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Anti-hyperglycemic property of *Hericium erinaceus* – A mini review

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ABSTRACT

Hericium erinaceus (H. erinaceus) is one of the widely used edible mushrooms around the world, primarily in Asian countries. *H. erinaceus* is used in traditional medicines, and mushroom based foods. The fruiting body and mycelia of *H. erinaceus* are extracted using the solvents, and several bioactive compounds were identified. Several studies have reported that those bioactive compounds exhibit many health benefits such as hemagglutinating, antimicrobial, immunomodulatory, antitumor, antioxidant, and anti-aging activities, *etc*. This manuscript consciously updated the information about the composition of *H. erinaceus*, *H. erinaceus* based foods, and anti-hyperglycemic property of *H. erinaceus.*

1. Introduction

Edible mushrooms are one of the acceptable functional foods for human and are being used for several hundred years. Mushrooms are known for its texture, flavor, and health-promoting property [1,2]. Especially, mushrooms are a rich source of all essential amino acids that are required by the human beings. They are considered as a healthy food because of its enriched protein and dietary fiber content with low calories and fat [3]. Thus far, more than two thousand mushrooms species have been reported [4,5]. Edible mushrooms have been screened and studied for several medicinal properties like anticancer, and antimicrobial activities. Moreover, mushrooms were used as alternative food based medicines [6,7].

Hericium erinaceus (*H. erinaceus*) is one of the well-studied edible and medicinal mushrooms that belongs to family Hericiaceae, order Russulales, and class Agaricomycetes. *H. erinaceus* has a prominent place in Chinese traditional medicine, and information about *H. erinaceus* is available in European and South American literature [8]. The fruiting body and mycelia of *H. erinaceus* have been reported for its several pharmacological actions, such as hemagglutinating, antimicrobial, immunomodulatory, antitumor, antioxidant, and anti-aging activities [9–14].

This manuscript summarizes the nutritional composition of *H. erinaceus* and recent developments on *H. erinaceus* based functional foods and scientific reports about the hypoglycemic property of *H. erinaceus*.

2. Composition of *H. erinaceus*

The chemical composition and bioactive compounds of fruit bodies and mycelia of *H. erinaceus* have been reported by several researchers. *H. erinaceus* contains structurally diverse compounds, and about seventy different secondary metabolites were estimated. Hericerins [aromatic compounds such as hericerin A, isohericenone J, isoericerin, hericerin, N-dephenylethyl isohericerin, hericenone J, 4-(3′,7′-dimethyl-2′,6′-octadienyl)-2-formyl-3-hydroxy-5-methoxybenzylalcohol, erinacene D, resorcinols, erinacerins, and hericenols], erinacines (erinacine A, and diterpenoids), erinacerins-isoindolin-1-ones (erinacerins C-L), erinaceolactones, glycoprotein (*H. erinaceus* polysaccharide-protein-5), polysaccharides (β-D-glucans), sterols (ergosterol,

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and erinarols G-J), vitamin B12 lactone (c-lactone), and volatile compounds (2-methyl-3-furanthiol, 2-ethylpyrazine, and 2,6-diethylpyrazine) have been reported to be present in the *H. erinaceus*. The health promoting ability of *H. erinaceus* is attributed to these chemical substances (Table 1).

3. *H. erinaceus* based functional foods

It is known that the dried powder of *H. erinaceus* fruiting body confined with protein (20%), carbohydrate (61%), fat (5%), ash (7%), amino acids (14.3 mg/g dry weight), and water (6%) content, whereas mycelia consists of protein (42%), carbohydrate (42%), fat (6%), ash (4%), amino acids (30.6 mg/g dry weight), and water (4%) content. The fungal body also contains unsaturated fatty acids, saturated fatty acids, and other elements. Some potential bioactive compounds such as γ-aminobutyric acid (GABA), ergothioneine, and lovastatin were also found to be reported in *H. erinaceus* [15]. Thus, mushroom *H. erinaceus* has been used to develop several functional foods and used to improve quality of the foods. The mushrooms are consumed as the main dish in dining or as a supporting food. Currently, mushroom based fermented non-alcoholic beverages are trending in the Asian countries.

