Vermicompost in Substrate and Casing Formulas for the Production of Brown *Agaricus bisporus*

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Abstract: A non-conventional, non-composted substrate was used to evaluate the influence of vermicompost replacement of peat moss in both the substrate and casing layer on the yield of brown *Agaricus bisporus* ('portabella' ECS-0305). The substrate was prepared with cereal grains, sawdust, peat moss, wheat bran and other minor ingredients. Vermicompost was added to the substrate (0 to 12%, dry wt) and 0 to 100% in the casing. It was possible to eliminate peat moss in both the substrate and the casing soil, although intermediate levels (4% peat + 4% vermicompost) gave better yields. One trial produced a biological efficiency of 96% (three flushes), improving on previous attempts to use a non-composted substrate to produce this mushroom.

Key words: Cultivation methods, Portabella, substrate for mushroom growing, mushroom casing, peat moss substitutes

1 Introduction

All commercial production of the button mushroom, *A. bisporus,* has depended on the use of composted substrates. These substrates normally contain straw bedded horse manure and other raw materials that are well composted. After an indoor pasteurization, the substrates are highly selective for *A. bisporus.*[1] Production of *A. bisporus* on non-composted substrate is possible but yields are generally less and time to production is longer. Till[2] was the first to demonstrate that *A.bisporus* could be grown on non-composted substrates and Sanchez and Royse[3] more recently reported successful production of this mushroom on a pasteurized substrate (110°C for 20 min) adapted from shiitake formulations. These latter suggested additional work to improve the substrate, and recommended that a wider variety of raw materials be examined. Furthermore, Sanchez and Royse [3] suggested that additional improvements in the formulation may eventually lead to the commercial use of non-composted substrates for this species, especially among small-scale producers.

The brown form of *A. bisporus,* 'portabella', is by far the fastest growing segment of the *Agaricus* market. Its market has increased substantially during recent years as no other edible mushroom has done: up 25.8% from 2001 to 2003.[4] Thus, the ability to produce this mushroom on non-composted substrate (NCS) may open the market to smaller producers who may not have access to compost. Efforts to reduce the cost of the NCS while increasing mushroom yield would help make this alternative economically viable. One of the most expensive ingredients in the formulation, difficult to find in certain areas, is peat moss. Peat moss plays an important role in the commercial cultivation of *A. bisporus* due to its structure and water holding capacity.[5] Several studies have examined alternative materials for peat moss for use as casing,[6] not only to reduce production costs but also to preserve the plant in nature. The use of worm compost instead of peat moss in both the substrate and casing may help to lower production costs and increase yields. Earlier work has demonstrated that worm compost can be used successfully when phase II compost is used.[7, 8] Therefore, we sought to examine the effect of worm compost from spent *Pleurotus* sp. substrate[9] as a substitute for peat moss in both NCS and casing.

2 Materials and Methods

2.1 Strain

We used *A. bisporus* 'portabella' ECS-0305 (WA 444) from the strain collection of Ecosur.

2.2 Substrate

A basic mixture containing (% dry wt) corn cobs (4%), sorghum grain (22%), gypsum (2%), ground soybean (5%), wheat bran (5%), ground corn leaves (5%), sheep manure (4%), primavera *Cybistax donnell-smithii* sawdust (15%), coffee pulp (5%), Pangola grass *Digitaria decumbens* (25%) and peat moss (8%) was used in the first trial.[10] In a second trial, the mixtures presented in Table 2 were used.

The vermicompost was prepared by using spent mushroom substrate from *Pleurotus ostreatus* cultivation. This was a spent mixture of corn straw and corncobs inoculated with the redworm *Eisenia fetida* and incubated for 3 months under cover, watered periodically to maintain 70% moisture until the compost was ready for use.[9]

2.3 Substrate preparation and spawning

The substrate ingredients were mixed in a plastic container (75 l), water was added to adjust moisture to 55% and the mixture was left overnight (15 hr). Aliquots (1 kg) of the mixture were bagged in filter patch bags (Unicorn Imp. & Mfg Corp, Commerce, TX, USA) then pasteurized at 110°C for 15 minutes in an autoclave. After cooling to 22-24°C, the substrate was spawned in a hood with 5% sorghum spawn.

