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Mushrooms: a review of health benefits, cultivation techniques, and nutritional analysis

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Abstract

The nutritional content of mushrooms, as well as the possible health advantages of mushrooms, are gaining widespread awareness around the globe. This paper provides an overview of the nutritional profile of Pleurotus mushrooms as well as production methods and prospective applications for these mushrooms. The advantages to health, such as the existence of bioactive substances, therapeutic characteristics, and hypolipidemic effects, are discussed in the article. It is emphasized that Pleurotus species are capable of growing on a wide variety of agro-wastes and lignocellulosic materials, and a number of various culture substrates and growth circumstances are explored. In addition, the essay examines the significance of genetic identification and fingerprinting techniques for the purpose of both the enhancement of strains and the manufacture of commercial quantities. The practices of environmentally responsible farming as well as the methods used by indigenous peoples for mushroom growing are discussed. In general, this article enlightens the reader on the nutritional and health benefits of Pleurotus mushrooms, as well as their potential for production and their function in environmentally responsible agriculture.

Keywords: Mushrooms, Health benefits, Cultivation techniques, Nutritional analysis, *Pleurotus species*.

Introduction

Because of their nutrient profile and the possible health advantages they may offer, mushrooms have garnered a substantial amount of interest in recent years. Pleurotus mushrooms, which are commonly referred to as oyster mushrooms, are one of the most well-liked and frequently farmed varieties of edible mushrooms. They provide a significant amount of essential nutrients as well as bioactive substances, both of which are beneficial to human health and

wellbeing (Khan and Tania, 2012). In many different cultures, pleurotus mushrooms have a long history of both culinary and medical usage (Guzman, 2000). The purpose of this review article is to offer a summary of the nutritional profile, production methods, and possible uses of Pleurotus mushrooms.

Composition in terms of nutrition and advantages to one's health

Mushrooms belonging to the genus Pleurotus are well-known for the high levels of protein, dietary fibre, vitamins, and minerals that they contain (Khatun et al., 2015). They also include bioactive substances such as polysaccharides and phenolic compounds, both of which have been connected with a variety of positive health effects (Khan and Tania, 2012). According to research, pleurotus mushrooms have qualities that make them effective against cancer, antimicrobial infections, and antioxidants (Golak-Siwulska et al., 2018). They have been shown to have hypolipidemic and hypoglycaemic effects, which make them useful for people who have hypercholesterolemia (Raman et al., 2014) and diabetes (Nayak et al., 2021).

Other Mushroom Species and Their Health Benefits

Agaricus species

Agaricus species, including the commonly consumed *Agaricus bisporus*, also known as button mushrooms, possess a favourable nutritional composition and offer several health benefits. They are a good source of protein, dietary fibre, vitamins (such as riboflavin, niacin, and pantothenic acid), minerals (including potassium, phosphorus, and selenium), and antioxidants (Mshandete and Cuff, 2008; Rodriguez et al., 2007). Button mushrooms have been associated with potential anti-inflammatory and anti-cancer effects. They contain bioactive compounds like beta-glucans and conjugated linoleic acid, which have been shown to modulate immune function and inhibit tumour growth (Zhang et al., 2004; Golak-Siwulska et al., 2018).

***Lentinula edodes* (Shiitake mushroom)**

Shiitake mushrooms have a long history of medicinal use and are well-regarded for their health benefits. They are rich in protein, dietary fibre, vitamins (particularly vitamin B complex), and minerals (such as copper, manganese, and zinc) (Mehmet and Sevda, 2010) (Akinmusire et al., 2011). Shiitake mushrooms contain bioactive compounds like lentinan, eritadenine, and beta-glucans, which have been linked to immunomodulatory effects, antiviral properties, and cholesterol-lowering activity. These mushrooms have also been studied for their potential to inhibit cancer cell growth and reduce the risk of cardiovascular diseases (Croan, 2004; Hoa and Wang, 2015).

Auricularia species

Auricularia mushrooms, commonly known as wood ear mushrooms, have gained recognition for their health-promoting properties. They are low in calories and fat but provide a notable amount of dietary fibre, protein, vitamins (particularly vitamin B complex), and minerals (including iron, zinc, and potassium) (Apetorgbor et al., 2013) (Sardar et al., 2017). Auricularia species contain bioactive compounds like polysaccharides, flavonoids, and phenolic compounds, which exhibit antioxidant, antitumor, and hypoglycemic activities. These mushrooms

have been studied for their potential to enhance immune function, lower blood glucose levels, and prevent oxidative stress-related diseases (Girmay et al., 2016; Liao et al., 2018).

