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Mushroom Substrate Selection: Factors Influencing Productivity and Sustainability

Harshal Lakdawala, Parth Desai, H. A. Pandya, Hiteshkumar Solanki
Department of Botany, Bioinformatics & Climate Change Impacts Management, Gujarat University, Ahmedabad – 380009, Gujarat, India

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ABSTRACT

Mushroom cultivation presents a promising avenue for sustainable food production and economic diversification, leveraging readily available agricultural and forestry byproducts as growth substrates. Diverse edible mushroom species, including Shiitake (Lentinula edodes), Oyster (Pleurotus spp.), King Oyster (Pleurotus eryngii), and Button (Agaricus bisporus), exhibit specific substrate preferences, influencing their nutritional and therapeutic properties. While global interest in mushroom farming is expanding, Namibia faces challenges such as climate and suitable strain availability. This review explores the potential of utilizing locally abundant resources as alternative substrates, focusing on Acacia bush sawdust, shredded Prosopis branches, Kalahari melon residues, millet straw, sorghum stalks, and groundnut shells. By comparing successful case studies from other regions, we aim to investigate the impact of these substrates on the growth, nutrition, and potential therapeutic properties of the selected edible mushroom species. This study aims to demonstrate the feasibility of adapting mushroom production to local resources and conditions in Namibia, promoting sustainable agriculture, rangeland restoration, and the creation of local economic opportunities.

I. INTRODUCTION

Oyster mushrooms (*Pleurotus spp.*) are profoundly well-known and flexible bunch of parasites known for their fragile, fan shaped fruiting bodies and gentle wonderful flavor (S.T. Chang, et al., 2004). These mushrooms are local to temperate and subtropical areas, and they grow on rotting natural matter, such as trees and plant byproducts (P. Stamets, 2011). There are a few species of Pleurotus mushrooms with *Pleurotus ostreatus* being the foremost common species grown by cultivators (Obodai, et al., 2003).

Oyster mushrooms are not only tasty but also very nutritious too. They contain very low calories and fat, making it a healthy addition to every diet. Oyster mushrooms are an excellent source of herbal protein and are a valuable option for vegetarians and vegans (R. Cohen, et al., 2002). They contain substantial

number of vitamins (particularly B1, B2, B3), vitamin D, potassium, iron and magnesium. Oysters are rich in antioxidants such as ergothioneine and polyphenols, protecting the body from the oxidative stress and inflammation (S. Khatun, et al., 2015).

Oyster mushrooms have long been recognized for their potential medicinal properties like immune system support, cholesterol lowering effects, anti-cancer properties (SP wasser.,2010). They contain compounds like beta glucans that may help stimulate the immune system and enhance the natural defenses of human bodies. Some studies suggest that oyster mushrooms can help reduce cholesterol levels, promoting heart health. Preliminary research indicates that certain compounds in oyster mushrooms may have anti-cancer effects, although more studies are needed to fully understand their potential.

Global importance of oyster mushrooms is of great importance globally due to culinary versatility, ecological value and economical values (DJ royse., 2014). Their mild flavor and tender texture make them suitable for a wide variety of dishes, from soup and stir-fries to salad and sauces. Oyster mushrooms are widely cultivated, especially in developing country. Providing a source of income for small scale farmers. They also contribute to waste reduction by breaking down agricultural byproducts like straw, sawdust, and coffee grounds.

One of the main reasons why mushroom is so popular is their adaptability and simple cultivation. They can be grown on a variety of organic substrates, including straw, sawdust, and agricultural waste such as cardboard. Their cultivation requires minimal equipment, allowing equal access for small farmers an urban breeder. Quick and fat growth, low maintenance, versatility under growth conditions. Oyster mushrooms grow rapidly and are often harvested within 3 to 6 weeks of inoculation of the substrate. Maintenance is relatively low, only stable temperature, air humidity and proper air flow are required. You can grow in different climate zone, from medium to subtropical regions, prosperity and even indoors.

The substrates are critical factors in a successful cultivation of mushrooms, including oyster mushrooms. While the substrate plays a key role in providing nutrients and structural support for mushroom growth, there are several challenges and opportunities related to its choice and optimization.

