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EFFECT OF WINDROW TURNING AND SEASONAL TEMPERATURES ON COMPOSTING OF HOG MANURE FROM HOOP STRUCTURES

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ABSTRACT

A study was undertaken to investigate the effect of windrow turning on composting of hoop manure (a mixture of partially decomposed hog manure and cornstalk). Three series of experiments were conducted: one during summer, one during winter, and one during spring. In all three series of experiments, windrows were either turned (once a week) or left unturned during the composting process, which lasted for 42 days. The effects of windrow turning were evaluated by measuring the physicochemical properties (temperature, oxygen concentration water content, pH, organic matter, and nutrients) of the hoop manure during composting. Turning affected a number of important physical and chemical parameters such as temperature, oxygen concentrations, and C and mass loss. The temperature of the unturned windrows took longer to drop to ambient temperature, had lower oxygen concentration, and C and mass loss than the turned windrows. These results suggest that the decomposition rate in turned windrows is much faster than the unturned ones. However, the final product from the two composting treatments (turned and unturned windrows) was similar in terms of the organic matter, nutrient contents, and C:N ratios. N loss was a major problem during composting of hoop manure. As much as 60% of the N in the hoop manure (both in turned and unturned windrows) was lost during composting, indicating that composting has significantly reduced the value of hoop manure as N fertilizer. These losses could be attributed to ammonia volatilization, leaching, and run-off. Overall, composting was similar in all three seasons (summer, winter, and spring). This study demonstrated that hoop manure could be successfully composted during winter.

Keywords: Composting, open-air windrows, compost turning, nitrogen loss, deep litter system

INTRODUCTION

Swine producers in the United States who are looking for lower cost structures to raise hogs have recently shown a great deal of interest in the so called hoop structures as swine production facilities [1]. The unit set-up cost is low compared to confinement facilities, as the internal infrastructure is less sophisticated (absence of slatted floors, scraper systems, and manure pits). These facilities rely upon the use of large amounts of bedding material (usually cornstalks) to absorb the hog feces and urine, similar to the deep litter system being practiced by hog farmers in Hong Kong, Japan, New Zealand and The Netherlands [2]. Hoop structures are somewhat different from conventional pig housing facilities as the animals in these structures are kept on a thick layer of bedding material. The environmental benefit of hoop structures is that no effluent needs to be discharged— the hog manure is decomposed in-situ and the hoop manure (a mixture of partially decomposed hog manure and cornstalk) can be used as soil amendment. The hoop manure is normally cleaned out after each group of pigs is sold (2–3 times a year), and either stored or composted in windrows. Composting of agricultural waste is used increasingly to reduce its weight and volume, and to improve the properties for its use [3–5]. Subsequent windrow composting studies also demonstrated a higher degree of homogeneity achieved in the composted material [5, 6].

Windrow turning is one of the composting strategies that affect the degree of decomposition, and quality of the composted product [4, 7, 8]. It is often cited as the primary aeration and temperature control during composting [9, 10]. However, the advantages and disadvantages of windrow turning during composting are heavily disputed. Some agriculturists advocate a slow composting process that involves little disturbance (i.e. infrequent turning) [11], while others are in favor of frequent turning to hasten aerobic decomposition and improve homogeneity of the composted product [7–9].

Several authors have investigated the effects of compost turning on different organic wastes such as household wastes [7], yard trimmings [4], and spent pig litter [8]. Because hoop structures are a relatively new technology, there is limited information available about the properties of manure generated from the system. Little information is also available on how its properties change during windrow composting (with or without turning), and how these changes would affect the properties of the composted product. Therefore, the present study was carried out to examine the effects of windrow turning on composting of hoop manure and properties of the end-product (compost). In this study, the effect of turning was evaluated by measuring the physicochemical properties of the hoop manure such as temperature, oxygen concentration, pH, and concentrations of total organic matter, total carbon, and nutrients during composting at different seasonal temperatures (summer, winter, and spring). Since nitrogen (N) and carbon (C) are important elements that are likely to be lost during composting, their losses were also evaluated.

