International Journal of Scientific Research in Biological Sciences
Vol.7, Issue.6, pp.58-66, December (2020)
Review Paper
E-ISSN: 2347-7520

Mushroom for the National Circular Economy

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Available online at: www.isroset.org

Received: 20/Oct/2020, Accepted: 25/Nov/2020, Online: 31/Dec/2020

Abstract- Within the circular bio-economy, effective mushroom utilization through the key utilize of resources is fundamental in terms of producing profitable bioproducts, feasible improvement, and maximizing biological and socio-economic benefits. Commercial mushrooms are delivered on biowaste such as straw, saw tidy, and wood chips. As such, mushroom-forming fungi change over low-quality waste streams into high-quality food. Spent mushroom substrate (SMS) is ordinarily considered a waste material. Encourage investigation and advancement are required to create effective advances to empower the proficient exploitation of bioresources from mushroom. More prominent thought should be connected to vitality pathways to support such technologies. In this manner, there's a request for development within the integrated approach in response to changing markets, and novel commercial models ought to be presented into the circular economy.

Keywords- Mushroom; Circular Economy; Fungi; Application; Spent Mushroom Substrate

I. INTRODUCTION

Due to the ever-increasing population and serious challenges of diet related health problems viz. malnutrition, diabetes cardiovascular, Covid-19 and drastic changes in food habits of new generations have force the scientists and policy makers both to find out some alternatives of conventional foods. Mushrooms are increasingly considered as a future food owing to its nutraceutical and nutraceutical properties(Pehrsson et al., 2003; Pavel 2009; Chang and Wasser 2017). The term "Nutraceuticals" can be characterized as a substance that will be considered a food or portion of a food that provides medical or wellbeing benefits just like the anticipation and treatment of infection. Mushrooms have gotten to be appealing as a useful food and as a source for the advancement of drugs and nutraceuticals (Lakhanpal and Rana 2005; Khatun et al., 2012). In expansion, fast consumption of agrarian and sky soaring fetched of agribusiness constrained the farming division to step up and adopt commercially, technically and financially practical agribusiness solutions (Shirur et al., 2016).

Hence, openings in application of nonconventional agri resources in this sector have abruptly jumped manifold. The alter within the mentality and potential part of normal assets have moreover pulled in the consideration of approach producers and financial analysts on feasible agribusiness in national economy.On the other hand, agro wastes are presently considered as important bioresources (Lee et al., 2008). India is an agrarian nation which create tremendous sum of agro biowaste after the collecting of crops. The non-food-based portion of crops such as the stalks, straw and husk are categorized under lignocellulosic biomass (Jordan et al., 2008; Phan and Sabaratnam2012). It contains cellulose, hemicellulose, and lignin which are progressively recognized as a profitable asset, for the generation of mushrooms. It's conceivable utilization as crude material for the generation of mushrooms and in this way use the SMS (spent mushroom substrate) to apply for animal nourish, composting, generation of bio-energy and sending of biomaterials have looked into in numerous publications. The utilize of mycelium-based items is regarded as biodegradable, maintainable and contributes to the change for feasible economy, which is one of our challenges in society nowadays (Zhu et al., 2013; Picornell-Buendía et al., 2016; Appels et al., 2019).

In contrast to today's fossil-based economy, which uses direct streams that lead to the exhaustion of fossil assets, circular economy approaches permit cycles to be closed by novel recyclable materials that can be produced from biowaste and secondary streams. The circular economy closes circles in mechanical manufacturing forms and minimizes waste. A bio-based economy points to supplant fossil-based assets and forms by maintainable choices which exploits renewable biomass for the era of items utilized in our everyday live. In this way, the development of mushrooms isn't as it were giving nutraceuticals, but

also to play imperative part in circular economy of a country. The targets of this article are to highlight the potential of mushrooms in circular economy of the nation.