II. CHALLENGES:

Here are some challenges like, specificity, cross reactivity, complexity, cost, stability. Achieving specificity toward only one target enzyme or molecule is a significant challenge, especially when dealing with similar enzyme or molecule is dealing with similar enzymes or molecules. Substrates may react with other enzymes or molecules, leading to inaccurate result or interference in reaction. Substrate can be complex, making it difficult to design and test them effectively. Developing and optimizing substrates can be expensive especially for specializes applications. Some substates may be unstable or degrade over the time, afectig their performance.

III.OPPORTUNITIES:

Here are some opportunities like, enhanced performance, increased selectivity, novel application, cost reduction and sustainability. An optimized substrate can improve the efficiency and accuracy of reactions or processes. Substrate optimization can lead to increased selectivity, reducing cross reactivity and improving specificity. Optimized substrate can be enabling new application in various fields such as diagnostics, therapeutic, and material science. Optimized substrate can reduce the amount of substrate needed, leading to cost savings. substrate optimization can be contributed to sustainability by reducing waste and improving resource utilization.

Types of substrates:

Lignocellulosic wastes cover a wide area of materials like sawdust, woodchips, old paper, and other byproducts from forest or the timber industry.

Agricultural residue contains materials like cereal straws (rice, wheat, grain), corn cobs, sugarcane bagasse and other crops.

Supplemented substrates that have been enhanced with some supplements, such as nitrogen sources (bran, soybean), carbohydrates (sugar and molasses), minerals.

Impact of different substrate on yield and quality of oyster mushroom

The selection and the preparation of the substrate or a growing media have a coordinate impact on the produce and the quality of mushrooms delivered. A well-prepared substrate that meets the great nutritional and physical necessities of the target mushroom species can essentially improve generation productivity and good product quality.

Yield:

Substrate wealthy in basic supplements and with favourable physical properties bolsters strong mycelial colonization and fruiting body improvement, driving towards higher yield. Reliable substrate quality and legitimate arrangement strategies are basic for maximizing production.

Quality:

The quality of mushrooms, with counting their estimate, shape surface texture, and dietary value is influenced by the substrate. Nutrient rich substrates delivered mushrooms with superior quality enhancement, surface and higher dietary substance. Substrates that are free from contaminants and arranged beneath sterile condition yield high quality mushrooms with less escapes.

Disease resistance:

Legitimately prepared substrates decrease the chance of defilement by competing microorganisms, other infectious agents and pathogens (González, A. A. M. et al., 2022). Sterilization or pasteurization of substrate is basic to dispose of destructive life forms and make a favourable environment for the target fungi (DJ royse., 2014). This practice enhances the wellbeing and efficiency of the mushroom crop (Chang ShuTing, et al., 2004).

Importance of substrates:

In mushroom cultivation substrate plays a crucial role, serving as the primary source of nutrients and providing the physical environment necessary for fungal growth and development. The selection and the preparation of substrates significantly impact the yield, quality and sustainability of mushroom production. This section delves into the multifaceted importance of substrates, exploring their nutritional roles, physical properties and broader implication for mushroom cultivation.

Nutritional role for substrates:

The substrate is basically blood vessels for fungi, providing all the essential nutrients necessary for their growth. Mushrooms, unlike plants which are non-photosynthetic. They rely on organic quality for carbon needs and their energy. Therefore, the nutritional composition of the substrate directly affect the growth, productivity and quality of products.

1. **Carbon source:** The main nutrient as required for the mushroom is carbon, obtained from complex organic compounds such as cellulose, hemicellulose and lignin found in plant. Substances such as straw, sawdust and agricultural residues are rich in these lignocellulosic material, making them ideal for growing mushrooms (Philippoussis, G. 2009).
2. **Nitrogen source:** nitrogen is another essential nutrient for the growth of the mushrooms. It is essential for the synthesis of protein, nucleic acid and other cell components. The substrate is usually added by nitrogen rich materials such as wheat, soy or urea to improve their nutritional records carbon/nitrogen ratio of the substrate is the main factor in determining the effectiveness of mushroom invasion and growth (Royse, D. J. et al., 2003)

