. Serum alanine aminotransferase (s-GOT) and serum aspartate aminotransferase (s-GPT) levels, ballooning degeneration, necrosis and portal triaditis [39] were lowered with pretreatment of *P. merrillii* (0.5, 1 and 2 g/kg b.wt.) extract. *P. gilvus* extract healed CCl_4-induced liver injury in rats by declining the levels of alanine aminotransferase, asparate aminotransferase, alkaline phosphatase, malondialdehyde and enhancing antioxidants (superoxide dismutase, catalase, and glutathione peroxidase) in serum. Pretreatment of *P. gilvus* resulted in the loss of hepatocytes, fatty changes, swelling and extensive necrosis of hepatocytes in centrilobular regions of the CCl_4-treated rats [40]. The compound, Phellinulin A isolated from *P. linteus* significantly inhibited hepatic fibrosis in rat hepatic stellate cells [41].

Anticancer

As per literature reports, *Phellinus* mushrooms possess antitumor potential [42–45]. Phelligridins C–F extracted from *P. igniarius* prevented cytotoxicity [46]. Polysaccharides of *P. gilvus* provide protection against the neoplastic effects of benzo (a) pyrene (BaP) by rapid down-regulation of mutant *p53* mRNA expression [47]. *P. linteus* and anticancer drug doxorubicin (0.5 mg/mL + 1.0 µg/mL) showed synergistic impact to induce apoptosis [48]. *Phellinus linteus* extract exerted antitumor effect against MFC7, NCI-H187 cancer cells [49] and K562 leukemia cells [50].

Antimicrobial

A number of mushrooms inclusive of *Phellinus* are known to have antimicrobial activity [51]. *Phellinus rimosus* and *P. linteus* showed antimicrobial activity against an array of pathogenic bacterial strains [52–53]. *P. torulosus* inhibited proliferation of gram (+) and gram (-) bacteria, yeasts, filamentous fungi and actinomycetes [54]. The aqueous extract of *P. gilvus* inhibited growth of *Lactobacillus plantarum* ACC 14917, *Escherichia coli* ATCC25922 and *Klebsiela pneumonia* ATCC10031 [55]. A similar negative impact of *P. igniarius* extract was observed against gram (+) and gram (-) bacteria [56]. The solvent cocktail *P. hartigii* showed antibacterial activity against *Shigella flexneri* [57]. The aqueous, ethyl acetate and methanol extracts of *P. swieteniae* and *P. merrillii* inhibited proliferation of *Acinetobacter baumannii*, *E. coli*, *P. aeruginosa*, *Salmonella typhi*, *Staphylococcus aureus, Streptococcus mutans* and growth of five fungal strains *Penicillium* sp., *Aspergillus fumigatous*, *A. niger*, *A. flavus* and *Mucor indicus* [58–59]. Sesquiterpenes of *Phellinus* sp. viz. *P. fastuosus, P. merrillii, P. aureobruneus, P. crocatus, P. lloydii* and *P. sublinteus* showed inhibitory effect against twelve virulent strains of bacteria and fungi [60]. The inhibitory action on the growth of *Aleternaria alternate* was noticed with *P. gilvus, P. rimosus* and *P. badius* extracts [61]. *Phellinus swieteniae* showed antibacterial activity against sixteen strains of *Acinetobacter baumannii* and human pathogenic *Acinetobacter* [62]. Proliferation of oral bacteria *Enterococcus faecalis, Actinomyces viscosus, Streptococcus salivarius, S. mutans* and *S. sanguis* grown in brain heart infusion (BHI) broth was inhibited with the application of *P. linteus* extract with minimum inhibitory concentration (MIC) 1250–5000 µg/mL and minimum bactericidal concentration (MBC) 2500–5000 µg/mL [63]. Antibacterial and antifungal effects of *P. igniarius* were also observed [64] In addition to antimicrobial activity**,** antiviral activity was observed with methanol and chloroform extract of *P. linteus* against *Plasmodium falciparum* with IC_{50} 3.15 and 3.08 g/mL respectively [49].

Antiinflammatory Activity

Phellinus linteus exhibited a dose dependent inhibition of croton oil-induced mouse ear inflammation (edema) [65]. *P. linteus* extract in lioppolysaccharide (LPS)-induced RAW264.7 macrophages, lowered iNOS promoter activity and nitric oxide production [66]. *Phellinus baumii* polysaccharides evoked murine splenocyte proliferation and prevented nitric oxide production in RAW264.7 murine macrophages [67]. Antiinflammatory action of *P. linteus* extract in RAW264.7 macrophages inhibited inflammation markers by prohibiting inflammatory cytokines, chemokines mediators and also by elevating antioxidant activity [68].

Immunomodulation

Phellinus mushrooms strengthened the immune system and this property can be attributed to their biochemical composition. *P. linteus* polysaccharides induced β-lymphocytes, elicited the number of plaque-forming cells, provoked the expression of splenocyte colony factor, Interlukin-3, granulocyte macrophage stimulating factor, thrombopoeiten genes leading to the growth and proliferation of splenocytes and bone marrow cells [69–72]. *P. linteus* extract declined IgE generation that may be due to elevation in IFN-$_\gamma$ production [73]. The proteoglycans of *P. nigricans* showed antitumor and immunomodulatory activities [74]. *P. linteus* extract inhibited ear swelling in BALB/c mice by enhancing the generation of interleukin-4 and IFN-γ from anti-CD3-stimulated mouse splenocytes [75]. Enhancement of the production of Th1- and Th2- type cytokines in mice was seen with oral administration of *P. linteus* extract [76].

Other Activities

Phellinus linteus proteoglycans proved beneficial in the treatment of collagen induced arthritis [77]. The compounds *Phellinus* furans A and B eluted from of *P. linteus* showed anticomplement capacity with IC_{50} values of 33.6 and 33.7 µM respectively in preventing the hemolytic activity of human serum against erythrocytes [78]. The compounds [2-Isobutyl-3-methyl furan-8.96-9.48; 2-Tert-butyl-4 (2,4,4-trimethyl pentan-2-yl) phenol-16.32-18.21; 3-Methyl-2-(2-methylallyl) furan-12.73-17.11; Tetradecan-1-ol-9.73-16.15; Bicycle[3.1.1]hept-2-ene-ecarbaldehyde-6.22-9.52; 3-Methyl-2-(2-methylbut-2-enyl) furan-18.68-8.67; 4-Methyl benzyl azide-24.07-30.97; 2,3-Epoxy-5,8-hexa decadien-1-ol-14.43-26.17 and 3-Methyl-2-(2-oxopropyl)] extracted from methanol extract of *P. adamantinus* exhibited various bioactivities such as antiviral, antibacterial, antineoplastic, antidiabetic and antiinflammatory [79]. At a dose of 200 mg/Kg b.wt. aqueous extract of *P. linteus* significantly decreased the synthesis of serotonin in brain and enhanced expression of monocarboxylate transporters (MCTs)1 and (MCTs)4 that in turn increased exercise endurance performance [80]. The benzofuran derivatives (ribisin A–D) extracted from the methanol extract of *P. ribis* at

concentrations 1–30 μM resulted in neurite outgrowth in NGF-mediated PC12 cells [81]. The skin whitening effect of *P. baumii* was observed in B16/F10 melanoma cells due to the Inhibition of tyrosinase [82]. Various reports regarding the pharmacological effects of different species of *Phellinus* are summarized in Table 1.

