Effects of different substrates as medium for mushrooms cultivation

Article · February 2022

DOI: 10.15413/ajfr.2021.0104

3 authors, including:

Kristine N. Haukongo
University of Namibia
1 PUBLICATION **0** CITATIONS
SEE PROFILE

Lydia Horn
University of Namibia
122 PUBLICATIONS **2,888** CITATIONS
SEE PROFILE

Academia Journal of Food Research 9(2): 032-037, August 2021
DOI: 10.15413/ajfr.2021.0104
ISSN: 2315-7763

Academia Publishing

Research Paper

Effects of different substrates as medium for mushrooms cultivation

Accepted 6th *October, 2021*

Kristine N. Haukongo*[1], Lydia N. Horn[2] and Muvari C. Tjiurutue[1]

*[1]Department of Biochemistry, Microbiology and Biotechnology, University of Namibia, Windhoek, Namibia.
[2]Zero Emissions Research Initiative, Multidisciplinary Research Centre, University of Namibia.

*Corresponding author. E-mail: kristinehaukongo@gmail.com

ABSTRACT

Different Mushrooms species prefer different substrates as growth medium. For example, medicinal mushrooms such as Shiitake, pearl and yellow oysters grow better on straws and gourmet. Reishi and Maitake grow better on sawdust and logs, whereas *Agaricus* mushrooms are grown on manure with the likes of button mushrooms, portobella mushrooms. As a result, mushrooms have gained interest around the world, not only because mushroom are easily cultivated using locally available agricultural waste, but also because mushrooms contribute to employment and reduce food scarcity, while meeting nutritional and health demands. In Namibia, mushroom cultivation is not well exploited due to various factors such as unfavourable climatic conditions and suitable mushroom strains. Different encroacher bushes and other related crop residues can be studied to establish the variation of mushroom nutrition and therapeutic properties as a result of mushrooms growing on different substrates. Therefore, the utilization of encroacher bushes locally could also contribute towards rangeland restoration and creating economic opportunities. This review aims at investigating the importance of mushrooms production at local levels using alternative materials as substrates in comparison to other countries as case studies.

Key words: Bush encroachment, employment creation, mushrooms, nutrition, substrates.

INTRODUCTION

Mushroom cultivation has gained interest among entrepreneurs, farmers as well scientists around the world over the past few decades. Several studies reported various methods to make mushroom cultivation more profitable and popular while at the same time focusing on evaluating the source of nutrition for mushroom mycelium (Fasehah and Shah, 2017). Alternatives for mushroom cultivation has been reported with varying success including wheat straw, cottonseed straw, cereal straw, corncob, sugar cane straw and sawdust. However, there has been no clear and precise information on the usage of wood chips as compared to other substrates used for mushroom cultivation (Masevhe et al., 2016). According to Nithyatharani et al. (2018), a substrate is any material containing lignin, hemi cellulose and cellulose and where the mycelium can grow until it forms a fruiting body (mushroom). Suitable substrates for mushroom cultivation are important because substrates can influence nutritional content, yield, quality, bioefficiency, economical costs as well influence cultivation time (Masevhe et al., 2016). For example, less than 15% of Africans are growing mushrooms due to lack of financial support, commitment, and lack of knowledge that mushrooms can be cultivated. In Africa, only South Africa, Zimbabwe and Kenya are producing mushrooms at commercial level (FAO, 2002; Kivaisi, 2007). The use of different substrates in mushroom cultivation provides different nutrients to the mushrooms being cultivated. However, Carrasco et al. (2018) reported that, there was still a gap in understanding the nutritional requirements of mushrooms. They secrete enzymes like lignin peroxidases,

quinone reductases, dehydrogenases, xylanase, cellulases or cellobiose dehydrogenase, laccases and lignin peroxidases during the growing process (Carrasco et al., 2018). Furthermore, these enzymes are instrumental in the breaking down of the lignocellulosic in the substrate. Studies indicate the need for oxygen and a specific PH in order to facilitate normal metabolism, as well as Carbon and Nitrogen for structural building and provision of energy (Ashraf et al., 2013).