3. **Potassium:** mushrooms generally contain a good amount of potassium, which is essential for maintaining fluid balance, nerve function, and muscle contraction. A typical serving (about 100g) of mushrooms can contain around 300-0400 mg of potassium, depending on the type (P Mattila, et al., 2002).
4. **Phosphorus:** Mushrooms supply phosphorus, which is considerable for bone wellbeing, vital production and cellular health. In a 100g serving, mushrooms generally contain around 100-150 mg of phosphorus (E Bernas, et al., 2006).
5. **Minerals:** substrate that provide different minerals and vitamins necessary for enzyme activity and metabolism in mushrooms. Factors such as phosphorus, potassium, calcium and traces of mineral such as zinc, copper and iron are very important for the growth of healthy mycelium and the body development of the fruit. Gypsum (calcium sulphate) is often added to the substrate to provide calcium and sulfur, improving structural integrity and the balance of the pH of the substrate (DJ Royse, 2010).
6. **Vitamins:** Mushrooms are known to be the right source of most vitamins such as thiamine(B1), riboflavin(B2), niacin, biotin, ascorbic acid, x-carotene (vitamin-A) and ergosterol (vitamin D) also active and folic acid and vitamin B12 are present in mushroom, although not in vegetables with the presence of vitamin C (4-8 mg/100g), Niacin and pantothenic (PH Mattila, et al., 1994).
7. **Moisture content:** moisture is very important for mushrooms metabolism and nutrient absorption. The substrate must maintain the optimal moisture level, usually from 60 to 70 %, to support the growth of mycelium. The substrate has good water retention, such as straw and sawdust, provide a favourable environment for the growth of mushroom.

Physical properties of substrates

The physical characteristics of the substrate, including its texture, aeration and structure play a significant role in supporting fungal growth. These properties influence the substrate's ability to retain moisture, facilitate gaseous exchange and provide a stable structural space for mycelial colonization (D Grimm, et al., 2018).

1. **Texture and structure:** the substrate's surface influences its porosity and their circulation. Course substrates like straw or wood chips permit for good aeration, which is significant for aerobic growth of fungus. On the other hand, fine substrates may compact and affect air circulation, leading to anaerobic conditions that are inconvenient to mycelium colonization. An ideal substrate helps in dampness maintaining and aeration.
2. **Aeration:** mushrooms that need oxygen to breathe and the full ventilation of the substrate provides regular oxygen while allowing the release of dioxide carbon is produced in metabolic processes. good ventilation prevents the accumulation of harmful gases and supports powerful mushroom growth. Techniques such as converting substrates or using perforated bags can improve ventilation.
3. **Moisture retention:** The ability of the substrate to maintain and retain moisture is essential to maintain the level of hydration necessary for the activity of the fungal. The substrates have good moisture retention properties, such as straw or fertilizer, providing continuous water to grown mushrooms, helping to reduce the need for regular watering.
4. **pH balance:** The pH level of the substrate affects the available nutrients and the growth of mushrooms. Most mushrooms are liked to be a little acidic with neutral pH (5.5 to 7.0). The addition of materials such as plasters or lime can help adjust the pH of the substrate to the optimum level for specific mushrooms (A Ghose, et al., 2023).

Effect of different substrate on growth of mushroom

This experiment was aimed to evaluate the effect of various substrate on the growth and performance of *Pleurotus sajor caju.* Four substrates were tested: rice straw, wheat straw, banana leaves, and sugarcane bagasse, each weighing 4.5 kg. the substrates were chopped, soaked, steam sterilized, and inoculated with grain spawn before neing incubated. The the study found that wheat straw and banana leaves resulted in fastest colonization on 19th day and fruiting on 20th and 21st days respectively, while rice straw took the longest time as compare to other substrate 24 days. sugarcane bagasse had slower colonization and harvest times, with the second harvest occurring significantly later after almost 54 days of sowing time. This data were analyzed using ANOVA, which showing significant parameters among the substrates. (Dubey D et al.,2019)

