Reuse of the Casing Layer from Mushroom Compost in Subsequent Mushroom Crops

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2013 Mushroom Compost Grant Report

Three cropping experiments were conducted investigating the feasibility of reusing the casing layer from a previous *Agaricus bisporus* mushroom crop for the production of a subsequent mushroom crop. In each experiment, the recycled casing layer originally consisted of 100 percent sphagnum peat moss with the addition of agricultural limestone to adjust the pH following standard Penn State procedures. The casing layer was removed each time from standard crops of *A. bisporus* at the Penn State Mushroom Research Center (MRC) after completion of standard cropping practices and a post-crop steaming. For each crop, the removed casing layer was uniformly broken up into a free-flowing material by hand, to improve the mix ability of the casing material.

CROP 1

The first crop, Crop 1213, was designed to test the impact different quantities of recycled casing mixed with fresh sphagnum peat would have on crop yield. The recycled casing material (RC) was mixed at different ratios with either fresh sphagnum peat moss (SP) or a black peat (BP) and applied to spawn run tubs to assess the yield potential of the different mixes (Table 1). Six replicate tubs each holding 22.7 kg of spawn run compost were cased with the different treatments. The pH was measured for each casing mixture to determine if any pH adjustments were required. Each pH of the different mixes was determined to be within a standard pH range for a casing mixture. Each casing mixture also was sent to the Penn State Agricultural Analytical Lab for chemical analyses.

Following casing, standard MRC cropping protocols were followed and mushroom weight data were collected for three breaks. Results from the cropping experiment demonstrated a reduction in total yield by all treatments compared to the control (Table 1). Interestingly, yield loss was not much different between treatments 3 and 4 (50 percent RC or using 75 percent RC). There was also no difference between 100 percent RC and the 50/50 blend using BP. Chemical analyses of these mixtures showed a relationship between soluble solids and the percent RC used in conjunction with SP. This increase in soluble solids corresponds with the increase in yield loss, which leads us to believe that the soluble salts are adversely affecting yields when recycled casing is used to case the crop.

Treatment Number	Treatment Description	Yield vs. Control (Percent Difference)	Casing Properties pH	Soluble salts (mmhos/cm)
1	100% SP	X	7.3	1.06
2	75% SP + 25% RC	-12.8	7.5	2.06
3	50% SP + 50% RC	-20.9	7.4	2.75
4	25% SP + 75% RC	-22.4	7.6	3.07
5	100 % RC	-26	7.6	3.62
6	50% RC + 50% black peat	-25	7.6	2.82

Table 1. Yield loss compared to control based on percent crop loss. SP = sphagnum peat moss RC=recycled casing

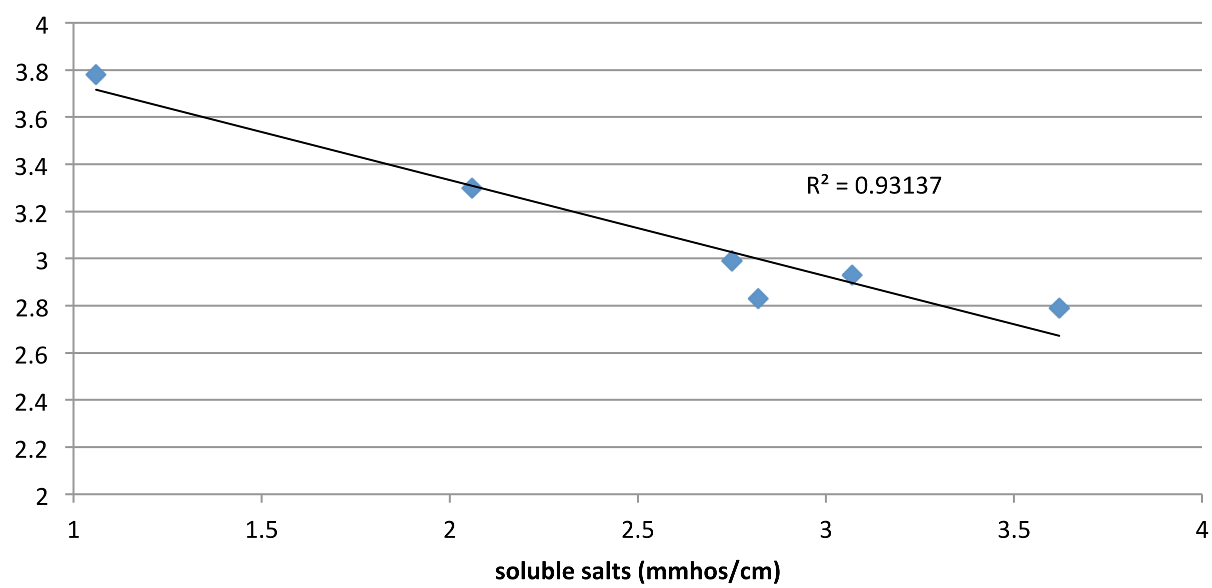

Figure 1. Crop 1 Yield versus casing soluble salt concentration (mmhos/cm)