Neglected encroacher bushes which are predominantly cleared from agricultural land can be used as substrate for mushroom cultivation creating more value addition while time generating income at the same. Specifically, encroacher bushes have potential to contribute to the economic development of the country when effective measures are put in place. For example, Honsbein (2014) suggested that if about 3% to 5% of encroacher bushes are cleared then farming with wood could become the most important sub-sector in primary agriculture, while the other parts could easily become useful as mushrooms substrates. Bush encroachment has negatively impacted the productivity of Namibian savannas and biodiversity as there has been no much knowledge on uses of these problematic species. A massive invasion of bushes such as *Acacia mellifera* (Black thorn), *Dichrostachyscineria* (Sickle bush), *Terminalia sericea* (Silver terminalia), *Terminalia prunioides* (Purple-pod terminalia), *Acacia erubescens* (Blue thorn), *Acacia reficiens* (False umbrella thorn) and *Colophospermum mopane* have been encountered in several parts of the country (De Kler, 2004), and could be regarded as a great source of mushrooms substrates. Encroacher bushes as alternative substrates need to be studied in order to determine their suitability on several mushroom parameters including yield, contamination rate, nutritional differences and how fast it colonises for use by farmers in mushroom production. This review aims to discuss alternatives including encroacher bushes as substrates for mushroom cultivation that are economic, environmentally friendly, as well as their impacts on mushroom growing parameters.

Materials used for mushroom cultivation as substrates

Farming with mushrooms can only be successful if quality spawn, quality substrate and best growing environment are availed. In addition, environmental factors like humidity and temperature contributes to mushroom cultivation (Uddin et al., 2011). According to Masevhe et al. (2016), mushrooms can be grown on different substrates, preferably on locally available substrates that are high in carbon, lignocellulosic substances (lignin, hemicellulose, cellulose), essential nutrients (nitrogen, iron, potassium and phosphorus) and sterile. Other sources of substrates include wood, papers, horticulture waste, leaves, wheat straw, cotton seed hulls and sugarcane residue (Siwulski et al., 2019). Previous studies showed that most of the agricultural waste can be used for mushroom cultivation. For example, sawdust, corncob, sugarcane bagasse has been used as mushroom growing substrates and proved to be successful as growing medium for mushrooms (Besufekad et al., 2019). Additionally, oyster mushroom have been cultivated on various agricultural waste substrates made from various plant materials such as rice straws, paddy straw, wheat straw, paper, paper, coffee pulp, cotton waste, cotton seed hulls, bean straw, crushed bagasse and molasses wastes (Owaid et al., 2015). Cereal straws such as wheat, rye, and oat make great substrate for mushroom growth. Some farmers use hardwood preferably decomposing wood such as that of Elm, beech, alder, ash, and cottonwood (Fasehah and Shah, 2017). Different mushroom species can effectively degrade substrates in different ways and most mushrooms can easily break down the plant fibers from straw. However, straws get easily contaminated as they tend to have a lot of microbes that compete with the mushroom mycelium (Mashudu et al., 2015). Various substrate used for mushroom cultivation can greatly be affected by different moulds and pests, which reduces its yield or even preventing the substrate from yielding any mushrooms at all (Ralph and Kurtzman, 2010). Therefore, cultivators pasteurise the substrate to reduce competition from contaminations (Diana et al., 2006). According to Siwulski et al. (2019), it is highly advantageous to mix different substrates in order to increase the nutrition for the mycelia to feed on. For example, a number of mushroom species have been grown on sawdust obtained from tree species, which are supplemented particularly with wheat bran. In addition, some cultivators occasionally use corn meal, and lime to balance the pH (Carrasco et al., 2018).

