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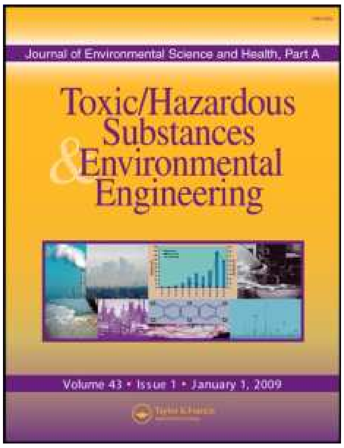

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THE ROLE OF FEED COMPOSITION ON THE COMPOSTING PROCESS. I. EFFECT ON COMPOSTING ACTIVITY*

Key Words: Composting, organic material, feed composition, temperature profiles, respiratory rates, chemical and physical properties

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ABSTRACT

In this study the influence of four feed augmentations on a commercial composting mixture have been investigated in a systematic manner using controlled laboratory experiments. The four feed augmentations studied were: grass clippings, leaves, cabbage and soya bean meal. Based upon the analysis of temperature/time data for the various composting systems, measurement of respiration rates, and physical and chemical characterization of the various materials, some scientific conclusions can be drawn. The addition of grass up to levels of about 30% can be tolerated. However, due to high moisture levels

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associated with grass, additional bulking agents may be required to accommodate higher grass loadings. The presence of high loadings of leaves in autumn may cause some retardation of the composting activity necessitating longer composting times. High moisture vegetables, such as cabbage, can pose processing problems when present in high loadings. Although these vegetables are easily compostable, the release of high water levels needs to be addressed if anaerobic activity is to be avoided. High levels of proteinous materials need to be balanced with cellulosic matter in order to minimize anaerobic activity. This arises because of their nutritional effect which results in high composting activities and a severe depletion of oxygen.

INTRODUCTION

The process of producing quality compost from the organic fraction of municipal solid waste presents a challenge to operators of commercial composting operations. Although there are numerous factors that can influence the composting process, there are two predominant elements: the characteristics of the feed material and the method of processing. The commercial processing technologies can be classified according to the method of aeration e.g. turned windrows, forced aeration, in vessel systems, etc. With each system the processing is controlled by physical factors such as temperature, moisture content and degree of mixing and aeration. Much has been written on these key environmental factors and the role that they play in the composting process (Finstein et al., 1986; Haug, 1993; Naylor, 1996), such that today's operator, measures and controls these processing parameters to ensure a successful composting facility is maintained. However, feed composition is just as important as the processing parameters in obtaining a quality product. Typical characteristics of the feed material that impact the composting process are particle size distribution (Jeris and Regan 1975, Parr et al., 1982) and carbon to nitrogen ratio (Parr et al., 1982, Campbell and Tripepi, 1991). If the particle size is too small, free air space in the system greatly decreases and may reach a critical level at which anaerobic conditions may arise and result in the production of compounds responsible for offensive odours. On the other hand, too large a particle size can lead to diffusion control kinetics which may inhibit the composting process. Consequently, it is usual to control the compost feed material with amendments to ensure that there is a balance between diffusion transport and oxygen supply (Haug, 1993).

While carbon is the basic building block of organic materials, a number of other elements are required as nutrients to support the microbiological processes. Nitrogen, as a constituent of proteins is an important nutrient for living organisms and as such receives attention from operators of composting facilities. A C/N ratio of 15 to 30 is seen to be the most desirable (Haug 1993). Because the nitrogen content of compostable materials can vary, (Golueke 1977, Kayragian and Ichobanogious, 1992) from nitrogen rich feeds such as grass clippings to low nitrogen containing materials such as cellulose, blending of the feeds is critical to achieving the required nutritional value.

The purpose of this study was to determine the effect of specific feed components on the compostability of a typical commercial organic feed material.

In an effort to more clearly demonstrate the effects the experiments were conducted in laboratory controlled reactors in which other external variables could be minimized or eliminated. The four compost feed augmenting materials examined were: grass clippings, leaves, cabbage and soya bean meal. The grass and leaves were selected due to their known seasonal contribution to the organic waste stream. The cabbage was selected as a high sulphur content feed material with the possibility of contribution to the increased production of odourous compounds. The soya bean meal was selected as a high protein, high nitrogen material which could also contribute to elevated odour levels.

EXPERIMENTAL

Materials

The basic organic feed material used in this study was obtained from the CORCAN composting facility located in Joyceville, Ontario. This facility processes about 25 tonnes per day of organic wastes consisting of primarily food residues, yard trimmings, agricultural wastes and wood wastes from various institutions and organizations in the Kingston area. Details of the process and materials processed have been provided in a recent detailed study (Day et al., 1998). Table 1 provides a listing of the ingredients used in making up the feed material at this commercial composting operation.

Also provided in this table are the measured physical and chemical characteristics of the ingredients that made up the compost feed.