Flammulina velutipes (Enoki mushroom)

Enoki mushrooms, scientifically known as *Flammulina velutipes*, have a delicate texture and a distinct flavour. They are low in calories and fat but rich in dietary fibre, vitamins (especially vitamin B complex), and minerals (such as copper, selenium, and potassium) (Singh et al., 2011; Zmitrovich and Wasser, 2016). Enoki mushrooms contain bioactive compounds like beta-glucans and polysaccharides, which have shown immunomodulatory, anticancer, and antimicrobial properties. These mushrooms have been studied for their potential to enhance the immune response, inhibit tumour growth, and protect against microbial infections (Stamets, 2000; Zhang et al., 2019).

Other commercially important mushroom species

Several other mushroom species have also been recognized for their health benefits. *Hericium erinaceus*, commonly known as the "lion's mane mushroom, is known for its potential neuroprotective effects and is being studied for its role in promoting brain health (Sekan et al., 2019). *Ganoderma lucidum*, also known as reishi mushroom, is highly regarded in traditional Chinese medicine for its immune-modulating properties and potential anti-cancer effects (Yamanaka, 2011). *Cordyceps sinensis*, a parasitic fungus, is used in traditional Chinese medicine for its purported energy-boosting, anti-fatigue, and aphrodisiac properties (Berch et al., 2007).

In addition to the mushroom species discussed earlier, there are several other commercially important mushroom species that offer various health benefits. Let's explore some of them:

Hericium erinaceus (Lion's Mane Mushroom)

Hericium erinaceus, commonly known as the "lion's mane mushroom, is a unique-looking mushroom with long, dangling spines. It has gained popularity in recent years due to its potential health benefits, particularly for brain health. Lion's mane mushrooms are a rich source of bioactive compounds such as hericenones and erinacines, which are believed to promote nerve growth factor (NGF) synthesis in the brain (Stamets, 2000).

Research suggests that the lion's mane mushroom may have neuroprotective effects and could potentially enhance cognitive function. Studies conducted on animals have shown promising results, indicating that lion's mane extract may help improve memory and learning abilities (Guo et al., 2007; Tolera and Abera, 2017). However, further research is needed to determine its effectiveness in humans and the specific mechanisms involved.

Ganoderma lucidum (Reishi Mushroom)

Ganoderma lucidum, commonly known as the reishi mushroom, has been revered in traditional Chinese medicine for centuries due to its potential health benefits. Reishi mushrooms have a unique appearance, with a shiny, reddish-brown cap and a woody texture. They are known for their immune-modulating properties and have been studied for their potential anticancer effects (Choi and Kim, 2003).

Reishi mushrooms contain bioactive compounds such as triterpenes, polysaccharides, and antioxidants, which contribute to their medicinal properties. These compounds have been found to stimulate the immune system, enhance the activity of natural killer cells, and inhibit the growth of cancer cells in laboratory studies (Ijeh et al., 2009; Kibar and Peksen, 2008). Reishi mushrooms may also have anti-inflammatory and antioxidant effects, which could potentially support overall health and well-being (Naraian et al., 2009).

***Cordyceps sinensis* (Cordyceps mushroom)**

Cordyceps sinensis is a unique mushroom that grows by infecting the larvae of insects, particularly caterpillars. It has a long history of use in traditional Chinese medicine and is known for its purported energy-boosting and anti-fatigue properties. Cordyceps mushrooms are rich in bioactive compounds such as cordycepin, polysaccharides, and adenosine, which are believed to contribute to their health benefits (Owaid et al., 2015; Ho et al., 2020).

Research suggests that cordyceps mushrooms may enhance physical performance and endurance by improving oxygen utilization and increasing ATP production in the body (Yang et al., 2013; Xiao et al., 2011). They have also been studied for their potential antioxidant, anti-inflammatory, and anti-ageing effects (Choi et al., 2018). Additionally, cordyceps mushrooms may have immunomodulatory properties, potentially supporting the immune system's function (Salehi, 2019). However, it's worth noting that most studies on cordyceps mushrooms have been conducted on animals, and more research is needed to fully understand their effects on humans.

These are just a few examples of commercially important mushroom species that offer unique health benefits. Each mushroom species has its own distinct composition of bioactive compounds, which contributes to their potential therapeutic properties. Incorporating a variety of mushrooms into the diet can provide a diverse range of nutrients and bioactive compounds, supporting overall health and well-being. However, it's important to note that individual responses to mushrooms may vary, and consulting with a healthcare professional is advisable before incorporating them into your diet.

These various mushroom species provide a range of health benefits due to their unique nutritional composition and bioactive compounds. Incorporating mushrooms into the diet can contribute to a well-balanced nutritional intake and potentially support overall health and well-being.

