STM JOURNALS

International Journal of
Cell Biology and Cellular Functions

Volume 3, Issue 1, 2025
January–June
DOI: 10.37591/IJCBCF

https://journals.stmjournals.com/ijcbcf/

Research IJCBCF

Edible Mushrooms: Management of Diabetes Mellitus and Phytochemical Screening of *Agaricus Bisporus*

Varun Mishra[1,*], Sarbjot Singh[2], Rajneesh Kaur[3], Brij Bhushan[3], Shruti Jaswal[4], Anita Devi[5], Anuneet Kaur[6]

Abstract

A metabolic disease characterized by elevated blood glucose levels; diabetes mellitus affects millions of people. If not treated on time, it causes problems, damage organs, and even life-threatening. Studies have shown that diabetes can be avoided and controlled with a healthy lifestyle that incorporates exercise and a balanced diet. While there are several synthetic medications available to treat this illness using them over an extended period of time is linked to a number of negative effects. As a result, researchers are paying more attention to medicinal plants and herbs since they are seen as a safer option. Edible mushrooms are a type of plant-based therapy that may help with diabetes. They are rich in natural compounds, like fibers, polysaccharides, phenolics, and alkaloids, and have long been known for their anti-diabetic, antioxidant, and cholesterol-lowering properties. The carbohydrates in mushrooms act as prebiotics, helping to change gut bacteria composition and reduce insulin resistance. The etiology of diabetes is covered in this review, along with an explanation of a few possible mushroom species with anti-hyperglycemic properties. It has also been studied how various polysaccharides found in mushrooms affect the composition of gut macrobiotic in animal models of diabetes.

Keywords: Metabolic, mushrooms, diabetes mellitus, T cells, β-cells, cellular processes

***Author for Correspondence**
Varun Mishra
E-mail: varunmishran8@gmail.com

[1]Student, Bachelor of Pharmacy (Final Year), Himachal Pharmacy College, Majhauli (Nalagarh), Himachal Pradesh, India
[2]Associate Professor, Department of Pharmacology, Himachal Pharmacy College, Majhauli (Nalagarh), Himachal Pradesh, India
[3]Associate Professor, Department of Pharmaceutical Chemistry, Himachal Pharmacy College, Majhauli (Nalagarh), Himachal Pradesh, India
[4]Assosciate Professor, Department of Pharmaceutics, Himachal Pharmacy College, Majhauli (Nalagarh), Himachal Pradesh, India
[5]Assistant Professor, Department of Pharmaceutical Chemistry, Himachal Pharmacy College, Majhauli (Nalagarh), Himachal Pradesh, India
[6]Assistant Professor, Department of Pharmacology, Himachal Pharmacy College, Majhauli (Nalagarh), Himachal Pradesh, India

Received Date: March 06, 2025
Accepted Date: March 08, 2025
Published Date: March 10, 2025

Citation: Varun Mishra, Sarbjot Singh, Rajneesh Kaur, Brij Bhushan, Shruti Jaswal, Anita Devi, Anuneet Kaur. Edible Mushrooms: Management of Diabetes Mellitus and Phytochemical Screening of *Agaricus Bisporus*. International Journal of Cell Biology and Cellular Functions. 2025; 3(1): 1–13p.

INTRODUCTION

Diabetes mellitus is a non-infectious endocrine disorder characterized by a disturbance in the metabolism of carbohydrates and is associated with hypoglycaemia [1]. Diabetes mellitus, also known as diabetes, has been connected to diseases that cause sweet urine and muscle loss. The pancreas secretes insulin, a hormone that regulates blood sugar levels. As these levels increase, the pancreas produces insulin, which maintains a steady blood glucose level. Diabetes patients produce either too little or no insulin, which causes hyperglycaemia [2]. Polydipsea, polyuria, polyphagia, weariness, nausea, vomiting, impotence in men, poor wound healing, and blurred eyesight are all signs of diabetes mellitus [3]. Diabetes mellitus which encompasses a range of metabolic illnesses, has become a significant global health concern [4]. Over the past 30 years, it has come to be recognized as a dangerous illness with a high rate of morbidity and mortality. Experts estimate that the number of people with diabetes in India will increase from 31.7 million in 2000 to 79.4 million by 2030 [5]. Reports

from Aroma World indicate that 61.3 million people in India suffer with diabetes, with the majority falling between the ages of 20 and 79. It might have about doubled by 2030. The majority of people with diabetes live in India, frequently known as the diabetes capital of the world, and are both rural and urban dwellers [6]. Because hormones and inflammation behave differently in women, female diabetic patients are more severely affected than male diabetic patients, People with less education are more likely to develop diabetes condition, against those who have received more formal education [7]. Between 2% and 3% of diabetic patients in the UK are hospitalized due to diabetic foot issues, which poses a serious health burden. It is estimated that people with diabetes mellitus have an active foot ulcer, and they may have a 25% lifetime risk of developing one [8]. Diabetes is becoming more common in cities across India. In metropolitan regions, the prevalence of diabetes is around six times higher than in rural ones. Reduced activity, weight gain and stress, dietary changes, malnutrition, alcohol consumption, and virus infections have been the primary causes of diabetes mellitus within the last 20 years [9]. The utmost percentages of people having diabetes are lives in developing countries [10]. Managing diabetic foot ulcers is becoming a growing financial burden, with the UK's National Health Service spending an estimated £580 million in 2010–2011, over half of which went toward community care [11]. Finding a treatment for diabetes mellitus without any adverse side effects is the biggest challenge facing medical professionals. According to the World Ethano Botanical, 800 medicinal plants are used to prevent diabetes mellitus, but only 450 of these have been proven in studies. Of these, 109 medicinal plants have a full mode of action that gives them their anti-diabetic effects. For thousands of years, both professionals and laypeople have used traditional medicinal plants to treat ailments like diabetes, cancer, and heart disease. For centuries, native plants have been used to manage diabetes in both China and India. Books, like Susruta Samhita and Charaka Samhita, are available that go into the phytopharmacology elements of diabetes and its detrimental consequences [12].

