

A COMPREHENSIVE REVIEW ON MUSHROOM MICROBIOME: A NON-DIARY PREBIOTIC, PROBIOTIC ALTERNATIVE INTERACTION WITH GUT MICROBIOTA AND HEALTH/IMMUNOLOGICAL BENEFITS.

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Abstract— Mushrooms being neither plant nor animal are placed during a kingdom, called Myceteae. Mushroom may be a macro fungus with a particular plant organ, which may be either epigeous or hypogeous and enormous enough to be seen with eye and to be picked by hand. Environmental factors like species of mushrooms, morphological a part of plant organ, developmental stages and age of mycelium, biochemical composition, and interval between the fructifications affect mineral accumulation in macro fungi. Due to their exposure to UV rays or sunlight, mushrooms are a natural, non-animal source of vitamin D2 that's capable of accelerating blood levels of this vitamin as effectively as a supplement. Mushroom polysaccharides are a sort of bioactive macromolecular which isolated from fruiting bodies, mycelia or fermentation broths of edible or medicinal fungus. Recently, mushroom polysaccharides have attracted tons of attention for regulating gut microbiota via reducing the amount of pathogens and stimulating the expansion of beneficial microorganisms, thus creating new possibilities for his or her use in nutraceutical and functional foods industries. This review article thus encapsulates the isolation, structural characterization techniques and the purification methodologies of the pertinent mushroom polysaccharides along with the degradation of mushroom polysaccharides in intestine and focuses on the impacts of mushroom polysaccharides on the human gut microbiota community and short chain fatty acids (SCFAs) productivity, and thereby the occurring beneficial effects of mushroom polysaccharides to host by targeting gut microbiota.

Index Terms— gut microbiota, immunological benefit, mushroom, prebiotic, probiotic, therapeutic, nutrition

1 INTRODUCTION

There are many recent studies focusing on health benefits of gut microbiota wherein, a study reveals that prebiotics can regulate the gut microbiota plays a significant role in regulating non-alcoholic fatty liver disease (NAFLD). Recent studies showcase the abilities of the gut microbiota to play a protective role in the host defense mechanism against pneumococcal pneumonia. Generally, the microbiota can be activated in favour of host health by various factors: like the probiotics which are the indicating microorganisms that help stimulate gut microbiota, the prebiotics that are the food components which are rich in oligosaccharides or polysaccharides and finally the synbiotics which are a combination of probiotics and prebiotic micro-organisms. The mushroom proteins contain all the nine essential amino acids that are required by humans for conduction of required metabolic processing activities on a daily basis of healthy body functioning. Apart from being an inexplicably good protein source of consumption, mushrooms are a relatively good ingredient for intake of the nutrients like phosphorus, iron and vitamins, including thiamine, riboflavin, ascorbic acid, ergo sterol, and niacin. Niacin is good for the digestive system and for maintaining healthy skin. Pantothen-

ic acid is good for the nervous system and helps the body make the hormones it needs.

2 CONSTITUENT NUTRITIONAL COMPOSITION AND PROPERTIES OF MUSHROOMS

The dry matter contents of mushrooms is generally observed to vary from 7.7% to 8.4% wherein the dry matter of mushrooms primarily constitutes very large amounts of carbohydrates that are ranging from 4.5 in *Agaricus bisporus* mushrooms also referred to as the commonly consumed white button mushrooms to approximately 5.8 g/100 g fresh weight in the *Lentinula edodes* variety. While the *Lentinula edodes* mushroom proved to be an especially good source of dietary fiber consisting of 3.3 g/100 g fresh weight, the other mushrooms contained about 1.5–2.4 g/100 g fresh weight. According to several amino acid analytical studies, the crude fat, ash content and protein content present in the different species of the mushrooms varied between 0.31–0.35, 0.49–0.78 and 1.8–2.09 g/100 g fresh weight, respectively. Time and again mushrooms have proven to be good sources of almost all the nine essential amino acids when compared with the common-

ly consumed vegetables. The mean nitrogen-to-protein conversion factor analyzed in the consecutive mushroom studies has been noted to be between the ranging values of 4.7 ± 0.21 respectively.