Table 1: Bioactivities reported for different species of *Phellinus*

***Phellinus* species**	**Part used**	**Extract/Fraction/ Compound**	**Bioactivity**	**Reference**
P. aureobruneus	Hymenophore	Sesquiterpenes	Antibacterial and antifungal	[60]
		Methanol extract	Antibacterial	[79]
P. badius	Hymenophore	Ethanol extract	Antioxidant	[102]
		Methanol extract	Antifungal and antioxidant	[61]
		Methanol extract	Antioxidant	[113]
	Hymenophore and mycelial biomass	Aqueous extract	Antidiabetic	[34]
P. baumii	Mycelium	Exopolysaccharides	Antidiabetic	[31]
		Exo- polysaccharides	Antidiabetic	[115]
	Hymenophore	Ethanol petroleum ether, chloroform, ethyl acetate, n-BuOH and ethanol-petroleum extract	Antioxidant	[102]
		Ethyl acetate extract	Antibacterial	[116]
		Aqueous, ethanol (50%, 80%, pure) and ethylacetate extract	Antioxidant	[86]
		Sesquiterpenes	Antibacterial and antifungal	[60]
P. contiguus	Hymenophore	Ehyl-acetate (soluble and insoluble) fractions and Methanol extract	Antioxidant	[26]
P. crocatus	Hymenophore	Sesquiterpenes	Antibacterial and antifungal	[60]
		Methanol extract	Antioxidant	[113]
P. gilvus	Hymenophore	Polysaccharides	Antitumour	[47]
		Aqueous extract	Antibacterial	[55]
		Polysaccharides	Hepatoprotective	[40]
		Aqueous, ethanol (50%, 80%, pure) and ethyl acetate extract	Antioxidant	[86]
		Ethanol extract	Antioxidant	[102]
		Methanol extract	Antioxidant and antifungal	[61]
	Mycelium	Polysaccharides	Antitumour	[103]
P. hartigii	Hymenophore	A solvent cocktail, dH_2O:ethylalcohol:methyl alcohol: acetone: CH_2Cl_2 (1:2.5:2.5:2:2)	Antibacterial	[57]
P. hippophaecola	Hymenophore	Aqueous, ethanol (50%, 80%, pure) and ethyl acetate extract	Antioxidant	[86]
P. igniarius	Hymenophore	Aqueous extract	Antibacterial	[56]
	Hymenophore	Phelligridin A	Antioxidant	[107]
		Phelligridin G	Antioxidant and cytotoxic	[109]
	Mycelium	Methanol extract and hot water extract	Antioxidant	[27]
	Hymenophore	Phelligridin H and Phelligridin I	Antioxidant	[25]
		Phelligridin J	Cytotoxic	
		Aqueous, ethanol (50%, 80%, pure) and ethyl acetate extract	Antioxidant	[86]
		Ethanol extract	Antioxidant	[102]
P. linteus	Mycelium	Exopolysaccharides	Antidiabetic	[117]
	Hymenophore	Exopolymers		[118]
		Ethanol extract	Antioxidant and antiangiogenc	[119]
		Methanol extract and its n-butanol fraction	Antibacterial	[53]
		n-butanol subfraction	Antiinflammatory	[65]
	Mycelium	Different solvent fractions	Antitumour	[120]
			Antioxidant	[24]
		Ethanol and Ethylacetate combined extract	Antiinflammatory	[68]
	Hymenophore	*Phellinus*furan A and *Phellinus*furan B	Anticomplement activity	[78]
	Mycelium	Chloroform, ethylacetate, methanol, water and boiled water extract	Antiallergic	[75]
		Hot water extract	Immunomodulatory activity	[71]
	Mycelium	Hispidin, 3,14´-bihispidinyl, hypholomine B and 1,1-distyrylpyrylethan	Antioxidant	[110]
	Hymenophore	Phellifuropyranone A	Antiproliferative	[111]
		Ethanol extract	Antiallergic	[73]
		Nine different protein glycation inhibitors from ethylacetate fraction	Antidiabetic	[32]
		10 different antioxidant compounds	Antioxidant	[36]
		*Phellinus*furans A and B	Anticomplement activity	[78]
		Aqueous extract	Antioxidant	[122]
		Crude methanol, chloroform and ethyl acetate extracts	Antimalarial, antioxidant and cytotoxic	[49]
		Aqueous extract	CNS activity	[80]
		Methanol and ethyl acetate extract	Antibacterial	[58]

	Mycelium	Hispidin from mycelial culture	Antidiabetic and antioxidant	[123]
	Hymenophore	Ethanol extract	Anticancer	[50]
		Polysaccharides	Antitumour	[124]
		Polysaccharides	Antioxidant	[18]
	Hymenophore	Aqueous, ethanol (50%, 80%, pure) and ethylacetate extract	Antioxidant	[86]
	Hymenophore	Ethanol extract	Antioxidant	[102]
		Aqueous extract	Antibacterial	[63]
		Hispidin	Antioxidant	[30]
	Mycelium	Ethanol extract and Phellinulin A	Hepatoprotective	[41]
P. lloydii	Hymenophore	Sesquiterpenes	Antibacterial and antifungal	[60]
P. merrillii	Hymenophore	Ethanol extract	Antioxidant and hepatoprotective	[39]
		Methanol and ethyl acetate extract	Antibacterial	[58]
		Ethanol extract and compounds (Hispidin, hispolon and inotilone) isolated from ethylacetate soluble fraction of ethanol extract	Antidiabetic	[16]
		Sesquiterpenes	Antibacterial and antifungal	[60]
		Methanol extract	Antioxidant	[113]
		Ethyl acetate and methanol extract	Antibacterial	[62]
P. pini	Hymenophore	Exopolysaccharides (EP-AV1 and EP-AV2)	Antiviral against herpes simplex virus 1 (HSV-1)	[33]
		Aqueous, ethanol (50%, 80%, pure) and ethylacetate extract	Antioxidant	[86]
P. rhabarbarinus	Hymenophore	Triterpenoids	Antioxidant and antitumour	[126]
P. ribis	Hymenophore	Polychlorinated compounds (chlorophellins A-C) from methanol extract	Antidiabetic	[121]
		Ribisins A–D	Against alzheimer's disease	[81]
P. rimosus	Hymenophore	Methanol extract	Antioxidant and antiinflammatory	[88]
		Ethyl acetate extract	Antioxidant and hepatoprotective	[35]
		Methanol extract	Antibacterial	[52]
		Methanol extract	Antifungal and antioxidant	[61]
P. sp.		Crude extract	Antimicrobial	[114]
P. sublinteus	Hymenophore	Sesquiterpenes	Antibacterial and antifungal	[60]
		Methanol extract	Antioxidant	[113]
P. swieteniae	Hymenophore	Ethyl acetate and methanol extract	Antibacterial	[58]
		Chloroform, ethyl acetate and methanol extract		[62]
P. torulosus	Hymenophore	Acetone, chloroform, ethanol and ethyl acetate	Antimicrobial	[54]
		Aqueous, ethanol (50%, 80%, pure) and ethylacetate extract	Antioxidant	[86]
P. tremulea *P. trivalis* and *P. tuberculosus*	Hymenophore	Aqueous, ethanol (50%, 80%, pure) and ethylacetate extract	Antioxidant	[86]