Around 15% of diabetics develop foot ulcers at some point, making it one of the most distressing complications of the disease. Diabetes mellitus is associated with various microvascular and macrovascular changes, leading to a range of complications [13].

CLASSIFICATION

Diabetes mellitus is classified into two main types: Type 1 and Type 2. These classifications were later included in the International Nomenclature of Diseases (IND) in 1991 and the tenth edition of the International Classification of Diseases (ICD-10) in 1992 [14].

Type 1 Diabetes Mellitus (T1DM)

Type 1 diabetes is called as insulin-dependent diabetes. It affects around 5% of people with diabetes all over the world, cause when the body has low insulin levels. Type 1 diabetes is divided into two types: (a) immune-mediated and (b) idiopathic. People below 30 with type 1 diabetes need insulin injections to manage their condition. In Type 1 diabetes (T1DM), the immune system's T cells by mistake attack the insulin-producing cells in the pancreas. CD8-positive T cells damage the islet cell membranes, that cause individuals permanently depend on insulin. If blood sugar levels aren't managed properly, they can cause severe complications and even lead to early death. In people with Type 1 diabetes, the immune system mainly targets insulin and a protein called glutamic acid decarboxylase (GAD). The protein GAD is naturally found in both the brain and the insulin-producing islets of the pancreas. In individuals with Type 1 diabetes, GAD acts as an autoantigen, meaning the immune system mistakenly targets it as a threat. The destruction of pancreatic β-cells can occur when autoreactive T cells and autoantibodies attack self-proteins, like GADA significant number of early-onset diseases, including Type 1 diabetes, have a genetic basis [15].

Different people lose β-cells at different speeds, according to the American Diabetes Association (ADA). Type 1 diabetes progresses differently for everyone. Infants often lose β-cells quickly, while adults usually experience a slower decline [16–19].

Type 2 Diabetes Mellitus (T2DM)

Type 2 diabetes is also known as adult-onset diabetes. With insulin resistance as a backdrop, the American Diabetes Association (2014) [20] explains the growing insulin secretor dysfunction. A prevalent characteristic of those with this kind of diabetes is insulin resistance [17]. This type of diabetes has risk factors that can be changed or cannot be changed. High blood pressure, obesity (BMI of 30 kg/m2), increased cholesterol levels, and inactivity are risk factors that can be modified. Non-modifiable risk factors for type 2 diabetes include genetics, family history, age, race, ethnicity, and a history of hyperglycemia, pre-diabetes, and/or gestational diabetes [18]. Often, type 2 diabetes is left untreated for years since it progresses slowly and can lead to long-term consequences. At this early stage, the impacts are clearly not considerable. The body ultimately begins to feel the effects, increasing the risk of various disorders, like microvascular issues. Despite having normal or elevated insulin concentrations, it is plausible to anticipate that these type 2 diabetics' islets of Langerhans β-cells will function normally due to their elevated blood glucose levels, which will result in even higher insulin levels [19]. Long-term diabetes complications affecting the kidneys, eyes, nerves, and blood vessels are the leading causes of illness and death in both Type 1 and Type 2 diabetics. According to Ross and Wilson, risk factors for diabetes include genetics, a sedentary lifestyle, obesity, and aging, particularly in middle-aged and older adults. The causes of diabetes are complex, and affected individuals are more prone to both microvascular and macrovascular complications [20].

GESTATIONAL DIABETES MELLITUS

Gestational diabetes mellitus (GDM) is a condition where glucose intolerance develops or is first diagnosed during pregnancy. Gestational diabetes (GDM) occurs when mothers develop difficulty processing sugar during pregnancy. It can also include those with previously undiagnosed, asymptomatic Type 2 diabetes or those who develop Type 1 diabetes during pregnancy [21].

Other Specific Type (Monogenic Type)

Mutations in the hepatocyte nuclear factor, a liver transcription factor on chromosome 12, are responsible for the most common form of monogenic diabetes, also known as beta-cell genetic abnormalities. Several types of diabetes start with high blood sugar levels, before the age of 25. This type of diabetes is also called maturity-onset diabetes of the young (MODY). Certain medications used for HIV/AIDS treatment or post-organ transplantation can also contribute to diabetes. Some families have genetic defects that impair the conversion of proinsulin to insulin, and these traits are inherited in an autosomal dominant manner. However, monogenic diabetes accounts for less than 10% of all diabetes cases [22].