2.1 MUSHROOM ROLE AS PREBIOTICS

Prebiotics are food ingredients (such as mushroom) that can stimulate the growth of beneficial microbiota. Oligosaccharides and fibers are the major constituents of prebiotics. Mushrooms are rich in several polysaccharides like galactans, chitin, mannans, xylans, hemicellulose, α -glucans and β -glucans making them efficient/suitable for prebiotic utilization. While the different varieties of mushrooms provide different health benefits, the popularly/widely consumed white button mushrooms (*Agaricus bisporus*) according to studies have shown an increase in microbial diversity along with stimulating the local inflammatory response and leading to alteration of gut microbial flora composition; which showcases that regular consumption of white button mushrooms might improve the gastrointestinal health and stimulate our immune system by protection against relevant/caused injury and damage by increasing the performance and adapting the overall morphology, production of catecholamines and their metabolites, composition of intestinal microbiota to relevant conditions, raises the antioxidant levels through microbiome alterations, with mutual rise in the lactic acid producing bacteria to improve intestinal health. Mushrooms especially play the role of prebiotics by effectively stimulating and enhancing the gut microbial proliferation and exponential growth, leading to the subsequent conferment of health benefits to the respective host. The current growing trends in food science and technology has displayed the association of prebiotics in the modulation of the human gut microbiota and the attenuation of uncountable occurring predominant diseases like hypertension, diabetes, obesity often observed in the growing American youth and different types of cancer. The primarily important sources of prebiotics in mushrooms are the indigestible mushroom polysaccharides that have the ability to inhibit pathogen proliferation by in turn enhancing the growth of probiotic bacteria in the gut that is the intestinal lining. The gut microbiota can contribute to the onset of several metabolic dysregulations, leading to inflammation in the intestine, liver, and brain.

Microbiota also regulates the energy metabolism. According to several studies, the stipe of fresh mushrooms generally used as low-cost animal feed and considered as waste due to their hard texture; contain potential to be converted into value-added products; wherein observations indicate a symbiotic interaction between microbial bacteria and polysaccharides from *Flammulina velutipes*, *Pleurotus eryngii*, *Lentinus edodes* mushroom wastes that alter the balance of probiotics like *Lactobacillus acidophilus*, *Lactobacillus delbrueckii*, *Lactobacillus casei*, *Bifidobacterium longum*, *Streptococcus thermophilus* thereby enabling them maintain a higher population/enhancing their survival even in colder storage conditions. Also further tolerance of probiotics against stimulated gastric acidity and bile juices

they may encounter also improved greatly under the supplementation of mushroom polysaccharides that displayed synergistic effect with the probiotics above 10^7 CFU/ml even at low concentrations of 0.1%-0.5% concentration thereby proving mushroom wastes as a low economic value alternative potential source of prebiotics.

2.2 MUSHROOM INTERACTION WITH HUMAN GUT MICROBIOTA

The medicinal mushrooms can act as immunomodulatory agents to activate gut microbiota. *Ganoderma lucidum* (GL) may be a frequently mentioned mushroom that has been reported to scale back obesity in mice by modulating the composition of gut microbiota. GL reduces weight, inflammation, and insulin resistance in mice fed a high-fat diet. The GL not only reverses gut dysbiosis—as indicated by the reduced Firmicutes/Bacteroidetes ratios and endotoxin-bearing Proteobacteria levels—but also alters the intestinal barrier probity and attenuates endotoxemia. The results confirm that GL are often used as a prebiotic agent to stop gut dysbiosis and obesity-related metabolic disorders in obese individuals. The regular consumption of *Agaricus bisporus* mushroom affects the intestinal microbiota composition, the consequential performance, the existing morphology and also the observed antioxidant levels of turkey poults. The results of this study state that *Agaricus bisporus* is able to improve both growth performance and antioxidant activity of turkey poults and it also significantly increased the numbers of lactic acid-producing bacteria and improved the condition of the intestine. Gut microbiota composition has been reported to change the gut barrier, affect fat proliferation, and affect energy metabolism, all of which may be changed through the utilization of prebiotics. *Lentinula edodes*-derived polysaccharide alters the spatial structure of gut microbiota in mice; in brief L2 treatment decreased the gut microbiota's diversity and evenness in the intestine, particularly in the colon and cecum. Other populations also changed in response to L2 treatment include Proteobacteria, Acidifaciens, Bacteroides, *Helicobacter suncus*, and *Alistipes*. Species of mushroom like Reishi promote growth of healthy gut bacteria, exhibit a soothing effect and can even support weight loss goals.