Bioactive Constituents

Vitamins

Vitamins are the organic compounds essential to an organism and are needed in limited amount. These have antidiabetic effect [83–85], free radical scavenging [86], work against retinopathy [87] and act as antioxidants [88]. *P. linteus* reported to have two isoforms of vitamin E: α- and γ-tocopherol [28].

Fatty acids

Fatty acids are important structural and functional components inside human body affaecting various metabolic pathways. *Phellinus* mushrooms like other mushrooms are low in fat content. This fat mainly comprises of various saturated and unsaturated fatty acids. Fatty acids like palmitoleic acid, linoleic acid, oleic acid, hexadecanoic acid and stearic acid were reported in *Phellinus* species [89]. The fatty acids such as palmitic acid, linoleic acid, oleic acid and stearic acid were found in *P. linteus* [28].

Some other pertinent metabolites

Phenols, flavonoids, alkaloids, sterols, triterpenes and anthraquinones were found in *Phellinus* mushrooms [90–91]. These mushrooms were found consisting of carbohydrates, proteins, fibers, minerals, vitamins as well as low quantities of fats [92–93]. Tremulane sesquiterpenes obtained from *P. igniarius* play role in vasoconstriction [94–95]. In *P. noxious*, alkaloids, tannins, flavonoids, phenols, terpenoids and anthocyanins have been reported [96]. *Phellinus* mushrooms are rich in β-glucans [97–98]. However, hot water extract of *P. linteus* contained both α-glucans and β-glucans [18]. Polysaccahrides of *Phellinus* species play various therapeutic roles including alleviation of septic shock [99–100]. Various species of *Phellinus* like *P. badius* were screened for exopolysaccharides [101–102]. Polysaccharides mainly β-glucans and protein bound polysaccharides have been detected from *P. linteus* [103]. Yellow pigment compounds called styrylpyrones and their derivatives have been detected in *Phellinus* mushrooms (Fig. 3) [104–105]. These compunds showed various activities, antiinflammatory, antidiabetic, antiplatelet aggregation and some provided protection from septic shock. Phelligridins C and D were isolated from *P. linteus* and reported as meshimakobnols A and B, respectively [106]. Phelligridimer A and pinillidine were isolated from *P. igniarius* and *P. pini* respectively [107–108]. Two novel furan derivatives (*Phellinus*furans A and B) were isolated from *P. linteus* [77]. Phelligridins A–J were isolated from *P. igniarius* together with inoscavin A, hispolon, and 4-(3,4-dihydroxyphenyl)-but-3-en-2-one [46, 109, 25]. Hispidin and its

dimers, 3, 14'-bihispidinyl, hypholomine B and 1, 1-distyrylpyrylethan were detected in cultured broths of and *P. linteus* [110]. In addition, the hymenophore of *P. linteus* was also reported to produce phellifuropyranone A [111]. Phellinins A1 and A2, new styrylpyrones were isolated from the culture broth of *Phellinus* sp. KACC93057P: II [112]. An antioxidant hispidin was extracted from the mycelial culture of *P. linteus* [125].

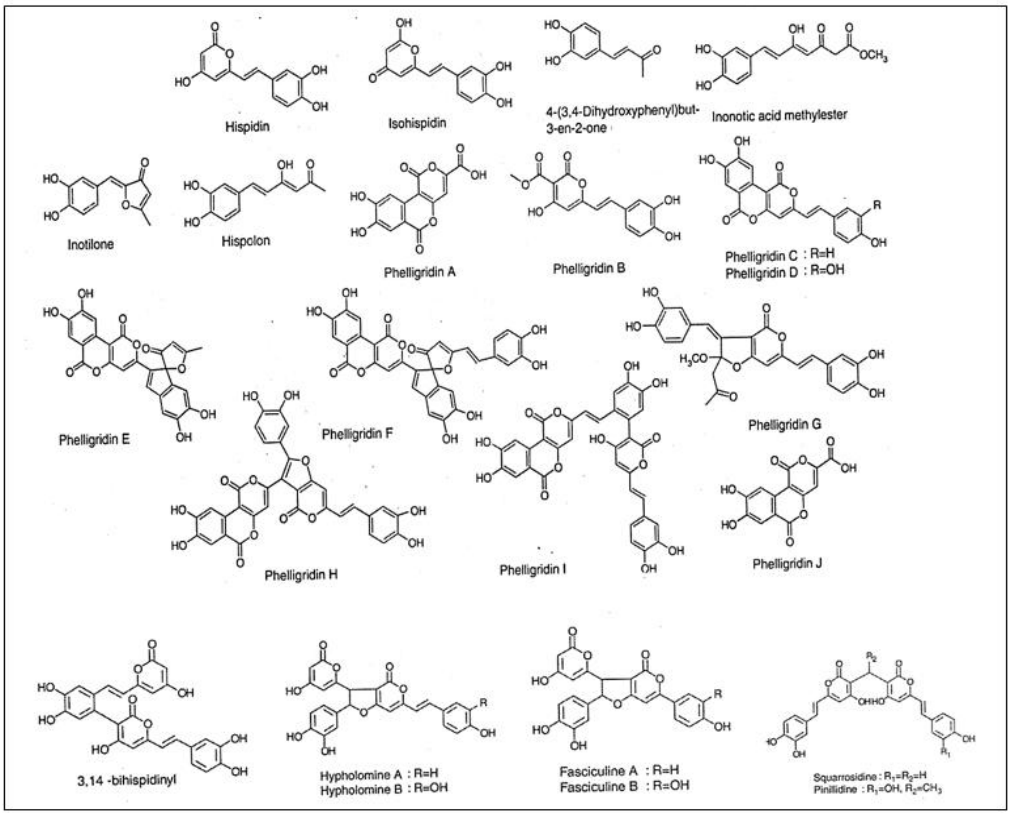

Fig 3: Structure of some important styrylpyrones isolated from *Phellinus* species

Results and Discussion

This review highlights the great pharmacological potential of genus *Phellinus*. In addition to the antioxidant properties, species of this genus possess anticancer, antidiabetic, anti inflammatory, antimicrobial, antifungal, antiviral and immunostimulatory activities. It is evident from the information assembled from different sources that the species of *Phellinus* possess tremendous pharmacological promise. The elution and characterization of bioactive compounds and systematic evaluation of bioactivities shall open a new door for management of several ailments with the aid of *Phellinus* mushrooms.