CROP 2

After observing a negative correlation between soluble salt content and mushroom yield during the first experiment (Figure 1), we attempted to leach the recycled casing material (RC) prior to reusing it, hoping to reduce the soluble salt concentrations. For the second experiment, crop 1303, recycled casing material was placed into a bleached growing tray from Penn State's Mushroom Test Demonstration Facility (1.24 m^2). Using a garden hose, water was added to the RC to induce leaching. However, due to the physical nature of the sphagnum peat moss, the material did not readily leach and held water until it was saturated at which point water pooled on the surface. The saturated RC was then thoroughly mixed by hand for 30 minutes to promote flow ability and induce leaching while applying more water. Then five different casing treatments were applied to eight tubs each holding 22.7 kg of spawn run compost (40 tubs total). RC and leached RC were applied at two different rates (25 percent and 50 percent)(Table 2). The pH was measured for each casing mixture to determine if any pH adjustments were required. Each pH of the different mixes was determined to be within a standard pH range for a casing mixture. Each casing mixture was also sent to the Penn State University Agricultural Analytical Lab for chemical analyses.

Following casing, standard MRC cropping protocols were followed and mushroom weight data was collected for three breaks. Only the 50 percent RC treatment that was not leached showed a noticeable decrease in total yield when compared to the control. Leaching, though difficult, did prove effective in reducing the conductivity levels in the SP:RC mixtures. Similar to the first experiment, there was a negative correlation between mushroom yield and soluble salt concentrations in the second crop, though it was not as strong a relationship as seen in the first experiment (probably due to the high yields seen in treatment number 4) (Figure 2).

Treatment Number	Treatment Description	Yield vs. Control (Percent Difference)	Casing Properties	
			pH	Soluble salts (mmhos/cm)
1	100% SP	X	7.2	0.96
2	75% SP + 25% RC	-1.7	7.2	1.80
3	50% SP + 50% RC	-8.9	7.4	3.23
4	75% SP + 25% Leached RC	+3.8	7.2	1.60
5	50% SP + 50% Leached RC	-1.0	7.3	2.43

Table 2. Yield loss compared to control based on percent crop loss. SP = sphagnum peat moss RC = recycled casing

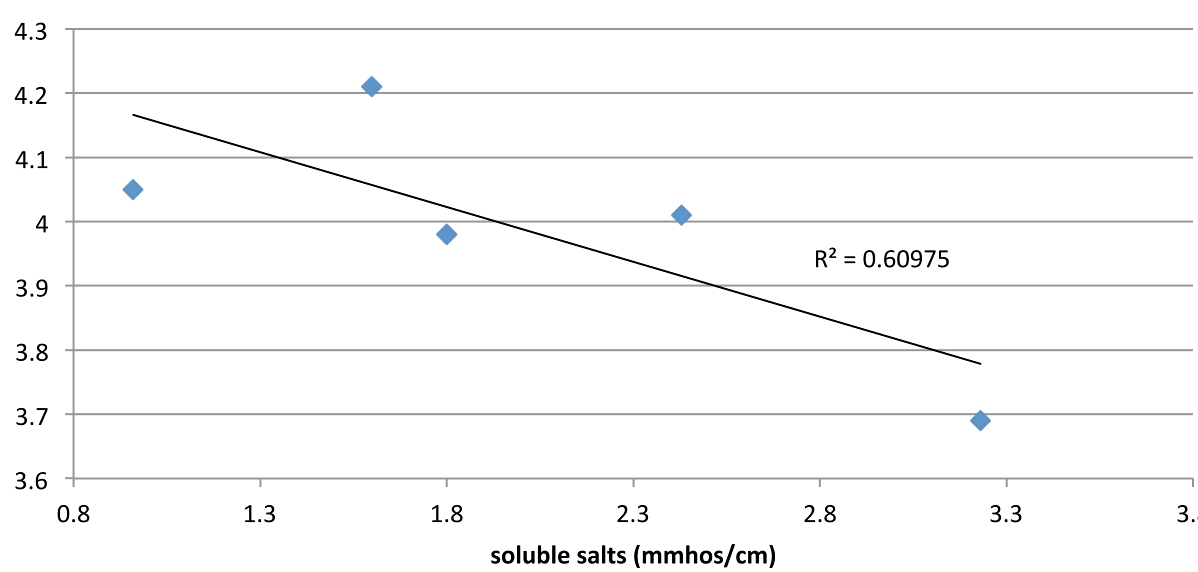

Figure 2. Crop2 Yield versus casing soluble salt concentration (mmhos/cm)

CROP 3

Due to the difficulties experienced with trying to leach the RC during crop 2, leaching was not attempted for the third crop. For the third crop, four different RC:SP mixes were used as casing materials. For crop 3 we decided that 50 percent would be the maximum recycle rate to keep conductivity levels lower in the casing mixes. Nine replicate tubs each holding 22.7 kg of spawn run compost were cased with the different treatments. The pH was measured for each casing mixture to determine if any pH adjustments were required. Each pH of the different mixes was determined to be within a standard pH range for a casing mixture. The conductivity of each casing mixture also was measured to determine if conductivity levels were again correlated with yield. For crop 3, casing conductivity and pH levels were measured in our lab using a Sension ™ benchtop dual channel multimeter. Following casing, standard MRC cropping protocols were followed and mushroom weight data were collected for three breaks. Results from the cropping experiment demonstrated very little difference in total yield compared to the control, with treatment 3 actually exhibiting an increase in yield (Table 3). Yield losses were not observed as levels of RC increased (along with soluble salt levels) as was seen in the previous cropping experiments (Figure 3). Nor were similar negative correlations between yield and casing soluble salt levels seen in the 3rd crop due to high yields obtained in treatment 3.