A total of eight basic control feed material samples were taken from the commercial composting operation during the course of this study (two for each

TABLE 1
Characteristics of Ingredients Used in Basic Control Feed Material

Material	Wt (%)	Moisture (%)	Bulk Density (g/cm^3)	Air Void (%)	C (%dry)	N (% dry)	C/N Ratio
Food Waste	32	71.7	0.99	0	48.0	2.71	17.9
Manure	25	65.4	n/d	n/d	40.4	1.7	24.3
Recyclate	20	47.8	0.24	68	41.3	1.8	22.7
Wood Chips	15	22.5	0.12	84	45.6	0.44	104.4
Shredded Paper and Cardboard	8	32.5	0.13	33	48.2	0.2	253.7

augmentation evaluation). The physical and chemical characteristics of these samples are summarized in Table 2 along with the calculated values derived from the feed composition.

Although some discrepancies were noted between the measured values and those calculated from the ingredients used to make up the feed, it was assumed that the measured values, because of the statistical sampling, were more meaningful. These measured values were used for the basic control feed samples for comparison purposes in the augmentation studies.

The four feed augmentation materials used in this study were fresh grass clippings, leaves (principally sugar maple), fresh garden cabbage, and soya bean meal. The physical and chemical characteristics of these augmentation materials are presented in Table 3.

TABLE 2
Characteristics of the Basic Control Feed Material

	Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	C (% dry)	N (% dry)	C/N Ratio
Calculated	55.2	n/d	n/d	44.4	1.33	33.4
Measured Average	65.7	0.66	39.1	42.3	1.99	21.4
S.D.	1.5	0.08	8.6	2.1	0.18	2.2
Min. value	63.4	0.52	29.7	39.2	1.73	18.8
Max. value	67.1	0.74	53.4	45.5	2.22	24.5

TABLE 3
Characteristics of the Feed Augmentation Materials

	Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	C (% dry)	N (% dry)	C/N Ratio
Grass	70.5	0.22	67.8	44.0	2.7	16.3
Leaves	63.7	0.21	72.0	52.8	1.0	53.1
Cabbage	89.6	0.51	46.8	43.0	1.6	27.7
Soya bean meal	6.7	0.68	n/a	44.8	8.3	5.4

As was expected the soya bean meal is an excellent source of nitrogen although its bulk density made it difficult to mix homogeneously and maintain desirable air porosity. The grass clippings, as expected were also a high nitrogen source and capable of adding extra nutrients to the basic control feed sample. The leaves meanwhile were low in nitrogen and therefore were expected to be a drain on the available nitrogen. Their low bulk density, however, could be a plus in assisting air porosity.

Sample Preparation

Each series of feed augmentation studies were carried out as follows. A 35 litre freshly mixed sample of the basic control feed material was transported from the commercial composting operation in Joyceville to the NRC laboratories in Ottawa (a distance of about 200 km). Once received in Ottawa, the sample was divided into 4 equal parts which represented the basic control feed material. One part was used as a control (0% augmentation) and the three remaining parts were augmented with 10%, 20% and 30% by weight of the material under study. After thorough mixing to ensure homogeneity, each test mixture was loaded into one of the four laboratory composters for processing. The leftover test materials were set aside for physical and chemical characterization. Once the composting tests were completed the compost was removed from the laboratory composters and once again subjected to physical and chemical evaluation to determine the changes that had occurred during the composting process.

The Laboratory Composting System

The laboratory composting system used in this study has been reported in detail previously (Day et al., 1998). Each composting unit is approximately 5 litres in volume, constructed from 10 cm diameter Pyrex glass piping. A schematic of one of the units and associated control system is shown in Figure 1. Each unit has a controlled and regulated air supply and three thermocouples are used to monitor the temperature. In addition to monitoring temperature, the

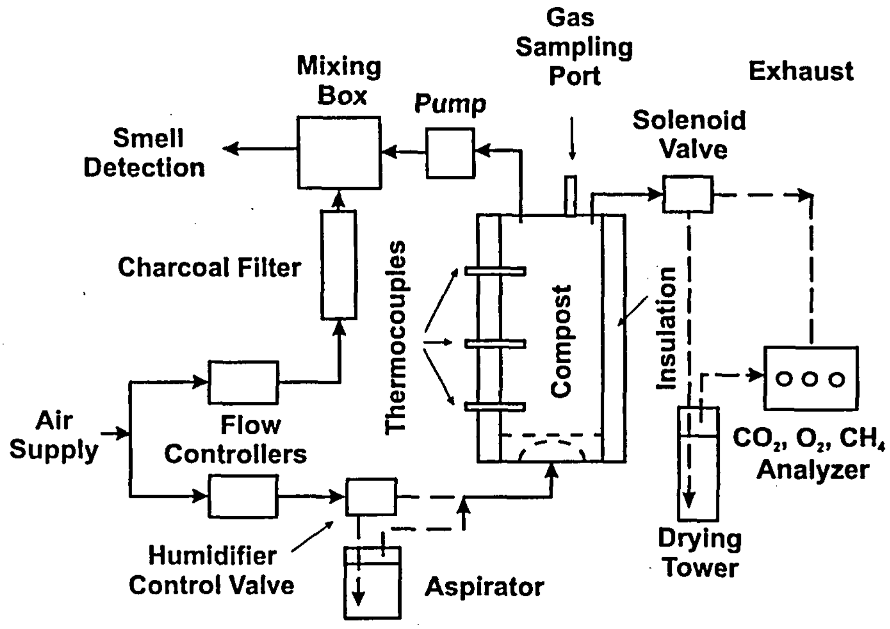

FIGURE 1
Schematic of the Laboratory Composting System.