Conclusion

This review summarizes studies reporting various bioactivities of *Phellinus* mushrooms which have been credited to the wide variety of secondary metabolites reported from them. The folk/traditional medicinal uses of *Phellinus* species need to be supported with scientific evidence of their activities as well as the isolation and characterization of constituents responsible for the activities of these mushrooms. This will lead to the discovery of new natural drugs against several human ailments.

Acknowledgements

The authors owe their thanks to Department of Botany, Punjabi University, Patiala, India for providing necessary facilities and University Grants Commission for granting Maulana Azad National Fellowship (MANF) (2011–2016) to the corresponding author.

Conflict of interest

The authors have no conflict of interest.

Abbreviations

ALT–Alanine aminotransferase; AST–Aspartate aminotransferase; BH–Brain heart infusion; b.wt.–Body weight; CNS–Central nervous system; CH_2Cl_2–Chloroform; dH_2O–Distilled water; EP–Exopolysaccharide; HSV-1–Herpes simplex virus; IFN-γ–Interferon gamma; LPS–Lipopolysaccharide; n-BOH; iNOS–inducible nitric oxide synthase; Normal butanol; P–*Phellinus*; PPAR-γ–Peroxisome proliferator activated gamma; ROS–Reactive oxygen species; sGOT–Serum alanine aminotransferase; sGPT–Serum aspartate aminotransferase; sp.–Species written for unidentified taxon; NGF–Neurite growth factor; MBC–Minimum bactericidal concentration; MIC–Minimum inhibitory concentration; Th-1–Type 1 T helper; Th-2–Type 2 T helper.

References

1. Bakshi BK. Indian *Polyporaceae* (on trees and timber). Indian Council of Agricultural Research, New Delhi, 1971.
2. Foroutan A, Jafary N. Diversity of heart and root rot fungi on park and roadside trees in Maharashtra, India. Journal of Applied Sciences and Environmental Management. 2007; 11:55-58.
3. Foroutan A, Vaidya JG. Record of New Species of *Phellinus* from Maharashtra India. Asian Journal of Plant Sciences. 2007; 6:633-637.

4. Ranadive K, Jagtap N, Vaidya J. Host diversity of genus *Phellinus* from world. Elixir Applied Botany. 2012; 52:11402-11408.
5. Kirk PM, Cannon PF, Minter DW, Stalpers JA. Ainsworth and Bisby's Dictionary of the Fungi (10th ed.). Wallingford, United Kingdom, 2008.
6. www.mycobank.org (Assessed on 6th March, 2018).
7. Ranadive KR. An overview of *Aphyllophorales* (wood rotting fungi from India. International Journal of Current Microbiology and Applied Sciences. 2013; 2(12):112-139.
8. Kaur H. Systematics of pileate poroid *Agaricomycetes* of Himachal Pradesh. Ph.D. Thesis. Punjabi University, Patiala, 2013.
9. Azeem U, Dhingra GS, Shri R. Some additions to the diversity of genus *Phellinus* Quél. from wood rotting fungal flora of district Dehradun (Uttarakhand), India. Research Journal of Life Sciences, Bioinformatics. Pharmaceutical and Chemical Sciences. 2017; 3(4):177-189.
10. Chen H, Tian T, Miao H, Zhao YY. Traditional uses, fermentation, phytochemistry and pharmacology of *Phellinus linteus*: A review. Fitoterapia. 2016; 113:6-26.
11. Su J, Cao XXB. Anhui Science & Technology Publishing House. Hefei, 1981.
12. Li SZ, Mu BCG. People's Medical Publishing House. Beijing, 2004.
13. Bao X, Duan J, Fang X, Fang J. Chemical modifications of obese the (1→3) α-D glucose homeostasis and insulin sensitivity in mice. Diabetes Obesity and Metabolism. 2001; 14:190-193.
14. Zhu T, Kim SH, Chen CY. A Medicinal Mushroom: *Phellinus linteus*. Current Medicinal Chemistry. 2008; 15:1330–1335.
15. Ganesh PN. Studies on wood-inhabiting macrofungi of Kerala. Ph.D. thesis. Calicut University, Calicut, 1998.
16. Huang GJ, Hsieh WT, Chang HY, Huang SS, Lin YC, Kuo YH. α- Glucosidase nd aldose reductase inhibitory activities from the fruiting body of *Phellinus merrillii*. Jornal of Agricultural and Food Chemistry. 2011; 59:5702-5706.
17. Yuan C, Huang X, Cheng L, Bu Y, Liu G, Yi F *et al*. Evaluation of antioxidant and immune activity of *Phellinus ribis* glucan in mice. Food Chemistry. 2009; 115:581-584.
