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The influence of spawn type and strain on yield, size and mushroom solids content of *Agaricus bisporus* produced on non-composted and spent mushroom compost

Delphina P. Mamiro, Daniel J. Royse *

Department of Plant Pathology, Mushroom Research Center, The Pennsylvania State University, University Park, PA 16802, USA

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Abstract

Two crops of *Agaricus bisporus* (J. Lange) Imbach were grown on mixtures of non-composted substrate (NCS)/spent mushroom compost (SMC) or pasteurized Phase II compost (control). NCS consisted of oak sawdust (28% oven dry wt), millet (29%), rye (8%), peat (8%), ground alfalfa (4%), ground soybean (4%), wheat bran (9%), and $CaCO_3$ (10%). Substrates included 25/75 NCS/SMC, 50/50 NCS/SMC, and 75/25 NCS/SMC, NCS and Phase II compost. Spawn types and strains were evaluated for their effects on yield, biological efficiency (BE), size and mushroom solids content. Spawn types included millet, casing inoculum (CI), 50/50 CI/millet, or NCS while mushroom strains were of the brown or hybrid off-white variety (U_1 type). Mushroom yields and BEs on substrate mixtures of NCS and SMC were comparable to non-supplemented Phase II compost. The highest yield (12.8 kg/m^2) and BE (70.9%) were produced on a substrate mixture of 50/50 NCS/SMC and spawn type NCS. Mushroom solids content (7.1%) was highest from the brown strain produced on a 50/50 mixture of NCS/SMC.

Keywords: Mushrooms; *Agaricus bisporus*; Spent mushroom compost

1. Introduction

The button mushroom, *Agaricus bisporus* (J. Lange) Imbach, is a mainstay of Pennsylvania agriculture, contributing almost $400 million annually to the economy of the state (USDA, 2006). It is produced on a composted substrate consisting of various raw materials including straw-bedded horse manure, hay, corncobs, cottonseed hulls, poultry manure, brewer's grain, cottonseed meal, hardwood bark and gypsum.

Offensive odors produced by the preparation of mushroom compost are a problem due to a combination of residential encroachment into rural areas and the heightened sensitivity of the general population to environmental issues (Duns et al., 2004). The most common measure to reduce offensive odors produced during the preparation of compost is the use of forced aeration of Phase I compost contained in bunkers or tunnels. In some studies, volatile sulfur compounds, the most offensive odors, were significantly reduced under forced aeration (Op den Camp et al., 1991; Noble et al., 2001) but this was not confirmed by other researchers (Duns et al., 2004). Since sulfur compounds such as mercaptans and sulfides have very low odor thresholds, near-complete elimination of these compounds would be required to reduce offensive odors from compost. Therefore, a novel method of mushroom substrate preparation without the generation of offensive odors is desirable.

It is possible to produce *A. bisporus* on non-composted substrates. Till (1962) and Lemke (1965) obtained yields comparable to Phase II compost after grinding, mixing, filling, sterilizing and spawning substrate in 200 L steel barrels. San Antonio (1971) produced mushrooms on cased grain spawn, and Murphy (1972), was able to obtain "good" mushroom yields by supplementing spent

* Corresponding author. Tel.: +1 814 865 3761; fax: +1 814 863 7217.
E-mail address: djr4@psu.edu (D.J. Royse).

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mushroom compost (SMC) with corncobs, cottonseed meal and hardwood sawdust. He concluded that up to 25% SMC could be mixed directly with fresh Phase I compost at fill with no adverse effects on yield. Mee (1978) obtained "good quality" mushrooms on a non-composted substrate (NCS) mixture of cold manure, *Sphagnum* peat moss and gypsum. Biological efficiency (BE) ranging from 30% to 77% was obtained when NCS was used to produce brown (Portobello) *A. bisporus* (Sanchez and Royse, 2001; Sanchez et al., 2002). Bechara et al. (2005) produced white mushrooms with a BE of over 150% when grain spawn was supplemented with delayed-release nutrient and placed on top of an auxiliary water reservoir of Perlite®.