2.4 Treatments

Several treatments were assayed to evaluate the influence of various levels of vermicompost, peat moss and $CaSO_4$ in the substrate (Tables 1 and 2) and of vermicompost and peat moss in the casing (Table 3).

Table 1. Treatments used to evaluate the influence of vermicompost and peat moss in substrate (92% basic mixture + 8% peat moss/vermicompost; dry wt basis)

Treatments	Percentage peat moss/vermicompost in substrate
T1 (Control)	Peat moss (8%) - vermicompost (0%)
T2	Peat moss (6%) - vermicompost (2%)
T3	Peat moss (4%) - vermicompost (4%)
T4	Peat moss (2%) - vermicompost (6%)
T5	Peat moss (0%) - vermicompost (8%)

Table 2. Treatments used to evaluate the influence of various levels of vermicompost, peat moss and gypsum ($CaSO_4$) in non-composted substrate (%)

Mixture ingredients	Proportion of ingredients (%)				
	T_6	T_7	T_8	T_9	T_{10}
Corn cobs	4	0	0	0	0
Sorghum	22	22	22	22	22
Gypsum	2	2	2	3	5
Ground Soybean	5	5	5	5	5
Wheat bran	5	5	5	5	5
Corn leaves	5	5	1	0	0
Sheep manure	4	4	4	4	4
Sawdust *(Cybistax donnell-smithii)*	15	15	15	15	15
Coffee pulp	5	5	5	5	5
Pangola grass *(Digitaria decumbens)*	25	25	25	25	25
Vermicompost	4	8	12	12	10
Peat moss	4	4	4	4	4
Total	100	100	100	100	100

Table 3. Treatments to evaluate the influence of mixtures of vermicompost and peat moss used as a casing layer

Treatments	Ingredients in casing layer
C1 (Control)	Peat moss (100%) - vermicompost (0%)
C2	Peat moss (75%) - vermicompost (25%)
C3	Peat moss (50%) - vermicompost (50%)
C4	Peat moss (25%) - vermicompost (75%)
C5	Peat moss (0%) - vermicompost (100%)

Substrate in this treatment equals T_3 (Table 1).

2.5 Cultivation methods

The cultivation method for portabella on non-composted substrate as outlined by Sánchez and Royse[3] was followed. Spawn run was completed (3 wk) in the dark at 22-23°C. Casing was applied and case hold lasted 3 weeks at 18 or 22-23°C as stated and 85% relative humidity.

2.6 Parameters evaluated

Biological efficiency (BE, ratio of fresh mushrooms harvested (kg)/kg dry substrate, expressed as percentage) and the yield in kg/m^2 was determined after the third break.

2.7 Experimental design and statistical analysis

Each experiment was conducted three times in a randomized array with five replicates per treatment. The ANOVA procedure was performed and means were separated by using the Waller-Duncan k-ratio t test.[11]

3 Results

3.1 Vermicompost in substrate

Table 4 shows the biological efficiency, yield and mean weight of mushrooms obtained at different concentrations of peat moss/vermicompost in the substrate. BE values varied from 66.0% (T_1, control) to 96.1% (T_3, peat moss 4% - vermicompost 4%). The statistical analysis (α=0.05) separated two groups: Group A was formed by T_3, T_4 and T_5 and corresponded to the higher values of EB (74.5 - 96%). Group B showed the lower values (66.0-83.0%), and was formed by treatments T_1, T_2, T_5 and T_4. T_1 (lowest BE= 66.0%) was statistically different to T_3. In regard to the mean weight of carpophores, they varied between 20.0 and 25.5 g. However, no statistical difference was found in between treatments. The yield varied from 17.79 to 25.46 kg/m^2. The statistical analysis separated two groups: Group A, formed by T_3, T_4, T_5 and T_2, with yield values between 19.8 and 25.46 kg/m^2, and group B formed by T_4, T_5, T_2 and T1 showed yield values between 23.05 and 17.79 kg/m^2.