ROLE OF MUSHROOMS IN DIABETES

It has been found to improve pancreatic function by boosting insulin production in β-cells, which helps lower blood glucose levels. If you have diabetes, you can safely eat mushrooms because they don't cause blood sugar spikes due to their low GI and GL content. Furthermore, the presence of vitamin B and polysaccharides in them may provide extra health advantages, particularly for individuals with diabetes, such as better control over blood sugar and cholesterol. Because mushrooms have a low glycemic index due to their low carbohydrate content, they are a beneficial component for diabetics. Mushrooms help lower blood pressure in two ways, as they are rich in potassium. Patients with diabetes may find that mushrooms are a suitable choice because they are low in calories and carbs. Due to their low glycemic index and possible anti-diabetic qualities, mushrooms may be beneficial for diabetics, according to certain research. Beta-glucans are a form of soluble fiber found in mushrooms, especially shiitake and maitake varieties, which are beneficial for diabetics. Research shows that beta-glucans can help control blood sugar by slowing down carbohydrate absorption and making the body more responsive to insulin. Patients with diabetes should consult their doctor frequently to find out how foods, like mushrooms, fit into their specific diabetes care plan. Keep in mind that although diabetics can include mushrooms in their diet, they should only do so as part of a well-rounded diet. Medication, blood sugar, and the patient's general health are all taken into consideration while creating the meal plan [23].

Polysaccharides from Mushrooms with Anti-Diabetes Potentials

Polysaccharides found in medicinal plants, grains, fruits, vegetables, edible mushrooms, and medicinal foods have several health benefits. These include lowering blood sugar and cholesterol, reducing inflammation, acting as antioxidants, and supporting gut health. These benefits are also linked to a decreased risk of diabetes. Polysaccharides found in mushrooms are naturally occurring substances that we often eat. Researchers have shown a great deal of interest in evaluating the anti-diabetic potential of mushroom polysaccharides because of their low toxicity, easy availability, and several bioactivities. *Cordyceps militaris, H. erinaceus, P. linteus, I. obliquus, C. ventricosum, G. lucidum, and Grifola frondosa* are the mushrooms that are usually studied. Recent research has revealed that several novel polysaccharides derived from a range of mushrooms including *Auricularia auricula*, *Auricularia polytricha*, and *Dictyophora indusiata*, have a number of pharmacological properties linked to potential anti-diabetic effects, such as enhancing hepatic glycogen synthesis, lowering insulin resistance and improving lipid metabolism.

Types of Mushroom Act of Diabetes

Agaricus Bisporus

Agaricus Bisporus (white button mushroom) is rich in dietary fiber and antioxidants, like vitamins C, D, and B (including B12, folates, and polyphenols), which may help support heart health and diabetes management.

Ganoderma Lucidum

The Ganodermaceae family, to which it belongs, is well known for its longevity and health benefits. It is known as "Ligzhi" in China and "Reishi" in Japan. Polysaccharides, organic germanium, β-glucans, phenols, lectins, steroids, lignins, microbials, vitamins, and amino acids are some of its bioactive constituents [24] It is common practice to combine Ganoderma lucidum with Cordyceps sinensis, a fungus believed to boost G. lucidum's efficacy [25].

Lentinus Edodes

The usage of shiitake mushrooms, or Lentinus edodes, to treat colds has been around for hundreds of years. For example, L. edodes is rich in fiber, β-glucans, proteins, lipids, carbohydrates, minerals, vitamins B1, B2, and C, ergosterol, lectins, and lentinans, among other vital components [26]. Shiitake mushrooms have been found to lower blood sugar, protect pancreatic beta cells, and enhance insulin production. Rats with diabetes caused by streptozotocin responded to an ex-polymer of L. edodes by producing more insulin and having lower plasma glucose levels than control rats [27].

Agaricus Blazeimurill

Despite its Brazilian origins, *Agaricus blazeimurill* is now often cultivated in Japan. This mushroom was once believed to boost the immune system, combat diabetes, high cholesterol, and digestive issues, as well as reduce physical and emotional stress. What gives it its bioactivity are mostly polysaccharides, lignins, and ergosterols [28]. It has been demonstrated that the polysaccharides in this mushroom are helpful in the treatment of diabetes through mechanisms, such as (a) Increasing insulin in the blood while lowering glucagon production in the pancreas; (b) use insulin more effectively by reducing insulin resistance and increasing sensitivity to it. (c) blocking the alpha-glucosidase enzyme, which slows down carbohydrate digestion and helps control blood sugar levels; (d) They help by boosting liver glycogen storage and regulating sugar metabolism; (e) glucose production in peripheral tissues, helping to regulate blood sugar levels; and (f) protect the body by neutralizing free radicals and reducing lipid peroxidation, which lowers oxidative stress [29].

Grifola Frondosa

Maitake mushrooms, popular in China, Japan, and Korea, have been enjoyed for centuries in China for their rich flavor. Anti-tumor, anti-diabetic, immune-regulating, and anti-HIV/AIDS/hepatitis properties are all present in these mushrooms. Along with having an effect on diabetic mice's immune systems, they display the hypolipidemic properties and effects of MT-α-glucan [30].

Pulmonarius Pleurotus

This kind of mushroom is nutrient-dense and may prevent diabetes. It contains large amounts of dietary fiber, vitamins, minerals, and polysaccharides. It is a good source of the necessary amino acids as well. Oyster mushrooms' great flavor and excellent nutritional value make them consumed all over the world. They have a number of health advantages and can be cultivated in a variety of climates [31].