II. MUSHROOM PRODUCTION

Development of mushrooms like *Auricularia, Flammulina* and *Lentinula* for the first time was around the year 600-800 Ad in China and other Asian nations (Chang and Wasser 2017). In other case, its research and development started as it were at the starting of the 20thcentury. Within the starting of the 20th century the focus was on the development of button mushroom basically in western nations. In first half of the 20th century the focus was on development of button mushroom within the West and to a lesser degree on shiitake within the East. Within the moment half of 20th century, there were fast changes in rate of development of mushroom generation and number of species brought beneath commercial development. By the end of 20th century the share of button mushroom in add up to world generation was less than 40 per cent, which in following ten a long time got to be around 30 percent.21st century, especially last ten years, have seen sudden fast rise in development of mushrooms other than button.

More than 2,000 species of mushrooms exist in nature, but around 25 are broadly acknowledged as food and few are commercially developed *Agaricusbisporus* is the foremost commonly developed mushroom around the world. It is taken after by *Lentinusedodes, Pleurotus* spp., and *Flammulinavelutipes*. Due to their dietary, tangible and particularly pharmacological characteristics wild mushrooms have pulled in the consideration world over. An exponential development in world mushroom generation has been watched by the scientific world. Due to tremendous increment in generation of shiitake, oyster mushrooms, wood ear mushroom and *Flammulina*, the commitment of these mushrooms to add up to world mushroom generation has expanded massively as compared to button mushroom, which is no more the number one mushroom in terms of share in global mushroom generation within the world(Pave 2009; Kumaret al., 2017; Sharma et al., 2017). At present shiitake, shellfish, wood ear and button mushroom contributing approximately 22, 19, 18 and 15%, individually in terms of total mushroom generation within the world (Singh et al., 2017). Different methods utilized for the development of mushrooms have been thoroughly surveyed in numerous publications (Mamiro et al.,2007).

Mushroom industry in India is overwhelmingly centred on white button mushroom which could be an exceedingly modern and capital-intensive action. The later generation information (official information of ICAR-DMR, Solan) appearing that, the share of button mushroom in India is most extreme amounting to 73% taken after by oyster mushroom which contributes around 16%. The full white button mushroom delivered in India from both regular and high-tech development units is assessed at 94676 metric tons. Out of this, roughly 8500 metric tons of button mushrooms was produced from the regular developing units found in Haryana and Punjab which accounted for 9% of total button mushroom production. By viably utilizing the regular varieties, the agriculturists of Punjab and Haryana locale have revolutionized the regular development handle with exceptionally less inputs. Nowadays mushroom is a vital agricultural cash crop and development of it is one of the greatest money-spinning endeavors in the world. Mushrooms are represented a showcase of 63 billion US dollars in 2013 which included therapeutic mushrooms (38%) and wild (8%) and developed eatable (54%) mushrooms. At a worldwide scale, utilization of mushrooms has expanded from 1 to 4.7 kg of developed edible mushrooms per capita within the period 1997 to 2013. Utilization is anticipated to encourage increment within the another a long time resulting in a deal going from 34 to 60 billion US dollar every year. In 2013, China produced 87% of the 35 billion kg of developed eatable mushrooms, most of which being consumed in this country. The top three consists of *Lentinula* (shiitake and relatives), *Pleurotus* (oyster mushrooms), and *Auricularia* (wood ear mushrooms) (Mehta et al., 1990; Ergönül et al., 2013).

III. SPENT MUSHROOM SUBSTRATE

Development of mushroom is considered as an eco-friendly and productive implies of the maintainable management of agro waste. In any case, dumping of "spent mushroom substrate" discharged after mushroom crop harvesting may cause different natural issues (Beyer 1996; Ma et al., 2014). SMS (spent mushroom substrate) is the left-over compost after collecting of one full crop of mushroom (Wuest and Fahy 1991). It has been reported that mushroom industry ought to arrange off more than 50 million tons of utilized mushroom compost each year (Fox and Chorover 1999). As of late, the term spent compost or went through mushroom substrate has been replaced by a more appropriate term, "post mushroom substrate" since it isn't 'spent' and is prepared to be encourage assaulted by a unused set of microorganisms (Ahlawat and Sagar 2007). During the recent years, natural legislation has constrained the mushroom cultivators to dispose off properly.At the same time the request for natural residues and compost has moreover expanded a few folds considering the sick effects of manufactured pesticides and fertilizers (Ahlawat and Sagar2007). The phenomena of degradation of crop build-ups have been extensible examined by numerous laborers (Rinker et al., 2004; Rinker, 2005;Rahi et al., 2009).