18. Kozarski M, Klaus A, Niksic M, Jakovljevic D, Helsper JPFGL, Griensven JLDV. Antioxidative and immunomodulating activities of polysccahride extracts of the medicinal mushrooms *Agaricus bisporous*, *Agaricus brasiliensis*, *Ganoderma lucidum* and *Phellinus linteus*. Food Chemistry. 2011. 129:1667-1675.
19. Lamrood P. Studies on Medicinally important fungi. Ph. D. Thesis. University of Pune, 2004.
20. Tsai SY, Tsai HL and Mau JL. Antioxidant properties of *Agaricus blazei*, *Agrocybe cylindricea* and *Boletus edulis*. LWT Food Science and Technology. 2007; 40:1392-1402.
21. Shon MY, Kim TH, Sung NJ. Antioxidant and free radical scavenging of *Phellinus baumii* (*Phellinus* of *Hymenochaetaceae*) extracts. Food Chemistry. 2003; 82:392–382.
22. Ajith TA, Janardhanan KK. Chemopreventive activity of a macrofungus *Phellinus rimosus* against N-nitrosodiethylamine induced hepatocellular carcinoma in rat. Journal of Experipmental Therapeutics and Oncology. 2006; 5:309-321.
23. Lee IK, Yun BS. Highly oxygenated and unsaturated metabolites providing a diversity of hispidin class antioxidants in the medicinal mushrooms *Inonotus* and *Phellinus*. Bioorganic and Medicinal Chemistry. 2007; 15:3309-3314.
24. Park IH, Chung SK, Lee KB, Yoo YC, Kim SK, Kim GS *et al*. An antioxidant hispidin from the mycelial cultures of *Phellinus linteus*. Archives of Pharmacal Research. 2004; 27:615-618.
25. Wang Y, Shang XY, Wang SJ, Mo SY, Li S, Yang YC *et al*. Structures, biogenesis, and biological activities of pyrano [4,3-c]isochromen-4-one derivatives from the fungus *Phellinus igniarius*. Journal of Natural Products. 2007; 70:296-299.
26. Lahiri SK, Gokania RH, Shuklab MD, Modic HA, Santanid DD, Shaha B. Evaluation of antioxidant activity of plant-parasitic macrofungus: *Phellinus durissimus* (Lloyd) Roy. Eurasian Journal of Analytical Chemistry. 2010; 5(1):32-45.
27. Lung MY, Tsai JC, Huang PC. Antioxidant properties of edible basidiomycete *Phellinus igniarius* in submerged cultures. Journal of Food Science. 2010; 75:18-24.
28. Reis FS, Barreira JCM, Calhelha RC, Griensven LJIDV, Ćirić AJ, Glamoclija J *et al*. Chemical characterization of the medicinal mushroom *Phellinus linteus* (Berkeley & Curtis) Teng and contribution of different fractions to its bioactivity. Food Science and Technology. 2014; 58:478-485.
29. Jeon YE, Lee YS, Lim SS, Kim SJ, Jung SH, Bae YS *et al*. Evaluation of the antioxidant activity of the fruiting body of *Phellinus linteus* using the on-line HPLC-DPPH method. Journal of Korean Society. Applied Biological Chemistry. 2009; 52(5):472-479.
30. Park JM, Lee JS, Song JE, Sim YC, Ha SJ, Hong EK. Cytoprotective Effect of hispidin against palmitate-induced lipotoxicity in C2C12 myotubes. Molecules. 2015; 20:5456-5467.
31. Cho EJ, Hwang HJ, Kim SW, Oh JY, Baek YM, Choi JW *et al*. Hypoglycemic effects of exopolysaccharides produced by mycelial cultures of two different mushrooms *Tremella fuciformis* and *Phellinus baumii* in ob/ob mice. Applied Microbiology and Biotechnology. 2007; 75:1257-1265.
32. Lee YS, Kang YH, Jung JY, Kang IJ, Han SN, Chung JS *et al*. Inhibitory constituents of aldose reductase in the fruiting body of *Phellinus linteus*. Biological and Pharmacological Bulletin. 2008a; 31:765–768.
33. Lee SM, Kim SM, Lee YH, Kim WJ, Park JK, Park YIl. Macromolecules isolated from *Phellinus pini* fruiting body: Chemical characterization and antiviral activity. Macromolecular Research. 2010; 18(6):602-609.
34. Sonawane HB, Ghole VS, Garad S. Hypoglycemic effect of Phansomba (*Phellinus badius*) Berk Ex Cooke) G. Cunn. on alloxan induced diabetic rats. Journal of Natural Remedies. 2013; 13(1):29-34.
35. Ajith TA, Janardhan KK. Antioxidant and antihepatotoxic activities of *Phellinus rimosus* (Berk) Pilat. Journal of Ethnopharmacology. 2002; 81(3):387–391.
36. Jeon TI, Hwang SG, Lim BO, Park DK. Extracts of *Phellinus linteus* grown on germinated brown rice suppress liver damage induced by carbon tetrachloride in rats. Biotechnolology Letters. 2003; 25:2093-2096.