Cultivation Techniques

Mushrooms belonging to the genus Pleurotus may be grown on a diverse selection of substrates, including agro-wastes and lignocellulosic materials (Khan and Tania, 2012). These mushrooms are able to cultivate themselves using a wide variety of agricultural by-products, including paddy straw, corn-based media, vegetable waste, and grasses (Singh and Singh, 2011; Bumanlag et al., 2018). Techniques for cultivation include preparing the substrate, inoculating the spawn, and maintaining environmental conditions in regulated settings (Shukla and Biswas 2000). When it comes to producing good yields, one of the most important factors is optimizing the growth

parameters, which include temperature, humidity, and light levels (Bumanlag et al., 2018).

Mushroom cultivation involves creating the optimal conditions for mushrooms to grow and develop. There are various cultivation techniques used, depending on the mushroom species and desired outcomes. Let's delve into some of the commonly employed cultivation techniques:

Substrate Preparation

The first step in mushroom cultivation is preparing the substrate, which serves as the growing medium for the mushrooms. Different mushroom species have specific substrate requirements. Commonly used substrates include agricultural waste materials such as straw, wood chips, sawdust, and agricultural residues. The substrate needs to be processed to remove contaminants, enhance its nutritional content, and create a favourable environment for mushroom growth.

Substrate preparation methods may involve sterilization, pasteurization, or a combination of both. Sterilization involves subjecting the substrate to high temperatures using steam or autoclaving to eliminate all microorganisms. Pasteurization, on the other hand, involves heating the substrate to lower temperatures to kill most microorganisms while preserving beneficial ones. Substrate preparation techniques aim to create a sterile or semi-sterile environment that is conducive to mushroom colonization and growth (Feeney et al., 2014).

Spawn Production

Spawn is the mycelium of the mushroom species that serves as the inoculum for mushroom cultivation. It is typically grown on a substrate such as grains (e.g., wheat, rye, or millet). Spawn production involves several steps, including selecting a pure culture of the desired mushroom species, inoculating the substrate with the culture, and allowing the mycelium to colonize the substrate.

To initiate spawn production, a small piece of mycelium from a pure culture is transferred to the sterilized grain substrate. The mycelium grows and spreads throughout the grains, creating a solid mass of colonized substrate called spawn. Spawn is usually stored in a controlled environment to maintain its viability until it is used for inoculating the growing substrate (Knop et al., 2015).

Inoculation and Incubation

Once the spawn is ready, it is used to inoculate the prepared substrate. This can be done through various methods, such as grain spawn, sawdust spawn, or liquid culture. Inoculation involves distributing the spawn evenly throughout the substrate to ensure uniform colonization.

After inoculation, the substrate is placed in a controlled environment with specific temperature and humidity conditions suitable for the mushroom species. This phase is known as incubation or spawning. During incubation, the mycelium grows and colonizes the substrate, breaking it down and absorbing nutrients. The length of the incubation period varies depending on the mushroom species and environmental conditions, but typically ranges from a few weeks to a couple of months (Singh and Singh, 2011).

Casing

For some mushroom species, a casing layer is added after incubation. Casing involves covering the colonized substrate with a layer of nutrient-rich material such as peat moss, vermiculite, or a mixture of various materials. The casing layer provides a microenvironment that promotes the formation of fruiting bodies (mushrooms).

Casing serves several purposes, including providing additional nutrients, regulating moisture levels, and promoting the initiation and development of mushrooms. It also acts as a protective layer against contaminants and helps maintain humidity around the developing fruiting bodies (Golak-Siwulska et al., 2018).

Fruiting and harvesting

After casing, the cultivation system is transferred to the fruiting environment. This environment typically has specific temperature, humidity, and lighting conditions that mimic the natural conditions required for mushroom formation. Fruiting triggers the development of mushrooms from the mycelium.

During the fruiting phase, mushrooms begin to form and grow from the casing layer. Proper humidity levels are maintained to prevent the mushrooms from drying out, while adequate ventilation ensures the removal of carbon dioxide and the replenishment of oxygen.

Identification of Genetic Variants and Improvement of Existing Strains

Techniques for genetic identification and fingerprinting are required for the characterization and improvement of Pleurotus strains. Molecular techniques have been utilized for the purposes of species identification, mating compatibility testing, and strain improvement (Urbanelli et al., 2007; He et al., 2017; Adeniyi et al., 2018). Some of these techniques include RAPD analysis, sequencing of the internal transcribed spacer (ITS), and AFLP analysis. These methods contribute to the commercial production of Pleurotus mushrooms by making it easier to choose disease-resistant and high-yielding variants of the fungus (Barh, 2019).