This experiment shows the effect of different substrate combinations on the growth, yield, and quality of grey oyster mushrooms (*Pleurotus ostreatus*). Using cotton waste, wheat straw and baobab fruit shells as base substrates, seven different treatments, including four mixtures, were evaluated. Results which shown that cotton waste led to the fastest spawn run, shortest time to first harvest, highest yield and the best biological efficiency. While mixing substrate sometimes improved specific parameters, none of the mixtures consistently outperformed cotton waste alone. The study highlights the significant influence of substrate type on various growth and yield parametrs, recommending cotton waste and/or a mixture of a cotton waste, wheat straw, and baobab fruit shells for optimal oyster mushroom production due to their superior performance and higher benefit cost ratios. (Muswati et al,. 2021)

This study investigated the growth and yield of *Pleurotus ostreatus* oyster mushrooms on different substrate like rice straw, rice straw + wheat straw, rice straw + paper, sugarcane bagasse, and alder sawdust, with all but the controlled supplemented with 10% rice bran. Rice straw alone proved to be the best substrate, yielding the highest number of mushrooms (381.85g) and biological efficiency (95.46%), followed by mixture of rice straw and wheat straw and another mixture is of rice straw and paper. While the other substrates showed some potential, they did not perform as well as in rice straw. Nutritional analysis also revealed that mushrooms grown on rice straw had the highest protein, fiber, carbohydrate, and energy content. The study concludes that while rice straw is a superior substrate, rice straw with wheat straw, rice straw with paper,and sugarcane bagasse can serve as alternative substrates for oyster mushroom cultivation, though with lower yields.(S. Sharma et al., 2013)

as per this experiment the growth and yield of oyster mushrooms *Pleurotus ostreatus* using various substrates like rice straw single substrate, rice straw mixed with wheat straw or paper, sugarcane bagasse, and alder sawdust, with all but the controlled supplemented with rice bran. Rice straw emerged as the superior substrate, resulting in the highest mushrooms yield and biological efficiency, followed by the rice straw mixtures. Nutritional analysis further indicated that mushrooms grown on rice straw had the best nutritional profile. while the rice straw is recommended as the optimal substrate, as per the study suggests that the other tested substrates could be use as alternatives, with reduced yields. (Mondal et al., 2010)

the impact of different agro-waste substrates likr sawdust, corncob and sugarcane bagasse, single or in combinations on the growth, yield and nutritional composition of *Pleurotus ostreatus* and *Pleurotus cystidiosus* oyster mushrooms, revealing that substrate with 100% corncob or 100% sugarcane bagasse yielded the highest cap diameter, stipe thickness, weight, yield and biological efficiency, and enhanced protein and mineral content, although with a longer initial harvest time for corncob, the carbon and nitrogen ratio of the substrates significantly corelated with colonization period, mushroom weight, demonstrating the feasibility of utilizing these agro-

wastes for efficient and nutritionally rich oyster mushrooms cultivation.(Hoa et al., 2015)

this study evaluated the impact of different agricultural waste substrates like wheat straw, paddy straw, chickpea straw, and their 1;1 combinations on the growth and yield of *Pleurotus djamor* oyster mushrooms, wheat straw emerged as the most effective substrate, yielding the highest yield(440g/kg dry substrate), shortest spawn run about 23 days, earliest first harvest on 30th day, longest crop period is about 60 days. While wheat straw combined with paddy straw resulted in the highest number of fruiting bodies and lobes, overall wheat straw singularly demonstrated the best performance, making it the recommended substrate for cultivating *Pleurotus djamor.* (S. Satpal, 2017).

The study evaluated the growth and yield of *Pleurotus ostreatus* using different agricultural waste substrates supplemented with wheat bran , corn sheath/corn cob/coit pith, paddy straw or ragi straw , and sugarcane bagasse. Results showed that paddy / ragi straw yielded the highest moisture content, fastest spawn run, and greatest number of fruiting bodies, while sugarcane bagasse resulted in highest total yield, stem length, and cap diameter. However, paddyor ragi straw demonstrated the highest biological efficiency, indicating its superior conversion of substrate to mushroom bio mass, suggesting that substrate composition significantly impacts *Pleurotus ostreatus*'s growth and yield. (S. Maheshvari et al., 2020)

