

A Comprehensive Review on Food and Medicinal Prospects of *Astraeus hygrometricus*

Gunjan Biswas^{1#}, Sudeshna Nandi^{2#}, Debashis Kuila¹, Krishnendu Acharya^{2*}

Gunjan Biswas^{1#}, Sudeshna Nandi^{2#}, Debashis Kuila¹, Krishnendu Acharya^{2*}

¹Department of Botany & Forestry, Vidyasagar University, Midnapore-721102, West Bengal, INDIA.

²Molecular and Applied Mycology and Plant Pathology Laboratory, Department of Botany, University of Calcutta, 35, Ballygunge Circular Road, Kolkata, 700019, West Bengal, INDIA.

Correspondence

Krishnendu Acharya

Molecular and Applied Mycology and Plant Pathology Laboratory, Department of Botany, University of Calcutta, 35, Ballygunge Circular Road, Kolkata, 700019, West Bengal, INDIA.

Phone no: 8013167310

E-mail: krish_paper@yahoo.com

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ABSTRACT

Edible mushrooms contain unique flavours and textures. They have high nutritional and medicinal values and have been consumed worldwide. *Astraeus hygrometricus* (Pers.) Morg. a wild ectomycorrhizal mushroom recognized as a food by the local people in South-East Asia as well as in Bihar, Jharkhand, South west India and South-Western region of West Bengal. However, it is considerably unknown to the communities in other parts of the world and it remains underutilized so far. Recent investigations from our laboratory have manifested the potential role of this mushroom in human health. Basidiocarps of *A. hygrometricus* are rich in proteins, carbohydrates, minerals, crude fibre and essential amino acids with lower concentration of fat. Experiments on animal models reveal the hepatoprotective, cardioprotective, anti-inflammatory, anticancer and hypoglycaemic efficacy of the mushroom. Additionally, researchers have found this taxon to contain many bioactive compounds shown to be responsible for antitumor, anti-leishmanial, anticandidal, antioxidant and immunomodulatory activity. The present review, summarized the scattered literature on *A. hygrometricus* with an emphasis on its nutritional and health promoting aspects.

Key words: Antioxidant, Astrakurkurone, Immunomodulation, Medicinal Mushroom, Nutritive Value.

INTRODUCTION

Mushrooms well recognized for their nutritional and culinary values¹ are historically familiar as essential part of human health and nutrition as a substitute to plant and animal-derived products.² Traditionally they have been used worldwide as resources of food and medicines³ and have huge potentiality in coming days to be used as regular therapeutic food.⁴ Edible mushrooms are low calorie-low fat food supplement with generous amount of proteins, carbohydrates, vitamins, minerals amino acids⁵ and dietary fibre.⁶ Mushroom usually possess antibacterial, antifungal, antiviral, antiparasitic, antioxidative, anti-inflammatory, antiproliferative, anticancer, anti-HIV, hypo-cholesterolemic, antidiabetic and anticoagulant activity.^{7,8} This review focuses on a particular mushroom, *Astraeus hygrometricus*, the incorporation of which in regular diet will be beneficial for human health and may be exploited as a good source of medicinal product.

Astraeus is the most common gasteromycete genera observed in temperate and tropical ecosystems.⁹ Till date, up to 10 species have been recorded from all around the world, distributed especially in the sandy soils of forests of Africa, Asia, Australia, Europe, Mexico, North America and South America.¹⁰ Morgan (1889) first identified *Astraeus* as a distinct genus with *A. hygrometricus* (Pers.) Morgan as the type and only species.¹¹ In India *A. hygrometricus* was first identified by Ahmad.¹²

Astraeus hygrometricus commonly known as false earthstar is an ectomycorrhizal¹³ non-cultivable wild edible mushroom, belonging to Astraeaceae family^{14,15}, growing symbiotically with the *Shorea robusta* G.f. roots during monsoon and post monsoon period in slightly acidic (pH 5.5 - 6.0) red lateritic forest soil and sandy loam soil¹⁶ Figure 1. Despite worldwide distribution of the genus, the geographical distribution of *A. hygrometricus* observed as a constricted one, dispersed mainly in China, India¹⁷ Laos, Northern Thailand¹⁸ Southern France, Trukey¹⁹ and Argentina.²⁰

Presently vast scientific data on the nutritive and medicinal attributes of this mushroom have been offered and each of the aspects will be detailed in the following sections. *Astraeus hygrometricus* being a potential mushroom with edibility and therapeutic value has not been studied so much. So, this review proposes to provide a comprehensive information on the macrofungus as a valuable health promoting medicinal food so that it serves as a ready-to-use material for further research on this mushroom.