Panellus Serotinus

In Japan, it is the most delicious and palatable fungus. This specific mushroom has been shown to have special liver-benefitting properties and to help prevent non-alcoholic fatty liver disease. It's a very valuable fungus known as mukitake. The cap is affixed laterally, and the edge is curved inward. It is 3 to 10 cm wide. The name is derived from the appearance of the cap, which was initially sticky but then spread out like an oyster. Violet, yellow, and olive are among the colors, with traces of dark brown and green [32].

Auricularia Auricular-Judae

Auricularia auricular-judae is widely cultivated in China, Taiwan, Indonesia, Malaysia, Thailand, and the Philippines. Other commonly grown mushroom genera include Flammulina, Auricularia, Lentinula, Pleurotus, and Agaricus. Most Auricularia species are edible and have medicinal benefits. The black fungus Auricula auricula-judae and the mushroom woodear have anticoagulant, cholesterol-lowering, and anticancer properties. Additionally, A. auricula-judae has hypoglycemic properties. These compounds help control how the body processes carbohydrates, lowering blood sugar and insulin levels in people with Type 2 diabetes. Efforts are currently being quantified to determine how these compounds might be used therapeutically for diabetes and other diseases (Table 1) [33].

Table 1. Types of Mushrooms and its family.

S.N.	Types of Mushrooms	Family
1.	*Agaricus bisporus*	Agaricaceae
2.	*Ganoderma Lucidum*	Ganodermataceae
3.	*Lentinus edodes*	Marasmiaceae
4.	*Agaricus blazeimurill*	Basidiomycetes
5.	*Grifola frondosa*	Meripilaceae
6.	*Pulmonarius Pleurotus*	Pleurotaceae
7.	*Panellus serotinus*	Mycenaceae
8.	*Auricularia auricular-judae*	Auriculariaceae

REVIEW OF LITERATURE

The characteristic of diabetes mellitus, a chronic metabolic disease that offers a major risk to life, is hyperglycemia, or increased blood glucose levels. Insulin that is either insufficient or not working properly causes the condition. Millions of individuals throughout the world suffer with diabetes and its complications. Interestingly, it has been shown that changing one's lifestyle can either prevent or delay type 2 diabetes, a serious preventable ailment. Despite their popularity, natural anti-diabetic drugs derived from medicinal plants may have unfavorable side effects and not be able to substantially alter the progression of diabetic complications. For decades, medicinal mushrooms have been researched as potential hypoglycemic and anti-diabetic medications. They are also prized as a traditional source of naturally occurring bioactive compounds [34].

Obesity and diabetes are the most common diseases. Numerous causes contribute to obesity, such as an imbalance in energy expenditure, environmental influences, food choices, and lifestyle decisions. Another effect of obesity is type 2 diabetes mellitus. Although there are many synthetic drugs available to address these conditions, people may experience side effects from them. People are therefore turning to easily available, affordable, and effective natural and herbal medicines. Because edible mushrooms are high in fiber, antioxidants, triterpenoids, alkaloids, and other phytochemicals, people have been

using them to heal a variety of ailments since ancient times. By changing cellular processes, active substances in mushrooms such lentinan KS-2, β-glucan, combelanin, and tremellastin significantly affect obesity and diabetes mellitus [35].

Due to a number of causes, such as a diet heavy in calories and a lack of exercise, obesity is becoming a global epidemic. Obesity is now acknowledged as a medical condition that raises the risk of type 2 diabetes mellitus, cardiovascular disease, and cancer, as well as negatively affecting longevity and quality of life. To address this issue, cost-effective, easily accessible, and safe anti-obesogenic methods are required. Many plants and mushrooms used in traditional Chinese medicine or as nutraceuticals contain antioxidants, fiber, and other phytochemicals with anti-obesogenic and antidiabetic characteristics as a result of the regulation of multiple cellular and physiological pathways [36].

Modern technology is becoming more and more important to human society on a daily basis. there are still three fundamental issues that humanity face and will continue to face: a lack of food, environmental pollution, and deteriorating health. In addition to being able to turn massive waste lignocellulosic biomass into food for humans and mushrooms are also capable of producing important mycomedical and nutriceutical products with several health advantages. If mushroom cultivation could be effectively managed the most important thing is to produce zero emissions. Furthermore, mushroom is based agriculture and industry may provide up new job prospects [37].

For the culinary-medical mushroom Auricularia auricular-judae, the crude polysaccharides were tested for their antibacterial and antioxidant qualities. Precipitation of alcohol and hot water extraction were used to extract these polysaccharides. The optimal conditions for extraction were accomplished at 70 mL/g of liquid to solid, 90 C, 4 hours, and extraction number 4. The greatest result was a crude polysaccharide yield of 6.89% with 76.12% purity. In antimicrobial studies, certain microorganisms and fungi were used. Raw A. auricula-judae was shown to have excellent antibacterial qualities against Escherichia coli and Staphylococcus aureus, but little activity against the other microbes [38].

MATERIAL AND METHODS

Plant Collection and Identification

Fruit bodies of *Agaricus Bisporus* (Figures 1 and 2) mushrooms that grow wild were obtained from the vegetable shop near by Nalagarh. Identification was carried out via review literature.

