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Mushroom cultivation on agricultural wastes for environmental sustainability and food security

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Abstract
India with its varied agro climatic zones is amenable to grow a wide variety of food crops and horticultural products. Due to extensive agricultural practices, lignocellulosic wastes are abundant in India. The role of fungi is significant in recycling of this organic waste and in releasing nutrients in the soil. The property of edible mushroom fungi to convert complex organic compounds into simpler ones is used to transform the useless agricultural waste into valuable product. It is also an environmental friendly method to reduce the nutrient level of agricultural wastes as acceptable range and to be used as manure. A blend of agricultural wastes gives high yield of mushroom in a cost effective manner. Farming of edible fungi on agricultural waste could aid in improving the socio-economic status of large percentage of populations especially in rural areas. Diversification in any farming system imparts sustainability. Mushrooms are one such component which not only impart diversification but also help in addressing the problems of quality food, health and environmental related issues. Production of edible mushrooms represents exclusive utilization of microbial technology for bioconversion of the agricultural wastes into nutritious food (mushrooms).

In order to promote this idea and establish mushroom production practices on agricultural wastes, there is a need to develop an infrastructure for the production of mushroom inoculums and train people in mushroom cultivation. These horticulture ventures have a promising scope to reduce environmental pollution caused by these wastes and also meet the food shortages, without undue pressure on land. This article focuses on utilising agricultural residues or waste for the cultivation of mushroom for food security as well as environmental sustainability. The main objective of this paper is to boost the mushroom industry and rural economy and to provide useful technical knowledge regarding important mushrooms species that grow on agro-wastes.

Keywords: sustainability lignocellulosic wastes; agriculture; recycling; nutrients; solid-waste management; food security; mushrooms

Introduction

India has huge resources which are favourable in developing mushroom cultivation technology into a large scale industry. Disposal of agricultural wastes is of prime concern as they are rich in nutrient and their clearance without pre-treatment can cause leaching in fields, causing environment pollution. Mushroom cultivation is very effective means for utilising agricultural solid waste into nutritious food. These processes not only convert the agriculture waste into good fertilizers but also convert the waste into protein rich super foods. Mushroom cultivation on these agricultural wastes can overcome this problem in the most eco-friendly way to reduce the level of nutrients at adequate range and to be used as manure. Also a defined combination of agricultural wastes will give high yield of mushroom in a cost effective manner.

In one study, it has found that production of one pound of mushrooms requires only 1.8 gallons of water and one kilowatt hours of energy and it generates only 0.7 pound of CO_2. The annual average yield of mushrooms is around 7.1 pound per square foot (Anonymous, 2017; Robinson *et al*., 2019) [1].

White button mushroom *(Agaricus bisporus)* is the most common edible mushroom in the United States and the second largest producer after China. It was assessed that India creates million tons of agrarian waste, leafy foods build-up, coir husk, dried leaves, pruning's, coffee husk, tea waste which can possibly be reused as substrate for mushroom generation prompting nutritious sustenance and additionally natural excrement for harvests (Poppe, 2000) [15]. In India, there are major five mushroom species that cultivated commercially viz., *Agaricus bisporus* (white button mushroom), *Pleurotus* spp. (oyster), *Volvariella volvacea* (paddy straw mushroom), *Calocybeindica* (milky mushroom) and *Lentinula edodes* (shiitake). Even though cultivation technologies of many exotic species have been standardized, the markets are still dominated by button mushroom *Agaricus bisporus*, oysters *Pleurotus spp*. and *Volvariella volvacea*. China is the world's largest producer of edible mushrooms, supplying over 30 million ton, or 87% of global supply (Royse *et al*., 2016) [23].