MATERIALS AND METHODS

The study was carried out at Iowa State University Rhodes Research Farm, Rhodes, Iowa. Three successive batches of pigs were raised in the hoop structures: Batch 1 (Hoop A, December 1997–April, 1998); Batch 2 (Hoop B, June–November 1998); and Batch 3 (Hoops C–E, December–May 1998) (Table 1). Finishing pigs, at approximately 23 kg each were placed in each hoop structure at a stocking density of 1 m^2 (~12 ft^2) per pig. The pigs were placed inside the hoop for a period of 4–5 months (Table 1). By the end of each production cycle, the hoop manure samples were collected at 24 different locations of the hoop manure bedding. The 24 subsamples were mixed to give one composite sample. A total of four composite samples were collected from each pen and were characterized in the laboratory (Table 1). Hoop A was left idle for two months before the hoop manure was removed and composted. The hoop manure in Hoops B–E was removed immediately after the pigs were sold, and was stacked in windrows for further composting and maturation.

Windrow composting

Three series of windrow composting experiments were conducted, each lasting 6 weeks (42 days): summer (June–July), winter (November–December) and spring (May–June). Four windrows (windrows 1–4) were set-up during the summer, four during winter (windrows 5–8), and 12 during spring (windrows 9–20) (Table 1). The reason for setting up 12 windrows, instead of 4 in the spring trial was to determine whether there were differences among windrows with the same treatments. Since the windrow experiment is an open composting system, the windrows can be exposed to several external environmental variables, and this may create variability even in windrows with the same treatment.

For each series of experiments, two methods of

Table 1. Treatments in the hoop structures, and properties of the cornstalk and hoop manure (cornstalk+pig manure) before clean out.

		Hoop manure				
		Batch 1	Batch 2	Batch 3		
Treatments/Properties	Cornstalk	Hoop A	Hoop B	Hoop C	Hoop D	Hoop E
		Treatments				
Number of hog raised	-	151	144	150	152	149
Bedding usage (kg)	-	12286	12200	15506	14395	15143
Raising period (months)	-	4	5	5	5	5
Composting windrow[*]		1–4	5–8	9–12	13–16	17–20
		Properties[†]				
Moisture content (%)	10	64	60	72	71	76
pH	ND	ND	8.6	7.5	7.9	7.5
Total N (g kg^{-1})	6.6	15	24.8	36.0	36.8	36.9
Total P (g kg^{-1})	1.2	9.3	11.4	11.5	12.3	11.4
Total K (g kg^{-1})	1.1	22.2	24.8	25.3	27.2	20.1
Total C (g kg^{-1})	51	312	249	409	423	398
C:N ratio	8:1	21:1	16:1	11:1	11:1	11:1
Total organic matter (g kg^{-1})	910	758	623	434	434	386
Ash content (g kg^{-1})	90	242	377	566	565	614

ND= not determined

[*] The hoop manure in windrows 1–4 was collected from hoop A whereas that of windrows 5–8 were collected from hoop B. Hoop manure in windrows 9–12, 13–16, and 17–20 were collected from hoops C, D, and E.

[†] Mean of four replicates are shown.

windrow construction: piling using a manure spreader (John Deere 450 Hydro-Push) or tractor loader (John Deere 6400 Tractor), and two compost turning treatments: turning once a week or no turning were used. Windrows 1, 3, 5, 7, 9,11, 15, 17, and 19 were turned weekly, whereas the other 10 windrows (windrows 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20) were left unturned during the entire period of composting. Windrows 1 to 4 had the following dimensions: 10m length, 2.5m width and 1.5m height. Windrows 5 to 20 had similar dimensions with windrows 1 to 4, except that they were shorter in length (6 m). Samples were collected from left, middle, and right side of the windrows at 30, 60 and 90 cm depths. These samples were combined and mixed to give a composite sample. Triplicate composite samples (approximately 1 kg) were collected from each windrow at day 0 and then weekly until the end of the composting trial (day 42).

