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HDC PROJECT M 3c

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Reduction of Pollution from Mushroom Composting Experiment II

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CONTENTS

Summary

An aerated, partially enclosed, 2-tunnel composting system was used as a method of reducing the odour and water pollution associated with conventional methods of compost production. The process consisted of a six-day, low aeration, 'high' temperature phase (compost temperature exceeding 75°C) followed by a conventional Phase II pasteurization. The effects of chopping the straw ingredient of the compost on the yield and quality of mushrooms and compost density were examined. The treatments were: (i) unchopped straw (ii) long chop length, mean 60 mm (iii) short chop length, mean 47 mm. The effects of adding recycled, processed compost (15% of the dry matter) to the compost ingredients on subsequent mushroom yield and compost density were also investigated.

There were no significant odour emissions from the composts, providing that O_2 concentrations in the compost (at a depth of 200-300 mm) remained above 5%. Straw chopping significantly increased mushroom yields from the composts, but there was no difference in yield between a short and a long straw chop length. The unchopped straw treatment had a higher moisture content than the chopped treatments, and this may have been responsible, at least partly, for the lower yield. The addition of recycled compost increased yield from the unchopped straw treatment but slightly reduced yield from the chopped straw treatments. Water absorption was improved and water applications were reduced by the addition of recycled compost. Compost bulk density was also slightly increased by this treatment.

Mushroom yields from the experimental composts (in kg/tonne) were similar to those obtained from commercial Phase II composts. However, bulk density of the experimental composts was lower, unless recycled compost was added to the ingredients.

Supplementation of the composts with Betamyl 1000 increased mushroom yield by 8.3%. The optimum moisture and nitrogen contents of the composts were 71% and 3.3% of dry matter respectively.

Recommendations for future work

1. Composts prepared with unchopped and long chop straw should be compared at the same moisture and nitrogen contents.

2. Although a nitrogen content of 3.3% dry matter at spawning appears to be optimum for yield, the effects of lower N contents, in conjunction with supplementation, should be examined, in order to reduce the poultry manure requirement.

3. The use of recycled compost at a lower inclusion rate should be examined.

4. Mushroom quality (firmness and size before opening) from the experimental composts appeared to be good, but more detailed comparisons with the quality obtained from commercial Phase II compost are needed.

5. Supplementation of the compost with other materials (eg. Promycel, Springboard, Champlus) should be examined.

6. The use of the compost for Phase III (spawn-run substrate) should be examined.

Introduction

In a previous HDC funded experiment (M3c), two methods of reducing pollution from mushroom composting were compared:

- A single tunnel system, preceded by a period of outdoor stacking.

- A two tunnel system whereby compost is first filled into a basic, low aeration tunnel, followed by a conventional tunnel pasteurization.

The 2-tunnel process resulted in a compost with a higher bulk density and mushroom yield potential than the single tunnel process. Control of compost temperatures in the single tunnel system was more difficult due to the greater activity of the compost. Adding recycled compost in the initial ingredients improved the water absorption and resulted in a small improvement in compost density.

The straw used for the single and 2-tunnel systems was 'short' chopped using a round bale chopper. Previous experiments with the single tunnel system (HDC Report M3) showed that short chopping of the straw improved compost density and mushroom yield. However, straw chopping is a costly and time consuming procedure. The need for straw chopping in the 2-tunnel process was investigated in the present experiment.

Scientific/Technical Target of the Work

1. To compare the yield and quality of mushrooms and the substrate density of compost using the two-tunnel system with different straw chopping treatments:

    a. Unchopped straw
    b. 'Long' chop length
    c. 'Short' chop length

2. To determine the effect of adding recycled compost on mushroom yield and compost density, in combination with the different straw chopping treatments.

Materials and Methods

Composting tunnels

Six bulk composting tunnels, four of which consisted of insulated polythene tunnels (internal dimensions 3 x 2.05 x 2.5 (high) m) and two consisting of modified insulated cargo containers were used for the experiment. A slatted steel bar floor with 75% air space was mounted 0.5m above the base of the tunnel, providing an air plenum through which air could be blown upwards through the compost. The tunnels were filled with an oscillating head conveyor and emptied with a Bobcat front end loader.