Treatment number	Treatment Description	Yield vs. Control (Percent Difference)	Casing Properties	
			pH	Soluble salts (µs/cm)
1	100% SP	X	7.89	0.273
2	75% SP + 25% RC	-3.0	7.85	0.361
3	63% SP + 37% RC	+9.9	7.48	0.518
4	50% SP + 50% RC	-1.6	7.74	0.500

Table 3. Yield loss compared to control based on percent crop loss. SP = sphagnum peat moss RC=recycled casing.

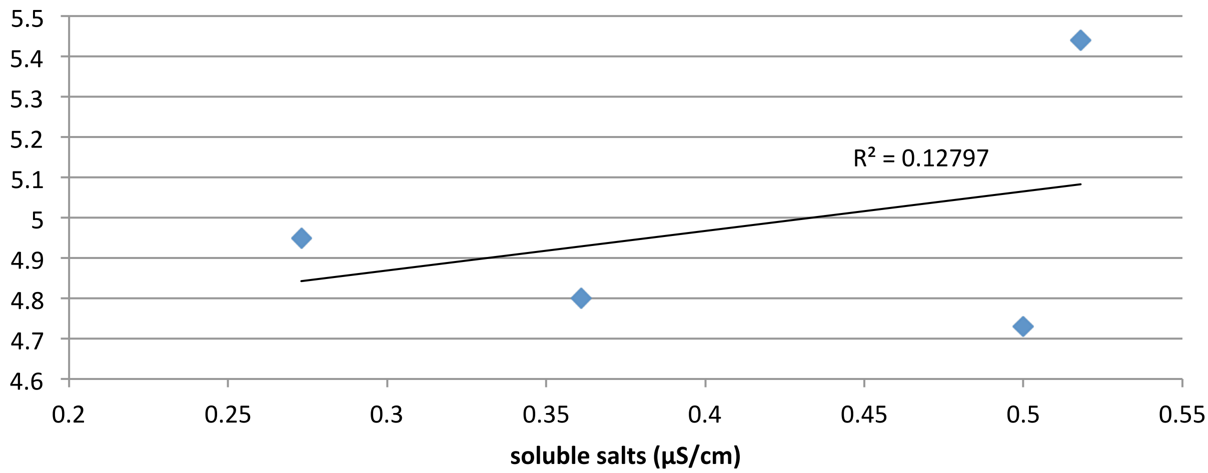

Figure 3. Crop3 Yield versus casing soluble salt concentration (mmhos/cm).

Summary

Mushroom crop yields appeared to decrease with an increased rate of recycled casing incorporated into the casing for crops one and two. A similar trend was observed in crop three except for treatment 3, which resulted in the highest yield. A reason for this high yielding treatment cannot be given for this crop. The third crop also showed minimal yield effects corresponding to a 50 percent recycled casing amount, though yield decreases of 21 and 9 percent were observed in the first two crops at this rate. Again, we cannot give a reason why yields did not drop with an increase in the amount of RC used in the final crop. For the third crop, soluble salts levels were lower for all treatments compared to the first two crops. However, these measurements were taken in our lab following a soils protocol that may have given different results from the ones obtained from Penn State's Agricultural Analytical Laboratory.

It appears that conductivity plays a key role in limiting the amount of RC that can be mixed back in with SP to produce a new crop based on the strong correlations observed in crops 1 and 2. Further studies need to be conducted to investigate the role of soluble salts in reducing mushroom yields and to determine at what rate RC can be incorporated into the casing layer without adversely affecting yield. If conductivity does prove to be the chemical property influencing yields, investigations into methods (both chemical and physical) to reduce soluble salts levels may prove helpful in allowing for the successful use of RC for new mushroom cropping. As well, the addition of RC in the casing layer may affect adversely other chemical or biological properties that also play a role in limiting yield.

Reuse of Casing and Compost for a Second Crop of Mushrooms

2014 Report for Mushroom Farmers of Pennsylvania

by

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This two year project was funded in 2012. This progress report covers the second year progress and we are submitting a proposal to continue for at another year of the project.

Introduction

Technology to separate the casing from the compost has been developed and in use in Europe (http://mushroommachinery.com/en/casing_separator_more). The casing separator equipment is placed between the emptying winch and shelving. During emptying the casing is removed from the compost with an auger and the compost travels straight ahead to a trailer. The separated casing is dropped onto a conveyor in the middle aisle and transported to a container or another trailer. Immediate and future advantages are possible. The direct advantage is that the separated mushroom casing is immediately suitable as a peat source for potted plants and seedlings. So the separated casing soil can be sold as is. One of the biggest advantages will be the possibility to re-use the separated casing and pasteurized mushroom compost to grow a second crop of mushrooms.