Agricultural waste mainly consists of cellulose and lignin materials which are the complex carbohydrates and breakdown of these materials is a very difficult task. They are insoluble and bind to inert substances in the soil. Hence these are out of reach of different bacteria in the soil. Mycelium of mushroom is able to release the extracellular enzymes, which are responsible for the degradation of lignin. *Pleurotus* and *Lentinus* have their own enzyme systems based on endoglucanase, laccase and phenoloxidases. The large amount of agricultural wastes and appropriate climatic conditions provide massive scope for oyster mushroom cultivation in Sagar, M.P. (Vyas *et al.* 2009) [31].

The property of edible mushroom fungi to convert complex organic compounds into simpler ones is used to transform the useless agricultural waste into valuable product (Jain *et al.*, 2003) [8]. Besides having many nutritional values they are also useful in waste management. The choice of mushroom species for the cultivation is depends upon the availability of growth media i.e. substrates. Oyster mushroom is the third most cultivated edible mushroom in the world (Royse, 2003) [22].

Agro-waste as a substrate

In India, agriculture sector contributes about 17 percent of country's total GDP which gives employment to approximately two third of the population. However, its potential has not been tapped due to under-development of the food sector in India (NIAM Research Study Report, 2011-12). India is the second largest agro-based economy with year-round crop cultivation, generates an outsized amount of agricultural waste, including crop residues. India generates about 500 Mt of agricultural waste per annum. In the absence of adequate sustainable management practices, approximately 92 Mt of crop waste is burned per annum in India, causing excessive particulate matter emissions and pollution. Burning of agricultural wastes is a major environmental concern as it is causing health issues as well as contributing to global warming (Bhuvaneshwari *et al*., 2019) [4].

Fungi can transform lignocelluloses waste into organic matter rich soil. In sustainable mushroom cultivation the important mushrooms species can recycle agricultural residues or any other organic waste into satiable food i.e. delicious protein rich mushrooms. Mushrooms get nutrition from cellulose, hemicelluloses and lignin, which are abundantly available in agricultural residues like wheat straw. Agricultural wastes such as wheat/paddy/rice straw, cotton/coffee straw, rice bran, molasses, banana leaves, tea leaves, cotton straw, saw dust etc. are the most commonly used for the cultivation of mushrooms.

For the cultivation of *Pleurotus* rice straw, wheat straw and cotton straw is generally used while for *Agaricus*, wheat straw is typically used. However, straw is overloaded with other microorganisms, and it is very essential to get free of these microorganisms, as the mushroom mycelium will be unable grow in their presence, especially when mushrooms are to be grown indoors.

Banana leaves and tea leaves are used for *Volvariella* and *Pleurotus* respectively. Sturion (1994) [27] proposed using banana leaves for the cultivation of *Pleurotus spp*. Sawdust must be supplemented with a nitrogen source like bran, urea, sunflower seed and horse manure. *Ganoderma* can be cultivated using sawdust (Shashitha *et al.*, 2016) [24]. Various legume crop wastes viz. soybean, mash clover, kulthi and mixture of soybean, mash and kulthi (1:1:1) were found effective in cultivating *P. sajor-caju* (Pal and Paul, 1985) [13]. Rana and Subag (1990) [18] recorded that gram pod waste together with wheat straw (1:1) improved mushroom yields by 5.26% over the wheat straw alone. Growth of oyster mushroom resulted similar in paddy straw and wheat straw while in sugarcane bagasse it resulted in low yield. Reason behind this selective high yield must be appropriate concentration of lignin, hemicelluloses, cellulose in substrate (Elahe *et al.*, 2016) [7].

Various agricultural substrates used for cultivation

In addition to the use of supplements a variety of combinations of agricultural wastes are also used for the cultivation of mushroom and are reported to be ideal substrate. Various oil seed cake, powdered pulses, wheat and rice bran etc are surprisingly added as supplements (Bahukhandi, 1990). Vegetable waste when used in combination with paddy straw resulted in high yield of oyster mushroom (Ralph *et al.*, 1994) [17]. The substrate for *Pleurotus spp*. cultivations supplemented with cotton linter (cotton seedcake) at the rate of 259g/3kg dry substrate (8%) had given the best results (Bano and Rajarathnam, 1979).