NUTRITIONAL ATTRIBUTES

Since antiquity man has been stalking for wild mushrooms as a source of food due to their chemical composition which is quite appealing from the

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Table 1: Macronutrients and energy content of *Astraeus hygrometricus*. Food energy is calculated using the equation: FE = (% CPX4) + (% lipids X 9) + (% COH X4).

Parameter analysed	Quantity	Reference
Moisture	83.87% (full body)	[25]
Carbohydrate	64.33 + 3.23 g/100 g dry weight	[27]
	29.48% (outer part)	[25]
	35.41% (inner part)	
Soluble Carbohydrate	54.4 % dry weight (mature)	[28]
	44.9 % dry weight (young)	
Protein	31.98 + 3.66 g/100 g dry weight	[25]
	16.47 + 1.35 g/100 g dry weight	[27]
	11.71% (outer part)	[25]
Free amino acid	4.66% (inner part)	
	6.48 + 0.90 g/100 g dry weight	[27]
Fat	3.20 + 0.85 g/100 g dry weight	[27]
	4.4±0.18 % dry weight (mature)	[28]
	2.7±0.05 % dry weight (young)	
	1.04% (outer part)	[25]
Ash	0.24% (inner part)	
	2.5% (full body)	[25]
	14.2±0.45 % dry weight (mature)	[28]
Fibre	27.6±0.29 % dry weight (young)	
	10.80 + 1.02 g/100 g dry weight	[27]
	12.3±0.28 % dry weight (mature)	[28]
	10.8±0.16 % dry weight (young)	
	0.02 (outer part)	[25]
Energy	0.13 (inner part)	
	336.74 g calories	[25]

nutrition point of view. Numerous species of wild growing mushrooms are extensively preferred to consume as a delicacy over cultivated fungi in many countries of Asia²¹ and central and eastern Europe.²² But credible estimation of the nutritive value of the wild growing mushrooms has so far been restricted due to scattered knowledge of their composition and confined report on the availability of their constituents.²² The role of *A. hygrometricus* as food, is considered to be of immense value as local people consume this mushroom with a belief that it cures several age-related disorders.²³ Nutritional data accumulated here provide a chemical basis for the health benefits of consuming *A. hygrometricus*.

Evaluating the nutritive value of mushrooms, the most vital factor is their moisture content, which directly affects the nutrient contents of mushrooms.²⁴ The moisture content estimated in *A. hygrometricus* was 83.87% which falls in the range (80-90%) characterized by researchers.²⁵

In dry matter constituent of mushroom, carbohydrates are present in the greatest amounts and forms the major part of mushroom nutrients constituting of about 50-65%.²⁶ Findings reveal that, on a dry weight basis, the basidiocarp as a whole is found to be rich in carbohydrate. The total carbohydrate content of *A. hygrometricus* was estimated to contain between 44.9-64.89%^{25-27,28} Table 1. Apart from total carbohydrate content, the soluble carbohydrate content of the mushroom is also determined to be 31.98 ± 3.66 g/100 g of dry tissue.²⁷ Edible mushroom usually contain both sugars and sugar alcohol. In fungal taxa sugar composition generally varies within species.²⁶ Studies revealed that *A. hygrometricus* include many sugars such as D-Glucose, D-Fructose, Trehalose, D-Mannose, D-Ribose, D-Arabinose, D-Xylose and D-Fucose

at a concentration of 0.88, 0.85, 0.50, 0.26, 0.12, 0.21, 0.03 and 0.10 mg/g dry wt. respectively and also include sugar alcohols like Mannitol, Glycerol, Myo-Inositol and Meso-Erythritol in it at a concentration of 6.52, 0.12, 0.14 and 0.02 mg/g dry wt. respectively²⁸ whereas galactose was initially measured with the help of paper chromatography.²⁹

Nutritive value of mushroom is predominantly related to their protein content as protein is a vital constituent of dry matter of mushrooms.³⁰ Findings showed that, crude protein content of *A. hygrometricus* do not show much variation and ranged from 14-16.47%^{25-27,28} Table 1. Mushroom protein is familiar to comprise of almost all the essential and few non-essential amino acids. The free amino acid content of this mushroom was 6.48 ± 0.90g/100 g of dry thallus.²⁷

The fat content in mushroom found to be too low as compared to protein and carbohydrate. The accumulated data on crude fat content of *A. hygrometricus* is highly comparable although values vary considerably from 1.28-4.4%^{25-27,28} indicating low fat content.