The probiotic bacteria mediated fermented mushroom beverages are effective functional foods. We have reported the production of L-glutamic acid (GA), and GABA rich fermented *H. erinaceus* juice using *Lactobacillus brevis* HP2 and *Lactobacillus fermentum* HP3 strains as a starter culture. Moreover, the factors (K_2HPO_4, pH, and temperature) influencing the production of GA and GABA was also reported [16]. Woraharn *et al.* [17] reported the development of L-glutamine and L-glutamic acid rich fermented *H. erinaceus* beverage using *Enterococcus faecalis* (G414/1) mediated fermentation. Probiotic mediated fermented *H. erinaceus* beverages are the best health promoting supplements with added probiotic benefits. Li *et al.* [18] described the use of *H. erinaceus* as a substrate for the production of vinegar and wine, and the product was found to be accepted by the human volunteers.

A dry powder of *H. erinaceus* mycelia has been used in preparing bread. Addition of 5% of *H. erinaceus* mycelia powder acted as additives in the preparation of bread, which also enhances the nutritional value of the bread. The presence of GABA and ergothioneine helps to improve the brain and heart functions [19–21].

4. Antihyperglycemic activities

Due to the high antioxidant potential and bioactive compounds, *H. erinaceus* has been used for the management of metabolic disorders, especially for diabetic treatments.

Wang *et al.* [22] demonstrated the anti-hyperglycemic property of methanol extract of *H. erinaceus* in streptozotocin induced diabetes Wistar rats. The supplementation of 20–100 mg of *H. erinaceus* extract per kg of body weight showed the reduction in blood glucose, serum triglyceride, and total cholesterol levels. The protective effect of methanol extract of *H. erinaceus* was found to be in a dose-dependent manner. About 100 mg of extract (per kg of body weight) supplementation showed a significant level of improvement in host health.

The hypoglycemic and antihyperlipidemic activities of aqueous extract of *H. erinaceus* have been reported using experimental rat model. The supplementation of *H. erinaceus* extract (100–200 mg/kg body weight) improved the serum insulin level and reduced the glucose level in streptozotocin induced diabetic rats. The researcher also reported that the supplementation of *H. erinaceus* aqueous extract exhibited antihyperlipidemic activities, and improved the free radical scavenging enzymes [23].

Yi *et al.* [24] reported that the ethanolic extract of *H. erinaceus* exhibited the anti-neuropathic pain activity in

Table 1
Composition and bioactivities of *H. erinaceus*.

S. No.	Compounds	Bioactivities	Refs
1	Hericerins Hericerin A, Isohericenone J, Isoericerin, Hericerin, N-dephenylethyl isohericerin, Hericenone J, 4-(3′,7′-dimethyl-2′,6′-octadienyl)-2-formyl-3-hydroxy-5-methoxybenzylalcohol, Erinacene D, Resorcinols, Erinacerins, and Hericenols.	Anticancer	[39–43]
2	Erinacines Erinacine A Diterpenoids	Neuroprotective	[44,45]
3	Erinacerins-Isoindolin-1-ones Erinacerins C-L	Anticancer	[46]
4	Erinaceolactones	Plant growth regulatory activity	[47]
5	Glycoprotein *H. erinaceus* polysaccharide-protein (HEG-5)	Hemagglutinating activity, Inhibit gastric carcinoma.	[48]
6	Polysaccharides β-D-glucans	Immune modulation	[49–52]
7	Sterols Ergosterol Erinarols G-J	Anti-inflammatory, antiproliferative	[41,49,53]
8	Vitamin B12 Lactone c-lactone	Inactive	[54]
9	Volatile Compounds 2-methyl-3-furanthiol, 2-ethylpyrazine, 2,6-diethylpyrazine	Antimicrobial	[55–57]

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Table 2
Reported antihyperglycemic activities of *H. erinaceus*.

