Part I Shiitake

Chapter 7

Shiitake Post Harvest

RECYCLING SPENT SHIITAKE SUBSTRATE

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In the production of any and all species, significant residual material remains after cultivation. Every tonne of mushrooms produced results in one to two tonnes of dry spent residual material. The important question in this day of limited natural resources and concerns over human health and the environment is, "What use or value does this residual material from mushroom production have?"

Shiitake, *Lentinula edodes*, represented 25% of the 1997 world mushroom production (Chang, 1999). This species is either cultivated on natural logs or on a "synthetic" logs. Natural log production utilizes various species of trees, especially oak. Trees are cut down after leaf fall and the wood is cut in lengths of about one meter. Within one month these logs may be inoculated with the shiitake fungus. After up to one year of incubation, the colonized logs are brought under conditions that initiate fructification. Mushrooms are harvested about twice per year for several years. Once production ceases, these logs are considered as spent. "Synthetic" logs for production of shiitake mushrooms are formed from sawdust, straw, corncobs or mixtures of these. Starch-based additives from cereals are often added to optimize the nutritional needs of the fungus. The growing materials are generally sterilized. After colonization is completed, environmental conditions are changed to initiate the formation of mushrooms. After several harvests, these synthetic logs are considered spent. Unfortunately, many growers discard the spent shiitake substrate (SSS) near the production rooms (Fig. 1A) or burn them as refuse (Fig. 1B). The discarded SSS is a repository and breeding area for diseases and insects near the mushroom farm. These pests may easily re-infest and contaminate growing materials and healthy new mushroom crops. Furthermore, the leachate from discarded SSS may enter surface waters, thereby polluting them. Burning the SSS pollutes the air, affecting not only its quality but also the usefulness of the surrounding area for living or recreation. The plastic bags used to hold the sawdust media can be problematic to the

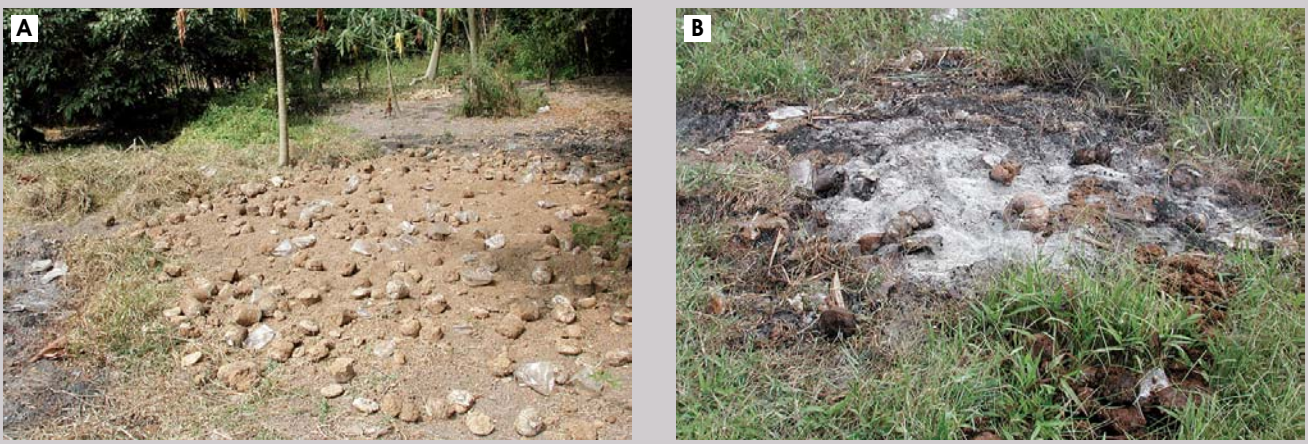

Figure 1. Spent shiitake substrate was emptied from the growing rooms and discarded into a field near the mushroom facility (**A**). Discarded spent shiitake substrate was burned after the mushroom crop was finished (**B**).

environment in their disposal. There are very few published articles that discuss the re-use of spent shiitake mushroom substrate. The following brief comments reference either published literature or personal communications in the re-use of spent shiitake substrate. Its reported uses are diverse but its documentation is sparse.