Based on the crude protein, fat and carbohydrate, the energy content of a food can be estimated. In dry weight, these mushrooms could provide high energy and wild growing mushrooms seem to have higher nutritive value than the cultivated species.³¹ Energy content of *A. hygrometricus* has been calculated to be high (336.74 g calories) declaring the mushroom as nutritionally superior.²⁵

Fresh mushrooms usually consist of both soluble and insoluble fibre. Insoluble fibre found in fresh mushrooms promotes regularity, good bowel health, slow digestion and adds staying power to foods whereas soluble fibre lower low density lipoprotein cholesterol level and combat cardiovascular disease.²⁷ Till date, there are only three reports regarding fibre content of *A. hygrometricus* ranging from 0.15 to 12.3%^{25,27,28} Table 1. Thus, *A. hygrometricus* may be treated as fibre rich high energy-low fat food which help to lose heavy weight, maintain healthy body and prevent different types of common diseases.

Mushroom usually consist of 5-12% of dry matter of ash²² and ash content gives a slight rough idea about the mineral content of fruiting bodies. The ash content of young *A. hygrometricus* was found to be 27.6%²⁸, quite higher than that of some other edible tropical and temperate basidiomes.^{32,33}

The fruiting bodies of mushroom is identified as a best source of vitamins as well as higher level of well assimilated mineral element. Researchers observed that mineral content of wild edible mushrooms were higher than the cultivated ones.^{32,34} In *A. hygrometricus*, two major vitamins i.e., water soluble vitamins, ascorbic acid and thiamine were found to be present in both inner and outer parts in the quantity of 3.26 (outer) and 0.26 (inner) mg/100g and 5.23 (outer) and 3.54 (inner) mg/100g respectively²⁵ and also possess rich source of various minerals that might play important roles in human life. Detail information of mineral content of the edible ectomycorrhizal fungi with associated references are indicated in Table 2.

PHYTOCHEMICALS

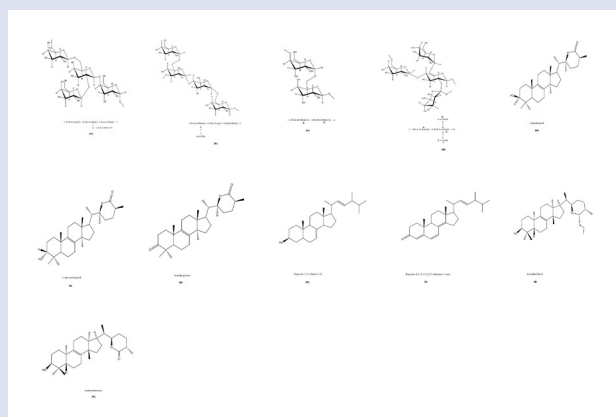
Mushroom own many therapeutic benefits, as they embrace several biologically active compounds. In present day, the secondary metabolites or bioactive compounds isolated from mushrooms have received huge attention for discovering new drugs or lead compounds. The bioactive components from mushrooms are turning into attractive sources of natural antioxidative, antitumor, antiviral, antimicrobial, and immunomodulatory agents.³⁵ In recent times different phytochemicals from *A. hygrometricus* were documented which includes various high and low molecular weight compounds. Most of these phytochemicals were screened for their medicinal possibilities which would be discussed in later sections of this review.

Table 2: Content of selected macro and micro minerals present in *Astraeus hygrometricus*.

Type of mineral	Mineral Name	Quantity	References
Macro	Ca	2.4 mg/g dry weight (mature)	[28]
		0.8 mg/g dry weight (young)	
		29.5 mg/100g (outer part)	[25]
		25.8 mg/100g (inner part)	
	P	2.2 mg/g dry weight (mature)	[28]
		5.7 mg/g dry weight (young)	
		935 mg/100g (outer part)	[25]
		405 mg/100g (inner part)	
	Mg	1.6 mg/g dry weight (mature)	[28]
		1.2 mg/g dry weight (young)	
		242 mg/100g (outer part)	[25]
		11 mg/100g (inner part)	
S	1.7 mg/g dry weight (mature)	[28]	
	5 mg/g dry weight (young)		
K	12.8 mg/g dry weight (mature)	[28]	
	26.1 mg/g dry weight (young)		
	2132 mg/100g (outer part)	[25]	
	1241 mg/100g (inner part)		
Micro	Fe	3254 mg/kg dry weight (mature)	[28]
		2059 mg/kg dry weight (young)	
		2.787 ppm (outer part)	[25]
		2.35 ppm (inner part)	
	Zn	203 mg/kg dry weight (mature)	[28]
		105 mg/kg dry weight (young)	
		0.897 ppm (outer part)	[25]
		0.448 ppm (inner part)	
	Mn	329 mg/kg dry weight (mature)	[28]
		81.7 mg/kg dry weight (young)	
		0.74 ppm (outer part)	[25]
		0.17 ppm (inner part)	
Cu	16.5 mg/kg dry weight (mature)	[28]	
	25.2 mg/kg dry weight (young)		
B	2.4 mg/kg dry weight (mature)	[28]	
	2.4 mg/kg dry weight (young)		