concentrations of carbon dioxide (CO_2), oxygen (O_2) and methane (CH_4) are measured in the exit gases using a Triple Landfill Gas Analyzer (ADCLFG20). All the data acquisition and composter controls were handled by a computer operating under LABVIEW software. All experiments with the laboratory composters were conducted in insulated vessels in a room maintained at 35 ± 1°C to minimize heat loss.

Material Analysis

All feed ingredients, feed mixtures, and composted materials were characterized using a variety of test procedures.

Bulk Density: Bulk densities were determined by weighing a fixed volume of material following a standardized compaction process (Day et al., 1998).

Air Voids: Following the determination of the bulk density, water was added to the container to displace the air and the weight of water added was used to calculate the percentage air voids in the samples.

pH: The pH of samples was determined by adding 10 g of homogenized material to 500 ml of distilled water, and stirring rapidly with a magnetic stirrer. The pH of the solution was measured once the sediment had settled.

Moisture: Moisture values were determined gravimetrically by drying 15 g homogenized samples at 105°C for 24 hours.

C, N Analysis: C, N analysis was performed on 0.1 g dried homogeneous samples using a LECO CHN-1000 Analyzer.

RESULTS AND DISCUSSION

The Basic Control Feed Material

It should be noted that each augmentation study was conducted using fresh, but different compost feed materials from the commercial composting facility. This meant that while the basic control feed material was made up according to the standard recipe, as outlined in Table 1, a certain amount of variability could be expected. Table 4 provides information on the measured physical and chemical characteristics of the basic control feed material used in each set of the four tests (i.e. the material with 0% augmentation). It was unlikely that the rather small variability in the measured properties observed in the basic control feed materials would significantly affect the results of the study.

The compostability of these different basic control feed materials with augmentation as measured by the temperature profiles, carbon dioxide formation and oxygen depletion are presented in Figures 2, 3 and 4 respectively.

TABLE 4
Characteristics of the Basic Control Feed Sample used in the Augmentation Studies

Control used in the tests with:	Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	pH	C (% dry)	N (% dry)	C/N Ratio
Grass	66.6	0.74	29.7	8.24	43.0	1.85	23.2
Leaves	66.6	0.52	53.4	7.05	45.5	2.09	21.7
Cabbage	66.1	0.62	41.6	7.20	42.4	1.70	24.5
Soya bean meal	67.1	0.68	39.6	7.30	39.1	2.1	18.9

In the case of the temperature-time profiles (Figure 2) all samples showed an initial rapid self heating to 45-55°C within the first 12 hours. However, while a couple of the samples showed a cool down period for about 30 hours, the other two continued their temperature rise, although at a slower rate. After this initial difference in behaviour all materials demonstrated self heating until temperatures in excess of 62°C were reached, usually within the first 5 days in the composters. Eventually, in all cases, the temperature of the composting materials gradually declined until the composting was stopped at the end of the 12 day test period. While these graphs give a detailed description of the composting activity, it can also be characterized by measuring the maximum temperature recorded by the middle thermocouple, and the heat output, which is obtained by integration of the area between the middle thermocouple temperature curve and the ambient temperature curve (35°C) measured from time zero to time 270 hours. These values are presented in Table 5.