At the completion of the crop much of the compost remaining is called spent mushroom substrate (SMS); more recently called mushroom compost (MC). MC has nutrients still available for the mushroom; however, it is more economical to replace the substrate and start a new crop. Where many mushroom farms are concentrated near an urban area, the disposal of MC is still a problem. Piled MC may become anaerobic and produce offensive odors and are no longer ignored by neighbors or environmental regulatory agencies. Understanding the mechanism(s) that are limiting yields and substrate utilization may lead to increased use of organic matter by the mushroom and will reduce the quantity of substrate left after cropping.

Producing a second crop of mushrooms by supplementing spent mushroom substrate with certain additives was first reported by Schisler, 1990. By adding a protein-lipid rich, delayed release supplement and hypnum peat at spawning, a second crop of mushrooms was produced on pasteurized post mushroom substrate. These results and those of an earlier study suggested that hypnum peat moss (Bonaparte Peat) adsorbed substance(s) that either interfered with nutrient availability or was toxic to the mushroom mycelium. By adsorbing this substance the mushroom mycelium was able to use some of the remaining nutrients in post mushroom substrate. Furthermore the spent substrate from the second crop was shown to have properties more conductive to plant growth and had properties similar to a potting soil. The high ion exchange capacity of the hypnum peat used in these studies suggested that one or more ions could be the adsorbed substances. The adsorption of these substances could also result in the reduced activity of a specific ion. It is possible the activity of another closely related ion increases, making that nutrient more available to the mushroom mycelium. Results of a previous study indicate various forms of chelators were effective in improving the later break yields of *A. bisporus* (Beyer and Muthersbaugh, 1996; Beyer, 1997 and 1998). This study has suggested other chelators or materials with a high CEC capacity also increase later break yields when added at spawning. The response of several chelators with a high affinity for Ca^{2+}, citric acid and the IR120-Na resin, a common conventional sorbent, suggested that chelating or adsorbing calcium ions may influence later break production.

The compositional changes of mushroom compost occurring during the growth cycle of the button mushroom have been reported by Chen, *et al*., 2000. Samples were collected during spawning, casing and the following four flushes and were analyzed for their elemental composition, carbohydrates and lignin. The carbohydrate analysis revealed a decrease in the total amount of about 40% of the identified monosaccharides during mushroom growth. The data also confirm that polysaccharides are the main fraction degraded (or utilized by the mushrooms) during the cropping period. This study suggests that the polysaccharide fraction of the mushroom substrate is the main organic fraction utilized during the process. In addition, alterations of lignin structures, possibly the formation of lignin-humic structures, have occurred although its relative content usually increases during mushroom cropping.

It has been reported over the years that the lignin-humic complex is important in the nutrition of the mushroom. Different types of humic materials have been used in attempt to improve yields in mushroom cultivation. Royse reported the use of Hydra-Hume, a Leonardite material, added at different stages of mushroom composting had some positive influence on yields, but would require further testing to confirm these results.

Our previous research conducted in 2012, funded by Giorgi Mushrooms, has suggested that zeolites were less effective than humic material in influencing yield of spent mushroom substrate added to Phase II compost at spawning time. However no casing mushroom compost (NCMC) with humic based materials added to it was somewhat effective in maintaining yields (Giorgi report 2013). Soil fertility products with this carbon technology® have been shown to improve soil structure by flocculating hard soils and caliche barriers to soften the soil. They diminish the stress of saline soils and heavy metals, facilitating the proper mineral nutrition of plants. These materials were further studied this past year with more positive results reported here.

Humic substances are the dark colored substances that remain after the natural biodegradation of biomatter, and whose distinct characteristics are their relative resistance to further biodegradation and highly heterogeneous molecular structure. Humic Acids is a broad term used in commerce and science to identify a class of isolated compounds that can be extracted from natural humic substances in a number of ways, typically with alkali solutions, and then precipitated from the alkaline aqueous solutions by acidification. Fulvic Acids is a broad term used in commerce and science to identify a class of isolated compounds extracted from natural humic substances that are soluble in both alkali and acidic aqueous solutions. Humic products are composed either in part or primarily of humic substances, humic acids and/or fulvic acids. Not all humic substances are the same so further testing using different materials are necessary.

The reuse of casing as casing for a second crop is being studied for this project. The problem with using this material appears related to a higher electrical conductivity that deceases yield, (Giorgi report 2013). Since the technology has been developed to separate the casing and the compost after post crop steaming we conducted further research to see if adding lesser amounts added to sphagnum peat would be feasible.

2013 Objectives:

1. Determine if chelating materials, such as humic materials delivered with a carbon based material can be added to casing separated mushroom compost to grow a second crop of mushrooms.
2. Characterize the physical and chemical changes in mushroom compost when these materials are added.
3. Determine if separated casing can be re-used as casing material.

Cropping Experiment #1

Materials and Methods

Mushroom Test Demonstration Facility (MTDF) composted substrate was prepared using standard methods, with Phase I taking place in an environmentally controlled aerated bunker. The standard composting formula for the MTDF consists of straw bedded horse manure, and switchgrass straw supplemented with poultry manure, gypsum and dried distiller's grain. The Phase I aerated composting period lasted 7 days, with the compost piles turned on day 3 and filled on day 7 into the trays for the Phase II at the Mushroom Research Ceneter (MRC) for a computer controlled temperature management. Temperatures were maintained according to standards for the MRC for 7 days when conditioning was completed and the substrate was ready to be spawned.