Sampling, sample measurements, and statistical analysis

During composting, the air and pile temperatures, and oxygen concentrations in the windrows were monitored. Pile temperatures were measured using a temperature probe, whereas oxygen concentrations were recorded using a compost monitor (Morgan Scientific, USA) The average temperature was determined by taking three measurements at the left, middle, and right side of the windrows at 30, 60, and 90 cm depths. Oxygen concentrations were measured at the left, middle, and right side of each windrow at a depth of 60 cm. For the turned windrows, the temperature and oxygen concentration measurements, as well as the sampling were taken after turning.

The hoop manure samples collected were characterized for water content (75°C 48 h); pH (1:5 hoop manure:water extract) using a pH electrode; ash and total organic matter contents (loss on ignition; 550°C for 5 h) [12]; total P and K (acid digestion method) [13] and total C and N using a Carlo Erba CN analyzer. The weight of the hoop manure from each windrow was measured at the beginning (day 0) and end (day 42) of composting, respectively, to determine the percentage reduction in mass. Initial and final volumes of the windrows were also calculated from dimensions assuming a parabolic cross section [14]. Mass N and C (N or C concentrations x dry weight of the windrow) in the windrows were determined, and the losses were computed.

A t-test [15] was performed to compare the effects of composting with and without turning.

RESULTS AND DISCUSSION

Characteristics of the manure removed from hoop structures

As shown in Table 1, the hoop manure removed from hoop structures was very alkaline with pH ranging between 7.5 and 8.6, and had high water content (between 64 and 76 %). The hoop manure also had abundant organic matter and nutrients (Table 1). These initial values were comparable with the ranges reported for other animal manures such as poultry litter [16], horse [17] and cattle [18]. In contrast, the C:N ratios were low (between 11:1 and 21:1) (Table 1). It has been found that in deep litter systems, the manure is decomposed rapidly within the bedding material resulting in the disappearance of C. At the same time, there is an accumulation of nutrients (N, phosphorus and potassium) and microbial biomass [19, 20]. The accumulation of nutrients was related to the continuous deposit of hog manure on the bedding during the hog raising period. While carbonaceous bedding is usually added to absorb the manure, C loss was generally greater than N loss, resulting in a decrease in the C:N ratio by (Table 2) the end of the production cycle. One of the problems associated with the use of hog manure is that it often contains high concentrations of heavy metals, salts, and excess accumulation of ammonium [21, 22], which may affect plant growth. Therefore, care must be taken in its use, and it is necessary to understand the characteristics of the composted product in order to avoid undesired effects. Bernal *et al.* [23] reported that composted manure contained more stabilized organic matter and higher concentrations of humic substances than fresh manure. The humic substances form stable complexes with heavy metals, thus making the heavy metals non water-extractable and biologically unavailable. During composting, the excess ammonium could also be reduced via the nitrification process. This would eliminate ammonium toxicity in the compost [24]. To complete the composting process, and in order to improve the agronomic value of the hoop manure, further composting in windrows would therefore be essential.

The initial hoop manure of the spring trial had higher concentrations of organic matter, C and N than that of the summer and winter trials (Table 3). This result is due to the fact that more cornstalk was added in hoops C, D, and E (Batch 3) than in hoops A (Batch 1) and B (Batch 2) (Table 1). The addition of more cornstalk bedding in hoops C, D, and E facilitated the absorption of N in the cornstalk. Hence, the N concentration of the hoop manure (collected from hoops C, D, and E) at the beginning (day 0) of the spring composting trial was higher than the summer and winter windrows. The application of bulking agents such as peat moss, rice husk, sawdust, and bark has been known to conserve N in animal manure [25, 26]. Morisaki *et al.* [25] and Barrington and Moreno [26] observed that these bulking agents posses high water and cation absorption capabilities, therefore the NH_3 binds tightly (physically and chemically) with the components of the bulking agents and so N losses are reduced. A similar phenomenon could have occurred in the present study.