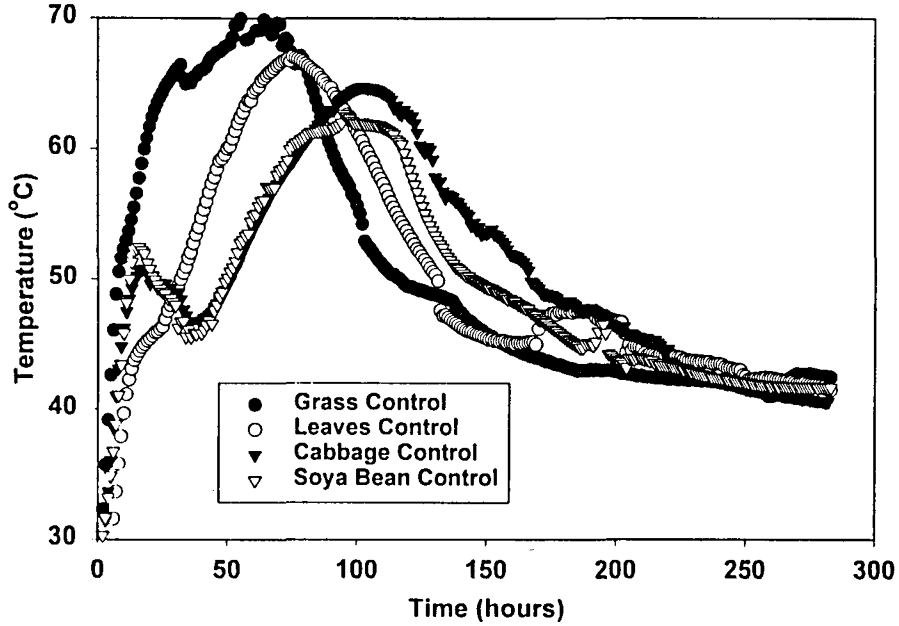

FIGURE 2
Temperature/time profiles of the basic control feed samples during the 12 day composting test period.

TABLE 5
Composting activity associated with the Basic Control Feed Samples used in the Augmentation Studies

Control used in the tests with:	Dry Mass Loss (%)	Max. Temp. (°C)	Heat Output (arb. units)	CO_2 Evolution (max. %)	Area	O_2 Depletion (min. %)	Area
Grass	32.8	70.4	4225	11.3	1013	7.7	1575
Leaves	35.6	67.0	3906	11.1	1041	6.4	1625
Cabbage	30.8	64.7	4215	7.5	482	10.6	936
Soya bean meal	26.7	62.6	3991	8.4	668	10.8	1255

From this data it can be seen that whilst there may be some variability in the measured maximum temperatures recorded, the areas under the curves (heat output values) are relatively constant with a coefficient of variation of less than 4%.

In addition to using temperature as a monitor of the composting process, we have found that monitoring respiration using dedicated carbon dioxide and oxygen sensors is a very useful technique. The levels of CO_2 and O_2 in the exit gases from these four control experiments are presented in Figures 3 and 4, respectively. Examination of these graphs clearly indicate the relationship between O_2 depletion and CO_2 production. For example the increases in CO_2 concentrations in Figure 3, correspond to decreases in O_2 levels (Figure 4) which coincide with the temperature increases noted in Figure 2. As in the case of total heat outputs, the integrated area below the CO_2 evolution curve and between the 21% level and the O_2 curve can be used to record the total carbon dioxide production and oxygen consumption throughout the 12 day composting process. These values have been compiled in Table 5. In terms of CO_2 production and O_2 depletion it can be seen that, while these curves may show some similarities the integrated areas show a much greater coefficients of variation. For example the coefficient of variation for total CO_2 evolution was 34%, while that for O_2 depletion was 24%.

In addition to measuring the characteristic parameters of the composting process, the changes in the physical and chemical characteristics of the composting material were also recorded as part of this study. These included

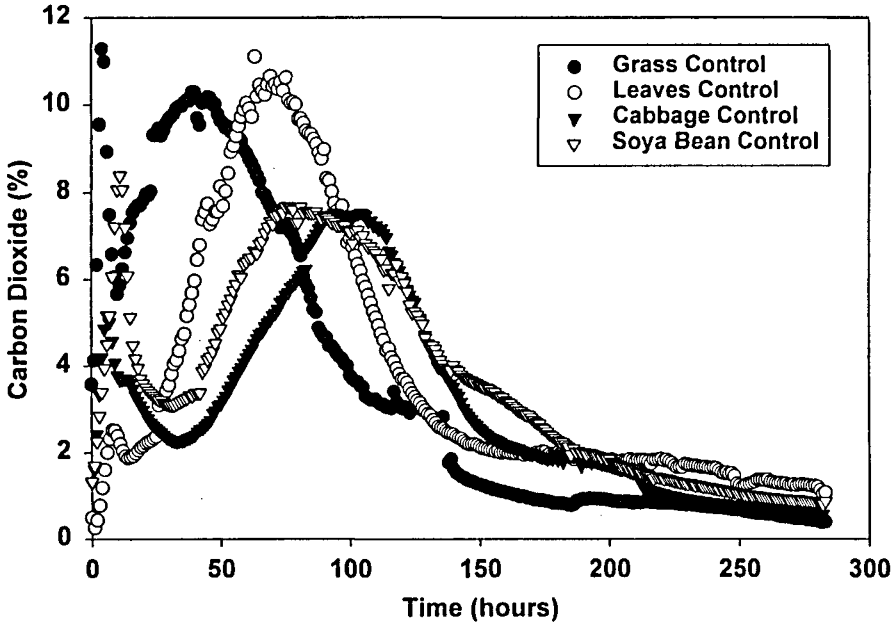

FIGURE 3
The evolution of CO_2 from the basic control feed materials during the 12 day composting test period.

