

Exploring Various Promising Green Strategy for Recycling Spent Mushroom Substrate through Destop Research Analysis



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Abstract

Disposal of waste generated after the harvesting of mushrooms is one of the major problems in mushroom cultivation industries. There is an urgent need for a technology that produces high value products from spent mushroom substrate. This need came as a result of a huge amount of spent mushroom substrate produced by the edible mushroom industry which is on an increase in many countries around the world. If not well maintained, spent mushroom substrate could cause major environmental problems which are already felt in many mushroom producing countries. Most problems reported are associated with lack of knowledge for treatment and disposal of spent mushroom substrate. Available information has revealed that many potential agricultural and industrial uses of spent mushroom substrate include fertilizer manufacturing, animal feed, compost for soil enrichment, treatment for coal mine drainage, bioremediation, enzyme extraction and novel bio-sorbent. This review aims at outlining some important techniques used in making use of the biological and agricultural waste emanating from mushrooms growing activities around the world. The review aims at availing some possible initiatives on reducing environmental waste through zero disposal of mushroom production waste while at the same time utilizing low value materials to produce value added products and generate income.

Keywords: Disposal of waste; Mushrooms; Organic materials; Lignocellulosic; Environmental pollution; *Agaricus bisporus*

Introduction

Mushrooms are macro fungi that produce fruiting bodies large enough to be seen with the naked eye. During its growth, a mushroom can decompose organic materials such as maize and wheat. Mushrooms contain low fat and low cholesterol levels and are used to treat patients with obesity and high cholesterol [1]. In addition, mushrooms are also high in fiber and contain essential amino acids. Edible mushrooms are cultured in media that usually consist of lignocellulosic agricultural waste such as crop straw [2]. According to Kulshreshtha [3], mushroom cultivation is regarded as an environmentally approachable way to recycle wastes emanating from agricultural production and related activities. Apart from spent substrate, mushroom production brings about mushroom fruit bodies or mycelium which are regarded as good nutritive and medicinal products. In addition, Langmuir isotherms reported of monolayer adsorption through mushroom fruit bodies or spent mushroom substrate [3]. Mushroom production has been on an increase and in Iran, mushroom production industries

has been on a rise and were reported to be generating more than 50,000 tons of spent mushroom substrate annually [3]. The generation of spent mushroom substrate was generally two times higher than the mushroom harvested. There is an urgent need to possibly make use of mushrooms spent substrate in order to curb environmental pollution. According to Cunha Zied et al. [4], making use of spent mushroom substrate is important because it allows a better use of the biomass which was meant for disposal but instead improved for energy efficiency and resource conservation. In 2016, market value of cultivated edible mushroom species is about 30–34 billion dollars and medicinal mushroom species is 10–12 billion dollars. Production of medicinal mushrooms is regarded as one of the contributors to the increase of SMS. Large medicinal macro fungi companies in China such as Sanghuang which is one of the largest and most important groups of in traditional Chinese medicine for the past two centuries uses wood log for mushrooms production [5]. The cultivation of any

mushroom strain results in the production of spent mushroom substrate which is high in organic matter, which according to Ma et al. [6], every kilogram of mushrooms produced emit about 6 kg of waste making it desirable for use as a soil amendment or soil conditioner. Valuable mushrooms such as *Lentinula edodes* and *Ganoderma Lucidum* are either cultivated on natural logs or on a synthetic medium formed in logs [7]. Substrate prepared specifically for growing mushrooms is a blend of natural products, for example at Zero Emission Research Initiative (ZERI) at the University of Namibia, the common materials used are maize, millet and wheat straws as well as woodchip [8]. Common ingredients used in other countries includes horse manure, hay, corn cobs, cottonseed hulls, poultry manure, brewer's grain, cottonseed meal, cocoa bean hulls and gypsum [9-11]. In some countries, spent substrate is spread in the field for one season to allow maturity, it is recommended that the aged spent substrate is good for soil improvement and crop growth. SMSs can also used as substrate for other mushroom forming fungi, animal feed and supplement and in the production of packaging and construction materials, bio-fuels and enzymes [1]. According to Chong & Rinker [12] landscape and gardening companies uses spent substrate as the choice ingredient for potting mixtures sold in supermarkets or garden centers.