Windrow composting of hoop manure

All windrows, irrespective of their differences in turning strategies maintained peak temperatures of 55 to 70°C (Figure 1).

Table 2. Chemical properties of the initial hoop manure.

Hoop	Windrow	C:N ratio	Ash ($g\ kg^{-1}$)	O. M. ($g\ kg^{-1}$)	Total C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Total P ($g\ kg^{-1}$)	Total K ($g\ kg^{-1}$)
				Summer trial				
A	1	22:1	249	751	289	13.1	8.3	23.4
A	2	20:1	263	737	312	15.8	9.2	21.9
A	3	20:1	209	791	325	16.0	10.2	23.2
A	4	20:1	245	755	321	15.5	9.5	20.7
				Winter trial				
B	5	16:1	383	617	264	16.9	8.9	26.1
B	6	16:1	486	514	239	15.1	11.1	24.0
B	7	16:1	402	598	237	10.0	14.5	22.9
B	8	24:1	472	528	262	13.9	14.4	26.0
				Spring trial				
C	9	11:1	356	641	374	35.6	10.8	25.7
C	10	12:1	266	734	426	37.0	11.3	26.0
C	11	12:1	260	740	429	38.0	10.4	24.0
C	12	12:1	292	708	411	33.8	13.7	24.8
D	13	12:1	257	743	431	34.5	12.5	29.7
D	14	12:1	238	762	442	35.5	12.3	25.7
D	15	13:1	280	720	418	33.4	11.7	22.5
D	16	9:1	309	691	401	43.8	12.8	30.7
E	17	9:1	425	575	334	36.9	10.8	24.8
E	18	11:1	317	683	396	36.0	10.5	25.5
E	19	11:1	267	733	425	37.3	14.0	30.0
E	20	12:1	244	756	438	37.6	10.4	25.2

O.M.= total organic matter.
Mean of three replicates are shown.

Table 3. Percent mass, volume, C and N losses during windrow composting of hoop manure.

		Parameters (% of initial)			
Hoop	Windrow	Mass loss	Volume loss	N loss	C loss
			Summer trial		
A	1	63	45	11	72
A	2	57	36	21	54
A	3	42	31	3	69
A	4	16	23	8	30
			Winter trial		
B	5	43	42	55	59
B	6	29	29	50	39
B	7	36	27	21	50
B	8	14	24	31	31
			Spring trial		
C	9	51	51	59	68
C	10	34	45	40	48
C	11	47	51	52	67
C	12	43	50	60	54
D	13	55	52	48	63
D	14	37	30	59	54
D	15	57	45	37	63
D	16	27	41	52	42
E	17	53	50	51	60
E	18	41	35	55	50
E	19	49	50	52	63
E	20	40	39	57	53

$$\text{Mass loss (\% of initial)} = \frac{\text{Initial mass of the windrow} - \text{Final mass of the windrow}}{\text{Initial mass of the windrow}} \text{x100}$$

$$\text{Volume loss (\% of initial} = \frac{\text{Initial volume of the windrow} - \text{Final volume of the windrow}}{\text{Initial volume of the windrow}} \text{x100}$$

$$\text{N loss (\% of initial)} = \frac{\text{Initial mass N} - \text{Final mass N}}{\text{Initial mass N}} \text{x100}$$

$$\text{C loss (\% of initial)} = \frac{\text{Initial mass C} - \text{Final mass N}}{\text{Initial mass C}} \text{x100}$$

