Effects of Straw, Sawdust and Sand Bedding on Dairy Manure Composting

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Abstract. Composting is an increasingly popular manure management tool for dairies. However, there is little information on the effects of common amendment and bedding types (straw, sawdust and sand) on windrow size, mass, volume, dry matter, and nitrogen losses during composting. In this study, straw, sawdust and sand bedded dairy manures were amended with either sawdust or straw and composted on multiple occasions. Results showed that starting windrow volumes for straw amended composts were 2.1 to 2.6 times greater than for sawdust windrows. Straw amended composts had lower initial bulk densities and temperatures, higher free air space values (75-93%), and near ambient interstitial oxygen concentrations during composting as compared to sawdust amended composts. Sand bedding resulted in greater compost densities, less weight loss and >50% more final compost on a per cow basis. All sawdust-amended composts self-heated to >55°C within 10 days. Sawdust composts without sand maintained these levels for more than 60 days meeting pathogen reduction guidelines. However, none of the straw-amended or sand bedded sawdust amended composts met the guidelines. All of the composts were stable after 100 days and exhibited manure volume and weight reductions relative to the initial manure. Initial compost C:N ratios ranged from 25:1 to 50:1 and the manure nitrogen lost during composting ranged from 2% to 38%. There was a negative correlation between initial compost C:N ratio and nitrogen loss (R^2=0.59). An initial C:N ratio of greater than 40 resulted in nitrogen losses less than 10% during dairy manure composting with all three bedding types.

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Introduction

Composting is becoming a popular alternative manure management method for dairy farmers. This process results in manure stabilization, mass and moisture reduction, and the reduction of pathogen levels (Willson and Hummel, 1975; Hong et al, 1983; Rynk et al., 1992; Haug, 1993; Lufkin et al, 1995; Lopez Real and Baptista, 1996; Keener et al., 2000; Wright and Inglis, 2002; Michel et al., 2002; Changa et al., 2003). The costs of the process can be often be offset by sales of compost off-farm. For example, composts can be sold for high value potting media mixes due to their ability to reduce diseases caused by soil borne plant pathogens (Hoitink and Fahy, 1986; Bollen, 1993; Hoitink and Boehm, 1999). Furthermore, as compared to raw manure and synthetic fertilizers, composted animal manures can reduce nutrient leaching when applied to agricultural fields (Pecchia, 1996; Leclerc et al., 1995). They can also be stored easily until value-added residential, organic or nursery markets provide an optimal price (Rynk et al., 1992; Hoitink et al., 1997; USDA, 2002; Michel et al., 2002). Raw or liquid stored manures, on the other hand, have limited uses, can be applied only to crop land just a few times during the year and are expensive to transport (Jongbloed and Lenis, 1998; James et al., 2004).

Dairy cows in freestall barns (1 Animal Unit=1000 lb) produce approximately 1986 kg of manure/AU/yr on a dry weight basis with a moisture content of 80-88% (Keener et al., 1999; James et al., 2004). Composting allows the entire manure stream to be treated without separation processes that multiply farm waste streams. Amendments must be added primarily to reduce its moisture content to the optimum range (60-65%) for composting (Rynk et al., 1991; Keener et al., 1999). Dairies use a variety of organic materials as bedding and compost amendments that principally include sawdust and straw (Ashfield, 1978; Rynk et al., 1992). Sand is also a popular bedding material. Compost amendments affect moisture content, free air space, decomposition rate, temperature, C:N ratio and oxygen concentrations during composting (Fraser and Lau, 2000; McCartney et al, 2002). Addition of amendments and the use of sand bedding also increases the amount of material that must be managed.

The design of composting systems for dairy farms has been hindered by the limited amount of information and knowledge about the mass and volume of compost produced relative to manure generated, the amount and properties of product (compost) remaining and available for sale at the completion of the process, and the impact of bedding/amendment types on composting rate, moisture loss, dry matter conversion, and nutrient loss, particularly that of ammonia (Barrington et al., 2002; Dewes, 1999; Bicudo et al., 2002; Gibbs et al, 2002). A better understanding of amendment effects should help farmers to design more rational systems for composting manures and optimize costs associated with their operation.