Uses of Spent Mushroom Substrate

One of the major environmental problems in the mushroom producing countries remains the treatment and disposal of the spent mushroom substrates (SMS). About 5kg of SMS is produced for each kilogram of mushrooms [7]. According to Food and Agriculture Organization, (2007) Spain produces SMS of approximately 800, 000 tons per annum. SMS can be turned into compost and pit soil that can be sold to local supermarket, nurseries as well as vegetable gardens in the surroundings. Spent mushroom substrate were used as a source of immobilized mushroom mycelium, which is an efficient adsorbent of pollutants in mines and industry allowing 70-90% of pollutants removal [3]. According to Rinker [7], spent mushroom substrate has been used as an enzymes for bioremediation, animal feed, and energy feedstock. Bioremediation is the process whereby living organisms such as bacteria, fungi, or green plants are used to remove or neutralize unwanted contaminants in air, soil, or water. Oxidation of phenol by crude extracts of SMS from *A. bisporus* was reported and laccase was identified as the main enzyme responsible for the oxidation [13]. This means that Phenol and polyphenolic compounds which are toxic pollutants, representing a major organic component in some industrial wastewaters can be destroyed by using SMS [13] Frutos et al. [14]. *Agaricus bisporus* spent substrate has been used as component in the diet of carp [15]. Spent substrate were investigated in a study to degradation and remove pesticide in some areas and were found to be very effective in their application [16].

Besides the good effects SMS has also some negative effects attached to it. For example the SMS of *Agaricus bisporus* affecting health and producing odors after disposal because it continues to compost after production [13]. In addition some of the possible uses of spent mushroom substrates are summarised as follow.

As a growing media for germination and growth of horticultural plants, soil improvement

Mushroom cultivation is one of the environmental friendly ways to recycle agricultural and agro-industrial wastes for the production of mushroom [3]. A study by [17], demonstrated that SMS from *Agaricus subrufescens* that was used as soil-based potting to grow lettuce was high in organic matter and a good source of N, P and K. The aerial dry weight of the lettuce was higher compared to the dry mass of the lettuce grown from chemical fertilizer. From the same literature *Lentinula edodes* SMS a sterilized non-compost substrate with high C/N presented a low degradation level and it is not suitable to be used as fertilizer unless N supplementation is used. Reported the effectiveness of MSM when used in the growing of cucumber (*Cucumis sativus* L. cv. Jinchun No. 2) and tomato (*Solanum lycopersicum* L. cv. Mandy) and results showed increased plant height, leaf area, fresh weight, dry weight and index of seedling quality grown in various ratios of SMS with perlite or vermiculite [18]. The use of immature compost increases microbial activity which causes oxygen deficiency as well as a variety of indirect negative effects on plant toxicity. Ribas et al. [17], recommended the use of fresh and untreated SMSs when used as a fertilizer and bioremediation agent simultaneously. Ribas et al. [17], further indicated that when SMS is without any heat treatment, it has the advantage of adding viable mycelia and several active enzymes produced by the fungus. Furthermore some SMS such as from *L. edodes* are used as fertilizer or soil conditioner, from the period of two months to two year of ageing because the salt content found in some fresh SMS may limits its immediate use as a growing media for plants [17]. Another way of using SMS is reuse in mushrooms cultivation as component of casing material or as supplement to new growth substrates in the new mushroom growing cycle [4].

As a growing media for containerized woody ornamentals

The SMS is formulated with lignocellulose materials from different sources such as wheat, rye or rice straw, sawdust and corncobs making it a great supplements to overcome nutritional limitations and to provide suitable substrate structure and pH for other crops to grow [18]. There is a new trend that replaces the current chemical adhesives with bio-based adhesives to reduce the use of toxic materials in the automotive and building materials. This is because new furniture releases formaldehyde levels up to more than 0.3ppm and this causes health problems [19]. Mycelium can be used as green adhesive material instead of the synthetic adhesive in wood production. The solid white mycelium will melt during hot-compression process and then

penetrate to form tight nets of cohesion and incoherent material within the SMS matrix which enhance the adhesive and bonding resulting in a strong bio-composite [19]. In addition, these thick mycelium layers also showed good water resistance properties.