High molecular weight compounds

Polysaccharides, polysaccharide-protein complexes and proteins are the high-molecular-weight (HMW) components obtained from mushrooms, recognized for their biological activities.³⁶ Investigations carried on *A. hygrometricus* showed the presence of different bioactive molecules like lectins, polysaccharides and protein complexes. Yagi *et al* (2000) first reported the presence of lectins from *A. hygrometricus*.³⁷ Later Pramanik and Islam (2000) characterized and introduced the first polysaccharide from the aqueous extract of *A. hygrometricus* containing D-galactose, D-glucose and D-galacturonic acid in the ratio of 1.9:0.9:1 (Figure 2a).²⁹ In later years Maiti *et al* (2008) extracted a water-soluble polysaccharide (Figure 2b) from an alkaline extract of the fruits of *A. hygrometricus* containing D-mannose, D-glucose, and L-fucose in a molar ratio of 1:2:1.³⁸ Similarly another research group isolated water soluble fraction from this macrofungus which on fractionation through chromatography

**Figure 1:** *Astraeus hygrometricus* in wild condition.**Figure 2:** Chemical structures of some phytochemicals isolated from *Astraeus hygrometricus*.

gave two homogeneous fractions. Fraction I (AQSI) identified as a α -(1 \rightarrow 4), β -(1 \rightarrow 6) linked glucan³⁹ (Figure 2c) and Fraction II (AQS-II) (Figure 2d) found to be a hetero polysaccharide containing 63% polysaccharide and 35% protein and the polysaccharide part containing glucose, galactose, and fucose in a 2:1:1 molar ratio.⁴⁰ The molecular weight of these polysaccharide fraction were learnt by a gel-filtration technique and found to be 2.04×10^5 and 22,000 daltons respectively and their structure were established by NMR spectroscopy.^{39,40} Apart from polysaccharide, protein fraction was also obtained from fresh fruiting bodies of *A. hygrometricus* by affinity chromatography and identified as Cibacron blue affinity eluted protein (CBAEP) fraction.⁴¹ This research group further extended their work by isolating a heteroglucan, designating this group of compound as AE2 which featured a high molecular weight and putative β -glucan structure consisting of glucose, galactose, mannose and fucose.⁴²

Low molecular weight compounds

Among various low molecular weight bioactive compounds, polyketides and terpenoids are most often reported from Basidiomycetes and Ascomycetes.⁴³ Takaishi *et al* (1987) isolated three new triterpenes called as Astrahyol, 3-epi-Astrahyol and Astrhygrone (Figure 2e, 2f, 2g) and two known steroids from *A. hygrometricus* and established their structure by chemical and spectroscopic means. Astrahyol ($C_{30}H_{46}O_3$)

showed the presence of two secondary and five tertiary methyl groups implying a lanostane skeleton, H NMR spectrum of 3-epi-Astrahycol ($C_{30}H_{46}O_3$) found very close to that of Astrahycol except that it had a 3- α -hydroxy group instead of 3- β -hydroxy group and Astrhygrone was obtained from the oxidation of Astrahycol and 3-epi-Astrahycol by Jones reagent. The steroids were confirmed as Ergosta-7,22-diene-3-ol (Figure 2h) and Ergosta-4,6,8-(14),22-tetraene-3-one (Figure 2i) by spectral comparison with literature data.⁴⁴ Later Lai *et al* (2012) extracted two new sesquiterpenoids, Astrakurkurool ($C_{32}H_{54}O_3$) and Astrakurkurone ($C_{30}H_{48}O_3$) from the powdered basidiocarp of *A. hygrometricus*. The fractions were isolated by silica gel column chromatography followed by structural elucidation of the compounds by using various spectroscopic techniques. Astrakurkurool (Figure 2j) was isolated as colorless needles whose molecular mass was 486.7 whereas Astrakurkurone (Figure 2k) was isolated as white amorphous powder with a melting point of 195°C.⁴⁵