Table 4. Biological efficiency, mushroom size and yield of *A. bisporus* 'portabella" ECS-0305 produced on a substrate containing five different concentrations of peat moss/vermicompost

Treatments	Biological efficiency (%)	Size (g)	Yield (kg/m^2)
T_1 - Basic mixture (peat 8%) (Control)	66.0B*	20.2A	17.79B
T_2 - Peat (6%)+ vermicompost (2%)	71.6B	20.0A	19.80AB
T_3 - Peat (4%) + vermicompost (4%)	96.1A	24.7A	25.46A
T_4 - Peat (2%) + vermicompost (6%)	83.0AB	25.5A	23.05AB
T_5 - vermicompost (8%)	74.5AB	23.1A	21.48AB

*Means followed by the same letter in the same column are not significantly different (α=0.05). Coefficient of variation for the experiment=16 %. Fruiting temperature was 18°C.

To determine the effect of further additions of vermicompost to the substrate, a second set of treatments was prepared. In this experiment, a constant 4% of peat moss was used and the amount of vermicompost was increased up to 12%. Also, the effect of varying levels of gypsum was examined. Results of this trial are shown in Figure 1. Biological efficiencies ranged from 55 to 78%. Higher levels of vermicompost increased BE (78% BE at 12% vermicompost). An increase of 1% gypsum (from 2 to 3%) had no effect on BE, but an increase of 3% (up to 5% gypsum content) resulted in a decrease in mushroom production (from 78% to 72%).

3.2 Casing layer

Figure 2 shows the results obtained when vermicompost was used instead of peat moss as casing. Although the biological efficiency varied between 66.9 and 81% (fruiting temperature, 22°C), no statistical difference (α=0.05) between treatments was detected. Mushroom size varied between 15.3 and 24.8 g, but these values were not significant.

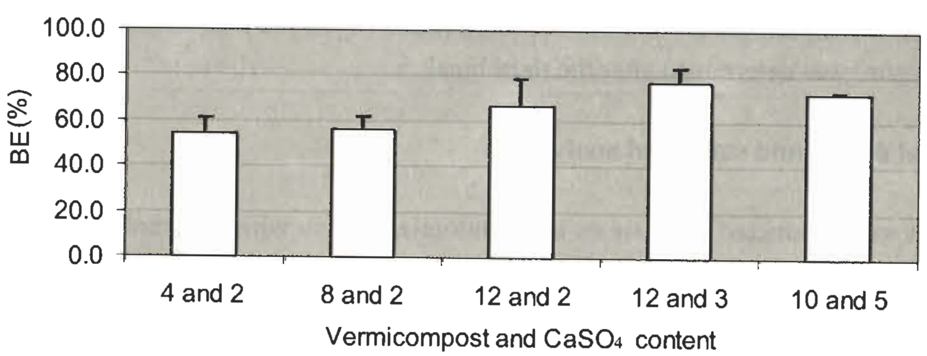

Figure 1. Influence of vermicompost and $CaSO_4$ content in substrate on biological efficiency of *A. bisporus* 'portabella' (fruiting temperature = 22°C