The objectives of this study were to compare the effects of the two most commonly used organic amendments (hardwood sawdust and wheat straw) and the use of sand bedding on the decomposition rate and overall mass, volume, carbon and nitrogen losses during full-scale windrow composting of dairy manure.

Methods

Feedstocks

Dairy manure (moisture content 83 ±3%) was obtained from the Ohio State University/Ohio Agricultural Research and Development Center (OARDC) dairy barn immediately after it was scraped from alleyways. Sand bedded manure was collected from a dairy farm that used approximately 0.22 lb wet sand/lb wet manure and was also prepared by adding sand to the OARDC manure described above. Straw (moisture content 10 ±3%) and hardwood sawdust (moisture content 9 ±3%) were used as amendments.

Windrow Composting

Compost windrows were prepared on four different occasions by mixing dairy manure with either sawdust (DM/SD1 to DM/SD4) or straw (DM/ST1 to DM/ST4). The windrows were formed on a ½ acre concrete composting pad with a 2% slope and a leachate collection system. The site was located on the Wooster campus of The Ohio State University. A feed mixing wagon with a load cell (accuracy within 4 kg) was used to weigh and blend the manure and amendments and determine the total initial and final windrow weights. Amendments were added to the manure to yield a mixture with a moisture content of approximately 65%. The sizes of the windrows were typical of those used on farms that utilize a tractor-pulled windrow turner. The cross sectional dimensions of the sawdust amended windrows averaged 2.9m x 1.2m (w x h) while those of the straw dairy manure windrows averaged 3.5m x 1.2m (w x h). The windrows ranged from 11 m (DM/SD3) to approximately 28 m in length (DM/SD1 and DM/ST1). Because of the time required to accumulate enough manure for each windrow, the manure was collected over four to seven days for each windrow. The final weights of the windrows were adjusted to account for the total weight of samples removed during the experiment.

Windrows were turned with a tractor-assisted, Aeromaster 120 windrow turner on days 1 and 4 during the first week and weekly thereafter through week 10. Thereafter, the windrows were turned once every two weeks for an additional six weeks (3 additional turns). Windrow DM/ST1 was turned again on day 135 and Windrow DM/SD1 on day 142 when final samples were removed. Samples were collected from windrows DM/SD2, DM/SD3, DM/SD4, DM/ST2, DM/ST3 and DM/ST4 after turning on day 116.

Laboratory Composting

Sand bedded manure (DM/S/SD) was composted in eight fully instrumented 200-liter laboratory reactors that simulated the windrows described above (Keener et al., 2000). Moisture content was varied by the addition of different amounts of hardwood sawdust amendment to a range of 50 to 65%. The compost was mixed weekly and removed when temperatures dropped to below 40 C.

Sampling

Three to six composite samples were collected on each windrow sampling day. Each sample consisted of approximately 20 liters of compost collected from a cross section of the windrow that was mixed thoroughly in a 120 liter (32 gal) container. Sub-samples of the composites were used for analyses. Reactor samples were taken after emptying and mixing the composts. The data presented are averages of composite measurements taken from replicate composters.

Chemical and Physical properties

Changes in chemical properties of the composts were monitored according to standard protocols specified by the US Composting Council (TMECC, 2002). Total nitrogen (N) and total carbon (C) analyses were performed with the Dumas combustion method (VarioMax N analyzer, Elementar Americas) (TMECC methods 04.02-D and 04.01-A). The detection limit for this instrument was 200 mg N kg-1. Total C was determined using coulometry. This instrument converts C in the sample to CO2 by oxidation at 1100°C. The detection limit was 1 mg C kg-1. Windrow length, width and height were measured using a tape measure and cross sectional area was estimated by observation of cross sectional geometry. Bulk density and free air space were measured by weighing a 21 l (5 gallon) volume of each composite sample. Water was added to replace the free air space and the sample was reweighed. Free air space was calculated assuming a water density of 1 g/cm3.