Spent mushroom substrate, spent mushroom compost, mushroom soil and recycled mushroom compost are all terms used to describe the production material that remains after mushrooms are harvested (AMI, 2005). SMC can be used as growth medium for plants (Romaine and Holcomb, 2001), an organic biocontrol agent that suppresses artillery fungi (*Sphaerobolus* spp.) (Davis et al., 2005; Davis and Kuhns, 2005), and as a soil amendment to improve turf (Landshoot and McNitt, 2005), fruit (Robbins et al., 1986), vegetable (Kaddous and Morgans, 1986; Male, 1981; Wang et al., 1984a,b), corn (Webber et al., 1997) and container plant production (Chong and Hamersma, 1997; Maher, 1991; Chong et al., 1991). SMC from one genus of mushroom can be used as growth medium for another genus of mushroom (Rinker, 2002). For example, SMC obtained after a crop of *Pleurotus ostreatus* can be used as compost for cultivation of *A. bisporus* (Harsh and Bisht, 1984).

SMC often is considered environmentally unfriendly, undesirable and represents a solid waste disposal problem for mushroom growers. Approximately, 60% of the US mushroom crop is produced in Pennsylvania; nearly 21.6 million m^3 of SMC is produced each year as a byproduct of the mushroom industry (Davis and Kuhns, 2005). In the USA, this byproduct exceeds 36 million m^3 annually (AMI, 2005). A method of utilizing SMC to produce a second crop of mushrooms would help alleviate the problem of solid waste disposal in the mushroom industry.

Schisler (1990) was able to obtain BEs of up to 78% after supplementing SMC with 1 kg/m^2 Bonaparte peat and 1.22 kg/m^2 of SpawnMate II, a commercial delayed release nutrient. Till (1962) obtained relatively high mushroom yields from autoclaved SMC composed of Phase II compost and additional nutritional supplements but had little success when the SMC was pasteurized. Huhnke and Sengbusch (1968) amended Till's procedure by further treating the substrate using a fermentation process after substrate sterilization. This process inhibited and prevented the subsequent development of mushroom competitors. Flegg and Randle (1968) used a pasteurized mixture of SMC, straw and Phase II compost to produce A. *bisporus*, but the number and weight of sporophores were not comparable to those from Phase II compost. SMC pasteurized at 66 °C for 24 h and stored under cover for several days contained mushroom mycelia, but also several molds such as *Monilia* sp. and *Trichoderma viride* (Flegg and Randle, 1968). A method of utilizing a mixture of NCS and SMC to produce *A. bisporus* has not been reported.

Most spawn of *A. bisporus* is prepared by commercial manufacturers (Fritsche, 1988). Grain spawn, first developed by Sinden (1932), is made by sterilizing a cereal substrate, inoculating the substrate with a pure culture of mother spawn and incubating the substrate until fully-colonized. Grain spawn is typically rye, millet or sorghum, supplemented with chalk, and contains a moisture content of 45–48%. The colonized grain may readily be mixed with various substrate formulations, thus providing many points of inoculation. Since spawn is normally sold on a weight basis, grains that have small seeds such as millet give a greater number of inoculation points per kg than large grains such as rye. However, large grains have a greater food reserve and can sustain the mycelium for longer periods of time during stress (Fritsche, 1988). Thus, different types of spawn may influence productivity.

Casing inoculum (CI) is a low nutrient, fully-colonized substrate added to the casing material to speed up colonization of the casing layer. Commercial production of CI evolved in the late 1980s as an alternative to farm-prepared, fully-colonized compost added at casing, termed CACing (Bodine, 2005). The beneficial aspects of using CI to inoculate casing material include shortening of the mushroom production cycle, elimination of the pathological risk, and cost effectiveness. The additional points of inoculum available in CI increase the growth and development of mushroom mycelium in the casing layer. When used as spawn to inoculate NCS or SMC, CI may increase the colonization rate of the substrate and thereby reduce the time required to complete a crop cycle.

The objectives of this research were to examine the effect of NCS and SMC on mushroom yield, size, and percentage solids, and to examine the influence of strain and type of spawn on growth and development of *A. bisporus* in NCS and SMC.

2. Methods

2.1. Non-composted substrate (NCS)

Ingredients for NCS included oak sawdust (28% oven dry wt), millet (29%), rye (8%), peat (8%), ground alfalfa (4%), ground soybean (4%), wheat bran (9%) and $CaCO_3$ (10%) (Sanchez and Royse, 2001).

2.2. Spent mushroom compost (SMC)

"Spent" mushroom compost (three breaks of mushrooms were harvested prior to termination of the crop) was obtained from the Mushroom Test Demonstration Facility (MTDF) at The Pennsylvania State University. The original compost for mushroom production was prepared from wheat straw-bedded horse manure mixed with