Wood as a growing medium for mushrooms

During the last 2000 years, mushroom cultivation on wood has been widely practiced particularly in Asia. Hard wood like birch, hickory, beech and oak are used as logs or sawdust. Cultivation done on logs is generally done by inoculating spawn into holes drilled on logs (Stamets, 2005). The logs are then incubated under tree shades for 1 yr before the first flush, mushrooms will then continue to grow for three to four yr (Levine, 2020). Hardwood species in general are good for *Lentinus edodes* (Shiitake mushrooms). It is used to cultivate a commonly known medicinal mushroom called *Ganoderma lucidum* and *Tremella fuciformis* (Stamets, 2000). *Ganoderma lucidum* (also known as Reishi) can be cultivated on logs by cutting a hardwood log 1 to 2 meters long and at least 1 meter in diameter, and this method gained popularity due to the presences of numerous bioactive compounds (Samantha,

2010). Reishi produces fruit bodies that are harder compared to other mushrooms the cap is flat, rounded shape and red or reddish-brown in colour (Siwulski et al., 2015). Among the mushrooms cultivated on hardwood is *Tremella fuciformis*, it is a commonly edible medicinal mushroom mostly grown in China. *Tremella fuciformis* belongs to the order *Tremellaces* and the family *Tremellacea*. It is commonly referred to as, snow fungus, snow ear, silver ear fungus, white jelly mushroom and white auricularia, (Shahrajabian et al., 2020).*Tremella* are reported to be mostly found in dead trees in tropical areas (Kuo, 2018). The fruiting bodies of *T. fuciformis* are described to be white or light yellow in colour (Devash, 2018).

Straw as a growing medium for mushrooms

Straw is the most widely used substrate for mushroom cultivation**,** readily available, easy to cut, cheap and can easily be pasteurized (Sharma et al., 2013). Among other mushroom species, Oyster mushrooms and *Volvariella volvacea* are grown on straw (Cai et al., 1999). It is used by soaking the substrate in water for as long as 10 to 12 hours and can be removed from water to drain excess water (Ahlawat, 2016). The soaked straw can also be mixed with chalk ($CaCO_3$) and wheat bran for supplementation. To eliminate unwanted fungi and bacterial growth the substrate is then sterilized at 121°C and 1.5 psi for 30 min in an autoclave or can be pasteurized for 2-4 h in drums (Owaid et al., 2015). Spawning is then carried out in transparent plastic bags under sterile conditions and the bags are incubated for a period of 1-2 months until the first flush. Some of the important aspects of mushrooms grown on straw are outlined in Table 1 (Sharma et al., 2013).

Compost as a growing medium for mushrooms

Some mushrooms are well adapted to growing on compost. Mushrooms that grow on compost are those that feed on manure, or decomposed agricultural waste. *Agaricus bisporus* (Button mushrooms) is one that is grown in a slightly unique way, it needs bacteria to decompose cellulose in order for the mycelium to feed on the substrate (Funda et al., 2017). Farmers first prepare a compost by mixing manure and straw which is left to rot for about 3 weeks (Sangeesta, 2021)**.** The compost is then pasteurised at 57-59°C for 6-8 h before spawning (Maheswari, 2013). The moisture of the compost plays a critical role, it must not be too moist or too dry, 65-72% is an ideal moisture preferred during composting. If the compost is too wet it prevents sufficient air flow needed for the mycelium development (Dupree, 2020). Like other mushroom species button mushrooms have tremendous benefits to human health and nutrition (Maheswari,2013). Button mushroom can be used in the fight of malnutrition, food insecurity and poverty faced in developing nations. According to Stamets (2000), this however can only be achieved if the best and nitrogen supplemented substrate is used to provide enough nutrients needed for mushroom growth. Cultivators normally use bran, chicken manure, Nitrate and Ammonia as nitrogen additives to the mushrooms (Stamets, 2000).

Soil as a growing medium mushroom

Soil growing mushrooms have symbiotic relationship with roots of trees or grasses, thus commonly known as mycorrhizal mushrooms ("myco" mean mushrooms and "rhizal" means roots) (Stamets, 2000). Truffle (*Tuber melanosporum*) is the most common mushroom that grows from the soil. Truffles are cultivated in orchards whereby the seedlings of host trees are inoculated with truffle spores before planting. Fischer et al. (2017) reported that it takes about 4-7 years before the first harvest of truffles. According to Booth (2019), truffles are non-identical from mushrooms they are round, firm, covered in warts, and have different size (Lee, 2020 and Rajarathnam, 2013). Truffles are grown in soils that are rich in calcium, furthermore farmers need to avoid environments with soil pollution and acid rain as these change the nutrients needed by truffle mycelium present in the soil which can have a negative effect on truffle cultivation (Stamets, 2000).