Preparation of Extracts

90% ethanol is utilized as the solvent in the maceration extraction process. Mushroom powder is extracted by dissolving it in ethanol solvent at a 1(g):10(ml) ratio. After shaking the sample for 48 hours at room temperature with a shaker and it was filtered. Additionally, the extract was evaporated at a temperature of 30–40°C using a rotary evaporator until a crude extract was produced [39].

Figure 1. *Agaricus Bisporus.*

Phytochemical Screening of *Agaricus Bisporus*

Positive and negative results from qualitative analysis of ethanol extract revealed the presence of important phytochemicals as flavonoids, saponins, and alkaloids.

Figure 2. Mushroom (*Agaricus Bisporus*).

Tests for Flavonoids

Alkaline Reagent Test

Flavonoids can be detected by adding a few drops of 2% NaOH solution, which produces a bright yellow color. This color disappears when diluted acid is added (Figure 3).

Figure 3. Alkaline reagent test.

Test for Alkaloids

Methanolic extract should be placed on a china dish. To get rid of the solvent and make sure the china dish is thoroughly dry, keep it over the boiling water bath. Remove the china dish from the water bath once it has dried, and then add enough diluted HCL to dissolve any remaining residue. Filtration is used to remove the remaining residue after the dried residue has been dissolved. Take roughly 2 milliliters of the liquid extract after filtering and place it in each of the two test tubes, one for comparison.

Now take few dropes of Mayer's reagent, Hager's reagent and Wagnar's reagent one by one in one test tube and compare the changes with reference test tube (Figure 4). Formation of cream colour ppt. indicates positive result for Mayer's test, formation of reddish brown ppt. indicates positive result for Wagnar's test and yellow ppt. for Hager's test [40].

Figure 4. Wagnar's test, Mayer's test, Hager's test.

Test for Saponins

Frothing Test

A test tube with 5.0 ml of distilled water and crude plant extract was mixed well. When the foam was forcefully stirred with a few drops of olive oil, saponins were visible in the look of the foam in the presence of saponins (Figure 5) [41].

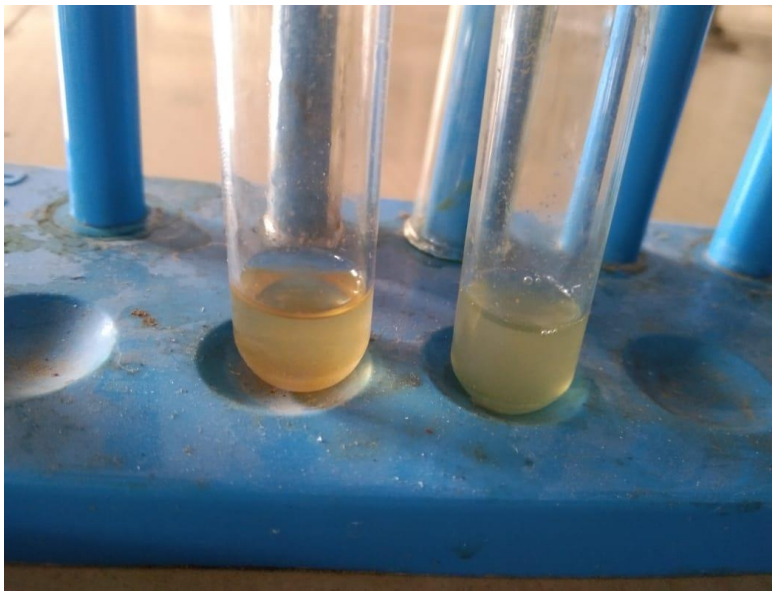

Figure 5. Saponins test.

Pharmacological Action of Mushrooms

Antioxidant

Ascorbic acid, phenolics, flavonoids, glycosides, polysaccharides, tocopherols, ergothioneine, and carotenoids are a few of the substances present in mushrooms that are known to have strong antioxidant properties [42]. A number of antioxidant compounds from mushrooms have been identified and quantified using spectrophotometric techniques, such as gas chromatography (GC), nuclear magnetic resonance (NMR), Fourier transform infrared (FT-IR), UV-VIS spectroscopy, and high performance liquid chromatography (HPLC) [43].

Anticancer

Mushrooms include a variety of bioactive substances, such as proteins, lipids, phenolics, alkaloids, ergosterol, selenium, folate, enzymes, and organic acids. Mushrooms contain several anticancer compounds, including antroquinonol, cordycepin, hispolon, lectin, krestin, polysaccharides, sulfated polysaccharides, lentinan, and Maitake D Fraction [44]. The strongest anticancer and

immunomodulatory chemicals found in mushrooms are called olysaccharides. β-glucan is one type of polysaccharide that is composed of a backbone of glucose residues connected by β-(1→3)-glycosidic bonds, often with side-chain glucose residues attached and linked by β-(1→6) connections [45].

Anti-Inflammatory

A wide range of bioactive substances, including polysaccharides, proteoglucans, terpenoids, phenolic compounds, steroids, and lectins, are produced by edible mushrooms. These compounds have various therapeutic effects, including boosting the immune system, fighting cancer, acting as antivirals, reducing oxidative stress, and lowering inflammation [46]. The concentration and effectiveness of bioactive compounds in mushrooms depend on factors, such as the mushroom species, growth substrate, cultivation and fruiting conditions, development stage, freshness, storage conditions, and processing or cooking methods [47].