MEDICINAL PROPERTIES

In traditional ancient therapies, medicinal mushrooms have a significant history of its uses.⁴⁶ In different countries, modern clinical practices are continuing to be rely on mushroom-derived preparations.⁴⁷ *Astraeus hygrometricus* is usually appreciated as herbal medicine in India and China.⁴⁸ Powder form of this mushroom found useful for healing burns, wounds and used as haemastatic agent in Chinese folk medicine.⁴⁵ Apart from nutritional data, scientific evidences acquired from the combination of *in vitro* and *in vivo* study of *A. hygrometricus* has provided a basis for its health-promoting effects. In this section, selected biological activities of *A. hygrometricus* has been discussed in relation to its profess medicinal benefits.

Antioxidative capacity

Organisms with inherent antioxidant defence systems, are usually not capable enough to completely defend oxidation stress-induced damage.⁴⁹ Thereby recently dietary supplements containing synthetic antioxidants such as butylhydroxytoluene (BHT), propyl gallate, tert-butylhydroxyquinone (TBHQ), butylated hydroxyanisole (BHA) and ethoxyquin (EQ), are highly in demand.^{50,51} However, few synthetic antioxidants under definite conditions may cause unfavourable toxic effects.^{52,53} Recent research works have labelled mushroom as a potential source of dietary antioxidants.^{49-54,55}

Astraeus hygrometricus has been immensely studied for its free radical scavenging activity and the resultant IC_{50} values recommend it as a potential defender against radical induced oxidative stress. Biswas *et al* (2010) demonstrated strong *in vitro* antioxidative activity of the ethanolic extract of basidiocarp and was effective for hydroxyl radical scavenging activity, superoxide scavenging activity, DPPH radical scavenging activity, β -Carotene bleaching inhibition assays and lipid peroxidation inhibition assay. The IC_{50} value of these experiments were in the range of 81.2-377.27 μ g/ml.²³ Phytochemically the ethanolic extract was rich in phenolic and flavonoid compound which magnifies the antioxidant capacity of the mushroom.⁵⁶ Biswas *et al* (2010) extended their observation that this mushroom have strong nitric oxide synthase (NOS) activation properties.²³ It has been strongly documented by the modern day scientific literature that both free radical scavenging and NOS activation are the key players for most killer diseases.⁵⁷

Phenolic rich methanolic extract of this mushroom have rich total antioxidant activity (IC_{50} value of 9.3 ± 0.3 μ g/ml).⁵⁸ The phenolic fraction of plants is usually interlinked to their antioxidant and antimicrobial activity. Singh (2010) quantified several phenolic compounds and found this mushroom to be rich in Protocatechuic acid, Ferulic acid, Salicylic acid, Anthralinic acid and Syringic acid. Total phenolic content was also determined spectrometrically as 1.4% in inner and outer part of the

mushroom respectively.²⁵ As *A. hygrometricus* possessed with phenolic compounds it seems to be a potential source of useful biological drugs.

In another study, a comparative method of antioxidant capacity was performed with raw and cooked fruit bodies of *A. hygrometricus* which indicated that antioxidant activity significantly decreased on boiling.⁵⁹ Similar observations were found in South-west India where *A. hygrometricus* is a traditional delicacy. They also investigated that total antioxidant activity decreased upto one-third in cooked mushroom.⁶⁰ After knowing the fact that cooking process reduced the antioxidant activity, it is recommended to consume boiled mushroom tissue as well as their broth to regain some antioxidant activity and retain its nutritive value.

Antimicrobial and Antiparasitic activity

Antimicrobial agents are widely and often indiscreetly used for therapeutic purposes worldwide.⁶¹ Emergent resistance of microorganisms against antibiotics due to non-selective use of commercial antimicrobial drugs has generated a serious clinical problem in the treatment of infectious diseases.^{62,63} Numerous compounds extracted from mushrooms were reported to own desirable antifungal and anti-bacterial activity.^{64,65}