Nutritional and medicinal benefits of mushrooms

Generally, there are a number of benefits that are associated to mushrooms of which many are influenced by the type of substrate used. This can range from environmental benefits, nutritional and medicinal benefits. Mushrooms can be dried to make tea, paper pulp, cosmetics or soup which increases their life span (Stamets, 2005). Medical mycology is an old tradition which also applies to mushrooms dating back to the first century (Wani et al., 2010). Mushrooms have a great range of nutritional contents, ability to treat different kinds of ailments and the fact that they can be grown both on a small scale and commercially for income make them ideal for growing almost everywhere (Anjana and Savita, 2017; Wani et al., 2010). In addition, mushrooms are considered as health diet food due to their medicinal benefits (Mowsurni and Chowdhury, 2013). Major medicinal properties of mushrooms have been documented (Wani et al., 2010; Mowsurni and Chowdhury, 2013). The medicinal properties attributed to mushrooms includes antibiotic, anticancer, immune response stimulating effects, antiviral activities and blood lipid lowering effects (Alam et al., 2007). Specifically, *Pleurotus* species are also rich in

Table 1: Comparison of colonization period, primordial initiation time and mushroom harvest time of *P. ostreatus* on different substrates (Reference).

Substrate	Supplements	Colonization period days	Primordial formation days	First harvest days
Rice straw	Control	22.40±1.10^{a}	26.40±1.67^{a}	32.40±1.67^{a}
Rice straw + Wheat straw	Rice bran	23.20±0.83^{b}	28.40±1.51^{b}	34.40±2.07^{ab}
Rice straw + paper	Rice bran	24.00±0.70^{bc}	29.60±0.54^{c}	35.40±1.14^{bc}
Sugarcane bagasse	Rice bran	24.80±0.83^{cd}	30.80±0.83^{bc}	36.60±1.14^{bc}
Sawdust t	Rice bran	26.00±0.70^{d}	31.60±1.14^{c}	37.80±1.48^{c}

Different letters along the column indicate significant differences of the mean (P = 0.05) according to Tukey's Btest (mean ± sd, n = 5).

medicinal values and they are one of the most consumed. *P. florida* have been proven to have antioxidant and antitumor activities in experiments. Other *Pleurotus* species inhibits hypertensive effects through its active ingredients, and they also possess antitumor activity and hypoglycemic effects (Alam et al., 2007; Ahmed et al., 2013; Mowsurni and Chowdhury, 2013).

Oyster mushroom have high medicinal value, and hence its consumption can aid in ameliorating and preventing many ailments which includes high blood, kidney problems, diabetes, cholesterol level, impaired immune response, hepatitis B, chronic, hypertension, heart disease, gastric cancers, fatigue syndrome and microbial infection (Mowsurni and Chowdhury, 2013). Various important health products have been made from mushrooms, while some of these efforts are currently being translated into healthcare products. For example in Ghana, Accra Polytechnic, in collaboration with Aloha Medicinal USA, has developed a product called Immune Assist 24/7 from tropical *G. lucidum* and other mushroom species for enhancing the immunity of HIV/AIDS patients (Anchang, 2014). *Pleurotus* species are generally, effective in the reduction chances of cardiovascular and artery related disorders including atherosclerosis (Alam et al., 2007). Based on Alam et al. (2007), the nutritional content of oyster mushroom present them to be ideal vegetable for cancer, heart and diabetic patients (Bhattacharjya et al., 2008). Antioxidants found in mushrooms contain protective agents against oxidative damage, Oyster mushrooms modulate the immune system, prevent atherosclerosis (Wani et al., 2010) and (Gunde-Cimerman, 1999). Mushrooms have antimicrobial activities which gives high chance of their bioactive compounds to act like antibiotics or antifungal in pharmaceuticals (Iwalokun, 2007). Owaid et al. (2015) indicated that *Pleurotus* species possess anti-fungal, anti-parasitic, anti-yeast and antibacterial activities. In addition, Oyster mushrooms modulate the immune system prevent atherosclerosis (Gunde-Cimerman, 1999). Studies also show that oyster mushrooms have antimicrobial activities which give high chance of their bioactive compounds act like antibiotics or antifungal in pharmaceuticals (Iwalokun, 2007). Owaid et al. (2015) also reported that *Pleurotus* species possess anti-fungal, anti-parasitic, anti-yeast and antibacterial activities. *Volvariella volvaceais* also a straw growing mushroom, which is mostly best grown in summer, due to its cold nature it can be cultivated in warm temperatures (Ahlawat, 2016). Straw mushrooms produce a multicomponent enzyme system consisting of endo-1,4-β-glucanase, cellobiohydrolase, and β-glucosidase for the conversion of cellulose to glucose (Cai et al., 1999).