1. Purification of water. Shiitake spent substrate has been used in the purification of water. Chang *et al*. (2000) reported its use in the treatment of acid mine drainage and D'Annibale *et al*. (1998) the treatment of effluents from olive mills.

2. Purification of soil. *Lentinula edodes* spent substrate has been used to remove and degrade pentachlorophenol (PCP) (Okeke *et al*., 1993; Chiu *et al*., 1998).

3. Food crops. Production of horticultural crops has been enhanced through the spent shiitake substrate being crushed (Fig. 2) or pelletized into an organic fertilizer (Clifford Keil, USA, pers. com.), applied to tomatoes (Lin and Chuen, 1993) or sugar cane production (Pan *et al*., 1989) or after composting to corn (Chang, 1997), radishes and tree seedlings (Cho *et al*., 1997) or other crops (Kimmons *et al*., 2003) or after vermiculture to crops (Pauli, 1999).

Figure 2. Spent shiitake substrate used as a crop fertilizer in China

4. Cultivation of other species. *Lentinula edodes* spent substrate has been recycled in the production of other mushroom species such as *Pleurotus* spp. (Jaramillo, C., Colombia, pers. com.; Royse, 1992; Nakaya *et al*., 1999), or mixed into *Agaricus* substrate (Jim Yeatman, USA, pers. com.).

5. Food for animals. Not only does shiitake serve as a nutritious food for humans but also researchers have investigated spent shiitake substrate as a food for animals. These studies include: ground waste logs from natural log shiitake cultivation (Yoshida *et al*., 1978), rice straw fermented with waste shiitake sawdust media, corn and molasses (Cho *et al*., 1997; Lin *et al*., 1998a, b), degradation studies (Braun *et al*., 2000; Min, 1991; Zhang *et al*., 1995) or indirectly as a substrate for production of worms (Pauli, 1999).

6. Biological control of diseases. Biological control of pests is important component of a food safety conscious society. Shiitake spent substrate has been used/studied in the suppression of *Rhizoctonia* damping-off of cabbage (Huang, 1997; Huang & Huang, 2000), disease incidence of tomato (Lin and Chuen, 1993) and as a medium for other biocontrol antagonists (Raziq and Fox, 2004).

7. Alternative fuel. Spent shiitake logs have been used as alterative fuel (Dias, E. S., Brasil, pers. com.; Pauli, 1999) (Figs. 3).

Figure 3. Spent shiitake substrate is first air dried (**A**) and then utilized as a fuel source for a mushroom drier (**B**).

8. Vermiculture. In China extensive production of worms from spent shiitake substrate are produced (Pauli, 1999).

9. Source of degradative enzymes. The spent substrate of the white-rot basidiomycete, *Lentinula edodes*, is a source of degradative enzymes (Mishra and Leatham, 1990).

10. Plastic bag recycling. Plastic bags are used to hold and form the shiitake substrate. These spent plastic bags can be recycled into other reusable plastic materials (sources: MushWorld; Hsu, L. , USA, Unicorn Imp. & Mfg. Corp., pers. com.) (Figs. 4).

Figure 4. Plastic bags are recycled into other products. Plastic bags are peeled from substrate by hand (**A**) or machine (**B**). The bags are transported to a centralized location for recycling (**C**) where they are cleaned mechanically (**D**). They are then heated into a mass (**E**) and reformed as raw material (**F**) to produce recycled plastic products.

Conclusion

The shiitake mushroom (*Lentinula edodes*), based on the limited published literature, has considerable potential to be re-used in bioremediation, crop production and pest management, animal husbandry, alternative farming, industrial processes or bioproducts. The re-cycling, as fuel, is a marginal re-use. However, the benefits are greater from other re-uses. In the short term, the best utilization of the spent substrate would be in the agricultural and horticultural industries as a soil amendment either directly or after composting. This utilization would not only enhance crop production but would have the potential to reduce pathogens of these crops. In general, agriculture and horticulture have benefited from re-use of spent mushroom substrates. In the long term, the spent shiitake substrate has the prospective as having significant value for commercial re-utilization in environmental reclamation and industrial sectors. Significant investment in research is required to determine the particular benefit to horticultural crops, the environment or the industrial sectors.

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