SMS is accessible in tremendous amounts after harvesting of the primary crop as 1 kg of new mushrooms results in 5-6 kg of spent substrate (Finney et al., 2009a). Prior SMS was considered a waste but presently consider as high-quality compost (Uzun 2004; Polat et al., 2009). Symposium held in Philadelphia, Pennsylvania in 1994 likely was the first occasions that formally tended to the investigate and employments of spent mushroom substrate.

Another conference held in Cuernavaca, Mexico was also totally devoted to the uses of spent mushroom substrate (Rinker et al., 2004; Rinker2002, 2005). Phan and Sabaratnam (2012) have given a great review for the potential uses of spent mushroom substrate with emphasis on chemicals for bioremediation, animal feed, and vitality feedstock.Staments (2005) has given point by point account of the numerous viable applications for organisms in fathoming today's natural challenges. Numerous other specialists have too highlighted the utilize of SMS for the generation of other mushrooms, to nourish animals and to move forward their wellbeing, to create biofuel generation more viably (Phan and Sabaratnam 2012), to deliver materials (Appels et al., 2018), and to extricate chemicals for businesses and bioremediation (Phan and Sabaratnam 2012). The potential application of SMS in different field are examined briefly as takes after:

a) Mushroom production

Possibilities of re-use of SMS in production of mushrooms have advocated by many workers (Flick1981; González Matute et al., 2011). SMS of *Agaricusbisporus*has been re-used for cultivation of *Agaricusbisporus* (Till 1963; Royse 1993; Schisler 1988; Rinker and Alm 1990; Mamiro et al., 2007; Mamiro and Royse 2008), *Auricularia* (Sharma and Jandaik 1994), *Lentinula* (Kilpatrick et al., 2000), *Pleurotus* (Mueller et al., 1984; Sharma and Jandaik 1994) and *Volvariella* (Poppe 2000). Similarly, SMS obtained from *Pleurotus* spp. has been re-used for the cultivation of *Pleurotus* spp. (Sharma andJandaik 1985, 1992;Shashirekhaet al., 2002; Pardo-Giménezet al., 2012a,b), *Agaricusblazei* (Gern et al., 2010; González-Matute et al., 2011) and *Stropharia* (Poppe 1995). Volvariella spent substrate has been reported as good for *Pleurotus* cultivation (Quimio 1988; Chang and Miles 1989). About 20% higher generation of *Pleurotussajor-caju* mushrooms is found in SMS gotten after gathering of *L. edodus* which cleared out 85% of the hemicellulose, 44% of the cellulose, and 77% of the lignin unused and supplanted with 10% wheat bran and 10% millet. Additionally, straw-based SMS from shellfish mushroom supplemented with 20% vermi-compost or sunflower seed frames demonstrated to be exceptionally successful for the generation of button mushrooms, *Agaricusblazei* (González-Matute et al., 2011; Royse et al., 2017).

b) Energy production

Due to the genuine environment concern with the expanding mindfulness almost worldwide warming Government is centering on the utilize of green power. Amid the later past potential of SMS as a crude material for the generation of biofuel has pulled in the consideration of the technologist's world over (Kapu et al., 2012). SMS of *Agaricusbisporus* went through substrate has been detailed as an imperative source for biofuel (Kapu et al., 2012, Maher et al., 2000; Williams et al., 2001; McCahey et al., 2003; Ryu et al., 2008; Finney et al., 2009 a,b,c) and biogas generation (Tumwasorn et al., 1980). *Pleurotus* spent substrate, as well, has been inspected as a source of biogas (Bisaria et al., 1983, 1990).A blend of dairy excrement and SMS of *Flammulinavelutipes* or *Pleurotuseryngii* have been detailed a critical source of methane generation. SMS can too be utilized as a source of sugars for bioethanol generation (Kapu et al., 2012). One gm sugars discharged from the hydrolysis of *P. ostreatus* SMS has been detailed to change over into around 0.5 g ethanol. Hence, 1 ton of SMS in these cases would abdicate up to 150 kg of ethanol. A sum of 187 g ethanol per kg dry matter was delivered from *P. ostreatus* SMS determined from sorghum chaff.In any case, generation costs of chemicals have been calculated to be between US$0.6 and 1.3 per gallon bioethanol, representing 40–87% of the sales price of the biofuel. The major advantage of utilize of SMS are the nearness of high amount, simple extraction of protein and no aging time is required (Mayolo-Deloisa et al., 2009). Such extracts may be utilized straightforwardly, either or not blended with proteins from other sources, to change over for occurrence lignocellulosic waste streams in sugars for second-generation biofuels. Similarly, *Lentinula edodes* spent substrate has too been detailed as an elective fuel (Pauli 1999; Asada et al., 2011; Lin et al., 2015).