Straw mushrooms promote the production of body fluid rich in Protein, Fat, Iron, Zinc, various amino acids and large amounts of Vitamin C (Ahlawat, 2016). Antioxidants are regarded as chemical compounds that protect cells from unstable molecules damage (Singh et al., 2020). These unstable molecules are free radicals and they are strong oxidants and those chemical entities with unpaired electrons (Mahendran et al., 2012). Overproduction of free radicals leads to oxidative stress and free radicals can cause random damage to the body and this includes DNA, protein, sugar and can lead to mutations and cancers (Singh et al., 2020). Furthermore, mushrooms have medicinal benefits such as antioxidants that defend the body against free radicals. Mushrooms extracts are inhibitory to sarcoma, and generally immunoceticals from mushroom species shown anticancer (Mahendran et al., 2012). Mushrooms extracts also have the ability to protect DNA a lot of mushroom species possess highly potent immune enhancers against cancer for both human and animals (Wani et al., 2010).

Importance of the mushroom spent substrates and economic benefits of mushrooms

The environment contains large volumes of unused lignocellulosic by-products from anthropogenic activities or by natural occurrence. In most case these lignocellulosic by-products are deposed off by burning or left to rot in the environment (Angadam et al., 2021). However, they can be utilized for mushroom cultivation which can be of great value. Agricultural waste constitutes valuable resources that can be used to contribute to the economy in various ways. For example, substrates can be reused to produce mushrooms or used as high-quality waste to make compost

that can be used in gardens to grow vegetables like spinach, cabbage or lettuce (Ringer, 2017). The spent mushroom substrate can be used as an alternative for energy production, to produce biofuels or can be used as firewood (Carrasco et al., 2018). In addition, used substrate can be used as animal feed to boost their health status as spend mushroom substrate is rich in nutrients. Spent substrate can also be used for bioremediation to remove unwanted contaminations in the air, soil and water (Ringer, 2017). Mushroom cultivation can easily be carried out by unskilled farmers and waste are used and turned into products that are edible and of high market value. Mushroom cultivation can contribute to food security and also can be an alternative to employment especially disadvantaged groups specifically women and disabled people (Tesfaw et al., 2015). Mushroom cultivation can be regarded as an important commercial asset because it has potential to generate income. Varieties such as *Agaricus bisporus, Lentinus edodes* and *Pleurotus* species are the most commercially and successfully cultivated mushroom (Owaid et al., 2015).

CONCLUSION

The use of different substrates has been proven to be significant in previous studies. Continuous studies with various possible substrates for mushroom cultivation could establish better ideas on best substrates to use. Therefore, farmers are encouraged to use locally available substrates from agricultural by-products that are abundant and economically feasible. Thus, mushroom cultivation could provide a vast array of income to developing countries at the same time eliminating problems such as bush encroachment. However, it should be noted that different substrates may influence mushroom parameters such as yield and nutritional content and farmers need to be cautious about this. Furthermore, spent mushroom substrate can be used as an alternative as feed stock minimizing environmental pollution. Mushrooms are important resources for food and medicine, they are rich in various nutrients and a wide range of health benefits such as boosting the immune system, promoting strong bones, providing an anti-cancer function as well as antidiabetic properties in humans. There is an ongoing discovery of new mushroom species which means more discoveries to the nutrition potentials they can offer to the human diet (Vanathi et al., 2016).