On barley straw and sugar beet pulp substrate complemented with rice bran, highest mushroom fresh weight and moisture content were achieved (Zadrail *et al*., 1992). Supplemented straw with cottonseed powder, yeast mud, groundnut cake and rice bran led best response concerning yield of *Pleurotus spp*. To cultivate *P. ostreatus* sawdust additionally to rice husks is reported as an optimal substrate (Singh *et al.*, 2012). The quality of *P. eryngii* was significantly affected by substrate ingredients. For *Pleurotus sajor-caju*, combination of soybean straw, wheat straw showed significantly highest yield while soybean straw and saw dust combination showed significantly lesser yield (Rani *et al.*, 2008).

Supplements used with agricultural wastes toboost up yield of mushrooms

An addition to the biological and chemical supplement with basal substrate has been a standard practice to reinforce the yield, nutritional and medicinal values. From the very beginning of mushroom agriculture; integrated use of varied nitrogen and carbon rich chemical and biological supplements was began to reinforce yield. Jandaik and Kapoor (1974) reported addition of oat meal and arhar dal powder for better yield of *Pleurotus spp*. Moreover, it had been observed that supplementation of mushroom beds with Horse Gram flour (Besan) after the spawn run significantly increased the mushroom yield (Bano *et al.*, 1978).

Agricultural wastes are used alongside supplements like gypsum, lime and urea. Gypsum provides calcium and regulates the acidity level during the expansion of the mushrooms. Water holding capacity of gypsum is high which prevent excess wetting of the substrate. Lime is employed to regulate pH. Mushroom cultivation needs appropriate nitrogen content for top yield, which may be fulfil by various components like, urea, bran, edible seed, molasses, manure (Reis *et al.*, 2012) [20].

Optimal conditions for cultivation of mushrooms

For significantly high yield of mushroom appropriate composition of biological and chemical supplements with basal substrate and optimum conditions of the environment during cultivation should also be maintained. The common optimum conditions should be maintained. The common optimum conditions that ought to be maintained during cultivation are mentioned as below.

Temperatures should be maintained between the range of 15-35°C and pH of about 6.5. Carbon dioxide (CO_2) level should be between 15-20% and humidity between 86-90%.Humidity levels and temperatures should be controlled at 86% and 10-28°C respectively.

Future aspects

India contributes 14% of total world vegetable production and therefore the total waste generated involves about 50 million tons once a year. These wastes are often used for the production of different mushroom species.

Mushroom cultivation being a labour-intensive and high profit venture; provides employment to small farmers who have less land or no land. For increasing the mushroom yield; rather than search of higher and cheap substrates and their supplements, the subsequent fundamentals are suggested which must be practiced: (a) search and identification of potent and novel varieties for better yield (b) search of temperature resistant varieties and (c) development of high yield and resistant transgenic strains through the strategy of genetic manipulations.

In addition, government and their organizations must turn their attention towards nourishing the institutions with the objectives of popularizing the technology of mushroom cultivation. They must facilitate the programmes of technology transfers from laboratory to fields as campaign was run before for other crops (Naraian *et al*., 2016) [10]. After being used for mushroom cultivation, the agro wastes can be used as manure for increasing fertility of agricultural field as now the nutrient contents are at suitable range.

Promoting mushroom cultivation on agro wastes would not only enable employment to the landless and economically weak sections but will also helpful to meet nutritional and medicinal needs to reduce malnutrition.

Conclusions

With the rapid growth of population, the increase of agricultural production seems to be difficult. Management of the agro-wastes and providing the growing population with food rich in protein are two important issues of which the utilization of agro-waste by growing mushrooms has created interest in researchers around the world. The edible mushrooms are significant as they exhibit several kinds of healing activity and at the same time are capable for wastes biodegradation.

Depending upon the region of the world, most of the agricultural waste is employed as a basis for substrates and supplements. Using different substrates are going to be a crucial; part for the waste management technology.