37. Kim SH, Lee HS, Lee S, Cho J, Ze K, Sung J *et al*. Mycelial culture of *Phellinus linteus* protects primary cultured rat hepatocytes against hepatotoxins. Journal of Ethnopharmacology. 2004a; 95:367–372.
38. Wang H, Wu G, Park HJ, Jiang PP, Sit WH, Van GLJ *et al*. Protective effect of *Phellinus linteus* polysaccharide extracts against thioacetamide-induced liver fibrosis in rats: A Proteomics Analysis and Chinese Medicine. 2012; 18:23
39. Chang HY, Peng WH, Sheu MJ, Huang GJ, Tseng MC, Lai MT *et al*. Hepatoprotective and antioxidant effects of ethanol extract from *Phellinus merrillii* on carbon tetrachloride-induced liver damage. American Journal of Clinical Medicine. 2007a; 35:793-804.
40. Park SC, Cheon YP, Son WY, Rhee MH, Kim TW, Song JC *et al*. Hepatoprotective effects of polysaccharides isolated from *Phellinus gilvus* against carbon tetrachloride-induced liver injury in rats. Toxicological Research. 2009a; 25(1):29-33.
41. Huang SC, Kuo PC, Hung HY, Pan T, Chen FA, Wu TS. Ionone Derivatives from the Mycelium ofm *Phellinus linteus* and the Inhibitory Effect on Activated Rat Hepatic Stellate Cells. International Journal of Molecular Science. 2016; 17:1-8.
42. Chihara G, Maeda Y, Hamuro J, Sasaki T, Fumiko F. Inhibition of mouse sarcoma 180 by polysaccharides from Lentinus edodes. Nature. 1969; 222:687-688.
43. Chung KS, Choi EC, Kim BK, Kim YS, Park YK. The constituents and culture of Korean *Basidiomycetes*: antitumor polysaccharides from the cultured mycelia of some *Basidiomycetes*. Archives of Pharmacal Research. 1982; 5:17-20.
44. Cun Z, Mizuno T, Ito H, Shimura K, Sumiya T, Kawade M. Antitumor activity and immunological property of polysaccharides from the mycelium of liquid-cultured Grifola frondosa. Journal of Japanese Society of Food Science Technology. 1994; 41:724-732.
45. Han SB, Lee CW, Jeon YJ, Hong ND, Yoo ID, Yang KH *et al*. The inhibitory effect of polysaccharide isolated from *Phellinus linteus* on tumor growth and metastasis. Immunopharmacology. 1999; 4:157-164.
46. Mo S et al. Phelligridins C-F: Cytotoxic pyrano[4,3-c][2]benzopyran-1,6-dione and furo[3,2-c] pyran-4-one derivatives from the fungus *Phellinus igniarius*. Journal of Natural Products. 2004; 67: 823–828.
47. Bae JS, Jang KH, Yim H, Park SC and Jin HK. Inhibitory effects of polysaccharides isolated from *Phellinus gilvus* on benzo(a) pyrene–induced fore–stomach carcinogenesis in mice. World Journal of Gastroenterology. 2005; 11: 577–579.
48. Collins L, Zhu T, Guo J, Xiao ZJ and Chen C-Y. *Phellinus linteus* sensitises apoptosis induced by doxorubicin in prostate cancer. British Journal of Cancer. 2006; 95: 282–288.
49. Samchai S, Seephonkai P, Sangdee A, Puntumchai A and Klinhom U. Antioxidant, cytotoxic and antimalarial activities from crude extracts of mushroom *Phellinus linteus*. Journal of Biological Sciences. 2009; 9: 778–783.
50. Shnyreva AV, Song W and Van GLJLD. Extracts of medicinal mushrooms *Agaricus bisporus* and *Phellinus linteus* induce proapoptotic effects in the human leukemia cell line K562. International Journal of Medicinal Mushrooms. 2010; 12(2):167-175.
51. Ranadive KR, Jite PK, Ranade VD and Vaidya JG. Flora of *Aphyllophorales* from Pune district-part I. Journal of New Biological Reports. 2013; 2(3): 188–227.
52. Sheena N, Ajith TA, Thomas MA and Janardhanan KK. Antibacterial activity of three macrofungi, *Ganoderma lucidum*, *Navesporus floccosa* and *Phellinus rimosu*s Occuring in South India. Pharmaceutical Biology. 2003; 41(8): 564–567.
53. Hur JM, Chun HY, Seung HH, Sook HL, Yong OY, Jong CP and Kang JK. Antibacterial effect of *Phellinus linteus* against methicillin-resistant *Staphylococcus aureus*. Fitoterapia. 2004; 75: 603–605.
54. Dulger B, Suerdem TB, Yesilyurt D, Hacioglu N and Camdeviren A. Evaluation of antimicrobial activity of macrofungus *Phellinus torulosus.* Journal of Biological Sciences. 2005; 5(4): 436-439.
55. Sittiwet C and Puangpronpitag D. Anti-*staphylococcus aureus* activity of *Phellinus igniarius* aqueous extract. International Journal of Pharmacology. 2008a; 4(6):503-505.
56. Sittiwet C and Puangpronpitag D. Antibacterial activity of *Phellinus gilvus* aqueous extract. International Journal of Pharmacology. 2008b; 4: 500–502.
57. Altuner EM and Akata I. Antimicrobial activity of some macrofungi extracts. SAÜ. Fen Bilimleri Dergisi, 14. Cilt 1. Say. 2010, 45-49.
58. Belsare MH, Bapat, GS, Ranadive, KR, Vaidya JG and Deokule SS. *In-vitro* susceptibility testing of some *Phellinus* species against *Acinetobacter baumannii* from Maharashtra India. Journal of Medicinal Plants Research. 2010; 4(13): 1335-1338.
59. Balakumar R, Sivaprakasam E, Kavitha D, Sridhar S and Kumar J.S. Antibacterial and antifungal activity of fruit bodies of *Phellinus* mushroom extract. International Journal of Biosciences. 2011; 1 (3):72-77.
60. Sonawane H, Bhosle S, Vaidya J, Asghar sharifi A, Garad S, Bapat G and Belsare M. *In vitro* evaluation of sesquiterpenoid extracts of *Phellinus* samples from western ghats of Maharashtra for antimicrobial activity. Journal of Phytology. 2011; 3(6):35-37.
61. Ayala-Zavala JF, Silva-Espinoza BA, Cruz-Valenzuela MR, Villegas-Ochoa MA, Esqueda M, González-Aguilar GA, Calderón-López Y. Antioxidant and antifungal potential of methanol extracts of *Phellinus* sp. from Sonora, Mexico. Revista Iberoamericana Micologia. 2012; xxx(xx):xxx-xxx
62. Belsare MH, Ranadive K, Bapat G, Garad S, Subhash, Deokule SS, Vaidya J. Screening of mushroom *Phellinus switeniae* (Murr.) S. Herrera and Bondart against clinical isolates of *Acinetobacter baumannii* Bouvet & Grimont. Elixir Applied Botany. 2013; 54: 12398–12399.
63. Yim NH, Jung YP, Cho WK, Kim T, Kim A, Im M and Ma JY. Screening of aqueous extracts of medicinal herbs for antimicrobial activity against oral bacteria. Integrative Medicine Research. 2013; 2: 18–24.
64. Nedelkoska DN, Pančevska NA, Amedi H, Veleska D, Ivanova E, Karadele M, Kungulovsk, D.. Screening of antibacterial and antifungal activities of selected macedonian wild mushrooms. Jour. Nat. Sci, Matica Srpska Novi Sad, No. 2013; 124: 333–340.
65. Kim SH, Song YS, Kim SK, Kim BC, Lim CJ and Park EH. Anti-inflammatory and related pharmacological activities of the n–BuOH subfraction of mushroom *Phellinus linteus.* Journal of Ethnopharmacology. 2004b; 93: 141–146.