First tunnel process

Compost (4t) was filled into a tunnel to a depth of 1.7 m and the end doors were left open. The airflow was set at $9m^3/h$, unless the oxygen concentration in the compost fell below 5%, in which case the airflow was increased to 13 m^3/h. After six days, the compost was emptied from the tunnel, mixed and re-wetted and then re-filled to a height of 1.5 m.

Second tunnel process (Phase II pasteurization)

A temperature regime based on a conventional bulk Phase II was used:

a. air input temperature set at 43°C, with compost temperatures being allowed to rise to 45-50°C during a 16-20h period (temperature equalisation).

b. Air temperature set at 57°C, with compost temperature maintained at 58-61°C for 6 h (pasteurisation).

c. Air temperature reduced to 43-45°C, with compost temperature maintained at 47-49°C allowing ammonia to clear (conditioning).

The end doors were closed during the second (Phase II) stage.

Temperature control of the air damper was overridden if the oxygen concentration in the recirculated air fell below 14% v/v, in which case the air damper was opened, reaching a maximum proportion of fresh air if the oxygen concentration fell to 12% v/v. Steam was injected into the air supply when the temperature fell more than 1°C below the air input temperature set point. Platinum resistance temperature sensors were mounted in the air space above and below the compost, and in four positions in the compost, in a 1.5 m square arrangement. Oxygen was monitored in the air above the compost using an 'Oxystor' sensor (AEM bv, Maasbree, Netherlands). Oxygen levels in the compost were monitored with a Draeger gas detector and type 6728081 sampler tube. Ammonia levels in the air above the compost were monitored with CH20501 sample tubes. Air pressure in the plenum was monitored with tube manometers (Type M-D Dwyer Instruments Inc).

Preparation of materials

The ingredients of the substrates were new season wheat straw (stored dry for 6-7 months), poultry manure and gypsum. An analysis of the organic ingredients is shown in the Appendix. Bales of straw were chopped according to the treatments in a round bale chopper (model 6-10, Kidd Farm Machinery Ltd, Devizes, Wilts), wetted and formed into stacks using a compost turning machine. Water was added in four applications to the stacks which were turned five times in a four-day period on the compost yard. The quantities of materials are shown in Table 1.

Straw chopping treatments

a. Unchopped straw
(Median and mean straw lengths 85 and 165 mm)

b. 'Long' chop length, produced with standard chopping blades on the bale chopper (median and mean straw lengths 40 and 60 mm).

c. 'Short' chop length, produced by attaching a short chop kit (Kidd Farm Machinery Ltd) to the bale chopper (median and mean straw lengths 30 and 47 mm).

Recycled compost treatment

a. Control (no further additions).

b. Recycled processed compost (15% on a dry matter basis) added to straw and poultry manure.

Water and poultry manure additions to the stacks were adjusted to achieve a compost mixture at the time of filling of the bulk tunnels with target moisture and nitrogen contents of 77-79% and 2.2 - 2.5% of dry matter respectively. The maximum stack temperature before filling are shown in Table 1.

Three replicate runs of the experiment were conducted, with the six treatments (3 straw chop lengths x 2 recycled compost treatments) allocated to different tunnels for each replicate run.

Cropping procedure

Following pasteurization and conditioning, the compost was cooled to 26°C and equal quantities were inoculated with mushroom spawn ('spawned') using the Hauser A12 and Le Lion X25 strains at a rate of 0.5% of compost fresh weight. Half of the compost spawned with each strain was supplemented with the soya meal-based 'Betamyl 1000' containing formaldehyde denatured protein, at a rate of 1% of compost fresh weight. Spawned compost (50 kg) was filled into wooden trays (internal dimensions 0.91 x 0.61 x 0.18(deep) m) and hydraulically pressed with a pressure of 1.03×10^7 Pa. Trays with spawned compost were then stacked in a spawn running room where the compost temperature was maintained at 26°C

± 1°C. About 14 days after spawning, the trays were covered (cased) with a moist mixture of sphagnum peat and sugar beet lime (4:1 v/v) to a depth of 45 mm. Casing spawn of the appropriate strain (Hauser A12 or Le Lion X25) was mixed into the casing at a rate of 4 kg/m^3 casing. Cased trays were stacked four high in cropping sheds, with six replicate trays of each spawn strain and supplement subtreatment from each compost treatment arranged in a randomized block design. For each replicate run of the experiment there were 144 trays per shed, with 24 trays from each of the six compost treatments. The compost temperature was maintained at 26°C for a further 6-7 days; fresh air was then introduced into the shed to obtain a CO_2 concentration of 0.1% v/v; air temperature and relative humidity were maintained at 17.5°C and 88% respectively. Mushrooms were picked as large buttons (diameter 30-40 mm) over a 30 day period (four flushes), with the first flush of mushrooms being picked *c.* 17 days after casing.