No Casing Mushroom Compost (NCMC) was obtained from Giorgi Mushroom Farms and was mixed with Bonaparte Peat (BP) and the NCMC treated with four different humic based materials (FH, ZP, BD and HB) then added to substrate at spawning time. The BP was pasteurized at 60 C for 1 hr before adding it to the substrate and the NCMC for 3 hrs longer while waiting for the BP to reach temperature. The BP and NCMC was then mixed together and added as 30% of the total wet weight in the tub. The substrate was spawned with a commercial off-white hybrid of *Agaricus bisporus* at a rate of 2% and supplemented with a commercial supplement at a rate of 4%. Fifty pounds of wet weight substrate was layered into a 2.75-square foot plastic growing tubs for each replicate and the substrate in each tub was pressed tightly. The tubs were placed on metal racks and moved to an environmentally controlled production room at the MRC with monitoring for temperature, relative humidity, and CO_2 for the duration of the 16 day Phase III.

Standard MRC casing material of sphagnum peat moss and agricultural limestone (50 lbs lime per 6 cub ft. bale of peat moss) and a commercial casing inoculum added (CI) and then applied onto crop. The room was flushed with fresh air and temperatures lowered 5 days after casing to initiate primordial development. First break harvest began 10 days after the fresh air flush, 16 days after casing. Mushrooms were harvested for 3 growing cycles, or breaks. Yield data was statistically analyzed for a completely randomized design and was analyzed using the Waller Duncan k-ratio t-test at a significance level of 0.05 to separate the means.

Results and Discussion

The substrates with the NCMC added (trs 2-7) had lower moisture content and higher ammonium (NH_4) than the untreated control substrates (trt 1)at spawning, Table 1. Other chemical and physical characteristics show little difference. The total and organic nitrogen content was higher in a few treatments (trts 3, 4, 6 and 7), but this difference was not correlated with difference in fresh mushroom yield.

Colonization before casing was excellent for trt 1, good to excellent for trts 3, 5, 6, 7 and good for trt 2 &4. The mycelia growth was vigorous for trt 1 and moderate to vigorous for all others.

Table 1 Substrate physical and chemical characteristics after spawning for no casing mushroom compost (NCMC), Bonaparte Peat (BP), and four types of humic materials (FH, ZP, BD and HB) when added to the NCMC and mixed into Phase II compost at spawning.

		Treatments						
		1	2	3	4	5	6	7
		Control	NCMC	NCMC & 5 lbs BP	NCMC & FH	NCMC & ZP	NCMC & BD	NCMC & HB
As is Basis:	pH	7.5	7.3	7.2	7.3	7.3	7.2	7.4
	Soluble Salts (1:5 w:w), mmhos/cm	11.42	12.37	12.67	13.51	13.81	13.35	12.47
	% Solids	30.6	33.8	32.9	33.2	35.8	34.3	32.1
	% Moisture	69.4	66.2	67.1	66.8	64.2	65.7	67.9
Dry Wt. Basis:	% Organic Matter	74.7	65.9	70.5	69.2	68.3	70.5	70.5
	% Total Nitrogen (N)	2.36	2.43	3.41	3.07	2.49	3.02	2.78
	% Orangic Nitrogen	2.34	2.39	3.38	3.02	2.43	2.97	2.74
	Ammonium N (NH_4-N), mg/kg	157.1	349.4	347.9	491	568.8	498.6	395.7
	Carbon (C)	37.2	34	41.2	38.2	33.7	38.9	34.2
	Carbon:Nitrogen (C:N) Ratio	15.70	14.00	12.1	12.40	13.50	12.90	12.30

The fresh mushroom yield on first break for the untreated control was significantly higher than the treatments with NCM added, Table 2. The second break yield had no significant difference between the control and treated compost. The BP treated substrate for third break was significantly lower that the NCMC treated substrate, but these two treatments were not significantly different than the control and other treatments. The results for total yield suggested that the control compost was significantly higher than the NCMC, NCMC+BP and NCMC+FH treated substrate, but not significantly different that the NCMC treated with the other humic materials.

These results may suggest that adding humic materials to the NCMC may have some influence on the availability of nutrients but it is not consistent. It is possible that NCMC had a negative influence on the substrate moisture at spawning Further testing was conducted in the second experiment reported here.

Table 2 Yield by treatments for no casing mushroom compost (NCMC), Bonaparte Peat (BP), and four types of humic materials (FH, ZP, BD and HB) when added to the NCMC and mixed into Phase II compost at spawning.

	lbs/ft^2							
Treatment	Break 1		Break 2		Break 3		Total	
1. Control	2.00	a	1.99	a	0.59	ab	4.58	a
2. 15 lb NCMC	1.19	b	1.64	a	0.72	a	3.54	b
3. 15 lb NCMC & 5 lbs BP	1.50	b	1.86	a	0.42	b	3.78	b
4. 15 lb NCMC & FH	1.14	b	2.03	a	0.51	ab	3.68	b
5. 15 lb NCMC & ZP	1.40	b	2.13	a	0.46	ab	3.99	ab
6. 15 lb NCMC & BD	1.26	b	2.14	a	0.51	ab	3.90	ab
7. 15 lb NCMC & HB	1.31	b	2.16	a	0.44	ab	3.91	ab