2.3 THERAPEUTIC AND IMMUNOLOGICAL BENEFITS OF MUSHROOMS

Mushrooms possess antioxidant activity, anti-hypertensive activity, hypocholesterolemic activity, hepatoprotective and immunopotentiating agents, liver protection, as well as anti-

inflammatory activity, anti-diabetic activity, anti-viral activity, and anti-microbial activity. They are considered as functional foods which can provide health benefits beyond the traditional nutrients. The polysaccharide β -glucan in WB mushrooms stimulates your immune system to activate macrophages and natural killer cells, which protect the body from infection, harmful organisms, and diseases, including cancer. Beta glucans being a type of soluble fiber that lowers blood cholesterol levels through its ability to form a gel-like substance when digested. It then traps triglycerides and cholesterol, preventing their absorption. White mushrooms are also rich in glutathione and ergothioneine wherein glutathione acts both as an antioxidant and detoxification agent and helps eliminate potentially harmful substances foreign bodies while ergothioneine protects DNA from oxidative damage and ergothioneine may also help reduce triglyceride levels after a meal. The consistent ergothioneine is also believed to help inhibit arterial plaque development which is a risk factor for major heart diseases that could lead to high blood pressure (hypertension) and heart stroke. Mushrooms are also rich in the antioxidant called selenium.

Several different existent antioxidant compounds which are namely the polyphenols, polysaccharides, ergothioneine, glutathione, selenium, and vitamin C are believed as the secret behind the mushroom's potential cancer-fighting properties. These antioxidants help our body to combat the harmful effects of oxidative stress that leads to immense cellular damage that can also accelerate cell aging and increase the risk of developing heart disease and causage of certain cancers. The main phenolic compounds in white mushrooms are flavonoids and phenolic acids, which have the potential to act both as antioxidants and pro-oxidants. As antioxidants, they help improve cell survival, while as pro-oxidants, they lead to cell death to prevent tumour growth.

1. Reishi Mushroom- Being a staple in Eastern medicine for several years and have been relied upon for relieving headaches. It is renowned for its supposed effectiveness to help stop the growth and spread of cancer cells. Its frequent consumption helps enhancement of the immune system, reduction in stress levels, improving the sleep cycle and to lessen fatigue. People also take Reishi mushroom for health conditions like high blood pressure. While playing the role of an adaptogen the reishi mushrooms have showcased the ability to increase natural killer cells that are mainly white blood cells which enable our body to fight against infection and disease.

2. Chaga Mushroom- Chaga mushroom consists a variety of antioxidants could have a potential role in lowering blood pressure and preventing poor cardiovascular health. Several research studies conducted on mice showcase claims that chaga mushrooms could probably help regulate the production of cytokines that support the immune system by enabling the cells to communicate with one another, further enhancing their ability to fight infections ranging from minor colds to life-threatening illnesses and disorders. Its role in cytokine production regulation could also be valuable to control inflammation. This points towards its potentiality in fighting autoimmune conditions and possibly other diseases.