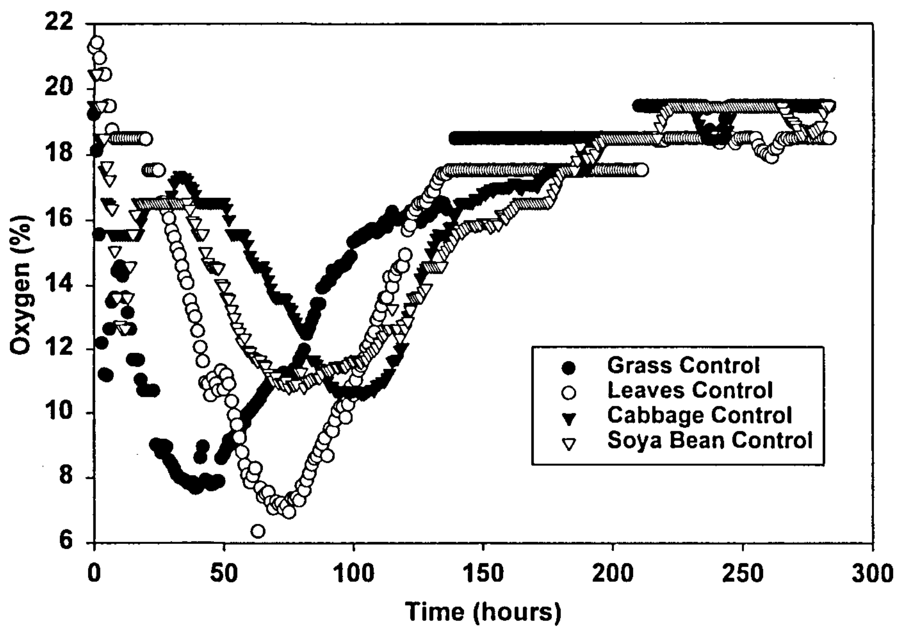

FIGURE 4
The oxygen depletion curves for the basic control feed materials during the 12 day composting test period.

measurement of moisture, bulk density, air voids, pH, carbon content, nitrogen content and C/N ratio. To establish a baseline for this study, the changes of these properties obtained with the basic control feed samples were determined and the results are presented in Table 6. Based upon this data it would appear that, with the exception of the measured bulk densities and air voids in the grass control, there is a great deal of consistency in the behaviour of the control samples. These changes can be summarized as follows. During composting, the moisture content of the material increases due to water formation in the process. This causes the bulk density to increase and the air voids to decrease. The total organic matter converted to CO_2 and H_2O is approximately 31.5% based upon mass balance calculations. The reduction of carbon content of about 5% is also responsible for a corresponding decrease in the C/N ratio of about 20-25% from to 22.1 to 16.8. Meanwhile the apparent increase in nitrogen content in the material could be the cause of the shift of pH from 7.4 to 8.7.

Based on this background information on the behaviour of the basic control feed samples it is now possible to focus on the results with the augmented experiments.

<u>The Role of Grass Augmentation</u>

The influence of grass on the composting process is summarized in Table 7. This table presents the data on heat evolution, CO_2 production and O_2 depleting as a function of grass added to the basic control feed material.

Analysis of this data clearly indicates that no simple trend can immediately be detected. However, applying statistical regression to the data

TABLE 6
Changes in the Characteristics of the Basic Control Feed material during 12 day of Laboratory Composting in each of the Augmentation Studies

Control used in the tests with:		Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	pH	C (% dry)	N (% dry)	C/N ratio
Grass	Initial	66.6	0.74	29.7	8.24	43.0	1.85	23.2
	Final	73.7	0.69	34.6	9.18	40.6	2.30	17.6
	Change	+10.8	-6.4	+16.4	+11.4	-5.6	+24.3	-24.0
Leaves	Initial	66.6	0.52	53.4	7.05	45.5	2.09	21.7
	Final	74.1	0.62	42.9	7.45	43.3	2.58	16.8
	Change	+11.4	+19.8	-19.6	+5.7	-4.8	+23.1	-22.7
Cabbage	Initial	66.1	0.62	41.6	7.20	42.4	1.70	24.5
	Final	72.9	0.71	35.5	8.94	38.5	2.2	17.5
	Change	+10.2	+14.3	-14.8	+24.2	-9.1	+26.9	-28.4
Soya bean meal	Initial	67.1	0.68	39.6	7.30	39.1	2.1	18.9
	Final	72.4	0.73	32.5	9.13	34.6	2.3	15.2
	Change	+8.0	+8.0	-17.8	+25.1	-11.6	+9.6	-19.4

revealed that the addition of grass to the basic control feed material can be tolerated at least up to a level of 30% by weight without adversely affecting the composting activity. In all cases maximum composting temperatures of 64°C or greater were achieved and the heat evolution, although showing some scatter, appeared to be independent of the weight of grass in the mixture. However, in