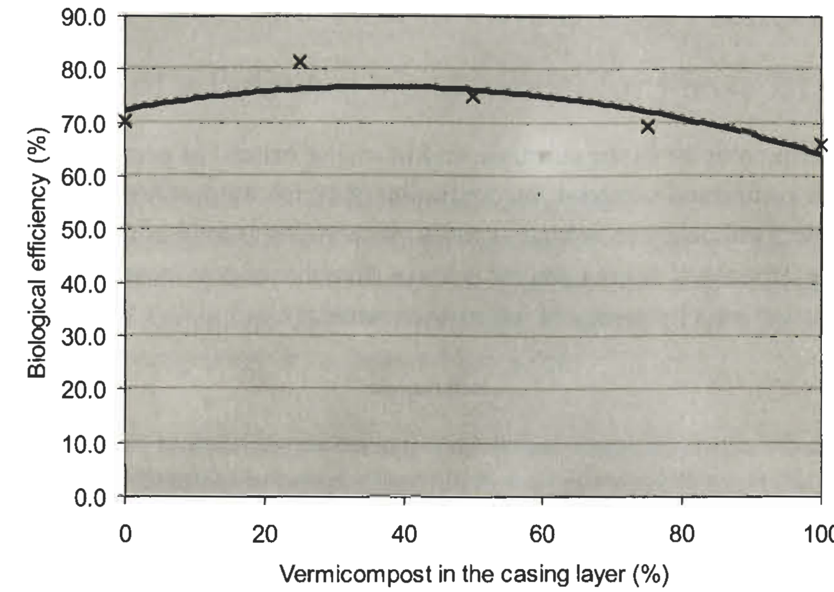

Fig. 2. Influence of vermicompost content in casing applied to non-composted substrate (NCS) colonized by *A. bisporus* 'portabella' on biological efficiency (fruiting temperature= 22°C)

4 Discussion

We evaluated the technical feasibility of using vermicompost as ingredient in NCS and in casing to produce portobella mushrooms. Our results demonstrated that reasonably good yields could be obtained when vermicompost derived from spent *Pleurotus* substrate was used. Yields (17.79- 25.46 kg/m^2) were similar or even better than those obtained at a commercial level with composted substrates and with a white strain of *A. bisporus.* In other studies, yields between 16.8 kg/m^2 [12] and 25.7 kg/m^2 [13] have been reported.
According to Schisler,[14] BE values between 50 and 70% are considered 'normal' when using white strains of *A. bisporus;* while BE values between 70 and 90% are considered as good. However, these values were presented before the widespread use of hybrid mushrooms. Thus, the values presented by Schisler should be increased to reflect the higher yield capacity of the hybrid mushrooms. Values in the range of 70-90% BE may now be considered 'normal' with good yields in the range of 90-100% 'good'. Our results would be considered in the 'normal' to good range since maximal BE values in both trials using vermicompost in the substrate and in the casing reached BE values between 81 and 96%, respectively.
The use of peat moss and vermicompost in 1:1 ratio as ingredient in the substrate gave better results than the control mixture, where only peat moss was used. This is considered an additional benefit because higher yields coupled with the use of low-cost, locally available raw material may improve the economic benefit to growers. Vermicompost may be used up to 12% in the substrate with improved yields. However, an increase in gypsum did not further improve yields. Although it has been demonstrated that pasteurized non-composted corn cobs and corn leaves can be used for growing portabella,[11] in the second trial good results were obtained without these corn byproducts, suggesting that a simplification of the formula, using less ingredients, is feasible.
The use of vermicompost instead of peat moss in casing had no effect on mushroom yield or size; thus, it is a suitable component to be used in rural areas where peat is difficult and very expensive to obtain. Vermicompost can be easily prepared by the grower from his or her own SMS.
It is important to note that spawn run and production temperatures are very important factors in obtaining higher yields. In our case, due to technical problems, the optimal temperature for the mushroom (18°C) could be maintained only during the first phase of the experiment (Table 4); later, the yields were lower, because

temperature in the fruiting room was too high (22°C). A small grower considering production of A. bisporus on NCS should keep in mind that temperature control is imperative to achieving optimum yields.

5 Conclusions

It is possible to use vermicompost in the substrate and in casing instead of peat moss to produce portabella mushrooms with a non-composted substrate. Incorporation of vermicompost instead of peat moss in the substrate improves biological efficiency to as high as (96%) with yields as high as 25.5 kg/m^2 over three breaks. Since the water holding capacity of worm compost is lower from that of peat moss, a grower will need to adjust initial moisture content and alter frequency of watering accordingly.

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