Antimicrobial activity of this macrofungus was tested with different extracts against *Bacillus cereus*, *Bacillus subtilis*, *Candida albicans*, *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Results indicated that *A. hygrometricus* have a narrow range of antimicrobial activity and among the tested strain, *Bacillus cereus*, *Escherichia coli* and *Staphylococcus aureus* were the most susceptible bacteria. All the extracts showed different levels of sensitivity towards the pathogenic microbes in *in vitro* condition and because of low antimicrobial activities of all the extracts, the minimal inhibitory concentration was not analysed.⁵⁶ Similar antimicrobial activity was tested with methanolic extract against three gram negative bacteria namely *Proteus vulgaris*, *Escherichia coli*, *Pseudomonas aeruginosa* and a yeast *Candida albicans* which exhibited strong inhibitory activity.⁶⁶ Further extension of this observation lead to the isolation of two pure lanostane type triterpenoid which showed remarkable anticandidal activity against the pathogenic strain, *Candida albicans*, which is completely resistant to antifungal drugs such as nystatin, fluconazole, and amphotericin-B.⁴⁵

Leishmania donovani, a harmful protozoan parasite is the causative agent of visceral Leishmaniasis that has caused high morbidity and mortality throughout the world. Antileishmanial drugs that are available in market, have raised questions due to their ineffectiveness, severe toxicity and side effects.⁶⁷ Mushroom and its metabolites are developing as cost-effective alternative therapeutic strategy against *Leishmania donovani*.^{68,69}

Mallik *et al* (2014) first worked with different extracts of *A. hygrometricus* to understand its anti-leishmanial activities where they had demonstrated that terpenoid fraction (AHFa) significantly seize the proliferation of *L. donovani* promastigotes *in vitro* by inducing apoptosis and water soluble polysaccharide fraction (AHFb) inhibited intracellular amastigotes *in vitro* by considerably releasing the essential anti-leishmanial molecule, NO and pro inflammatory cytokine IL-12.⁶⁸ Previously Lai *et al* (2012) made a preliminary study using an active compound Astrakurkurone which have exhibited a significant promastigocidal activity against *Leishmania donovani* promastigotes.⁴⁵ The mechanism behind the promastigocidal activity of astrakurkurone was unveiled by Mallik *et al* (2015) where the proliferation of *L. donovani* promastigotes were inhibited by astrakurkurone by selective ROS production leading to mitochondrial dysfunction as well as depleting reduced glutathione. Astrakurkurone seen to be quite effective against clinically important intracellular amastigotes, with significant low IC_{50} of 2.5 μ g/ml.⁶⁹ Further extension of their study demonstrated that astrakurkurone boost the immune efficiency of host cells by generating protective cytokines, interleukin 17 and γ -interferon leading to parasite clearance both

in vitro and *in vivo*. Above that, astrakurkurene was found safe for immunosuppressive patients with visceral leishmaniasis.⁷⁰ Thus, detailed study against promastigotes opened an evident possibility for astrakurkurene as a potential source of non-toxic anti-leishmanial molecule.

Anti-diabetic activity

Diabetes mellitus, or simply, diabetes is a life-threatening chronic metabolic disease affecting more than 180 million people worldwide, is caused by lack of insulin or insulin dysfunction, characterized by higher level of glucose in blood.^{71,72} Mushroom extracts were widely used as an ideal therapeutic food for diabetic patients due to their high fibre and low-fat content.⁷³

Study showed a remarkable hypoglycemic action of ethanolic extract produced from *A. hygrometricus* on alloxan-induced diabetic mice. Orally administered ethanolic extract at a dose of 500 mg/kg of body weight decreased the blood glucose levels in both acute and subacute study. The dose seemed to improve the tolerance for glucose signifying augmented peripheral glucose utilization in the animal model at the time of the oral glucose tolerance test.⁷⁴ Moreover, it was found that mushrooms with higher amount of mannitol are considered as a useful food for diabetic patient and *A. hygrometricus* found to contain higher amount of mannitol.²⁸ Hence *A. hygrometricus* when taken in adequate quantities can serve as medicinal food for diabetic patient.

Hepatoprotective activity

Liver damage being a global disorder usually caused by oxidative stress,⁷⁵ alcohol, carbon tetrachloride, galactosamine, paracetamol; chemotherapeutic agents and antitubercular drugs are causing hepatotoxicity and severe liver damage.^{76,77} Throughout the world, studies have revealed that natural antioxidants may function in curing certain hepatic damages.⁷⁸ Hepatoprotective properties have also been reported for mushroom extracts and mushroom-derived molecules.⁷⁵

Current studies of Biswas *et al* (2011) revealed the hepatoprotective action of the ethanolic extract of *A. hygrometricus* against CCl₄ induced chronic hepatotoxicity in animal model. Results indicated that antioxidants present in the extract might terminate the chain reaction cascade of CCl₄ intoxication by scavenging the intermediates free radicals. Treatment with extract decreased the serum markers like glutamate pyruvate transaminase, glutamate oxaloacetate transaminase, bilirubin and alkaline phosphatase towards normal as well as augmented the antioxidant defence enzymes of liver. Histopathological studies also supported the data.⁷⁹