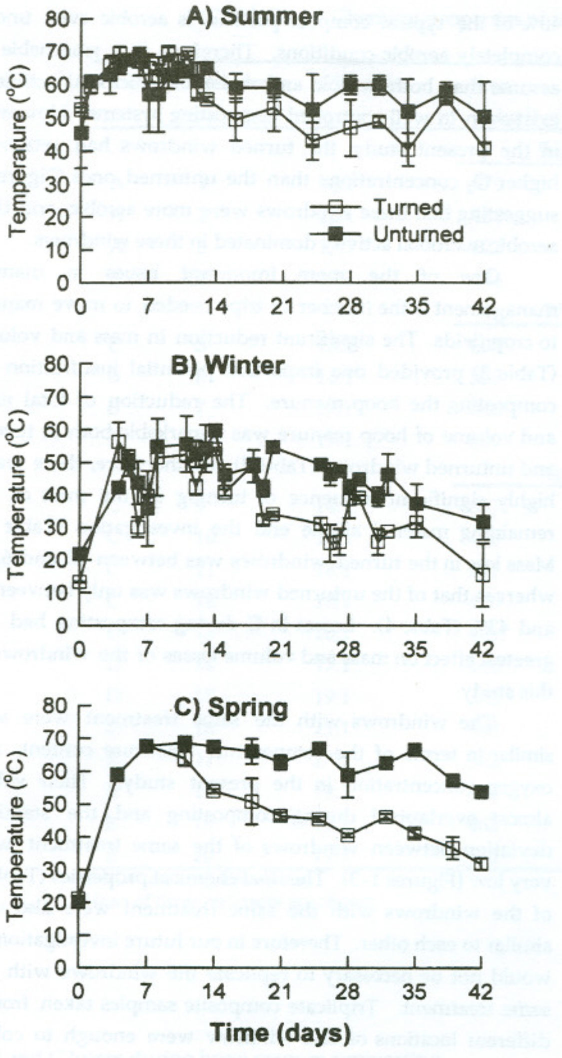

Figure 1. Changes in air and pile temperatures during a 6-week composting process. Mean and standard deviation of two replicate treatments are shown.

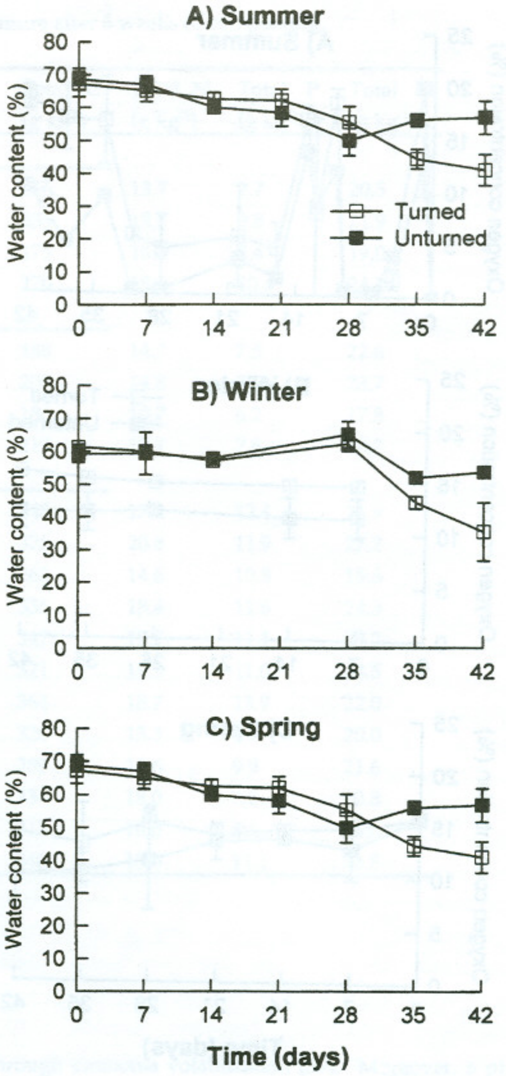

Figure 2. Changes in water content during a 6-week composting process. Mean and standard deviation of two replicate treatments are shown.