REFERENCES

Ahlawa OP, Bindvi A, Paddy Straw Mushroom (Volvariellavolvacea)Cultivation, ICAR-Directorate of Mushroom Research, Chambaghat, Solan (HP), (2016) 165-170.

Ahmed M, Abdullah N, Ahmed KU, Borhannuddin Bhuyan B (2013). Yield and nutritional composition of oyster mushroom strains newly introduced in Bangladesh', Pesquisa Agropecuaria Brasileira, 48(2): 197–202. doi: 10.1590/S0100-204X2013000200010.

Alam N, Khan A, Hossain MDS, Ruhul Amin SM, Khan LA (2007). Nutritional Analysis of Dietary Mushroom- Pleurotus florida Eger and Pleurotus sajor-caju (Fr .) Singer, Bangladesh Journal of Mushrooms, 1: 1-6.

Anchang KY (2014). Current Developments in Mushroom Biotechnology in Sub-Saharan Africa, WSMBMP Bulletin, (2014): 1-13.

Angadam JO, Ntwampe SKO, Chidi BS, Wei Lim J, Okudoh VI (2021). Lignocellulosic Waste Pretreatment Solely via Biocatalysis as a Partial Simultaneous Lignino-Holocellulolysis Process, Catalyst (2021): 1-13.

Anjana S, Savita J (2017). Oyster mushroom: Answer to human ailments. Asian J. Pharm. Clin. Res.10(4): 24–27.

Ashraf J, Asif Ali M, Ahmad W, Ayyub CM, Shafi J ((2013)). Effect of Different Substrate Supplements on Oyster Mushroom (Pleurotus spp.) Prod. Food Sci. Technol. 1(3): 44-51

Bhattacharjya DK, Paul RK, Nurudin MD, Ahmed KU (2008). Comparative Study of the Nutritional Composition of Oyster Mushrooms Cultivated in Bangladesh Comparative Study of the Nutritional Composition of Oyster Mushrooms Cultivated in Bangladesh', (July 2020), pp. 1–7.

Cai J, Chapman SJ, Buswell SJ, Chang S (1999). Production and Distribution of Endoglucanase, Cellobiohydrolase,and b-Glucosidase Components of the Cellulolytic System ofVolvariellavolvacea, the Edible Straw Mushroom, American Society for Microbiology, 2 (65) (1999) 553-554.

Carrasco J, Zied DC, Pardo JE, Preston GM, Arturo Pardo-Giménez A (2018). Supplementation in mushroom crops and its impact on yield and quality. AMB Expr 8:146.

De Kler JN (2004). Bush encroachment in namibia, bush encroachment research, Monitoring and Management Project, pp. 10-273.

Diana F, Indrea D, Apahidean AS, Apahidean M, Pop R, Moldovan Z, MăniuŃiu D, Ganea R, Paven I (2006). Importance of Substrate Dizinfection on Oyster Mushroom (Pleurotus Sp.) Culture, Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 34(1): 48–53.

Fasehah NS, Shah A (2017). Effect of using various substrates on cultivation of pleurotussajor-caju. J. Eng. Sci. Technol. 12(4):1104-1110

Fischer CR, Oliach D, Bonet JA, Colinas C (2017). Best Practices for Cultivation of Truffles. Forest Sciences Centre of Catalonia, Solsona, Spain; Yaşama Dair Vakıf, Antalaya, Turkey. (2017) 68pp. ISBN: 978-84-697-8163-0.

Funda A, Mustafa NO, Mohammad AS (2017). The nutritional and medical benefits of agaricusbisporus: A review. Journal of microbiology, biotechnology and food science. doi: 10.15414/jmbfs.2017/18.7.3.281-286.

Kivaisi AK (2014). Mushroom cultivation in Tanzania Department of Molecular Biology and Biotechnology (former Applied Microbiology Unit), University of Dar es Salaam, Tanzania, pp. 1-49.

Kuo.Mhttps://www.mushroomexpert.com/tremella_fuciformis.html,(2018). Retrieved (10/07/21).