Cardioprotective activity

Cardiac hypertrophy and ensuing heart failure is one of the most recognized sources of death in worldwide.⁸⁰ Nitric oxide, an inhibitor of platelet aggregation has been reported to develop favourable effects under various cardiovascular conditions through the increase of both cyclic AMP and GMP levels that inhibits platelet aggregation both *in vitro* and *in vivo*.⁸¹ Mushrooms are an upcoming component in the development of dietary supplements and functional foods that are now utilised to prevent cardiovascular problems. The fatty acid profiles of various mushroom seem to contribute to the reduction of cholesterol levels in the serum.^{82,83}

In view of Biswas *et al* (2011) ethanolic extract of *A. hygrometricus* can inhibit platelet aggregation, prostaglandin synthesis and stimulate NO synthesis in human blood platelets thereby reducing the incidence of myocardial infarction, cardiac hypertrophy and vascular death among patients with cardiovascular ailment.⁸¹ This suggest that ethanolic extract of *A. hygrometricus* might have a role in preventing the development and progression of coronary artery disease as well as might act as fresh remedial approach against cardiac hypertrophy.

Immunomodulatory activity

In recent time, many bioactive compounds were isolated from mushrooms and among which immunomodulators have gained much attraction based on their rising growth in the immunotherapy sector. Mushroom being natural source of immunomodulating agent are safer substitutes to chemical drugs in medicine.⁸⁴

Water-soluble Fraction I, isolated from the aqueous extract of the *A. hygrometricus* fruit bodies exhibited strong splenocyte activation at a dose of 10ng/mL and stimulates T cells, B cells, macrophages, and thereby promote the immune responses.³⁹ Another polysaccharide designated as AE2 studied for macrophage-stimulating activity displayed enhanced production of nitric oxide and cytokines. AE2-treated macrophages showed amplified phagocytic potential⁴² and activated immune cells as well as enhanced cytokine production from splenocytes in *in vitro* culture.¹⁷

Protein fraction, Cibacron blue affinity eluted protein (CBAEP) isolated from this mushroom had a stimulatory effect on splenocytes, thymocytes and bone marrow cells within the animal model. Further it intensified the mouse natural killer cell cytotoxicity and activated macrophages to produce NO.⁴¹ These findings will be useful in considering *A. hygrometricus* as a possible source of an immunomodulator. Mushroom-derived polysaccharides are usually being explored for therapeutic properties for a prolong time, but their way of action of immunomodulatory properties is not well established. Macrophages and monocytes recognize glucans or heteroglucans through the interaction with cell surface receptors such as Scavenger receptors, Dectin1, Toll-like receptors⁸⁵⁻⁸⁷ and activate Akt, MAPKs (mitogen-activated protein kinases) pathway. Mallick *et al* (2011) documented the involvement of p38 MAPK pathways, PKC, MEK (MAPK/ERK kinase), ERK1/2 and JNK in the activation of RAW cells using AE2, whereas it failed to induce phosphorylation of JAK2/STAT1 pathway.⁸⁸

Anti-inflammatory activity

Inflammation is regarded as the complex biological response to expel injury or harmful stimuli such as pathogens, damaged cells or irritation⁸⁹ and found to be involved in the development of several chronic diseases such as arthritis, arteriosclerosis, obesity, diabetes, neurodegenerative diseases and cancer.⁹⁰ The nonsteroidal anti-inflammatory drugs that are commonly administered to reduce inflammation in the body have shown to possess significant side effects.^{91,92} Present studies demonstrated that presence of bioactive compounds in whole mushrooms and their extracts may present efficacious anti-inflammatory activity.⁹⁰ Ethanolic extract of *A. hygrometricus* exhibited noteworthy anti-inflammatory effect as demonstrated by Biswas *et al* which is very much comparable to that of nonsteroidal anti-inflammatory drugs. Phytochemically the extract is rich in phenol and flavonoids which enhance the capacity to prevent both acute and chronic inflammation in laboratory animal model where acute oedema was induced by carrageenan and dextran and chronic inflammation in paw was induced by formalin.⁹³