For the turned windrows, peak temperatures were maintained for about 2–3 weeks. After peaking, the temperature in the turned windrows dropped quickly to close to air temperature. For the unturned ones, peak temperatures lasted between 3 and 6 weeks of composting. The unturned windrows maintained relatively high temperatures due to heat accumulation. During winter, compost temperatures were maintained at around 60 to 62°C (Figure 1b) even when winter air temperature was –20°C. The water content in all windrows did not vary significantly during the first 30 days of composting (Figure 2). It remained between 60 and 71% for all treatments, which is near the optimal range for efficient composting [27]. In this range, microorganisms can move easily from fibre to fibre in the aqueous environment with enough free space to provide significant oxygen mass transport [28, 29]. It has been known that oxygen concentration is an important parameter affecting the composting process [4, 7]. Suler and Finstein [30] reported that oxygen concentration in the exit gas need to be at least within the range of 10 to 18% to prevent a decrease in metabolic activity based on CO_2 evolution. In the present study, the oxygen concentration in all treatments varied between 0 (anaerobic) and 20% (aerobic) during composting, irrespective of whether the windrows were turned or not (Figure 3). This result suggests that both aerobic and anaerobic metabolism occurred in all windrows during composting. A recent theoretical composting model by Hamelers [31] revealed that only the outer shell, equivalent to

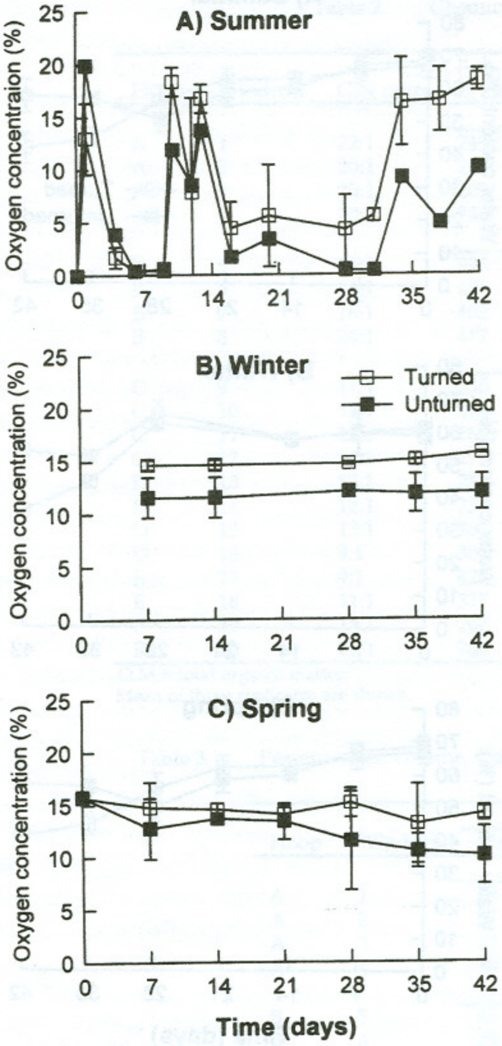

Figure 3. Changes in oxygen concentrations during a 6-week composting process. Mean and standard deviation of two replicate treatments are shown.

40% of the typical compost particle, is aerobic even under completely aerobic conditions. Therefore, it is reasonable to assume that both aerobic and anaerobic microbial activities exist even in well-controlled composting systems. However, in the present study, the turned windrows had relatively higher O_2 concentrations than the unturned ones (Figure 3) suggesting that these windrows were more aerobic, and that aerobic microbial activity dominated in these windrows.

One of the more important issues in manure management is the number of trips needed to move manure to crop fields. The significant reduction in mass and volume (Table 3) provided one important potential justification for composting the hoop manure. The reduction of total mass and volume of hoop manure was remarkable both in turned and unturned windrows (Table 3). Furthermore, there was a highly significant influence of turning on the mass of the remaining material at the end the investigation (Table 4). Mass loss in the turned windrows was between 36 and 63%, whereas that of the unturned windrows was only between 14 and 43% (Table 4). Losses in C during composting had the greatest effect on mass and volume losses of the windrows in this study.