TABLE 7
Composting Activity in Grass Augmented Compost Samples

Grass Augmentation Level (%)	Dry Mass Loss (%)	Max. Temp (°C)	Heat Output (arb. units)	CO_2 Evolution (max. %)		O_2 Depletion (min. %)	
				(max. %)	Area	(min. %)	Area
0	32.8	70.4	4225	11.3	1013	7.7	1575
10	41.9	64.6	3777	9.1	636	13.8	1103
20	26.4	72.0	5093	12.1	957	9.6	1545
30	35.7	67.3	3729	18.5	1420	5.8	2118

terms of respiratory activity as measured by CO_2 and O_2 levels, it would appear that high grass loadings are responsible for higher respiration levels, as indicated by increased CO_2 and decreased O_2 levels. This observation could simply be a reflection of the greater bio-availability of the organic matter associated with grass, not to mention the added nutritional effect associated with the higher nitrogen levels.

In terms of the characteristics of the feed material and composted product produced in the laboratory composter, this data is presented in Table 8.

This data clearly shows the increase in nitrogen of the feed material due to the grass augmentation, with the concentration increasing from 1.85% when no extra grass is present (basic control feed material) to 2.33 when the feed contains 30% grass. Because the grass also has a slightly higher moisture content (70.5%) than the basic control feed material (66.6%) there is also a slight increase in moisture content. The moisture content of the final compost is also higher,

TABLE 8
Changes in the Characteristics of Grass Augmented Compost Samples

Grass Augmentation Level (%)		Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	pH	C (% dry)	N (% dry)	C/N ratio
0	Initial	66.6	0.74	29.7	8.24	43.0	1.85	23.2
	Final	73.7	0.69	34.6	9.18	40.6	2.30	17.6
	Change	+10.8	-6.4	+16.4	+11.4	-5.6	+24.3	-24.0
10	Initial	66.3	0.63	38.2	7.97	41.2	1.98	20.8
	Final	75.8	0.75	27.3	9.09	40.1	2.21	18.1
	Change	+14.4	+20.4	-28.6	+14.1	-2.6	+11.8	-12.9
20	Initial	67.6	0.61	42.1	8.03	43.8	2.25	19.5
	Final	76.4	0.82	21.6	9.11	40.2	2.35	17.2
	Change	+13.1	+34.8	-48.8	+13.4	-8.3	+4.2	-11.9
30	Initial	67.1	0.52	46.5	8.16	44.0	2.33	18.9
	Final	75.4	0.81	24.6	9.10	39.9	2.47	16.2
	Change	+12.3	+53.9	-47.1	+11.5	-9.3	+5.9	-14.3

particularly at higher grass concentrations. The largest changes, in the physical properties, however, were noted in the bulk densities and air voids. The addition of grass to the basic control feed material resulted in the bulk density increasing substantially while the air void were reduced during the composting process. The loss in carbon content of the material also appears to be larger with the higher grass content. This observation being consistent with measured increased respiration values noted for CO_2 and O_2.

The Role of Leaves Augmentation

Once again there appears to be a large scatter in the data with no clear progression being noted (Table 9).

However, the application of regressional analysis to the data, does allow some overall trend to be elucidated. For example it would appear that both the maximum recorded temperatures and total heat output decrease as the weight of leaves is increased. At the same time it would appear that respiratory rates are also decreasing as the leaves content increases from 0% to 30%. These results seem to suggest that the high leaves content in the basic feed material is detrimental to the composting process, despite the acknowledged benefit of leaf mulch for agricultural applications.

The influence of leaves on the characteristics of the initial feed material and final compost material has been summarized in Table 10. Interestingly, despite the low nitrogen content of the leaves employed in this study (1.0%), their augmentation to the basic control feed material appeared to have a negligible effect on the measured nitrogen concentration and consequently the C/N ratio. The moisture content of the initial material also behaved independently of the level of leaves augmentation. The moisture level in the final feed, on the other hand appears to be reduced as the leaves content in the initial feed increases. Despite the apparent lack of effect on the initial moisture content, leaf augmentation does appear to be responsible for a marked reduction in the initial bulk density and a corresponding increase in the percentage air voids in the compost samples. Thus leaves should improve the aeration of the system and

TABLE 9
Composting Activity in Leaves Augmented Compost Samples

Leaves Augmentation Level (%)	Dry Mass Loss (%)	Max. Temp (°C)	Heat Output (arb. units)	CO_2 Evolution (max. %)	Area	O_2 Depletion (min. %)	Area
0	35.6	67.0	3906	11.1	1041	6.4	1625
10	41.3	58.6	2846	4.6	510	14.3	987
20	35.1	65.0	3570	4.9	411	13.6	939
30	35.1	59.3	3221	10.4	809	6.9	1407