3. Maitake Mushroom- These species of mushrooms contain chemicals which could help our body fight tumors, stimulate the immune system and metabolic processes and can lower the blood sugar and lipid level concentrations. Being declared as a natural remedy for diabetic patients, individuals with high blood pressure, and high cholesterol widespread researched is being conducted to determine its role as a potential cancer-fighting drug. Maitake mushrooms display their ability to spur the activity in our infection fighting immune cells like the natural killer cells and T-cells that are supposedly thought to help in inhibition of the growth in cancerous cells. A component of beta-glucan known as the D-fraction present in Maitake mushrooms has also been shown to have possessed the anti-tumor activity characteristics. Researchers have also discovered that the Maitake mushroom treatment can improve ovulation cycle rates for women suffering from Polycystic Ovary Syndrome (PCOS) in combination with other ingredients though at the time-being its utilization may not be as effective as clomiphene tablets and there still exists further scope for its optimum extraction of benefits for industrial and health gains.

4. Coriolus versicolor Mushroom- Several extracted polysaccharide compounds from the Coriolus variety called PSK (polysaccharide krestin) and PSP (polysaccharide peptide) have shown ability to improve the immune system functioning in patients with certain cancers when utilized along with chemotherapy wherein they help slow cancer growth and boost the immune system. They have since long as been utilised for treatment of herpes, for curing the liver disorders like hepatitis, chronic fatigue syndrome (CFS) and several occurring pulmo-

nary disorders. The Coriolus mushroom help in reducing the existent phlegm in the throat during cough and infection, improve the bodybuilding results in athletes and thereby increase their stamina and energy during sports. They help to cure the ringworm and even skin conditions like impetigo and are utilized for treatment in the upper respiratory, urinary, and digestive tract infections. The Coriolus mushroom also helps in reducing the toxic effects and pain caused by the chemotherapy and radiation therapy, thereby increasing the effectiveness of chemotherapy and not only prolonging an individual's lifespan but also raising the quality of life in the cancer patients and increasing their appetite which otherwise is a common problem faced upon occurrence of most disorders and infections.

5. **Laetiporus sulphureus Mushroom-** This variety of mushroom exhibit widespread benefits wherein the extracts prepared from it's fruiting bodies or mycelia showcase a number of medicinal properties like immunomodulation, antitumor characteristics, anti-inflammatory and antioxidant properties, the antimicrobial activity and antihyperglycemic interactions because of their biologically active components present like constituent phenolics. This species of mushroom specifically produces the Laetiporus sulphureus lectin (LSL) that exhibits numerous haemolytic and haemagglutination activities. Haemolytic lectins are sugar-binding proteins that lyse and agglutinate the disease-causing cells. These biochemical activities are promoted when bound to carbohydrates in general.

3 CONCLUSION-

The dietary mushroom inclusion has been observed to have significantly benefitted the affected performance as per studies conducted in turkey and poultry specimens with due inclusion of exerted changes in intestinal microbial community interaction, intestinal integrity and antioxidant protective activity and is consistent with improvements in overall physical performance. There are several edible mushrooms that have significant medicinal metabolites and the various species of mushrooms can make better prebiotics to stimulate the gut microbiota wherein though there exist several widespread sources of beneficial prebiotics like seaweed however mushrooms have the upper hand advantage due to their easy availability, accessibility and extensive painstakingly conducted studies in comparison to other prebiotic ingredients. With the

gut microbiota playing a significant role in enhancing useful interactions within the gut microbiome by changing the pathological conditions of survival and promoting apt survival for the useful species for efficient metabolic processing and are potential functional food ingredients with huge scope in the relevant booming food and nutritional health supplement manufacturing industries. With extensive studies covering the genetic occurrence of changes in microbiota upon frequent consumption of different mushroom specimen in the ecogenomics and metagenomics field, their health potential in curing innumerable diseases at a low cost efficient farming condition and research are especially of interest for researchers in developing countries to explore their pharmacokinetic abilities, host and cell interaction, possible toxicity in certain varieties and the dosage and side-effects of consumption in combination with other compounds. Nevertheless, the scope of mushrooms in our nutritional engulfing diet is only expanding it's horizons of essential dietary benefits and their increased consumption leading of widely rising sustainable farming and start-up opportunities that point towards their bright future and optimum utilization.