The windrows with the same treatment were very similar in terms of the temperature, moisture content, and oxygen concentration in the present study. Their values almost overlapped during composting and the standard deviation between windrows of the same treatment were very low (Figures 1–3). The final chemical properties (Table 5) of the windrows with the same treatment were also very similar to each other. Therefore in our future investigations, it would not be necessary to replicate the windrows with the same treatment. Triplicate composite samples taken from 9 different locations of one windrow were enough to collect statistically valid data.

Table 4. Effect of windrow turning on some important composting parameters.

	Results of t-test	
Parameters	P value	Significance
Temperature (°C)	< 0.0001	***
Oxygen concentration (%)	< 0.0001	***
Moisture content (%)	0.2900	NS
C loss (%)	<0.0001	***
N loss (%)	0.6200	NS
Mass loss (%)	0.0490	*
Volume loss (%)	0.0800	NS

NS= not significant at P ≤ 0.05.

Table 5. Chemical properties of the hoop manure after 6 weeks of composting.

Hoop	Windrow	C:N ratio	Ash ($g\ kg^{-1}$)	O.M. ($g\ kg^{-1}$)	Total C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Total P ($g\ kg^{-1}$)	Total K ($g\ kg^{-1}$)
				Summer trial				
A	1	16:1	579	421	216	13.7	9.7	20.5
A	2	22:1	458	542	335	15.5	9.8	21.9
A	3	17:1	621	379	175	10.3	8.4	19.0
A	4	17:1	444	556	270	15.6	10.4	24.2
				Winter trial				
B	5	13:1	634	366	188	14.7	7.5	22.6
B	6	14:1	533	467	205	14.8	8.5	23.7
B	7	17:1	546	454	186	10.7	6.2	17.8
B	8	17:1	509	491	210	12.7	7.8	28.2
				Spring trial				
C	9	14:1	581	419	243	17.2	13.4	21.9
C	10	16:1	438	562	326	20.8	11.9	27.2
C	11	18:1	547	453	263	14.6	10.3	15.6
C	12	18:1	420	580	336	18.4	11.6	24.3
D	13	20:1	401	599	347	17.7	11.1	22.2
D	14	17:1	446	554	321	19.3	11.0	23.5
D	15	19:1	373	627	364	18.7	13.9	22.0
D	16	21:1	448	552	320	15.3	8.3	20.0
E	17	17:1	502	498	289	16.6	9.9	21.6
E	18	19:1	424	576	334	18.0	9.0	20.8
E	19	19:1	463	537	311	16.0	8.6	20.6
E	20	19:1	413	587	340	18.0	11.1	23.8

O.M.= total organic matter.
Mean of three replicates are shown.

N and C losses during hoop manure composting

Another issue of considerable importance in manure utilization is the extent of nutrient and C losses during composting. The nutrient that has received the most attention in composting systems is N since it is the most essential element for plant nutrition [32, 33]. Carbon is an element that is also critically important during the composting process as it provides energy that drives microbial activity. To reveal actual losses, mass N and C losses (% of initial) were calculated during composting (Table 3). The turned windrows had higher C loss (50 to 63%) than the unturned windrows (30–54%) (Table 3). This C loss was basically through bio-oxidation of organic C to CO_2 during composting. The C loss in this investigation was higher that the losses reported from other manure [34, 35].