As a source of clean energy

The transition to bio-resource economy in a petroleum based economy is ideal by using renewable natural resources and adding value through biological life processes. In previous studies it shows that SMC such as straws can be combusted in a bubbling fluidized-bed to generate power with high efficiency [20]. Herrero-Hernández et al. [16] reported that SMS is the best suit for adsorption of pollutants which can be reused and recycled for the adsorption of pollutants as many times as possible by using different chemical treatments and by modifying it in activated carbon form. The spent mushroom substrate work by binding with positive charge metals whereby adsorbs metals which are present in the solution and involved in metal chelation [3,21].

Woodchip-derived SMSs have a high moisture and oxygen content that result in low heat value which is not suitable as bio-fuels. These materials cannot be burned as smokes from combustion of these materials that contain high lignocellulosic content are detrimental to the environment.

As a source of construction and packaging materials

Combustion of SMS leads to production of ash usually about 10% of its original value. This ash can be used as a chemical activator to enhance the pozzolanic reactivity of pulverized fuel ash in the cement industry [20]. According to Khoo et al. [19] the SMS is used in the formulation of bioblocks, and during hot-compression process, the solid white mycelium melt and then penetrate to form tight nets of cohesion and incoherent material within the SMS matrix which enhance the adhesive and bonding resulting in a strong bio-composite. The SMS have also been used in manufacturing of biodegradable bioblocks which is done using a green synthesis approach and the mycelium as a natural adhesive material [22]. Another way in which SMS was successfully used was the design and thermoforming of growth trays, tray sterilization, filling trays with mycelium inoculated substrates filling and allowing growth to occur, and after that, convection drying/inactivation of the grown parts follows [23]. According to Joshi et al. [23], the construction materials such as bioblock showed great thermal stability, hydrophobic properties combined with mechanical strength. This could be great source of construction materials especially among poor resource farmers where the SMS is usually remain unused and contributing to environmental pollution. Various studies on the production of biodegradable and sustainable feedstock are on an increase, with the aim to replace petroleum-based materials commonly used for single- or multi-use packaging applications [24]. A study by Khoo et al. [19] reported on different types of spent mushroom

substrates that were compressed with specific designed mould with optimal temperature at 160°C and 10mPa for 20min to produce bio-boards. In addition, biobords made from *Ganoderma lucidum* SMS displayed the highest internal bonding strength up to 2.51mPa [19]. Among other importance of the SMS was the density profile which is very light, buoyant, and highly hydrophilic making it an ideal material for both construction and packaging. R Ziegler et al. [24] further reported that the surface hardness test showed that the material has a soft outer surface with high elasticity. The SMS is also an ideal material for packaging applications due to its lightweight, resiliency, and biodegradability.

Environmental rehabilitation

Soil fauna contribute greatly to litter decomposition and soil organic matter stabilization. *Protatia brevitansis* is a soil dwelling insect [7]. Its larvae feed on large amounts of crushed straw and sawdust. This insect larva is commercially raised to produce high quality organic fertilizer and edible proteins. PB larvae can convert woodchip derived SMS and increase the total nutrient and seed germination index [1]. Cadmium metal is released by anthropogenic activities such as mining, phosphorus fertilizers and sewage irrigation. It is very toxic and is readily taken up by most plants [24]. Since *L. edodes* has the ability to improve microbial activity it may have an important role in bioremediation because it may harbor microbes that have the ability to degrade this heavy metal. Biochar is biomass pyrolyzed and it has been taken as the most effective organic amendment to immobilize heavy metals and improve soil quality, owing to its high alkalinity, large specific surface area, rich pore structure, and cation exchange capacity [25]. Overdose biochar will not only pollute the environment but also change the composition of soil material, which may affect the soil normal functions. To prevent these disadvantages, a combination of SMS and alkaline amendments may be a promising approach that compensates mutual functions. It has been reported that when lime is mixed with other organic amendments, soil pH, electrical conductivity (EC), and precipitations of soluble ions might be further increased [25]. According to Udochukwu et al. [26]; Sriherwanto et al. [27], mushrooms can be served as green adsorbent which can accumulate pollutants from the surroundings and reduce their concentration. Since the mushroom mycelium can be used in the live or dead form, the SMS will be best suited to be used in the form of green adsorbed.

Conclusion

Based on the literature research and information available, SMS could be a great resource for income generation once the equipment and technical know how is available. Production of mushrooms cannot only result in the production of mushroom fruiting body but the byproduct are great source of building materials, organic matter and soil amendment. This article was

reviewing literature to see the possible way in which SMS can be better utilized in Namibia and beyond.

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