TABLE 10
Changes in the Characteristics of the Leaves Augmented Compost Samples

Leaves Augmentation Level (%)		Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	pH	C (% dry)	N (% dry)	C/N ratio
0	Initial	66.6	0.521	53.4	7.05	45.5	2.09	21.7
	Final	74.1	0.624	42.9	7.45	43.3	2.58	16.8
	Change	+11.4	+19.8	-19.6	+5.7	-4.8	+23.1	-22.7
10	Initial	64.5	0.40	55.8	6.51	45.3	1.95	23.3
	Final	73.2	0.41	56.8	7.29	44.9	2.79	16.1
	Change	+13.6	+1.7	+1.7	+12.0	-0.7	+43.2	-30.7
20	Initial	65.9	0.37	62.9	7.01	46.8	2.11	22.2
	Final	70.6	0.34	62.8	7.30	43.7	2.74	15.9
	Change	+7.1	-8.1	-0.1	+4.1	-6.7	+30.1	-28.2
30	Initial	64.9	0.37	61.3	6.58	46.5	2.11	22.1
	Final	72.5	0.35	61.8	7.06	46.4	2.78	16.7
	Change	+11.6	-5.9	+0.8	+7.3	-0.1	+32.0	-24.3

assist oxygen diffusion. In terms of mineralization, the addition of leaves appears to have little effect on the carbon content of the material and the calculated weight loss, with the values for the leaves augmented samples being almost identical to those obtained for the basic control feed material.

The Role of Cabbage Augmentation

Cabbage augmentation was included in this study to address odour concerns (Part II) [Krzymien 1998] rather than composting action. The results of the composting activity of mixtures containing cabbage are, however, presented in Table 11. Unfortunately, the results presented in this table are confusing and contradictory. Based upon the mineralization data it would appear that as the weight of cabbage in the feed is increased, the actual amount composted decreases. While the measured heat evolution data would appear to confirm this observation, it appears contradictory to the respiration data. Both CO_2 formation and O_2 depletion appear to increase as the weight of cabbage in the feed increases. Thus in terms of compostability the presence of high levels of cabbage does not appear to be a major concern.

The effect of cabbage augmentation on the feed characteristics, meanwhile are presented in Table 12.

From this table it can be clearly seen that the moisture content of the feed material increases substantially with increased cabbage content. At the 30% augmentation level, the compost feed material had a moisture content of 81.1%. Because of the high moisture level of the cabbage (89.6%) this is not unexpected. This high initial level of moisture also translated into a high final moisture level in

TABLE 11
Composting Activity in Cabbage Augmented Compost Samples

Cabbage Augmentation Level (%)	Dry Mass Loss (%)	Max. Temp (°C)	Heat Output (arb. units)	CO_2 Evolution (max. %)	Area	O_2 Depletion (min %)	Area
0	30.8	64.7	4216	7.5	482	10.6	936
10	15.6	57.3	3175	5.1	433	14.8	690
20	7.4	65.7	4623	10.9	1505	6.3	2058
30	7.9	56.6	3631	8.1	860	10.9	1235

TABLE 12
Changes in the Characteristics of the Cabbage Augmented Compost Samples

Cabbage Augmentation Level (%)		Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	pH	C (% dry)	N (% dry)	C/N ratio
0	Initial	66.1	0.62	41.6	7.20	42.4	1.7	24.5
	Final	72.9	0.71	35.5	8.94	38.5	2.2	17.5
	Change	+10.2	+14.3	-14.8	+24.2	-9.1	26.9	-28.4
10	Initial	75.2	0.65	40.0	7.60	41.7	1.8	23.8
	Final	73.9	0.71	34.1	8.94	40.2	2.3	17.5
	Change	-1.7	+9.0	-14.7	+17.6	-3.8	31.2	-26.6
20	Initial	78.2	0.65	39.8	7.38	41.2	1.7	24.8
	Final	76.0	0.90	12.0	8.96	38.5	1.9	20.3
	Change	-2.9	+39.8	-69.8	+21.4	-6.6	+14.5	-18.4
30	Initial	81.1	0.61	43.7	7.69	41.4	2.0	20.5
	Final	79.0	0.92	12.2	9.01	39.3	2.4	16.6
	Change	-2.7	+50.6	-72.0	+17.2	-5.2	+17.2	-19.1

the compost product. However, despite the high initial moisture level some drying does occur during the composting process. The net effect of having a higher moisture content material certainly influenced the changes noted in the bulk density and air voids during the composting process. Because of this high moisture level in cabbage, once composting commenced a marked increase in bulk density is observed with a corresponding loss in air voids within the composting materials. The net result is the production of substantial quantities of water which had to be drained from the composter in order to maintain air flow. While the basic control feed materials produced about 16 ml of drainable water during the 12 day of composting, a value typical for most experiments in this study, cabbage at a loading of 20% and 30% produced 159 and 248 ml of drainable water, respectively. Thus from an operational point of view high cabbage loadings could cause serious moisture problems leading to undesirable low levels of air porosity and possible operational difficulties. While draining of excess liquid from the laboratory reactors may have alleviated the problem, it is clear that additional bulking agents would be required at a commercial composting facility to process this type of material.