c) Bioremediation

Potential of SMS has been fundamentally talked about as a vital elective for viable and eco-friendly administration of natural contaminations. SMS gotten from *Agaricusbisporus* blend with other materials is reported to have noteworthy potential in expulsion of H_2S (Shojaosadati and Siamak 1999) or unstable natural compounds from air (Mohseni et al., 1998; Mohseni and Allen 1999), treatment of metal-contaminated water from different territories (Anon 1997; Newcombe and Brennan 2010; Manyin et al., 1997; Toptas et al., 2014; Hammack and Edenborn 1992; Groudev et al., 1999. *A. bisporus* spent substrate/enzymes has moreover been attempted for its impact on zinc, cadmium and lead in soil (Shuman and Li 1997;Shuman 1998, 1999a,b), the corruption of chlorophenols, polycyclic fragrant hydrocarbons, or fragrant monomers (García-Delgado et al., 2015), inhibition of nitrification (Bazin et al., 1991) and remediation of mining contaminated soils (Courtney and Harrington 2012).*Pleurotus* sp. SMS have also been utilized for the expulsion of copper, nickel, polycyclic aromatic hydrocarbons, phenol substance, pesticides and material dyes (Lau et al., 2003;Tay et al., 2010; Tay et al., 2011; Martirani et al., 1996; Karas et al., 2015; Chang et al., 2014; Singh et al., 2011). *Lentinula edodes* spent substrate has been attempted for treatment/removal of different sorts of poisons in effluent (Chiu et al., 1998; Chang et al., 2000; D'Annibale et al., 1998; Chen et al., 2008). So also, SMS of *Ganoderma lucidum* has been broadly utilized for the expulsion of different poisonous natural compounds (Liao et al., 2012). There are a few reports where SMS have been tried for fluoride methylene blue and sulfa anti-microbials evacuation from drinking and waste water (Yan and Wang 2013;Zhou et al., 2014a; Yan et al., 2015;Chen et al., 2015).

d) Compost

Serious health and natural concerns almost engineered fertilizers, advanced agrarian practices presently centering on nonconventional sources of fertilizers. Hence, mushroom SMS have pulled in the consideration world over (Courtney and Mullen 2008; Guo et al., 2001). Jarecki et al. (2005, 2012) expressed that *Agaricus* leachate can be utilized to supplement the nutrient necessities of plants. Spent substrate have been utilized as fertilizer. SMS of *Agaricusbisporus* and *A. subrufescens* (syn. *A. blazei, A. brasiliensis* have been comprehensively examine for its potential application as fertilizers for the generation of different nursery crops, vegetables, blossoming plants etc.(Poole and Conorer 1974;Ribas et al., 2009; Medina et al., 2009; Kwack et al., 2012).So also, *Pleurotus* spp. spent substrate has been attempted for numerous vegetables and spices (Batista et al., 2000; Kwack et al., 2012;Adamović et al., 2007; Medina et al., 2009). Appropriateness of SS as of numerous other mushrooms viz., *Lentinula edodes* (Lin and Chuen 1993;Ribas et al., 2009) and *Flammulinavelutipes*(van Tam and Wang 2015) have too been considered for their application as excrement for the generation of vegetables. Uzun (2004) detailed that due to moderate discharge of supplement from SMS is slower in this manner plants can utilize them more successfully). In expansion, SMS makes strides soil structure by expanding natural matter, smaller scale supplements, water capacity, microbial movement, soil temperature, and by diminishing soil compaction and altogether expanded yield of the crops (Bradley et al., 2015). Viability of SMS has too expanded when utilized in combination of different other combination. SMS have moreover detailed as a novel crude fabric for biofertilizer generation.