Cropping Experiment #2

Materials and Methods

No Casing Mushroom Compost (NCMC) was obtained from Giorgi Mushroom Farms and was mixed with Bonaparte Peat and or Sphagnum Peat (SP), BP and SP and NCMC treated with four different humic based materials (FH, ZP, BD and HB) then added to substrate at spawning time. The NCMC, BP and SP were pasteurized at 60 C for 1 hr before adding it to the substrate and the NCMC was added as 30% of the total wet weight in the tub. The substrate was spawned with a commercial off-white hybrid of *Agaricus bisporus* at a rate of 2% and supplemented with a commercial supplement at a rate of 4%. Fifty pounds of wet weight substrate was layered into a 2.75-square foot plastic growing tubs for each replicate and the substrate in each tub was pressed tightly. The tubs were placed on metal racks and moved to an environmentally controlled production room at the MRC with monitoring for temperature, relative humidity, and CO_2 for the duration of the 16 day Phase III.

At spawning, the PII compost was observed to be of medium length, chocolate brown in color, with no detectable odor of ammonia. Some of the treatments had lower pH and moisture content than the untreated control, Table 3. The NCMC with BP had higher organic and total nitrogen than the control and other treatments. The treatments with NCMC had higher ammonium (NH_4) when compared to the control substrate. Results of the other chemical and physical characteristics were similar for all treatments and control substrates.

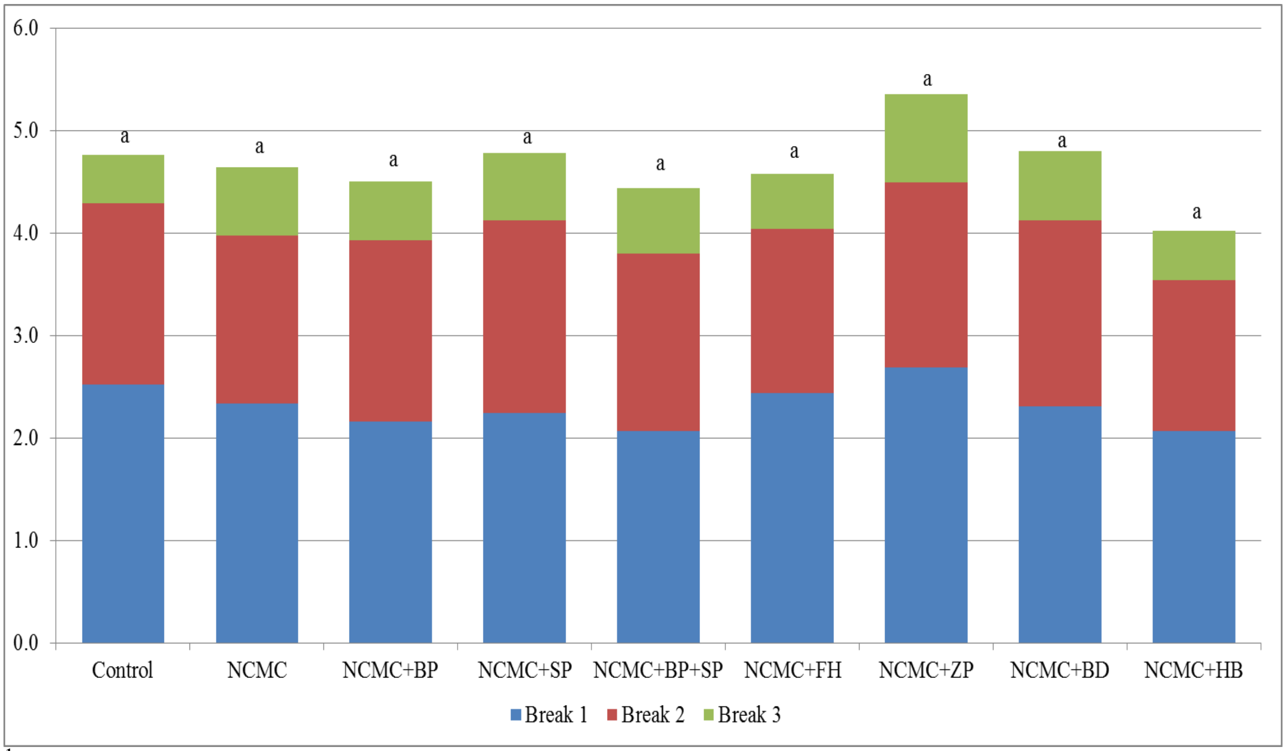
Table 3 Substrate physical and chemical characteristics after spawning for no casing mushroom compost (NCMC), Bonaparte Peat (BP), Sphagnum Peat)SP and four types of humic materials (FH, ZP, BD and HB) when added to the NCMC and mixed into Phase II compost at spawning.