This study characterized oyster mushroom under south Gujarat conditions, involving a survey, morphological analysis, and evaluation of mycelial growth, spawn production, and biochemical composition, the survey identified *P. cystidiosus, P. populinus, and P. ostreatus* results showed that *Pleurotus ostreatus* content highest crude protein, nitrogen and ash content, while *P. populinus* had the highest moisture. Mycelial growth varied across media and temperatures, with optimal growth at 30 celsius. Spawn production was fastest on maize and bajra grains for *Pleurotus cystidiosus,* sorphum and wheat for *P. populinus,* and sorghum and maize for *P. ostreatus.* This study finds provide insights into the cultivation and nutrional potential of these oyster mushroom in the region. (M. M. Chaudhary, 2017)

As per the study of S kumar the production and economics of oyster mushroom (*Pleurotus ostreatus*) cultivation using various agro-wastes substrates like wheat straw, paddy straw, sugarcane leaves sugarcane bagasse, maize stalk and pearlmillet stalk in eastern uttar Pradesh. The results of this experiment showed that wheat straw was the most effective substrate, yielding the highest mushroom yield (710.50 g/kg dry substrate), biological efficiency (71.05%), net returns (63.37/kg Indian rupees) and benefit cost ratio (2.52) compared to other substrates, indicating its potential for commercial oyster mushroom cultivation and eco friendly agro-wastes management in the region. (S. kumar et al., 2023)

This study wvaluated the yield and nutritional composition of newly introduced oyster mushroom strains in Bangladesh comparing *Pleurotus high-king, P. ostreatus, and P. geesteranus* to the commercially common *P. ostreatus. P. geeesterinus* demonstrated superior economic yield, biological performance, and nutritional content, particularly in protein and minerals, surpassing the commonly cultivated *P. ostreatus.*while *P. high-king* exhibited rapid primordia growth. *P. geesteranus's* overall performance suggests it as a promising candidate for commercial cultivation in bangdadesh due to its enhanced yield and nutritional benefits. (M. Ahmed et al., 2013)

This study analyzed the nutritional properties of two popular oyster mushrooms in bangladesh, *Pleurotus sajor caju* and *Pleurotus florida,* revealing them as a rich source of protein and fiber, with low lipid content and substantial mineral content. *Pleurotus sajor caju* exhibited higher protein levels, while *P. florida* had slightly more carbohydrates and fibers. Both species showed notable mineral concentrations, with variations in specific elements. Furthermore, the analysis of different mushroom parts indicated that pileus and gills are protein rich, while the stipe is fiber

rich, highlighting the nutritional value of these mushrooms and suggesting their potential as a diatary supplements to address protein deficiencies and support various health needs. (N. Alam, et al., 2007)

This study evaluated the impact of different agricultural waste subatrate like cotton waste, wheat straw and paddy straw) on the growth, yield and nutritional composition of three oyster mushroom species (*P. sajor caju*, *P. ostreatus*, and *P. djmor).* Cotton waste was identified as the most effective substrate, resulting in faster spawn running, earlier primordia initiation, higher yields, and a greater number of fruiting bodies. *P. ostreatus* exhibited the highest protein content, while *P. sajor caju* has the highest fiber and ash content, and *P. djmor* showed the highest fat and carbohydrates levels. The researches demonstrate the potential of utilizing agricultural waste for efficient oyster mushroom cultivation, offering a valuable source of nutrition and a sustainable waste management strategy. Cotton waste boosted oyster mushrooms yields, especially with *P. sajor-caju* has more fiber and ash, *P. djmor* has contains rich amount of fat and carbs. Hence, cotton waste led in overall yield, despite paddy straw's initial advantage. (J. Ashraf, et al,.2013)

This study investigated the impact of different substrates on the growth and yield of oyster mushrooms (*Pleurotus ostreatus*). The experiment conducted in totally controlled greenhouse environment, compared paddy straw, maize cob + paddy straw, sugarcane bagasse + paddy straw, and sawdust + paddy straw. Results showed that paddy straw alone resulted in the shoetest colonization and fruiting initiation periods, the highest biological efficiency, and favourable pileus and stalk diameters. While maize cob + paddy straw yielded the highest total fresh weight, paddy straw demonstrated superior efficiency, suggesting it as the most effective and economical substrate for oyster mushroom cultivation. (HP Sitaula et al., 2018)

Wide ranging implications for mushroom cultivation

The importance of substrates extends beyond immediate cultivation outcomes to broader economic, environmental and social implications.