Compost analysis

Composts were analysed for pH and dry matter, total nitrogen, ammonium (NH^+_4) and ash contents at the time of filling the bulk tunnels and at the end of the composting period.

A measurement of compressed bulk density was made by determining the weight of compost which filled the 0.91 x 0.61 x 0.18 m cropping trays after a pressure of 1.03 x 10^7 Pa had been applied for 5s. A subjective assessment of gaseous pollution resulting from compost odour was made when the stacks were filled into the tunnels, and at the time of emptying and refilling of the two tunnel system.

Results and Discussion

Composting process

In the first and third replicate runs of the experiment, none of the treatments resulted in strong odours associated with conventionally prepared Phase I composts. In the second replicate run of the experiment, O_2 levels of 2-3% were detected in parts of the long and short chopped straw composts during the Phase I tunnel stage, at a depth of 200-300 mm. On emptying the tunnels some anaerobic zones were found in the compost, resulting in foul odours.

Maximum compost temperatures of 78-81°C were achieved after 1.5-2.5 days of the Phase I tunnel stage. Compost temperatures then gradually declined to 60-70°C by the end of the 6 day period. Compost ammonia levels in the Phase I tunnel stage were 400-800 ppm. During the Phase II stage, ammonia levels peaked at 300-500 ppm, and declined to zero after 4-6 days in all the composts, irrespective of the treatments.

Compost analysis

Compost N content increased from 2.3-2.6% of dry matter at filling to 3.0-3.4% of dry matter at spawning (Tables 2 and 3). The moisture content of composts with recycled compost was slightly lower at the time of filling but higher at spawning than that of the other composts (Tables 2 and 3). The pH of the composts at spawning was high (7.9), although NH_4^+ levels were generally around 0.05% of dry matter. The compost bulk densities of different straw chopping treatments were not significantly different (Table 3). The addition of recycled compost resulted in a small increase in bulk density.

Long or short straw chopping significantly reduced the amount of water which needed to be added to the ingredients to achieve a moisture content of 77-80% at filling (Table 1). The addition of recycled compost to the ingredients also reduced the water requirement.

Mushroom yield

Mushroom yields in four flushes from the different treatments are shown in Table 4. In the first replicate crop, the short chop and recycled compost treatment produced a much lower yield than in the second and third replicate crops, and trays from the first replicate of this treatment supplemented with Betamyl produced very few mushrooms. The analysis of this compost at spawning was similar to the other composts, and the temperatures during the process were also normal.

Compost prepared with unchopped straw produced a lower yield than compost prepared with chopped straw, although the difference was reduced by the addition of recycled compost. There was no difference in yield between composts prepared with long or short chopped straw, but the addition of recycled compost reduced yields (in kg/tonne compost) slightly. Supplementation of the compost with Betamyl 1000 resulted in an 8.3% yield increase. There was no significant difference in yield between the strains A12 and X25.

Yields after 3 flushes from the different treatments are compared with commercial Phase II and HRI 'Formula 3' composts in Table 5. The Formula 3 compost is a 20-day Phase I, 7-day bulk pasteurised Phase II compost. The highest average yield was obtained from the Formula 3 compost. The highest yield from the experimental composts was from the long chop length treatment, which was not significantly different to the commercial Phase II compost yield.

The Formula 3 compost had the highest bulk density (Table 5). The experimental composts with recycled material had a bulk density slightly below that of commercial Phase II. The average analysis of commercial Phase II and Formula 3 composts are shown in the Appendix, Table A2. The commercial Phase II composts had, on average, a lower pH and lower N and moisture contents than the experimental or Formula 3 composts.