e) Feedstock

SMS being rich in supplements, the conceivable outcomes of re-use SMS as animal feedstock has been attempted by numerous specialists. SMS of *Agaricusbisporus* has critical potential as feedstock of animals such as calves (Fazaeli et al., 2014), sheep (Wilson et al., 1983) and dietary component for ruminants (Langar et al., 1982; Fazaeli and Masoodi 2006; Ayala et al., 2011; Kim et al., 2011a). *Pleurotus* spp. went through substrate has moreover been utilized as a nourish stock for cattle/ruminant bolster (Kakkar et al., 1990; Adamović et al., 1998; Bae et al., 2006; Kim et al., 2011a,b, 2012);ruminants (Permana 1990; Zadrazil and Puniya 1995); buffaloes (Bakshi et al., 1985; Kakkar and Dhanda 1998); chickens (Azevedo et al., 2009), elk, goats, sheep and sheep (Calzada et al., 1987a,b). *Lentinula edodes* SMS has been detailed to play noteworthy part in ruminant assimilation (Zhang et al., 1995; Lin et al., 1998a, b; Braun et al., 2000). The positive impacts on wellbeing parameters of chicken by shiitake extricates. Numerous other SMS viz., *Volvariellavolvacea* (Sevilla et al., 1989), *Coprinus fimetarius, Flammulinavelutipes* (Lee et al., 2006) and *Ganoderma balabacense* (Liu et al., 2015) have been detailed advantageous for overall execution of animals. In expansion, a mushroom-based diet can fortify the resistant reaction of fish (Mann et al., 1994).

f) Bio- materials

In the race to find sustainable materials that will reduce our ecological footprint and many serious environmental issues related to the leftover of various synthetic materials like polythens, packing materials, insulators etc forced the scientists to search for new ecofriendly materials. Fungal specially mushrooms mycelium as an alternative of synthetic materials have attracted the attention of a large number of workers. Mushroom characteristics viz., capacity to form large networks) and extraordinary potential to colonize lignocellulosic material make the highly suitable organisms for the production of biomaterials. Applications as bricks., furniture acoustic dampers, absorbents, paper, textiles, and vehicle and electronic parts have also been suggested by some workers (Islam et al., 2017; Haneef et al., 2017; Xing et al., 2018). Different viewpoints of biomaterials have been broadly looked into by numerous specialists. Applications of fungal biomaterial have numerous focal points over manufactured materials. Bricks gotten from mycelium have been detailed as a super strong, water, mould and fire-resistant building material. The innovation diminishes manufacturing necessities (Holt et al., 2012; Jones et al., 2017).

Myco-board can be utilized like medium-density fibre board/particle board without the extremely unsafe formaldehyde utilized within the stick. The method of producing with mycelium brings a huge reduction in utilizing fossil powers. Bio fabrication could be a carbon impartial building handle and can eliminate artificial separator utilized in dividers, utilize of molecule board and other non-load bearing structures. Mycelium items can give other benefits such as termite sealing (it can pull in termites but when eaten cause an organism spore to actuate inside the termite murdering it and making a fungus whose spores repulse other termites).The energy required for manufacture is little and there's a enormous reduction in development waste as the item is 100 percent biodegradable and can be utilized as soil. Mushroom brick that can be 200,000 times milder than steel, 10,000 times less solid than a normal lodging brick, but competent of holding the identical of 50 cars. It has been detailed that mycelium bricks when placed together in a couple of hours, the material fuses together. The development can be halted when the substance is dried, making an unbending fabric which can be sanded and painted. The mycelium bricks are bulletproof and retain carbon dioxide, making them an economical fabric for the development of our future buildings. Some article described the“Moving to Damages? Biomaterials point the way” basically underscored the scope of fungal biomaterial in different applications at Damages.