S. No.	Experimental model	Supplementation	Outcome	Refs
1	Alloxan-induced diabetic mice	Polysaccharides of *H. erinaceus* (6–25 mg/kg b.wt)	Reduced blood glucose level. Enhanced the sugar tolerance level.	[26]
2	Streptozotocin induced diabetes Wistar rat	Methanol extract of *H. erinaceus* (20–100 mg/kg b.wt)	Reduced blood glucose, serum triglyceride and total cholesterol levels.	[22]
3	Streptozotocin mediated diabetes induced Wistar rat	Aqueous extract of *H. erinaceus* (100–200 mg/kg b.wt)	Reduced serum glucose level. Improved serum insulin level. Improved antioxidant enzyme activities. Reduced lipid related disorders.	[23]
4	Alloxan induced diabetic neuropathic Wistar rat model	Ethanol extracts of *H. erinaceus* (40 mg/kg b.wt)	Reduced serum and urine glucose level. Improved the enzyme activities (lactate dehydrogenase, glutathione peroxidase, glutathione reductase, catalase, Na^+K^+ATPase, and glutathione S transferase) and inhibition of lipid peroxidation. Attenuation of diabetic neuropathy.	[24]
5	Streptozotocin induced diabetes Wistar rat.	Probiotic mediated fermented *H. erinaceus* Juice	Reduced blood sugar level, slightly increased the serum insulin level. Improved the health status of experimental rat	Unpublished data

alloxan induced diabetic neuropathic Wistar rat model. About 40 mg of an ethanolic extract of *H. erinaceus* (per kg of body weight) supplementation reduced the neuropathic pain, increased the inhibition of lipid peroxidation and improved the activities of antioxidant enzymes such as lactate dehydrogenase, glutathione peroxidase, glutathione reductase, catalase, Na^+K^+ATPase, and glutathione S transferase in the experimental rats. The report claimed that the enhancement of antioxidant system of the host by *H. erinaceus* extract could be responsible for the amended diabetic neuropathy.

Wu and Xu [25] reported the *in vitro* antidiabetic nature of *H. erinaceus* and revealed that inhibition of α-glycosidase and aldose reductase activity was in a dose-dependent way. Xue *et al.* [26] explained the reduction of blood glucose, and improvement of sugar tolerance level in alloxan-induced diabetic mice supplemented with polysaccharides of *H. erinaceus*.

The fermented *H. erinaceus* juice supplementation enhanced the health of streptozotocin induced diabetic rats. The body mass and serum insulin level were increased, and the fasting plasma glucose was reduced in the diabetes rats of the supplemented group. The level of inflammatory markers was reduced, which confirms that the fermented *H. erinaceus* juice prevents the diabetes rat from inflammatory damages (Unpublished data) (Table 2).

5. Other health benefits

Apart from antihyperglycemic activity, *H. erinaceus* has been reported for exhibiting several health benefits. For example, agglutinin of *H. erinaceus* exhibited antiproliferative activity against hepatoma, and HIV-1 reverse transcriptase inhibitory activity [27]. The polysaccharides of *H. erinaceus* could regulate the pro-inflammatory cytokines, induce the macrophage mediated immune response, and induce the dendritic cells maturation [28,29]. *H. erinaceus* nullifies the gastric mucosal injury, and gastric ulcer [30]. The free radical scavenging, hepatoprotective, neuroprotective, neurodegenerative, hypolipidemic, anti-fatigue, and anti-aging activities of *H. erinaceus* polysaccharides have also been reported [31–36]. *H. erinaceus* polysaccharides were found to be active against *Helicobacter pylori* [37].

6. Conclusions

The mushroom *H. erinaceus* is composed of many bioactive compounds with proven health promoting properties. Several patents were filed for the pharmacological applications and formulations made using the bioactive compounds of *H. erinaceus*, especially polysaccharides [38]. Still, a gap remains in transferring the information to the needy people. *H. erinaceus* is an affordable natural, healthy food. The improvement of existing foods and development of new *H. erinaceus* based functional foods are necessary to explore the medicinal property of the mushroom for the betterment of human life, primarily to treat and manage the diabetic condition. Further, scientific information is required concerning the influence of *H. erinaceus* supplementation on the hyperglycemic status of humans, the prescribed dose for the management of the diabetic condition, and affordable form of supplementation (like fermented *H. erinaceus* juice, or *H. erinaceus* extract, *etc.*), which help to advance the alternative medications for diabetes.

Conflict of interest statement

All authors declare that they have no conflict of interest.

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