		Treatments								
		1	2	3	4	5	6	7	8	9
		Control	NCMC	NCMC+BP	NCMC+SP	NCMC+BP+SP	NCMC+FH	NCMC+ZP	NCMC+BD	NCMC+HB
As is Basis:	pH	7.4	6.8	6.6	6.1	6.6	7	7.2	7.2	6.4
	Soluble Salts (1:5 w:w), mmhos/cm	10.72	12.69	13.55	13.32	12.77	12.56	12.21	13.16	14.74
	% Solids	32.3	36.9	37.2	40.2	36.4	40.3	33.4	32.9	40.3
	% Moisture	67.7	63.1	62.8	59.8	63.6	59.7	66.6	67.1	59.7
Dry Wt. Basis:	% Organic Matter	77.3	73.6	70.8	76.1	74.0	76.0	73.9	75.6	72.0
	% Total Nitrogen (N)	2.61	2.79	3.36	2.92	2.75	2.60	2.53	2.92	2.86
	% Orangic Nitrogen	2.61	2.77	3.32	2.88	2.73	2.58	2.51	2.89	2.81
	Ammonium N (NH_4-N), mg/kg	22.0	214.5	348.2	378.3	264.3	272	198.6	306.2	468.8
	Carbon (C)	38.2	36.7	40.2	42.8	39.4	35.5	37.3	41.3	36.5
	Carbon:Nitrogen (C:N) Ratio	14.70	13.20	12	14.70	14.30	13.60	14.70	14.20	12.80

At casing, spawn growth was subjectively assessed. Colonization was determined to be excellent for the control treatment (1), slightly less than excellent for treatment 2, good for treatment 3, 6, 7, 8 & 9 and slightly less than good from treatments 4 & 5. Mycelium growth was vigorous for the control (1), moderate for treatment 2 while all other treatments were slightly less than moderate growth. Rhizomorphs were moderate for treatment (1) with moderate to few rhizomorphs for treatment (2) while all others had few rhizomorphs. No sectoring was observed for all treatments. Compost condition was normal for all treatments with some nuisance molds on treatments (3, 4, 5, 6, 7, 8 & 9). Spawn condition was normal.

The first break and total yield for the control substrate was not significantly different compared to all other treatments, Figure 1. The untreated substrate treatment was not significantly different in first break, second, third and total yields, when compared to the substrates with just NCMC and NCMC with the humic materials. The addition of the humic materials to NCMC appeared to increase utilization of the spent substrate. Note the trend for the highest yield of the NCMC+ZP humic material and the trend of the hemicellulose in Figure 2.

Figure 1 Yield by treatments for no casing mushroom compost (NCMC), Bonaparte Peat (BP), Sphagnum Peat (SP) and four types of humic materials (FH, ZP, BD and HB) when added to the substrate at spawning time.



[1]Data in the same column with the same letter(s) are not significantly different.

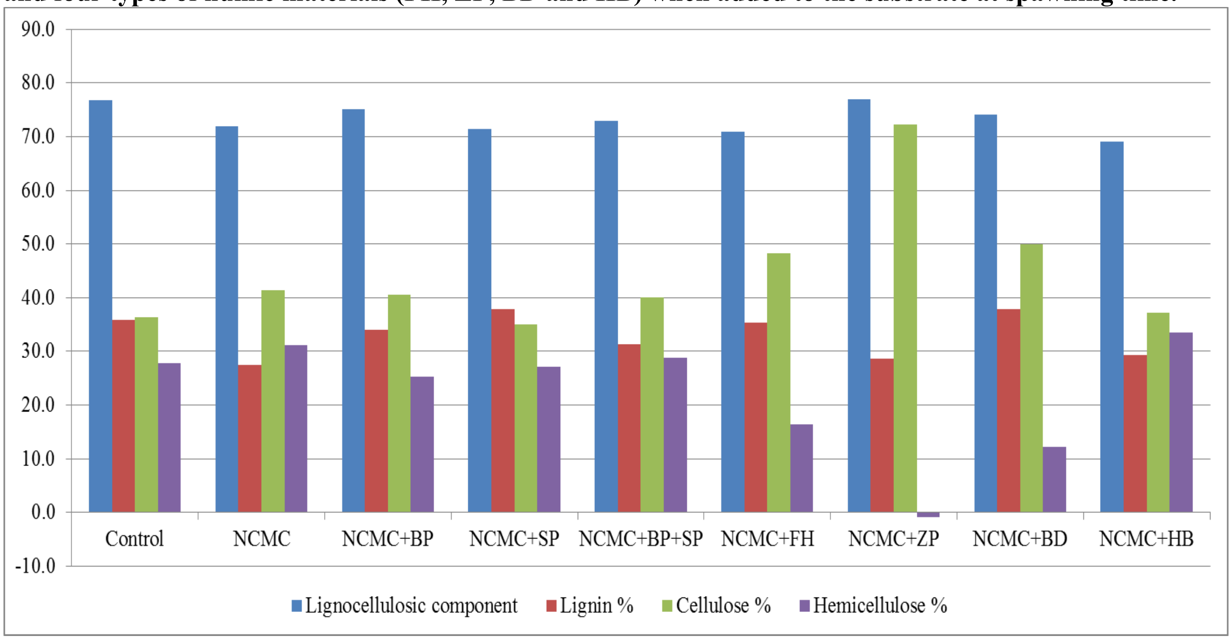
Objective 2 - Characterize the physical and chemical changes in mushroom compost when these materials are added.

In addition to the physical and chemical characteristic reported in Table 3, we analyzed the substrates from the second experiment for lignocellulosic component, %lignin, % cellulose and % hemicellulose at spawning, mid-cropping and the end of the crop prior to post crop steaming. End of the crop results are reported in Figure 2 the other samples are presently being analyzed as we held the samples at 0^{o}C, until the yield results were completed.