Relationship between compost analysis and mushroom yield

Figs. 1 and 2 show the mushroom yields from M3c Expts I and II (2-tunnel treatment) plotted against compost nitrogen and moisture contents. Fig. 1 indicates that the optimum N content at spawning is around 3.3% of dry matter, although there appears to be little effect on yield between 3.1 and 3.5%N. The optimum compost moisture content is around 71%, although there is no clear effect of moisture content on yield between 69% and 74%. There were no significant relationships between compost pH, ammonium or ash contents or bulk density and mushroom yield.

Conclusions

1. There were no significant odour emissions from any of the treatments providing that O_2 concentrations in the compost (at a depth of 200-300 mm) remained above 5%.

2. Straw chopping significantly increased mushroom yield from the composts, but there was no difference in yield between a short and a long straw chop length.

3. Straw chopping did not affect compost bulk density but water absorption of the ingredients was improved.

4. The addition of recycled compost in the initial ingredients (at 15% on a dry matter basis) increased yield from the unchopped straw treatment but slightly reduced yield from the chopped straw treatments.

5. The addition of recycled compost reduced the water applications by improving the water absorption of the blended materials. The final bulk density of the compost was also slightly improved.

6. Mushroom yields from the experimental composts (in kg/tonne) were similar to those obtained from commercial Phase II composts. The bulk density of the experimental composts was lower, unless recycled compost was added to the ingredients, in which case there was only a small discrepancy.

7. Total processing time for the two tunnel stages was 13 days.

8. Supplementation of the composts with Betamyl 1000 increased mushroom yields by 8.3%.

9. The optimum moisture and nitrogen contents of the composts were 71% and 3.3% of dry matter respectively.

Table 1 **Materials used in preparing composts (kg/tonne fresh compost, excluding water added) and maximum stack temperatures**

Replicate	Chopping treatment	Straw	Poultry manure	Recycled compost	Water litres/t	Max stack temp °C
1.	Unchop	485	485	0	2924	76
	Unchop & Recyc.	333	297	350	2101	79
	Long	511	459	0	2845	68
	Long & Recyc.	333	297	350	1828	75
	Short	511	459	0	2908	56
	Short & Recyc.	333	297	350	1681	82
2.	Unchop	485	485	0	3550	28
	Unchop & Recyc.	333	297	350	2371	15
	Long	511	459	0	1896	44
	Long & Recyc.	333	297	350	1904	25
	Short	511	459	0	2824	21
	Short & Recyc.	333	297	350	1852	16
3.	Unchop	485	485	0	3516	72
	Unchop & Recyc.	334	296	350	2464	63
	Long	511	459	0	2497	43
	Long & Recyc.	334	296	350	1974	47
	Short	511	459	0	2242	78
	Short & Recyc.	334	296	350	1674	37

* Gypsum was added at 30 kg/tonne straw and poultry manure.

Table 2 Compost analysis at filling of bulk tunnels

Replicate	Treatment	Percentage of dry weight			Moisture %	pH
		N	NH_4^+	Ash		
1.	Unchop	2.26	0.42	12.0	80.2	8.1
	Unchop & Recyc.	2.14	0.44	13.5	77.4	8.0
	Long	2.23	0.55	13.9	77.6	8.0
	Long & Recyc.	2.67	0.48	14.5	74.8	8.1
	Short	2.08	0.46	13.5	77.6	7.9
	Short & Recyc.	2.71	0.56	15.3	74.3	8.1
2.	Unchop	2.73	0.70	20.8	80.6	8.1
	Unchop & Recyc.	2.51	0.62	21.1	79.3	8.3
	Long	2.47	0.72	16.7	77.5	7.7
	Long & Recyc.	2.61	0.66	19.6	76.4	8.1
	Short	2.49	0.74	14.4	78.0	8.2
	Short & Recyc.	2.43	0.65	19.3	76.9	7.9
3.	Unchop	2.39	0.52	16.6	80.0	7.7
	Unchop & Recyc.	2.24	0.49	14.5	80.8	8.1
	Long	2.34	0.71	15.4	76.8	8.3
	Long & Recyc.	2.57	0.61	15.6	77.5	8.0
	Short	2.59	0.68	15.4	76.9	7.9
	Short & Recyc.	2.73	0.69	15.8	76.6	8.3
Mean	Unchop	2.46	0.55	16.5	80.3	8.0
	Unchop & Recyc.	2.30	0.52	16.4	79.2	8.1
	Long	2.35	0.66	15.3	77.3	8.0
	Long & Recyc.	2.62	0.58	16.6	76.2	8.0
	Short	2.39	0.63	14.4	77.5	8.0
	Short & Recyc.	2.62	0.63	16.8	75.9	8.1