Genetic improvement plays a crucial role in enhancing the productivity, quality, and disease resistance of mushroom strains. Through the identification of genetic variants and the implementation of breeding programmes, researchers aim to develop improved mushroom strains with desirable traits. Let's explore the process of identifying genetic variants and improving existing strains in detail:

Genome Sequencing and Analysis

The first step in identifying genetic variants is to sequence and analyze the genome of the target mushroom species. Advances in DNA sequencing technologies have made it possible to obtain high-quality genome sequences, providing valuable insights into the genetic makeup of mushrooms.

Genome analysis involves identifying genes responsible for various traits such as yield, flavour, aroma, nutritional composition, and resistance to diseases. Comparative genomics studies also allow researchers to identify genetic variations among different strains and populations of mushrooms.

Marker-Assisted Selection (MAS)

Marker-assisted selection is a technique used to identify and select individuals with desirable traits based on genetic markers

linked to those traits. Genetic markers are specific DNA sequences associated with particular traits or genes of interest.

By identifying markers associated with traits such as yield, disease resistance, or nutritional content, breeders can efficiently select individuals with those traits for further breeding programmes. MAS accelerates the breeding process by enabling the selection of desirable traits at an early stage without the need for time-consuming and resource-intensive phenotypic evaluation.

Breeding Programmes

Breeding programmes aim to combine desirable traits from different mushroom strains through controlled mating and selection. This involves crossing compatible strains to create hybrid progeny with improved characteristics.

Selective breeding is performed based on the identified genetic variants and markers associated with desirable traits. By selecting individuals with the desired genetic makeup and phenotypic performance, breeders can gradually improve the strains over successive generations.

Genetic Transformation

Genetic transformation involves the introduction of specific genes into a mushroom strain to confer new traits or enhance existing ones. This technique allows for the direct manipulation of the mushroom's genetic makeup.

Genetic transformation can be achieved through various methods, such as agrobacterium-mediated transformation, particle bombardment, or protoplast fusion. By introducing genes associated with traits such as increased yield, enhanced disease resistance, or improved nutritional content, researchers can develop genetically modified mushroom strains with improved characteristics.

Genomic Selection

Genomic selection is a relatively new approach that utilizes genomic information to predict the breeding value of individuals without the need for phenotypic evaluation. This technique combines the information from genome-wide markers with phenotypic data from a training population to develop predictive models.

Genomic selection enables breeders to select individuals with desirable traits at an early stage, accelerating the breeding process and reducing the time and resources required for phenotypic evaluation. It also allows for the simultaneous improvement of multiple traits by considering their genomic associations.

Methods of Farming That Are Friendly to the Environment

By using waste products from agriculture as substrates, the cultivation of Pleurotus mushrooms represents an environmentally responsible method of farming (Adebayo and Martínez-Carrera 2015). They have the ability to transform lignocellulosic wastes into food sources that are nutritious and useful, thereby decreasing waste and encouraging the concepts of circular economies (Patil et al., 2010). Indigenous mushroom growing approaches, which make use of regional resources and traditional mushroom cultivating expertise, have also been investigated (Wendiro et al., 2019). These methods not only contribute

to the safety of the food supply but also support the sustainability of the ecosystem.

Conclusion

The nutritional prowess and potential health advantages offered by Pleurotus mushrooms, also known as oyster mushrooms, present a captivating avenue for both the food industry and the realm of human health. These remarkable fungi can be cultivated using an array of lignocellulosic materials and agricultural waste products, showcasing their versatility and sustainability.

The nutritional profile of Pleurotus mushrooms is impressive, boasting a rich composition of essential nutrients such as proteins, dietary fibre, vitamins, and minerals. With their low-calorie and low-fat nature, these mushrooms make for a wholesome addition to a balanced diet. Notably, Pleurotus mushrooms stand out as a superior plant-based protein source, providing all the essential amino acids required for protein synthesis in the body.

Moreover, the dietary fibre content of Pleurotus mushrooms contributes to their health benefits by aiding in digestion, promoting satiety, and supporting proper bowel movements. These mushrooms also harbour an assortment of bioactive compounds, including polysaccharides, beta-glucans, phenolic compounds, and antioxidants, which have been linked to immune-enhancing properties and potential protection against chronic diseases.

The cultivation of Pleurotus mushrooms on lignocellulosic materials and agro-waste products serves as an ecologically sound and economically viable solution. By utilizing substrates such as straw, sawdust, and agricultural residues, these mushrooms not only contribute to waste management but also demonstrate an environmentally friendly approach to recycling and repurposing agricultural by-products.

In essence, Pleurotus mushrooms embody a paradigm shift in food production with their exceptional nutritional content and health-promoting properties. Incorporating these mushrooms into our diets can enrich our culinary experiences while providing an array of health benefits. Nonetheless, further research is warranted to delve deeper into the bioactive compounds present in Pleurotus mushrooms and unravel their intricate mechanisms of action in supporting human health.

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