However, most agricultural wastes comprise of toxic constituents like heavy metals, herbicides, pesticides etc, which may be absorbed by mushrooms, the traces or concentration of those substances has not been determined within the cultivated mushrooms.

Mushroom cultivation on agricultural wastes will contribute to food security and rural sustainable development. To sustain the food production and security, maximum mushroom cultivation is extremely important factor which plays a crucial role to satisfy the demand of food scarcity along side low calorie nutritious food. The vision of the study of agricultural waste utilization by mushrooms involves within the exploration of the yield, the method environments, its biological effectiveness and safety of cultivated mushrooms. Depending upon the varied biochemical parameters, the morphological and biochemical studies of cultivated mushrooms have also to be taken into consideration for further studies.

References

1. Anonymous. The Mushroom Sustainability Story: Water, Energy and Climate Environmental Metrics 2017 study, produced by leading sustainability analysis and research firm SureHarvest, 2901 Park Avenue, Suite A Soquel, CA 95073, 2017. www.sureharvest.com.
2. Bahukhandi D, Munjal RL. Cultivation of *Pleurotus* sp. on different agricultural residues. Indian Phytopath,1989:42(4):492–495.
3. Bano Z, Rajarathanam S. Studies on the Cultivation of Pleurotus Sajor-Caju. The Mushroom Journal,1982:115:243-245.
4. Bhuvaneshwari S, Hiroshan Hettiarachchi, Meegoda Jay N. Crop Residue Burning in India: Policy Challenges and Potential Solutions Int. J. Environ. Res. Public Health,2019:16(5):832.
5. Bonatti M, Karnoppa P, Soaresb HM, Furlana SA. Evaluation of Pleurotus Ostreatus and Pleurotus Sajor-Caju Nutritional Characteristics When Cultivated In Different Lignocellulosic Wastes. Food Chemistry,2004:88:425-428.
6. Dhar BL, Neeraj Shrivastava. Mushrooms and Environmental Sustainability Available from, 2010: https://www.researchgate.net/publication/325120361_Mushrooms_and_Environmental_Sustainability [accessed May 03 2021].
7. Elahe KJ, Mehrdad J, Shahin E. King oyster mushroom production using various sources of agricultural wastes in Iran. International J Rec Org Waste Agr,2016:5:17-24.
8. Jain AK, Vyas D. Cultivation of Three Pleurotus Sp. On Different Substrates. J. Basic Appl. Mycol,2003:2:88-89.
9. Jandaik CL, Kapoor JN. Studies on cultivation of Pleurotus sajor-caju (Fr.) Singer. Mush Sci,1974:9(1):667–672.
10. Naraian R, Singh MP, Ram S. Supplementation of basal substrate to boost up substrate strength and oyster mushroom yield: an overview of substrates and supplements. Int. J. Curr. Microbiol. App. Sci.,2016:5:543–553. doi:10.20546/ijcmas.2016.505.056.
11. NIAM Research Study (2011-12). Handling of agricultural wastes in APMCs NIAM Research Study Report. National institute of agricultural marketing (a govt. of India organization) Jaipur, Rajasthan, 2016, 1-18.
12. Nicolcioiu MB, Popa G, Matei F. Mushroom Mycelia Cultivation on Different Agricultural Waste Substrates. Romania Scientific Bulletin Series F. Biotechnologies, 2016, 20.
13. Pal J, Paul YS. Cultivation of Pleurotus sajor-caju on lyma wastes. Indian J Mycol Pl Pathol,1985:15(1):76–78.
14. Poonam D, Deepak V. Effect of different agro-waste substrates and their combinations on the yield and biological efficiency of *Pleurotus sajor- caju*. IOSR J Pharm Bio Sci,2013;8:60-64.
15. Poppe J. Use of Agricultural Waste Materials in the Cultivation of Mushrooms. Ed. LJL Van Griensven. Science and Cultivation of Edible Fungi,2000:1&2:3–23.
16. Quimio TH. Introducing *Pleurotus Flabellatus* for Your Dinner Table. Mushroom Journal,1978:69:282-283.
17. Ralph H, Kurtzman J. Nutritional needs of mushroom and substrate supplements. In: Nair MC (editor), Advances in mushroom biotechnology, 1994, 106-110.