The Role of Soya Bean Meal Augmentation

The augmentation with soya bean meal was not undertaken as an investigation from a practical composting situation, but principally as a convenient means of introducing a high nitrogen source to the feed. The aim was to determine the role of available nitrogen in the composting process and its effect on the characteristics of the materials. The results obtained with these augmentation levels of nitrogen are summarized in Table 13.

TABLE 13
Composting Activity in Soya Bean Meal Augmented Compost Samples

Soya Bean Level (%)	Dry Mass Loss (%)	Max. Temp. (°C)	Heat Output (arb. units)	CO_2 Evolution (max. %)	CO_2 Evolution Area	O_2 Depletion (min. %)	O_2 Depletion Area
0	26.7	62.6	3991	8.4	668	10.8	1255
10	42.7	67.5	4308	7.8	517	9.8	1239
20	34.0	66.0	5840	11.4	1210	6.4	2011
30	31	61.7	4635	17.8	2927	2.5	3525

From this data it is quite clear that the augmentation of the basic control feed material with a nitrogen rich material such as soya bean meal caused significant increases in the composting rate as measured in terms of heat output and respiration rates. Although there was a large amount of scatter in the mineralization data, the general trend was an increase of activity with increased nitrogen levels. On the other hand, the heat outputs and respiratory values for CO_2 evolution and O_2 depletion all show substantial increases with soya bean content. In effect at the 20 and 30% soya bean levels the magnitude of CO_2 formation and O_2 depletion were such that measurable quantities of methane were also recorded, indicating some degree of anaerobic behaviour.

Meanwhile, the characteristics of the feed material and compost produced in these soya bean augmentation studies are presented in Table 14.

The data indicates that soya bean meal increases the nitrogen content from just over 2% for the basic control feed to about 5% in the case of the 20-30%

TABLE 14
Changes in the Characteristics of Soya Bean Meal Augmented Compost Samples

Soya Bean Augmentation Level (%)		Moisture (%)	Bulk Density (g/cm^3)	Air Voids (%)	pH	C (% dry)	N (% dry)	C/N ratio
0	Initial	67.1	0.68	39.6	7.30	39.1	2.1	18.9
	Final	72.4	0.73	32.5	9.13	34.6	2.3	15.2
	Change	+8.0	+8.0	-17.8	+25.1	-11.6	+9.6	-19.4
10	Initial	58.7	0.66	43.5	7.20	40.2	3.8	10.5
	Final	73.2	0.77	35.9	9.01	31.2	2.1	15.1
	Change	+24.7	+18.1	-17.4	+25.1	-22.2	-46.1	+44.3
20	Initial	56.3	0.64	45.6	7.10	42.4	4.7	9.0
	Final	67.4	0.66	42.6	9.15	38.8	3.2	12.1
	Change	+19.6	+3.4	-6.5	+28.9	-8.5	-31.9	+34.4
30	Initial	54.5	0.65	51.0	7.1	41.8	4.87	8.7
	Final	63.4	0.58	49.7	9.14	36.7	3.4	10.8
	Change	+16.5	-9.9	-2.7	+28.7	-12.2	-29.0	+23.7

augmented samples. Consequently, the addition of nitrogen does significantly influence the C/N ratio which decreased from about 19 for the basic control feed to about 9 for the 20-30% augmented material. In addition, because the soya bean meal has a low moisture content (6.7%) its augmentation to the basic control feed causes a measurable reduction in the moisture content of the initial feed material.

This reduced moisture content has the effect of reducing the initial bulk density of the material and causing the air voids to increase. These changes clearly facilitate oxygen diffusion, which combined with the added nutrient value favour high composting activity.

CONCLUSION

Based upon the results of this systematic, scientific study several conclusions can be drawn. Grass can be accommodated into a commercial composting feed up to a level of about 30% without adversely affecting the composting process or the characteristics of the product. However, because of its high moisture content the addition of more bulking agents may be required when large quantities of grass are processed. As a feed material, grass has the advantage of bringing nitrogen to the feed which can promote bacterial activity and accelerate the composting process. Leaves are an expected augmentation to the feed material when fall collections reach their peak. While our studies do not show any major negative effects, it would appear that leaves are not as easily composted as other components in the feed and may be responsible for a certain amount of respiratory retardation. As such longer composting periods may be required when dealing with compost feeds with high leaves content. The addition of high moisture vegetables such as cabbage, could potentially cause problems of excessively wet materials for processing. High concentrations of cabbage in this study resulted in a feed material with a high bulk density and low percentage air voids. However, despite these moisture related problems, composting activity as measured by CO_2 evolution and O_2 depletion did not show any decreased activity, if anything the respiratory activity increased as a result of increased cabbage content. The addition of a high protein nitrogen source significantly enhances composting activity and respiratory activity. If present in high concentrations excessive depletion of oxygen becomes a serious possibility with the associated problems of potential anaerobic activity. Consequently, it might be appropriate to balance high protein materials with cellulosic matter in order to achieve the desired C/N ratio.

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