1. Environmental implications

In sustainable agriculture mushroom production can be integrated into sustainable farming practices which uses agricultural waste as a growing medium, contributing to waste management and soil regeneration. (Verma, S. (2023)). The process of growing mushrooms produces minimal waste and carbon emissions, making it an environmentally friendly option. (Gupta, N. (2022)).

2. Nutritional and medicinal benefits

Mushrooms are very low in calories, carbohydrates, fat, and sodium. They are also rich in essential nutrients such as selenium, potassium, riboflavin, niacin, vitamin D, proteins, and fiber (Rinker, D. L. (2017)). They are also used in traditional medicine for their healing properties. They are known to help in the prevention and treatment of various diseases which includes Alzheimer, Parkinson's, hypertension, and cancer (Verma, S. (2023)).

3. Economic opportunities

Mushrooms can be providing a sustainable source of income for rural commodities. It requires minimum resources and space, making it accessible to small scale farmers. If we look at the market the demand for mushrooms is increasing due to their nutritional and medicinal benefits. This opportunities for farmers to tap into new markets and make them strong financially. (N. Gupta et al.,2022)

Importance of the mushroom growing substrates

Mushroom cultivation presents significant economic benefits by offering a sustainable income source, particularly for rural communities, through accessible small-scale farming. The rising market demand for mushrooms, driven by their nutritional and medicinal value, creates opportunities for farmers to expand into new markets and increase profits through value-added products like dried mushrooms and extracts

(Philippoussis, A. N. (2009)). Furthermore, it generates diverse employment opportunities in substrate preparation, cultivation, harvesting, and marketing, while simultaneously promoting sustainable agriculture by effectively utilizing agricultural waste and contributing to soil. Mushroom substrates are vital, providing essential nutrients for mycelium growth and a supportive environment for colonization (Chang ShuTing, et al., 2004). They retain crucial moisture, ensuring proper hydration for metabolic processes (Philippoussis, A. N. (2009)). Utilizing agricultural waste like straw and sawdust, they promote sustainable farming (Aguilar-Rivera, N., et al.,2012). Substrate choice directly influences yield and quality, allowing for tailored cultivation of various mushroom species, such as oyster, shiitake, and button mushrooms (Obodai, M, et al., 2003). Proper preparation, including sterilization, minimizes contamination risk (Macias González, et al., 2022). Cost-effective, using readily available materials, substrates make mushroom farming accessible (D Priadi, et al., 2018). They are the foundation of successful cultivation, impacting everything from growth to harvest quality (Chang ShuTing, ET AL.,2004). Generation, thus enhancing overall farm productivity.

IV. CONCLUSION

Oyster mushroom cultivation offers a sustainable and nutritious food source, with substrate selection being a critical factor for success. While rice straw, wheat straw and cotton waste are frequently identified as superior substrates, other agricultural wastes can be effectively utilized. Researchers should continue to investigate optimal substrate combinations and adapt cultivation practices to local conditions to maximize yield and nutritional benefits. The selection and utilization of diverse substrates remains paramount in optimizing mushroom cultivation, as substrate choice profoundly influences mushroom yield, growth parameters, and nutritional composition, evidenced by numerous studies. Continued exploration of locally abundant and cost-effective agricultural byproducts is crucial for empowering farmers, particularly in developing countries, offering a viable income stream and a sustainable solution for managing agricultural waste and addressing environmental challenges like bush encroachment. It is imperative that farmers are cognizant of specific substrate-mushroom interactions, ensuring the production of high-value mushrooms that meet consumer demands, and the sustainable reuse of spent mushroom substrate as livestock feed or soil amendment presents an opportunity to minimize environmental pollution and promote a circular economy. Recognizing the immense nutritional and medicinal potential of mushrooms, rich in essential nutrients and offering diverse health benefits, is crucial, as ongoing research and discovery of new mushroom species promise to further expand our understanding of their nutritional contributions to human health; therefore, promoting mushroom cultivation through the utilization of locally sourced, diverse substrates is not only a viable economic strategy but also a significant step towards enhancing food security, improving public health, and fostering environmental sustainability.

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