The results suggest little difference in the total lignocellulosic component and %lignin of the untreated control substrate compared to the substrate with NCMC added and or treated with different humic materials. The NCMC+ZP humic material had higher cellulose and lower hemicellulose that the untreated control substrate and all the other NCMC treated substrates with either BP, SP or the other humic materials. This result is of some interest since this substrate had the highest yield of all the substrates in this test. Until we have the analysis for these substrates at spawning and mid-crop can we confirm if this is significant or not. It is known that hemicellulose is one of the materials that declines over the cropping period, Chen et al, 2000).

These results are preliminary and further testing is planned for the next year of the project, if funded.

Figure 2 Total lignocellulosic component, % lignin, % cellulose and % hemicellulose in the substrates at the end of the crop when No Casing Mushroom Compost (NCMC), Bonaparte Peat (BP), Sphagnum Peat (SP) and four types of humic materials (FH, ZP, BD and HB) when added to the substrate at spawning time.



Objective 3 - Determine if separated casing can be re-used as casing material.

An experiment was conducted investigating the feasibility of reusing the casing layer from a previous *Agaricus bisporus* mushroom crop for the production of a subsequent mushroom crop. The recycled casing layer originally consisted of 100% sphagnum peat moss with the addition of agricultural limestone to adjust the pH following standard Penn State procedures. The casing layer was removed from a standard crop of *A. bisporus* at the Penn State University Mushroom Research Center (MRC) after completion of standard cropping practices and a post-crop steaming. The removed casing layer was uniformly broken up into a free-flowing material by hand, to improve upon the mix ability of the casing material. The recycled casing material was then mixed at different ratios (10, 20 and 30% by volume) with fresh sphagnum peat moss and applied to a new crop to assess the yield potential of the different mixes (Table 4).

Results from the cropping experiment demonstrated no significant difference in yield when compared to the control. Interestingly, a 7% yield loss was not significantly different from the control casing. Additional experiments will be run to further investigate this relationship to confirm the results from previous experiments. Additionally, future cropping experiments will included the use of recycled casing materials with the conductivity levels reduced to determine if reduction in the soluble salts will allow for more efficient use of recycled casing in future crops.

We attempted to leach recycled casing to remove the soluble salts, but the material became a muddy mess and would not leach unless it was worked by hand to get the leachate out. We felt it was not practical to remove the salts by leaching. It is possible materials like ionic resin may work, but that needs to be tested.

Table 4 Yield by treatments for recycled casing.

	lbs/ft^2							
Treatment	Break 1		Break 2		Break 3		Total	
Control	1.66	a	2.11	a	0.65	a	4.42	a
10% recycled casing	1.41	a	2.01	a	0.71	a	4.13	a
20% recycled casing	1.46	a	1.85	a	0.76	a	4.07	a
30% recycled casing	1.39	a	1.88	a	0.82	a	4.10	a

[1]Data in the same column with the same letter(s) are not significantly different.

Year 2 Objective – Determine if supplementing different layers of the substrate influences mushroom yield.

Recently it has been discussed that the yield of each break may be related to the nutritional value of the different depths of the substrate in a container. We conducted a second experiment to see if using different supplement rates in three layers of our research tubs would influence break yield or total yield, Table 5. These results suggest that the 1% supplement rate in the different layers had no significant difference in yield than the 2.0% supplement rate in all layers. These results did not support the findings we found last year (2013 report), however the amount of supplement used was lower than in each of the two layers last year's trial, so further testing at higher rates is needed. Although no significant difference was noted in this second trial, the trend of the yield was similar to the results of the first test. Supplementing the bottom layer had lower yields and bio-efficiency on first break when compared to supplementing the top layer. Further testing will be conducted the next year of this project using higher supplement rates in two and three layers of the containers.

Table 5 Fresh mushroom yields of substrate supplemented at different layers in the tub.

Treatment	lbs/ft² Break 1		Break 2		Break 3		Total		Kg/m²	% Bio-Efficiency
3.5% Supplement - Control	1.84	a	2.38	a	0.65	a	4.86	a	23.73	91.26
3% Supplement in three layers	1.44	a	2.18	a	0.88	a	4.50	a	21.96	84.48
4% Supplement in three layers	1.41	a	2.31	a	0.71	a	4.44	a	21.67	83.34
3% Supplement in top 1/3 layer	1.56	a	1.78	a	0.70	a	4.05	a	19.74	75.93
3% Supplement in middle 1/3 layer	1.66	a	2.06	a	0.74	a	4.46	a	21.78	83.78
3% Supplement in bottom 1/3 layer	1.39	a	2.06	a	0.82	a	4.26	a	20.80	80.02
4% Supplement in top 1/3 layer	1.71	a	2.15	a	0.82	a	4.67	a	22.81	87.73
4% Supplement in middle 1/3 layer	1.59	a	2.10	a	0.73	a	4.41	a	21.54	82.87
4% Supplement in bottom 1/3 layer	1.57	a	2.27	a	0.57	a	4.41	a	21.52	82.77

[1]Data in the same column with the same letter(s) are not significantly different.

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