18. Rana RS, Subag LS. Effect of Legume Pod Waste Addition on Biological Efficiency of Pleurotus sajor-caju Proc. Ann. Conf. on Mushroom. Hissar: Soc. Mycol. Pl. Path, 1990, p19–20.
19. Rani P, Kalyani N, Prathiba K. Evaluation of Lignocellulosic Wastes for Production of Edible Mushrooms. Applied Biochemistry and Biotechnology,2008:151:151-159.
20. Reis FS, Barros L, Martins A, Ferreira I. Chemical Composition and Nutritional Value of the Most Widely Appreciated Cultivated Mushrooms: An Inter-Species Comparative Study. Food and Chemical Toxicology,2012:50:191-197.
21. Robinson B, Winans K, Kendall A. Jeff Dlott & Franklin Dlott (2019). A life cycle assessment of *Agaricus bisporus* mushroom production in the USA. Int J Life Cycle Assess,2012:24:456-457. https://doi.org/10.1007/s11367-018-1456-6.
22. Royse DJ. Cultivation of Oyster Mushroom. College of Agricultural Sciences. The Pennsylvania State University Park University: Agricultural Research and Cooperative Extension. Cat Ul207 3m1/03acg4562, 2003.
23. Royse DJ, Baars J, Tan Q. Current overview of mushroom production in the world. Edible and Medicinal Mushrooms, Technology and Applications, 2016, p5–13.
24. Shashitha KN, Shlini P, Kavitha GS. Vegetable Waste-A Potent Substrate for Cultivation of *P. ostreatus*. Int Res Stud Biosci,2016:6:5-9.
25. Singh MP, Singh VK. Biodegradation of Vegetable and Agro Wastes by *Pleurotus sapidus:* A Novel Strategy to Produce Mushroom with Enhanced Yield and Nutrition. Cell Mol Biology (Noisy-Le-Grand),2012:58:1-7.
26. Sonali DR. Cultivation and Study of Growth of Oyster Mushroom on Different Agricultural Waste Substrate and Its Nutrient Analysis. Adv. Appl. Sci n b Res, 2012.
27. Sturion G. Utilização Da Folha De Bananeira Como Substrato Para O Cultivo De Cogumelos Comestíveis (*Pleurotus Spp*.). Piracicaba: Esalq/Usp. 56p. (Tese Mestrado), 1994.
28. Tan YH, Wahab MN. Extracellular Enzyme Production during Anamorphic Growth in the Edible Mushroom, *Pleurotus sajor-caju*. W Micro Biotech,1997:13:613-617.
29. Thongklang N, Luangharn T. Testing agricultural wastes for the production of *Pleurotus ostreatus*. Mycosphere,2016:7:766-772.
30. Udayasimha L, Vijayalakshmi YC. Sustainable Waste Management by Growing Mushroom (*Pleurotusflorida*) On Anaerobically Digested Waste and Agro Residues. Int J Eng Res Tech,2012:1:12.
31. Vyas D, Chaubey A, Dehariya P, Wagay AJ, Bajpai A. Perspectives on Agripreneurship and Rural Development, ICARD. International Conference on Agripreneurship & Rural Development, BHU, Varanasi, India, 2009, 463-470.
32. Goyal R, Grewal R, Goyal RK, Grewal RB. Vitamin and mineral content of Agaricus bisporus (white button) and Pleurotus sajor-caju (dhingri) mushrooms. Int. J. Food Sci. Nutr. 2020;5:100-2.
33. Zadrail F, Dube HC. The Oyster Mushroom-Importance and Prospects. Mushroom Resource,1992:1:25-32.