Table 3 Compost analysis at spawning

Replicate	Treatment	Percentage of dry weight			Moisture %	pH	Bulk density kg/m³
		N	NH_4^+	Ash			
1.	Unchop	3.07	0.04	18.8	75.6	7.9	530
	Unchop & Recyc.	3.42	0.07	20.4	73.5	7.9	560
	Long	3.15	0.07	19.8	72.5	7.9	530
	Long & Recyc.	3.03	0.05	18.1	74.9	8.0	500
	Short	3.04	0.05	20.1	69.4	7.7	560
	Short & Recyc.	3.09	0.06	21.7	73.5	8.0	530
2.	Unchop	3.19	0.07	24.8	76.0	8.0	530
	Unchop & Recyc.	3.35	0.09	25.7	75.6	7.9	530
	Long	3.38	0.06	18.0	70.3	7.9	500
	Long & Recyc.	3.16	0.02	19.2	71.4	7.7	500
	Short	3.14	0.04	20.2	69.2	7.9	480
	Short & Recyc.	3.35	0.07	23.7	69.8	7.9	560
3.	Unchop	2.97	0.04	20.4	76.0	7.8	510
	Unchop & Recyc.	3.62	0.04	24.4	75.5	7.9	530
	Long	3.12	0.04	22.0	66.4	7.9	480
	Long & Recyc.	3.66	0.05	25.9	72.7	8.0	580
	Short	3.48	0.03	22.8	69.2	7.7	480
	Short & Recyc.	3.51	0.03	24.6	69.6	7.9	480
Mean	Unchop	3.08	0.05	21.3	75.9	7.9	523
	Unchop & Recyc.	3.46	0.07	23.5	74.9	7.9	540
	Long	3.22	0.06	19.9	69.7	7.9	503
	Long & Recyc.	3.28	0.04	21.1	73.0	7.9	527
	Short	3.22	0.04	21.0	69.3	7.8	507
	Short & Recyc.	3.32	0.05	23.3	71.0	7.9	523

Table 4 Mushroom yield from 4 flushes, kg/tonne compost at spawning

Replicate	Treatment	Control A12	Control X25	+ Betamyl A12	+ Betamyl X25	Mean
1	Unchop	161	154	227	228	193
	Unchop & Recyc.	270	249	275	287	270
	Long	279	280	297	288	289
	Long & Recyc.	235	252	235	263	246
	Short	257	269	285	273	272
	Short & Recyc.	205	206	-	-	-
2.	Unchop	230	203	265	251	237
	Unchop & Recyc.	297	286	302	309	299
	Long	327	339	353	366	346
	Long & Recyc.	327	313	351	345	334
	Short	357	328	358	351	348
	Short & Recyc.	284	313	300	310	302
3.	Unchop	144	162	145	184	159
	Unchop & Recyc.	238	242	250	228	237
	Long	256	262	281	263	266
	Long & Recyc.	258	240	254	248	250
	Short	292	270	287	277	282
	Short & Recyc.	292	294	307	287	295
Mean	Unchop	178	173	212	221	196
	Unchop & Recyc.	268	259	275	275	269
	Long	287	294	310	309	300
	Long & Recyc.	273	268	280	285	277
	Short	302	289	310	300	300
	Short & Recyc.	260	271	304*	299*	284

* Excluding rep 1.

Table 5 **Mushroom yield in 3 flushes from commercial Phase II, HRI 'Formula 3' and Experimental Composts, kg/tonne compost at spawning.**

Compost	Yield, kg/t (A12 unsuppl.)	Bulk density, kg/m^3
Commercial Phase II*	254	542
HRI Formula 3*	272	569
Unchop	158	523
Unchop & Recyc.	248	540
Long	255	503
Long & Recyc.	241	527
Short	246	507
Short & Recyc.	243	523

* Mean of 12 composts

Fig. 1 Relationship between mushroom yield and compost nitrogen content, Experiments I and II