During composting, N could be lost due to ammonia volatilization [31], run-off and leaching [18], and denitrification [36]. Environmental factors such as aeration, temperature, and C:N ratio of the initial composting material have also been reported to affect losses during composting [31, 37, 38]. Bertoldi *et al.* [37] reported that N loss was greater with turning (18% N loss) than with forced-aeration methods (5% N loss). A very low C:N ratio would lead to N loss through ammonia volatilization [39]. Moreover, a pH > 7.0 and a temperature >45°C would also enhance ammonia volatilization [31, 38]. Such a loss would decrease the fertility value of the mature composted product. In this investigation, both turned and unturned windrows had a relatively high N loss during composting (Table 3). It is interesting to note that N loss was not significantly affected by compost turning (Table 4), despite the greater air contact and opportunity for volatilization provided by frequent turning events. The N loss could be attributed mainly to ammonia volatilization (as the pH was > 7.0 during composting and the initial C:N ratio was low), leaching, and run-off. The greatest N loss was found in hoop manure windrows composted during the spring. Losses in these windrows were between 40 and 59%. It appears that the initial C:N ratio was the most critical factor affecting the N loss during the spring trial. The C:N ratio of the hoop manure was lower during spring (9:1 to 12:1) than the summer (21:1 to 22:1) and winter (16:1 to 24:1) windrows. Also, large numbers of rainfall events occurred during spring trial, which enhanced leaching and run-off and thereby contributed to the increased N loss (Table 3) in the hoop manure windrows in this composting trial. Eghball *et al.* [18] found 20 to 40% N loss, and 42 to 62% C loss during composting of beef cattle manure, in run-off and leaching from composting windrows during rainfall.

Effects of compost turning during composting

Understanding the effects of various composting strategies such as turning is important since the composted product ultimately will be used as a soil amendment. Turning significantly affected a number of important composting parameters such as temperature, oxygen concentration, and mass and carbon loss in this investigation. The temperature of the unturned windrows took longer to drop to ambient temperature, had lower oxygen concentration, and C and mass loss than the turned windrows. These results suggest that the decomposition rate in turned windrows proceeded much faster than the unturned ones. The composting process, with its requirements for turning and aeration is one of the important steps to produce a good quality compost product. In unturned windrows, aerobic conditions prevail mostly at the outer surface of the windrows, while anaerobic conditions dominate inside [3]. This result would slow down the composting process and so, longer composting period may be required [3, 8]. When windrows were turned in this experiment, the proportion of the compost materials (cornstalk and hog manure) were blended to some degree of consistency. Periodic turnings improved the compost consistency and diminished the importance of initial mixing. Also, during turning, the outer layer of the windrow (where temperatures are close to ambient level) is transported into the inner part of the pile, exposing it to thermophilic temperatures (55–70°C), and destroying weed seeds and pathogens that are in it. This process could not be achieved in unturned windrows. Therefore, periodic turning is required for effective and efficient composting of hoop manure.

Nutrient loss, specifically N, can be a major problem in composting hoop manure. More than half of the total N content of the hoop manure could be lost during composting. P and K losses were also significant, presumably through run-off and leaching since the available forms of these two elements are not volatile. Although composting had significantly reduced the value of hoop manure as N fertilizer, the composted manure hoop manure had high organic matter content (Table 5). This would enhance its value as a soil conditioner. Other advantages of composting include the significant reduction in mass and volume of the hoop manure, which reduce transportation cost. The net effect of these advantages and disadvantages are likely to vary with individual farms. Therefore, effective strategies to conserve nutrients in outdoor windrows will be an important topic of our future investigations.

Effect of seasonal temperatures on composting

Seasonal temperatures did not have a strong effect on composting of hoop manure. Overall, composting in the winter was similar to that of summer and spring. The results of this investigation showed that, contrary to the popular regional belief, outdoor windrow composting was possible during winter climates even after prolonged sub-freezing weather. The temperature variations (Figure 1b) reflected that active decomposition took place within the windrows during the winter composting trial. Moreover, winter composting did not involve some practical considerations that were not required during other seasons. For example, the windrows did not need to be covered even when snow and heavy winds were present.

Although the data presented in this paper are rather preliminary, the results of this study present some useful information regarding the effects of compost pile management (turning) and season on compost process variables. However, the changes in plant available forms of nutrients (i.e. ammonium, nitrate, and available P and K), microbial properties (i.e. microbial respiration, CO_2 evolution during incubation, and pathogen detection assay) and phytotoxicity during composting must be measured in the future to understand the composting process better, and to evaluate the quality and suitability of hoop manure compost as a soil amendment.

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