Mycomaterials are actually fire-retardant, a basic component in sealed, pressurized, oxygen-rich living spaces. They are too great insulin, once more,

exceptionally imperative on a planet where daily temperatures can reach a nippy minus 73 °C. And unlike numerous standard Soil materials, mycelia don't deliver off poisonous gasses. Another challenge of Martian living is radiation. On Soil, the melanin in our skin (generally) secures us from the Sun's destructive UV beams. But Mars' thinner environment and need of an attractive field make radiation introduction a genuine issue. Melanin-rich organisms, in any case, are able to retain radioactivity and seem possibly make radiation-blocking structures.Biomaterials are the way of the longer term. They are useful, ecologically dependable, and economical. And since they are bio-based, they have the potential to self-grow and self-repair. In spite of the fact that we are battling to quickly scale up our utilize of maintainable biomaterials on Soil, Damages gives us the opportunity to begin from scratch (https://synbiobeta.com/moving-to-mars-biomaterials-point-the-way/).Cerimi et al (2019) have fundamentally talked about the status of patent in different nations. Analysts and structural and development industry are right now centering on advancement and applications of mycelium-based materials for redesign, rebuilding, wood, keen concrete and divider requirement materials etc. In spite of the fact that, SMS contain tremendous sum of mycelium, but broad examinations are required to institutionalized the innovation for generation of unadulterated mycelium.

g) Isolation of enzymes and bioactive molecules:

SMS is considered as a vital source of proteins for their applications in ecologically friendly by-products (Mayolo-Deloisa et al., 2009; Singh et al., 2002; Phan and Sabaratnam 2012). After gathering, the spent mushroom compost is known to have tremendous amount of extra-cellular chemicals. Among the different extracellular chemicals, laccase (EC 1.10.3.2) has been detailed as the foremost prevalent in SMS of many mushrooms counting *A. bisporus* (Mayolo-Deloisa et al., 2009), *Pleurotussajor-caju* (Kumaran et al., 1997; Singh et al., 2003), *P. ostreatus, L. edodes, Flammulinavelutipes* and *Hericiumerinaceum* (Ko et al., 2005). Lignin peroxidase has also reported at higher sum within the SMS of *P. sajor-caju* (Singh et al., 2003). Innovation employed for the recuperation of protein from SMS have thoroughly been examined in numerous publications (Chen et al., 2004; Nagai et al., 2002; Quaratino et al., 2007; Ullrich et al. 2005; Benavides and Rito-Palomares 2008; Mayolo-Deloisa et al., 2009). Magette et al. (1998) have critically reviewed the problems associated with re-use of SMS in enzyme extraction.

IV. CONCLUSIONS

Worldwide mushroom generation has expanded quickly last decades and is anticipated to assist increment within the future due to the require for more high-quality nourishment with a diminished natural impact. Nowadays mushroom is considered as a vital green cash crop and its development is one of the biggest money-spinning endeavors within the world. There are diverse options to utilize these gigantic sums of SMS within the most circular way. SMS is not respected as a waste but as a renewable asset from the mushroom industry. SMS is presently re-use in a number of green innovations viz., recuperation of chemicals, bioremediation of poisons, generation of mushrooms, compost, creature nourish, fertilizer, biofuel and biomaterials. The number and rate of obvious advancements within the field clearly shows that fungal bio-based materials will impressively shape long run of material sciences and material applications.These can be considered as an amazing renewable and degradable material elective with a high advancement potential and have the potential to supplant current petroleum-based materials.

Commercial reasonability of these depends on topographical area, accessibility of waste streams, fertilizers, and nourishment and bolster assets. The circular economy closes circles in mechanical manufacturing forms and minimizes waste. A bio-based economy points to supplant fossil-based assets and forms by feasible options which misuses renewable biomass for the era of items utilized in our day by day live. A current drift in fungal biotechnology i.e. re –use of SMS will contribute to both. Together, SMS has awesome potential in a circular economy but we are in awesome require for quantitative models anticipating natural affect and financial reasonability. Advance investigate should be centered on standardization of utilize of SMS, financial practicality, enhancement of integration of mushroom and SMS generation within the agri- and horticultural system, re-use of waste stream of greenhouses.

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