4 FIGURES AND TABLES-

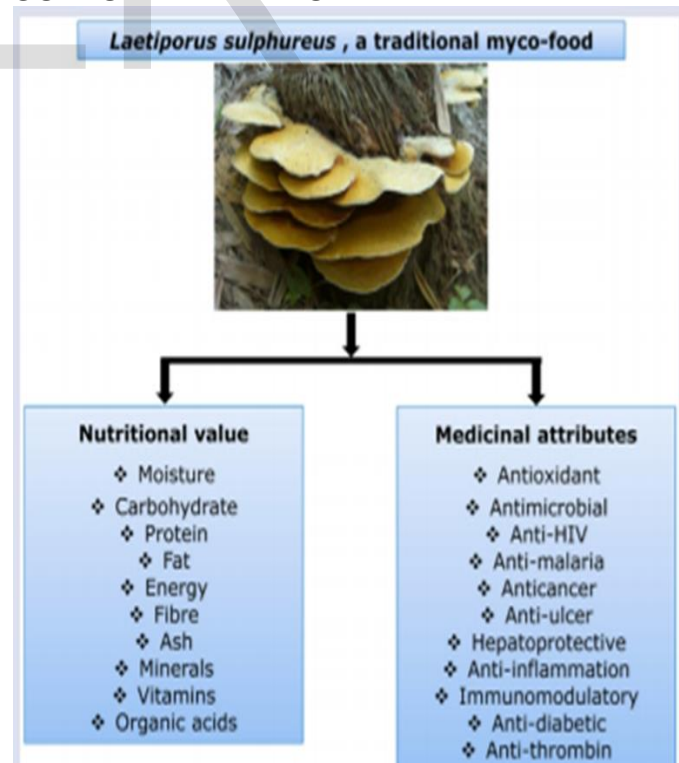


Figure1: Nutritional and therapeutic properties of different species of mushrooms.

Medicinal Mushroom	Active Immunomodulators	Health Benefits	Gut Microbiota Regulation
<i>Grifola frondosa</i>	MD-fraction Grifolan	The <i>Agaricus blazei</i> -based mushroom extract-Andosan exerts protection against intestinal tumorigenesis in A/J Min/+ mice.	Andosan may also have influenced the composition and activity of microbiota in the A/J Min/+ mice.
<i>Pleurotus tuberregium</i>	Polysaccharides	It showcases antihyperglycemic characteristics and oxidative stress in diabetic rats on a high fat diet.	There are possible roles of gut microbiota in the polysaccharide-induced attenuation of obesity and hyperglycemia.
<i>Ganoderma lucidum</i>	GLP(AI), Ganopoly, Ganoderans	It reduces obesity in mice by modulation in composition of gut microbiota.	GL has decreased Firmicutes-to-Bacteroidetes ratios. Reduced endotoxin-bearing Proteobacteria levels. It also maintains intestinal barrier integrity and reduces metabolic endotoxemia.
<i>Agaricus bisporus</i>	Polysaccharides	Displays anti-bacterial property .	White button mushrooms increase microbial diversity and accelerate the resolution of citrobacter rodentium infection in mice.
<i>Polyporus umbellatus</i>	Polysaccharides	Studies exhibit integrative fungal solutions for protecting bees.	Increases the intestinal microbiome to regulate host health.
<i>Trametes versicolor</i>	Krestin (PSK), PSP	Prevents host from diarrhea, <i>Clostridium difficile</i> infection, and inflammatory bowel disease.	Polysaccharopeptide from <i>Trametes versicolor</i> regulates the gut microbiota to maintain the host health.
<i>Lentinula edodes</i>	Lentinan, KS-2	<i>Lentinula edodes</i> -derived polysaccharide rejuvenates mice in terms of immune responses and gut microbiota.	L2 reverses the gut microbiota structure, such as the reduced ratio Firmicutes/Bacteroidetes, the increased Bacteroidia, the decreased Bacilli and Betaproteobacteria, the increased Bacteroidaceae, the decreased Lactobacillaceae, and Alcaligenaceae.

Figure2: Therapeutic and Immunological benefits of mushrooms that can possibly prove as prime ingredients in nutraceuticals.

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