Anticancer activity

Cancer is the second largest cause of death in worldwide in people of various ages and background. The common anti-cancer drugs accessible in market produce various side-effects and create hurdle in clinical management.⁹⁴ Selected mushrooms of higher Basidiomycetes known to be effective against cancer for many years⁹⁵ and its antitumor activity has been first demonstrated by Lucas *et al* (1957).⁹⁶ In recent years, the notable effect of mushrooms and their metabolites drawn the attention of scientists for their antineoplastic activity.⁹⁷

Astraeus hygrometricus demonstrated strong chemopreventive activity as explained by Biswas *et al* (2012). Ethanolic extract containing chemopreventive agents strongly inhibited cancer by initiating cell cycle de-regulation and apoptosis on Ehrlich's ascites carcinoma cells grown in

animal model. The apoptogenic action of the extract might be expressed as a result of the occurrence of antioxidant phenolic and flavonoid compounds.⁹⁸ Furthermore, the same ethanolic extract of *A. hygrometricus* was found as a powerful activator of NOS enzyme²³ and it had been formerly reported that nitric oxide synthase (NOS) activation had an inhibitory effect on various types of cancers including Ehrlich's ascites carcinoma.^{99,100} This might be an added value on the inhibition of Ehrlich's ascites carcinoma.

Heteroglucan, AE2 obtained from *A. hygrometricus*, exhibited significant antitumor activity. It was noted that administration of AE2 to tumour-bearing mice significantly reduced the tumour growth, prolonged their survival rate and instigated the reversal of tumour-mediated immunosuppression.¹⁰¹ However, the underlying mechanism of immunostimulation wants further investigation. In another study the bioactive protein fraction, CBAEP from *A. hygrometricus* showed antiproliferative properties in a mouse model through the induction of apoptosis in tumor cell lines of Mouse melanoma (B16-F0), colon cancer (HT-29), HeLa, Dalton's lymphoma (DL) and sarcoma-180.⁴¹

CONCLUSION

Although limited number of investigations were carried on medicinal and nutritional aspects of *A. hygrometricus*. But from this literature review, it's evident that *A. hygrometricus* have tremendous potentiality in preventing many human ailments. Many endeavours are needed to explore this mushroom, as various bioactive compounds have been identified from this macrofungus but only a few of them are known with their biological activities, so further in-depth study should be carried on the mechanism of action as data in this regard is not satisfactory. Additional work should be directed with this indigenous mushroom to explore the possibility of its utilization or domestication for further processing and their utilization in nutraceutical preparations.

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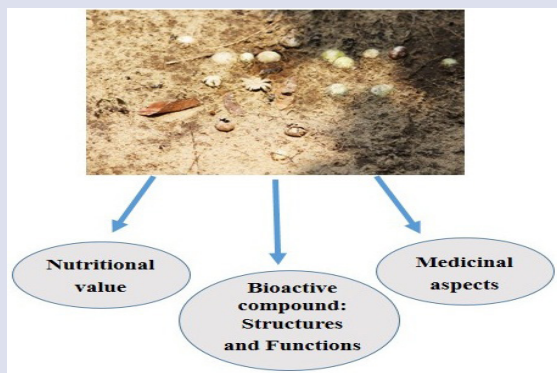
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GRAPHICAL ABSTRACT



ABOUT AUTHORS



Gunjan Biswas, Ph.D., Assistant Professor, Department of Botany & Forestry, Vidyasagar University, Midnapore, West Bengal, India.



Sudeshna Nandi, Research Scholar of Molecular and Applied Mycology and Plant Pathology Laboratory, Department of Botany, University of Calcutta, Kolkata, India.



Debashis Kuila, Research Scholar, Department of Botany & Forestry, Vidyasagar University, Midnapore, West Bengal, India.



Krishnendu Acharya, M.Sc, M.Tech, Ph.D., Professor, Molecular and Applied Mycology and Plant Pathology Laboratory, Department of Botany, University of Calcutta, Kolkata, India.

SUMMARY

- *Astraeus hygrometricus*, an ectomycorrhizal edible mushroom, commonly consumed by forest dwellers and ethnic people.
- Basidiocarp of this macrofungi contains considerable amount of carbohydrate, protein, fibre, minerals, vitamins, essential amino acids and very minute concentration of fat.
- *Astraeus hygrometricus* have wide range of medicinal value such as hepatoprotective, cardioprotective, anti-inflammatory, hypoglycaemic, antitumor, anti-leishmanial, anticandidal, antioxidant and immunomodulatory activity which has been highlighted to emphasize its importance to the modern scientific community.
- *Astraeus hygrometricus* may emerge as a suitable source for application in nutraceutical, functional food and pharmaceutical industries.

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