66. Kim BC, Choi JW, Hong HY, Lee SA, Hong S, Park EH, Kim SJ and Lim CJ. Heme oxygenase-1 mediates the anti-inflammatory effect of mushroom *Phellinus linteus* in LPS-stimulated RAW264.7 macrophages. Journal of Ethnopharmacology. 2006; 106:364-371.
67. Chang ZQ, Oh BC, Rhee MH, Kim JC, Lee SP, Park SC. Polysaccharides isolated from *Phellinus baumii* stimulate murine splenocyte proliferation and inhibit the lipopolysaccharide induced nitric oxide production in RAW264.7 murine macrophages. World Journal of Microbiology and Biotechnology. 2007b; 23:723-727.
68. Park H-J, Han ES, Park DK, Lee C and Lee KW. An extract of *Phellinus linteus* grown on germinated brown rice inhibits inflammation markers in RAW264.7 macrophages by suppressing inflammatory cytokines, chemokines, and mediators and up-regulating antioxidant activity. Journal of Medicinal Food. 2010; 13(6):1468-1477.
69. Song KS, Cho SM, Lee HM, Kim SB, Han KSKO, Yoo ID. B-lymphocyte-stimulating polysaccharide from mushroom *Phellinus linteus*. Chemical and pharmaceutical Bulletin. 1995; 43:2105-2108.
70. Kim HM, Han SB, Oh GT, Kim YH, Hong KH, Hong ND and Yoo ID. Stimulation of humoral and cell mediated immunity by polysaccharide from mushroom *Phellinus linteus*. International Journal of Immunopharmacology. 1996; 18:295-303.
71. Matsuba S, Matsuno H, Sakuma M, Komatsu Y. *Phellinus linteus* Extract Augments the Immune Response in Mitomycin C-Induced Immunodeficient Mice. eCAM: Evidence based complement alternative medicine. 2008; 5(1):85-90.
72. Won TJ, Kim MS, Woo JS, Han SB, Hwang KW. Hematopoietic Effect of *Phellinus linteus* Polysaccharide in mouse splenocytes and bone marrow cells. The Journal of Applied Pharmacology. 2007; 15:230-234.
73. Lim BO, Yamada K, Cho B-G, Jeon T, Hwang S-G, Park T, *et al*. Comparative study on the modulation of IgE and cytokine production by *Phellinus linteus* grown on germinated brown rice, *Phellinus linteus* germinated brown rice murine splenocytes. Food Science and Biotechnology. 2004; 68(11):2391-2394.
74. Li X, Li LJ, Xu Z, Wen MT, Shan C, Li PZ. Anti-tumor and immunomodulating activities of proteoglycans from mycelium of *Phellinus nigricans* and culture medium. Interbnational journal of Immunopharmacology. 2008; 8:909-915.
75. Inagaki N, Shibata T, Itoh T, Suzuki T, Tanaka H, Nakamura T, *et al*. Inhibition of IgE-dependent mouse triphasic cutaneous reaction by boiling water fraction separated from mycelium of *P. linteus*. Evidence Based Complement Alternative Medicine. 2005; 2:369-74.
76. Oh GS, Lee MS, Pae HO, Kwon J, Lee SS, Jeong JG, *et al*. Effects of oral administration of *Phellinus linteus* on the production of Th1- and Th2- type cytokines in mice. Immunotoxicology. 2006; 28:281-293.
77. Kim GY, Kim SH, Hwang SY, Kim HY, Park YM, Park SK, *et al*. Oral administration of proteoglycan isolated from *Phellinus linteus* in the prevention and treatment of collagen-induced arthritis in mice. Biological and Pharmacological Bulletin. 2003a; 26:823-31.
78. Min BS, *et al*. Two novel furan derivatives from *Phellinus linteus* with anti-complement activity. Bioorganic and Medicinal Chemistry Letters. 2006; 16:3255-3257.
79. Rajeshwari S, Kriushnapriya S. Anticancer activities of phytochemicals from a wood rot Mushroom *Phellinus adamantinus* - *in silico* and *in vitro* approach. International Conference on Bioscience, Biochemistry and Bioinformatics (IPCBEE). IACSIT Press, Singapore. 2011; 5:198-202.
80. Seo JH, Sung YH, Kim KJ, Sheen MS, Lee EK, Kim CJ. Effects of *Phellinus linteus* administration on serotonin synthesis in the brain and expression of monocarboxylate transporters in the muscle during exhaustive exercise in rats. Journal of Nutritional Science and Vitaminology. 2011; 57:95-103.
81. Liu Y, Kubo M, Fukuyama Y. Nerve growth factor-potentiating benzofuran derivatives from the medicinal fungus *Phellinus ribis*. Journal of Natural Products. 2012; 75(12):2152-2157.
82. Lee JS, Shin DB, Lee SM, Kim SH, Lee TS, Jung DC. Melanogenesis inhibitory and antioxidant activities of *Phellinus baumii* methanol extract. Korean Journal of Mycololgy. 2013; 41:104-111.
83. Luong KVQ, Nguyen LTH, Nguyen DNP. The role of vitamin D in protecting type 1 diabetes mellitus. Daibetes Metabolism Research Review. 2005; 21:338-346.
84. Harding AH, Wareham NJ, Bingham SA, *et al*. Plasma vitamin C level, fruit and vegetable consumption and the risk of new onset type 2 diabetes mellitus: The Europen prospective investigation of cancer–Norfolk prospective study. Archives of International Medicine. 2008; 168:1493-1499.
85. Martin C. Therole of Vitamins in prevention and treatment of type 2 diabetes and its complications. Journal of Diabetes Nursing. 2013; 17:376-83.
86. Seephonkai P, Samhai S, Thongsom A, Sunaart S, Kiemsanmuang B, Chakuton K. DPPH radical scavenging activity and total phenolics of *Phellinus* mushroom extracts colleted from northeast of Thailand. Chinese Journal of Natural Medicine. 2011; 9(6):0441-0445.
87. Tanaka S, Yoshimura Y, Kawasaki R, *et al*. Fruit intake and incident diabetic retinopathy with type 2 diabetes. Epidemiology. 2013; 24:204-211.
88. Ajith TA, Janardhanan KK. Antioxidant and antiinfammatory activities of methanol extract of *Phellinus rimosus*. Indian Journal of Experimental Biology. 2001; 39:1166-1169.
89. Deng K, Zhang Y, Ren Z, Xie L, Peng W, Gan B. Simultaneous determination of five fatty acids in *Phellinus* sp. by high-performance liquid chromatography with photodiode-array method. Journal of Medicinal Plants Research. 2011; 5(3):2816-2821.
90. Azeem U, Dhingra GS, Shri R. Taxonomic, physicochemical and biochemical evaluation of *Phellinus allardii* (Bres.) S. Ahmad. Asian Journal of Science and Technology. 2016; 7(10):3646-3654.
91. Azeem U, Dhingra GS, Shri R. Evaluation of taxonomy, physicochemical parameters, and mycochemical composition of wood decaying Indian fungi *Phellinus gilvus* (Schwein.) Pat. and *Phellinus torulosus* (Pers.) Bourdot & galzin: A comparative study. International Journal of Phytopharmacy Research. 2018; 9(1):17-25.
92. Kalač P. Chemical composition and nutritional value of European species of wild growing mushrooms: A review. Food Chemistry. 2009; 113:9-16.
93. Wang XM, Zhang J, Wu LH, Zhao YL, Li T, Li JQ *et al*. A mini-review of chemical composition and nutritional