Anti-Aging

Traditional Chinese medicine has utilized reishi mushrooms, sometimes known as the "fungus of immortality," for thousands of years to slow down and avoid the effects of aging [48].

Anti-Tumor

It has long been believed that mushrooms are both edible and therapeutic because several species have been found to have anticancer compounds. The most well-known and potent substances found in mushrooms that have immunomodulatory and anticancer properties are polysaccharides [49].

Anti-Viral

Mushrooms contain bioactive polysaccharides that have inhibitory, antiviral, antibacterial, and antifungal properties. Studies on drugs derived from mushrooms have showed promising results against SARS-CoV-2 in humans. Eating mushrooms is a safe and efficient way to boost immunity as a neutraceutical supplement [50].

Anti-Parasitic

Asian countries have been using the popular medicinal plant *Ganoderma lucidum* for many years because of its many health benefits. Extract from *G. lucidum* and its pure components have demonstrated antibacterial activity against bacteria, yeasts, and parasites [51].

Anti-Microbial

The antibacterial activity of the acetone and methanol extracts of the investigated mushrooms was relatively strong. Both extracts had MICs ranging from 1.25 to 10 mg/mL for the bacteria and fungi under investigation. Generally speaking, acetone extracts have greater antibacterial activity than methanol extracts. When it came to Enterococcus foecalis, the acetone extract of *Leccinum carpini* mushrooms showed the strongest antibacterial activity (MIC = 1.25 mg/mL). Minimum inhibitory concentrations (MIC) of *Leccinum carpini* against bacteria were found to be 1.25–5 mg/mL and 2.5–10 mg/mL in the acetone and methanol extracts, respectively [52].

Hepatoprotective

Ganoderma lucidum is the most researched mushroom. *Ganoderma lucidum* is the most widely researched medicinal mushroom. More than 400 chemical compounds have been identified in G. lucidum, mainly including polysaccharides, triterpenoids, nucleosides, ergosterols, fatty acids, proteins/peptides, and trace elements. G. lucidum's bioactive components, particularly its polysaccharide and triterpenoid components, have been proposed to be responsible for the protective benefits against toxin-induced liver damage [53].

Anti-Diabetic

Auricularia auricula-judae, *Agaricus Bisporus*, *Ophiocordyceps sinensis*, *Ganoderma lucidum*, and *Pleurotus* species have therapeutic potential for managing diabetes and its related complications. Most

Auricularia species are edible and have medicinal benefits. *Auricula judae*, also known as wood ear mushroom, has anticoagulant, anticancer, and cholesterol-lowering properties. Additionally, A. *auricula-judae* has shown hypoglycemic effects.

Result

- *Alkaloids Test:* Formation of Mayer's test shows negative results and formation of Wagnar's test and Hager's test shows positive results towards presence of Alkaloids in the sample.
- *Saponins Test:* Formation of Frothing shows positive results towards presence of saponins in the sample.
- *Flavonoids Test:* Formation of alkaline reagent shows positive results towards presence of flavonoids in the sample (Table 2).

Table 2. Result of phytochemical screening of mushroom (*Agaricus Bisporus*).

Test	Result
Alkaloids test	
• Mayer's test	–
• Wagnar's test	+
• Hager's test	+
Saponins test	
• Frothing test	+
Flavonoids test	
• Alkaline reagent test	+

CONCLUSION AND FUTURE PERSPECTIVE

Medicinal mushrooms have been used for years for their health benefits and offer a promising opportunity for developing new treatment. However, there are no specific standards or clear guidelines for using mushrooms to manage hyperglycemia. This is likely due to limited data on their effectiveness in diabetes treatment and the lack of a well-defined molecular mechanism to confirm their antidiabetic potential. Hence, there is a need to focus on investigating the precise mechanisms and effectiveness of medicinal mushrooms in managing diabetes.

REFERENCES

1. Kumar A, Goel MK, Jain RB, Khanna P, Chaudhary V. India towards diabetes control: Key issues. Australasian Med J. 2013;6:524–31.
2. Bordoloi R, Dutta KN. A review on herbs used in the treatment of diabetes mellitus. J Pharm Chem Biol Sci. 2014;2:86–92.
3. Vision 2020 UK. IDF Diabetes Atlas, 7th Edition. Available from: http://www.vision2020uk.org.uk/idfdiabetes-atlas-7thedition
4. King H, Aubert RE, Herman WH. Global burden of diabetes, 1995–2025: Prevalence, numerical estimates, and projections. Diabetes Care. 1998;21:1414–31.
5. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. Diabetes Care. 2004;27:1047–53.
6. Ozkum D, Akı O, Toklu HZ. Herbal medicine use among diabetes mellitus patients in Northern Cyprus. J Med Plant Res. 2013;7:1652–64.
7. Recent TP. Trends in therapeutic approaches for diabetes management: A comprehensive update. J Diabetes Res. 2015;11.
8. Health and Social Care Information Centre (HSCIC). National Diabetes Foot Care Audit report 2014-2015. Report, England and Wales, March 2016.
9. Narayan DS, Patra VJ, Dinda SC. Diabetes and Indian traditional medicines: An overview. Int J Pharm Pharm Sci. 2012;4.
10. Kumari MS, Lakshmi KN, Prasanna TVVNL, Swapna K, Jyothi AS, Prasanth T. Natural herbs vs allopathic drugs: To treat diabetes. Indo Am J Pharm Sci. 2016;3:415–22.