Mahendran S, Anandapandian KTK, Shankar T, Chellaram C, Vijayabask PP(2012) . Antioxidant Properties of Ganoderma Lucidum Crude Exopolysaccharide. Indian J. Innov. Dev. 8: 1–6.

Masevhe MR, Soundy P, Taylor NJ (2016). Alternative substrates for cultivating oyster mushrooms (Pleurotusostreatus). South Afr. J. Plant Soil 33(2): 97-103.

Mashudu R, Masevhe, Puffy S, Nicolette JT (2015). Alternative substrates for cultivating oyster mushrooms (Pleurotusostreatus), South African journal of plant and soil (2015).

Levine M (2020). Practical Farmers of Iowa 2020 Growing and Selling Shiitake Mushrooms, pp. 1-65.

Mowsurni F, Chowdhury M (2013). Oyster Mushroom: Biochemical and Medicinal Prospects'. Bangladesh J. Med. Biochem. 3(1): 23–28.

Nithyatharani R, Kavitha US, PG Student (2018). Cultivation of oyster mushroom using different substrates. Int. J. Creat. Res. Thoughts 6(1): 332-338.

Owaid MN, Nassar BN, Abed AM, Turki AM (2015). Effect of cellulosic matter and container size on cultivation and yield of oyster mushroom *Pleurotus ostreatus'*. J. Med. Herbs Ethnomed. 1(1): 59–63.

Dupree R (2020). https://www.hobbyfarms.com/grow-mushrooms-on-compost. retrieved (30/08/2021).

Ralph H, Kurtzman RH (2010). Pasteurization of mushroom substrate and other solids'. Environ. Sci. Technol. 4: 936–941.

Rinker D (2017). Spent Mushroom Substrate Uses: Technology and Applications, pp. 427-457.

Samantha (2010). https://www.gardenguides.com/92802-grow-shiitake-mushrooms. Retrieved (9/07/2021).

Sangeesta S (2021). https://www.lowimpact.org/infoarticle/how-to-grow-button-mushrooms/. Retrieved (9/07/2021).

Shahrajabian HM, Sun W, Shen H, Cheng Q (2020). Chemical compounds and health benefits of Tremella, a valued mushroom as both cuisine and medicine in ancient China and modern era. Amazonian J. Plant Res. 4(3):692-697.

Singh J, Khanna S, Dwivedi V, Pandey S, Kumar Mishra VK (2020). Role and Importance of Antioxidant in Medical Science- A Review. Int. J. Pharma Bio Sci. 1(3) (2020) b129-134 http://dx.doi.org/10.22376/ijpbs.2020.11.2.b129-134.

Siwulski M, Rzymski P, Budka, A. et al (2019). The effect of different substrates on the growth of six cultivated mushroom species and composition of macro and trace elements in their fruiting bodies. Eur. Food Res. Technol. 245: 419–431.

Siwulski M, Sobieralski K, Golak-Siwulska I, Sokół S, Sękara A (2015). Ganoderma lucidum (Curt.: Fr.) Karst. – health-promoting properties. A review, Herbal Pol. 61(3):105-118.

Stamets P (2000). Growing Gourmet and medicinal mushrooms, (3rd Ed)New York, USA p, 5-157.

Stamets P (2005). Mycellium running: How mushrooms can help save the world. (1st Ed). New York, USA, pp. 24-57.

Tesfaw A, Tadesse A, Kiros G (2015). Optimization of oyster (Pleurotus ostreatus) mushroom cultivation using locally available substrates and materials in Debre Berhan, Ethiopia'. J. Appl. Biol. Biotechnol. 3(01): 15–20.

Uddin MN, Yesmin S, Khan M.A, Tania M, Moonmoon M, Ahmed S (2011). Production of Oyster Mushrooms in Different Seasonal Conditions of Bangladesh, Journal of Scientific Research. doi: 10.3329/jsr.v3i1.6130.

Wani BA, Bodha, RH, Wani AH (2010). Nutritional and medicinal importance of mushrooms'. J. Med. Plants Res. 4(24): 2598–2604.