value of edible wild-grown mushroom from China. Food chemistry. 2014; 151:279-285.
94. Wu XL, Lin S, Zhu CG, Yue ZG, Yu Y, Zhao F *et al*. Homo-and heptanor-sterols and tremulane sesquiterpenes from cultures of *Phellinus igniarius*. Journal of Natural Products 2010; 73:1294-1300.
95. Yin RH, Zhao ZZ, Chen HP, Yin X, Ji X, Dong ZJ *et al*.. Tremulane sesquiterpenes from cultures of the fungus *Phellinus* igniarius and their vascular-relaxing activities. Phytochemistry Letters. 2014; 10:300-303.
96. Nagadesi PK, Aravind G, Kannamba B. Taxonomy and Bioactive chemicals from *Ganoderma* and *Phellinus* of India. An international Journal. 2016; 8(2):240-246.
97. Jeong SC, Cho SP, Yang BK, Jeong YT, Ra KS, Song CH. Immunomodulating activity of the exopolymer from submerged mycelial culture of *Phellinus pini*. Journal of Microbiology Biotechnology. 2004; 14:15-21.
98. Zaidman BZ, Tassin M, Mahajna J, Wasser SP. Medicinal mushroom modulators of molecular targets as cancer therapeutics. Applied Microbiology Biotechnology. 2005; 67:453-468.
99. Shin JY, Lee S, Bae IY, Yoo SH, Lee HG. Structural and biological study of carboxymethylated *Phellinus linteus* polysaccharides. Journal of Agriculture and Food Chemistry. 2007; 55:3368-3372.
100. Kim GY, Roh SI, Park SK, Ahn SC, Oh YH, Lee JD *et al*. Alleviation of septic shock in mice by acidic polysaccharide isolated from *Phellinus linteus*. Biological and Pharmacological Bulletin. 2003b; 26:1418-1423.
101. Bapat G, Vaidya J, Garad S, Bhosle S, Ranadive K, Belsare M. Screening of four species of *Phellinus* and optimizing *Phellinus badius* for biomass and exopolysaccharide production. International Journal of Applied Biology. 2011; 2(2):14-17.
102. Yang Y, Wang Q, Liu Y, Wang W, Feng N, Wu DI. Antioxidant activities of extracts from the genus *Phellinus* species. Proceedings of the 7th International Conference on Mushroom Biology and Mushroom Products (ICMBMP7), 2011, 232-241.
103. Li SC, Yang XM, Ma HL, Yan JK, Guo DZ. Purification, characterization and antitumor activity of polysaccharides extracted from *Phellinus igniarius* mycelia. Carbohydrate Polymers. 2015; 133:24-30.
104. Lu TL, Huang GJ, Lu TJ, Wu JB, Wu CH, Yang TC *et al*. Hispolon from *Phellinus linteus* has antiproliferative effects via MDM2-recruited ERK1/2 activity in breast and bladder cancer cells. Food and Chemical Toxicology. 2009; 47:2013-2021.
105. Lee IK, Yun BS. Styrylpyrone-class compounds from medicinal fungi *Phellinus* and *Inonotus* spp. and their medicinal importance. Journal of Antibiotic. 2011; 64:349-359.
106. Nagatsu A *et al*. Identification of novel substituted fused aromatic compounds, meshimakobnol A and B, from natural *Phellinus linteus* fruit body. Tetrahedron Letters. 2004; 45:5931-5933.
107. Wang Y, Wang SJ, Mo SY, Li S, Yang YC, Shi JG. Phelligridimer A, a highly oxygenated and unsaturated 26-membered macrocyclic metabolite with antioxidant activity from the fungus *Phellinus igniarius*. Organic Letters. 2005a; 7:4733-4736.
108. Wangun HVK, Hertweck C. Squarrosidine and Pinillidine: 3, 3¢-Fused Bis (styrylpyrones) from *Pholiota squarrosa* and *Phellinus pini*. Eurasian Journal of Organic Chemistry. 2007, 329-23295.
109. Wang Y, Mo SY, Wang SJ, Li S, Yang YC. Shi JG. A unique highly oxygenated pyrano[4,3-c][2]benzopyran-1,6-dione derivative with antioxidant and cytotoxic activities from the fungus *Phellinus igniarius*. Organic letters. 2005b; 7:1675-1678.
110. Jung JY, Lee IK, Seok SJ, Lee HJ, Kim YH, Yun BS. Antioxidant polyphenols from the mycelial culture of the medicinal fungi *Inonotus xeranticus* and *Phellinus linteus*. Journal of Applied Microbiology. 2008; 104:1824-1832.
111. Kojima K, Ohno T, Inoue M, Mizukami H, Nagatsu A. Phellifuropyranone A: A new furopyranone compound isolated from fruit bodies of wild *Phellinus linteus*. Chemical and Pharmaceutical Bulletin. 2008; 56:173-175.
112. Lee IK, Seo GS, Jeon NB, Kang HW, Yun BS. Phellinins A1 and A2, new styrylpyrones from the culture broth of *Phellinus sp*. KACC93057P: I. Fermentation, taxonomy, isolation and biological properties. Journal of Antibiotics. 2009; 62:631-634.
113. Sonawane H, Vaidya JG, Garad SA, Bhosle SR. Antioxidant activity of folk medicinal mushroom 'Phansomba' from Western Ghats of Maharashtra (India). Journal of Pharmacy Research. 2012; 5(1):202-204.
114. Sonawane H, Bhosle S, Garad S. Antimicrobial activity of some species of *Phellinus* and *Ganoderma* from Western Ghats of India. International Journal of Pharmaceutical Sciences and Research. 2012b; 3(6):1795-1799.
115. Hwang HJ, Kim SW, Lim JM, Joo JH, Kim HO, Kim HM *et al*. Hypoglycemic effect of crude exopolysaccharides produced by a medicinal mushroom *Phellinus baumii* in streptozotocin-induced diabetic rats, Life Sciences. 2005; 76:3069-3080.
116. Hong SB, Rhee MH, Yun BS, Lim YH, Song HG, Shin KS. Department of clinical laboratory science1. 2016. Synergistic anti-bacterial effects of *Phellinus baumii* ethyl acetate extracts and β–Lactam antimicrobial agents against Methicillin–resistant *staphylococcus aureus*. Annals of Laboratory Medicine. 2016; 36:111-116.
117. Kim DH, Yang BK, Jeong SC, Park JB, Cho SP, Das S *et al*. Production of a hypoglycemic, extracellular polysaccharide from the submerged culture of the mushroom, *Phellinus linteus*. Biotechnology Letters. 2001a; 23:513-517.
118. Kim DH, Yang BK, Jeong SC, Hur NJ, Das S, Yun JW *et al*. A preliminary study on the hypoglycemic effect of the Exopolymers produced by five different medicinal mushrooms. Journal of Microbiology and Biotechnology. 2001b; 11(1):167-171.
119. Song YS, Kim SH, Sa JH, Jin C, Lim CJ, Park EH. Anti-angiogenic, antioxidant and xanthine oxidase inhibition activities of the mushroom *Phellinus linteus.* Journal of Ethnopharmacology. 2003; 88:113-116.
120. Nakamura T, Matsugo S, Uzuka Y, Matsuo S, Kawagishi H. Fractionation and anti-tumor activity of the mycelia of liquid-cultured *Phellinus linteus*. Bioscience Biotechnology and Biochemistry. 2004; 68(4):868-872.
121. Lee IK, Lee JH, Yun BS. Polychlorinated compounds with PPAR-gamma agonistic effect from the medicinal fungus *Phellinus ribis*. Bioorganic and Medical Chemistry Letters. 2008b; 18(16):4566-4568.
122. Park BJ, Lim YS, Lee HJ, Eum WS, Park J, Han KH *et al*. Anti-oxidative effects of *Phellinus linteus* and red ginseng extracts on oxidative stress-induced DNA

damage. Biochemistry and Molecular Biology Reports. 2009b; 42:500-505.
123. Jang JS, Lee JS, Lee JH, Kwon DS, Lee KE, Lee SY *et al*. Hispidin produced from *Phellinus linteus* protects pancreatic β-cells from damage by hydrogen peroxide. Archives of Pharmacy Research. 2010; 33(6):853-861.
124. Xue Q, Sun J, Zhao M, Zhang K, Lai R. Immunostimulatory and anti-tumor activity of a water-soluble polysaccharide from *Phellinus baumii* mycelia. World Journal of Microbiology and Biotechnology. 2010; 27:1017-1023.
125. Park IH, Chung SK *et al*. An Antioxidant Hispidin from the mycelial Cultures of *Phellinus linteus*. Archives of Pharmacal Research. 2004; 27:615-618.
126. Feng T, Cai JL, Li XM, Zhou ZY, Li ZH, Liu JK. Chemical constituents and their bioactivities of mushroom *Phellinus rhabarbarinus*. Journal of Agriculture and Food Chemistry. 2016; 64(9):1945-1949.