11. Kerr M, Rayman G, Jeffcoate WJ. Cost of diabetic foot disease to the National Health Service in England. Diabet Med. 2014;31:1498–504.
12. Prabhakar PK, Doble M. Mechanism of action of natural products used in the treatment of diabetes mellitus. Chin J Integr Med. 2011;17.
13. Boulton AJ. The pathway to foot ulceration in diabetes. Med Clin North Am. 2013;97:775–90.
14. DeFronzo RA, Bonadonna RC, Ferrannini E, Zimmet P. Pathogenesis of NIDDM. In: International Textbook of Diabetes Mellitus. 1997. p. 635-712.
15. Poudel A, Savari O, Striegel DA, Periwal V, Taxy J, Millis JM, et al. Beta-cell destruction and preservation in childhood and adult onset type 1 diabetes. Endocrine. 2015;49:693–702.
16. Wojcik JL, Devassy JG, Wu Y, Zahradka P, Taylor CG, Aukema HM. Protein source in a high-protein diet modulates reductions in insulin resistance and hepatic steatosis in fa/fa Zucker rats. Obesity (Silver Spring). 2016;24:123–31.
17. Triplitt C, Solis-Herrera C, Cersosimo E, Abdul-Ghani M, Defronzo RA. Empagliflozin and linagliptin combination therapy for treatment of patients with type 2 diabetes mellitus. Expert Opin Pharmacother. 2015;16:2819–33. Fukuoka Y, Choi J, Gonzalez SB, Arai S. Family history and body mass index predict perceived risks of diabetes and heart attack among community-dwelling Caucasian, Filipino, Korean, and Latino Americans–DiLH survey. Diabetes Res Clin Pract. 2015;109:157–63.
18. Chawla A, Chawla R, Jaggi S. Microvascular and macrovascular complications in diabetes mellitus: distinct or continuum? Indian J Endocrinol Metab. 2016;20:546–51.
19. Tripathi KD. Essentials of medical pharmacology. 7th ed. New Delhi: Jaypee Brothers Medical Publisher; 2013. p. 258-281.
20. Harris MI. Undiagnosed NIDDM, clinical and public health issues. Diabetes Care. 1993;16:642-52.
21. Verge CF, Gianani R, Kawasaki E, Yu L, Pietropaolo M, Jackson RA, et al. Predicting type I diabetes in first-degree relatives using a combination of insulin, GAD, and ICA512bdc/IA-2 autoantibodies. Diabetes. 1996;45:926-33.
22. Ahmad N, Bansal R, Rastogi AK, Kidwai JR. Effect of PHA-B fraction of Agaricus bisporus lectin on insulin release and 45Ca2+ uptake by islets of Langerhans in vitro. Acta Diabetol Lat. 1984;21:63–70. doi: 10.1007/BF02582088.
23. Obodai M, Narh Mensah DL, Fernandes Â, Kortei NK, Dzomeku M, Teegarden M, et al. Chemical characterization and antioxidant potential of wild Ganoderma species from Ghana. Molecules. 2017;22:196. doi: 10.3390/molecules22020196.
24. Klupp NL, Kiat H, Bensoussan A, Steiner GZ, Chang DH. A double-blind, randomized, placebo-controlled trial of Ganoderma lucidum for the treatment of cardiovascular risk factors of metabolic syndrome. Sci Rep. 2016;6:29540. doi: 10.1038/srep29540.
25. Li J, Cai C, Zheng M, Hao J, Wang Y, Hu M, et al. Alkaline extraction, structural characterization, and bioactivities of (1→6)-β-d-glucan from Lentinus edodes. Molecules. 2019;24:1610. Available from: http://doi.org/10.3390/molecules24081610
26. De Silva DD, Rapior S, Hyde KD, Bahkali AH. Medicinal mushrooms in prevention and control of diabetes mellitus. Fungal Divers. 2012;56:1–29. Available from: http://doi.org/1010.1007/s13225-012-0187-4.
27. Firenzuoli F, Gori L, Lombardo G. The medicinal mushroom Agaricus blazei Murrill: Review of literature and pharmaco-toxicological problems. Evid Based Complement Altern Med. 2008;5:3–15. doi: 10.1093/ecam/nem007.
28. Vitak T, Yurkiv B, Wasser S, Nevo E, Sybirna N. Effect of medicinal mushrooms on blood cells under conditions of diabetes mellitus. World J Diabetes. 2017;8:187. Available from: http://doi.org/1010.4239/wjd.v8.i5.187
29. Lei H, Guo S, Han J, Wang Q, Zhang X, Wu W. Hypoglycemic and hypolipidemic activities of MT-α-glucan and its effect on immune function of diabetic mice. Carbohydr Polym. 2012;89:245–50. Available from: http://doi.org/10.1016/j.carbpol.2012.03.003
30. Khan MA, Tania M. Nutritional and medicinal importance of Pleurotus mushrooms: An overview. Food Rev Int. 2012;28:313–29. Available from: http://doi.org/10.1080/87559129.2011.637267