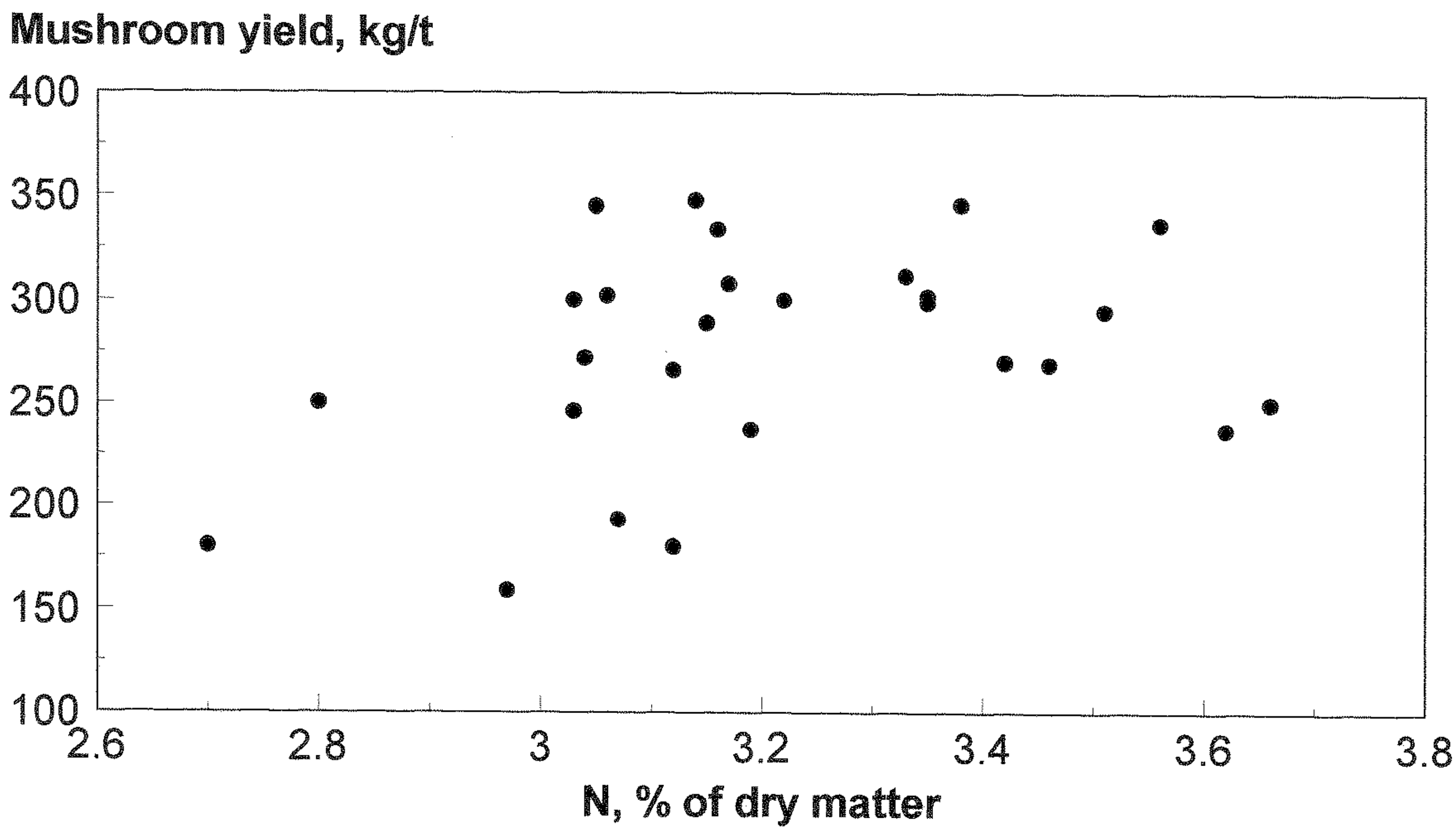
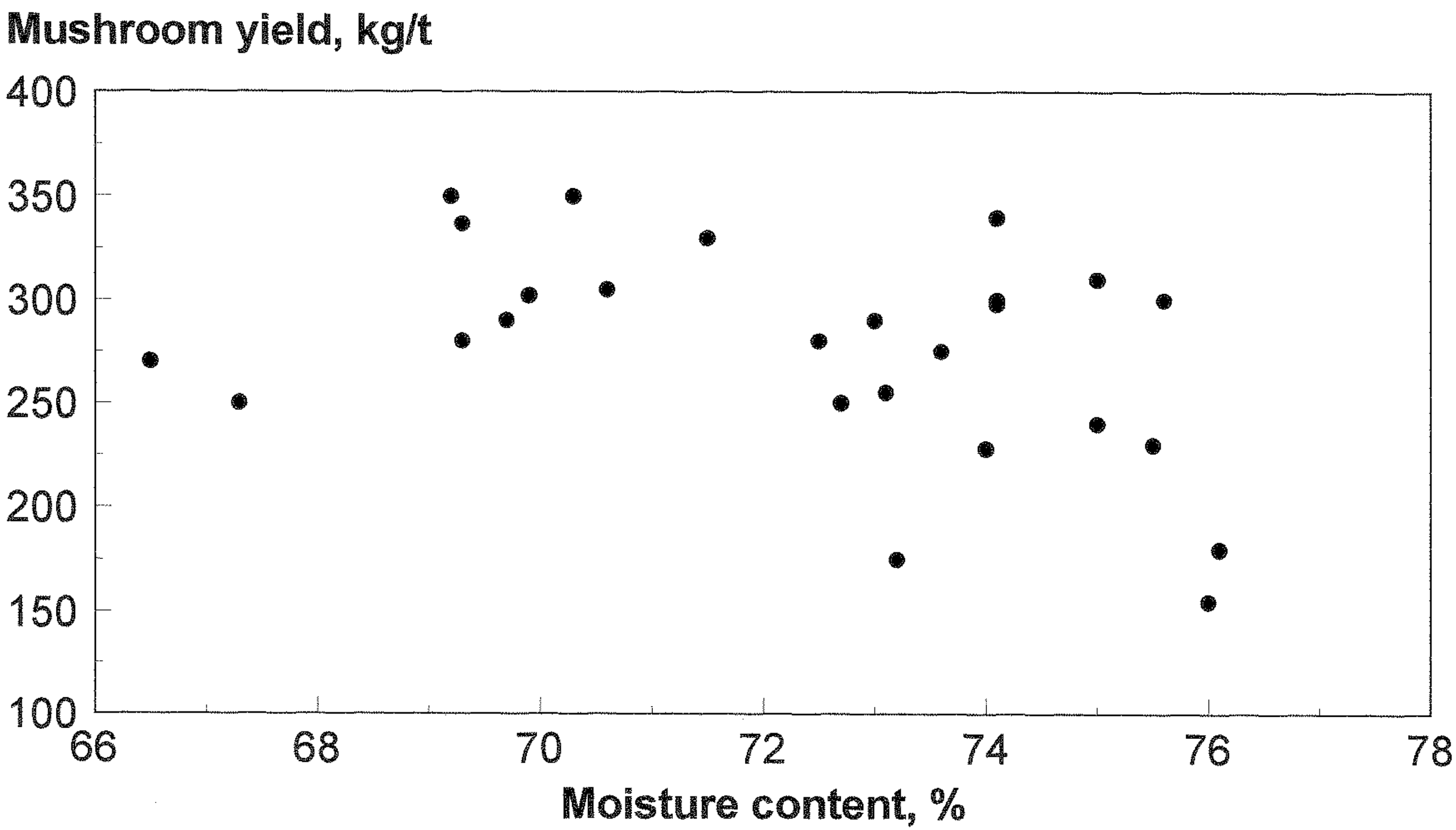


Fig. 2 Relationship between mushroom yield and compost moisture content



APPENDIX

TABLE A1 Analysis of organic ingredients used in the composts

Ingredient	% dry matter	% of dry matter	
		N	Ash
Wheat straw	82.9 - 85.8	0.52 - 0.56	4.7 - 6.5
Poultry manure	72.3 - 84.0	4.42 - 4.68	13.8 - 15.8

TABLE A2 Compost analysis at spawning, mean of 12 composts

Compost	Percentage of dry weight			Moisture %	pH
	N	NH_4^+	Ash		
Comm. Phase II	2.70	0.05	20.3	67.1	7.38
HRI Formula 3	3.06	0.05	22.4	72.4	7.66