31. Valverde ME, Hernández-Pérez T, Paredes-López O. Edible mushrooms: Improving human health and promoting quality life. Int J Microbiol. 2015;2015:376387. Available from: http://doi.org/10.1155/2015/376387
32. Royse DJ. A global perspective on the high five: Agaricus, Pleurotus. Proceedings of the International Conference on Mushroom Biology and Mushroom Products, New Delhi, India; 2014 Nov 19–22. p. 2010–15.
33. De Silva DD, Rapior S, Fons F, Bahkali AH, Hyde KD. Medicinal mushrooms in supportive cancer therapies: An approach to anti-cancer effects and putative mechanisms of action - A review. Fungal Divers. 2012;55:1–35.
34. Chaturvedi VK, Singh A, Dubey SK, Hetta HF, John J, Singh MP. Molecular mechanistic insight of hepatitis B virus mediated hepatocellular carcinoma. Microb Pathol. 2019;128:184–94.
35. Agarwal S, Vaseem H, Kushwaha A, Gupta KK, Maurya S, Chaturvedi VK, et al. Yield, biological efficiency and nutritional value of Pleurotus sajor-caju cultivated on floral and agro-waste. Cell Mol Biol. 2016;62:1–5.
36. Cai M, Lin Y, Luo YL, Liang HH, Sun P. Extraction, antimicrobial, and antioxidant activities of crude polysaccharides from the wood ear medicinal mushroom Auricularia auricular-judae (higher basidiomycetes). Int J Med Mushrooms. 2015;17:591–600.
37. Syafrizal, Ramadhan R, Kusuma IW, Egra S, Shimizu K, Kanzaki M, et al. Diversity and honey properties of stingless bees from meliponiculture in East and North Kalimantan, Indonesia. Biodiversitas. 2020;21(10):4623–30. Available from: http://doi.org/10.13057/biodiv/d211021.
38. Obafemi TO, Onasanya A, Adeoye A, Falode JA, Daniel DJ, Irefo EF, et al. J Appl Pharm Scie. 2019;9(5):065-72.
39. Lavi I, Levinson D, Peri I, Tekoah Y, Hadar Y, Schwartz B. Cancer Lett. 2010;85:1977-90.
40. Du M, Huang S, Zhang J, Wang J, Hu L, Jiang J. Open J Forest. 2015.
41. Kozarski M, Klaus A, Vunduk J, Zizak Z, Niksic M, Jakovljevic D, et al. Nutraceutical properties of the methanolic extract of edible mushroom Cantharellus cibarius (Fries): Primary mechanisms. Food Funct. 2015;6:1875–86. Available from: http://doi.org/10.1039/C5FO00312A
42. Klaus A, Kozarski M, Niksic M, Jakovljevic D, Todorovic N, Van Griensven LJLD. Antioxidative activities and chemical characterization of polysaccharides extracted from the basidiomycete Schizophyllum commune. LWT Food Sci Technol. 2011;44:2005–11. Available from: http://doi.org/10.1016/j.lwt.2011.05.010
43. Ayeka PA. Potential of mushroom compounds as immunomodulators in cancer immunotherapy: A review. Evid Based Complement Altern Med. 2018;2018:7271509. Available from: http://doi.org/10.1155/2018/7271509
44. Chen J, Seviour R. Medicinal importance of fungal beta-(1→3), (1→6)-glucans. Pt 6. Mycol Res. 2007;111:635–52. Available from: http://doi.org/10.1016/j.mycres.2007.02.011
45. Badalyan S. Edible Ectomycorrhizal Mushrooms. Berlin, Germany: Springer; 2012. Medicinal aspects of edible ectomycorrhizal mushrooms. p. 317–34.
46. Guillamón E, García-Lafuente A, Lozano M, D´ Arrigo M, Rostagno MA, Villares A, et al. Edible mushrooms: Role in the prevention of cardiovascular diseases. Fitoterapia. 2010;81(7):715–23. Available from: http://doi.org/10.1016/j.fitote.2010.06.005
47. Dugler B, Gonuz A, Gucin F. Antimicrobial activity of the macrofungus Cantharellus cibarius. Pakistan J Biol Sci. 2004;7:1535–39.
48. Ajit TA, Janardhana KK. Indian medicinal mushrooms as a source of antioxidant and antitumor agents. J Clin Biochem Nutr. 2007;40:157–62.
49. Rahi DK, Malik D. Diversity of mushrooms and their metabolites of nutraceutical and therapeutic significance. J Mycol. 2016;2016:1–18.
50. Hanahan D, Weinberg RA. The hallmarks of cancer. Cell. 2000;100:57–70. Available from: http://doi.org/ 10.1016/S0092-8674(00)81683-9
51. Behera BC, Verma N, Sonone A, Makhija U. Antioxidant and antibacterial activities of lichen Usnea ghattensis in vitro. Biotechnol Lett. 2005;27:991–95.
52. Zhou CY, Jia W, Yang Y, Bai YQ. Experimental studies on prevention of several kinds of fungi polysaccharides against alcohol-induced hepatic injury. Edible Fungi. 2002;24:36–37.

53. Valverde ME, Hernández-Pérez T, Paredes-López O. Edible mushrooms: Improving human health and promoting quality life. Int J Microbiol. 2015;2015:376387. Available from: http://doi.org/10.1155/2015/376387.