Temperatures were recorded at 3 locations along the length of each windrow prior to windrow turning at six points per location. Measurements were made at 1/3 and 2/3 depths on either side and from the top giving 18 data points per sampling time per windrow (Michel et al., 1996). Temperature data was collected 3 times per week using a hand-held 0.6m temperature probe. Oxygen concentrations were measured once per week (DM/ST1 and DM/SD1) or three times per week (DM/ST2-4 and DM/SD2-4) using a hand-held Teledyne Series 320 portable oxygen-analyzer (City of Industry, CA). Temperature was measured at three locations in reactors (Hansen et al., 1993).

Table 1. Mean chemical properties of initial dairy manure composts made from sawdust (DM) or sand bedded dairy manure (DM/S) amended with sawdust (SD) or straw (ST). Values reported are on a dry weight basis except moisture content which is on a wet weight basis.

Compost ID	Moisture (% wet)	Volatile Solids (%)	Total Carbon (%)	Total N (%)	C:N Ratio (g/g)	pH	Bulk Density (wet kg/m^3)
DM/SD1	65	91.3	46.4	1.4	32.9	8.8	380
DM/SD2	66	94.6	45.4	0.9	49.5	8.2	379
DM/SD3	65	93.5	45.5	1.0	45.5	7.8	387
DM/SD4	67	94.4	44.7	0.9	50.8	8.2	368
DM/ST1	67	82.9	44.1	1.8	25.1	8.2	54
DM/ST2	62	94.3	44.7	1.1	39.0	8.2	42
DM/ST3	53	94.2	43.7	1.2	35.2	6.4	39
DM/ST4	55	92.7	44.2	1.2	37.0	8.7	173
DM/S/SD1	54	73.6	36.1	0.7	54.0	7.3	411
DM/S/SD2	61	65.2	33.5	0.8	42.4	7.4	519
DM/S/SD3	61	60.7	31.8	0.8	38.5	7.4	590
DM/S/SD4	65	57.6	28.7	1.1	26.5	7.4	711

Results

Feedstock and Initial Compost Properties

The dairy manures without sand were mixed with the straw or sawdust amendments to give a moisture content of approximately 65% (Table 1). Sand bedded manure was amended with sawdust to give four different moisture contents ranging from an absolute moisture content of 65% (DM/S/SD4) to an ash free moisture content of 65% (DM/S/SD1).

Because of variations in N-content of the manures and the amount of sawdust amendment used, initial C:N ratios of the windrows ranged from 25:1 to 50:1 (Table 1).

Enough compost was prepared to form windrows of approximately 28 m in length. Due to effects of the two amendments on compost bulk densities, the total weight of material in the sawdust amended windrows was nearly twice that in the straw amended windrows of the same size. The sand bedded manure compost had initial bulk densities nearly an order of magnitude greater than the straw amended dairy manure composts and 40-60% greater than the sawdust amended windrows (Table 1) However, the amount of manure on a volume basis was similar to the amount in the sawdust amended windrows.

Weight and Volume Changes during Composting

Based on literature estimates of manure generation per animal unit (James et al., 2003) and the amount of bedding used in the dairy, straw and sawdust bedded manures were generated at a rate of 12,000 to 13,000 kg/AU/yr respectively (Fig. 1). After amendment addition, the total weight of these composts was 4000-5000 kg greater. The use of sand resulted in approximately 50% greater initial manure and compost weights on a per cow basis (Fig. 1).

After composting, the total weight of the compost decreased dramatically in all but one of the composts (DM/ST3). For example, windrow DM/SD1 decreased from 30,241 to 5,273 kg and windrow DM/ST1 decreased from 23,696 to 4,000 kg (Table 2). The percent mass loss ranged from 41-83% for the sawdust amended windrows and from 2 to 83% for the straw-amended windrows. Weight losses for the sand bedded manure composts ranged from 22 to 32%.

Because of heavy rainfall, moisture content increased in one of the straw amended windrows (DM/ST4). In all four of the sawdust amended composts, 2 of the 4 straw amended composts, and 3 of 4 of the sand bedded manure composts the final compost weight was less than that of the original manure (Fig. 1). This contrasts with liquid manure systems where the weight of manure increases substantially compared to that removed from the barn due to the addition of water to improve manure flow and settling properties.

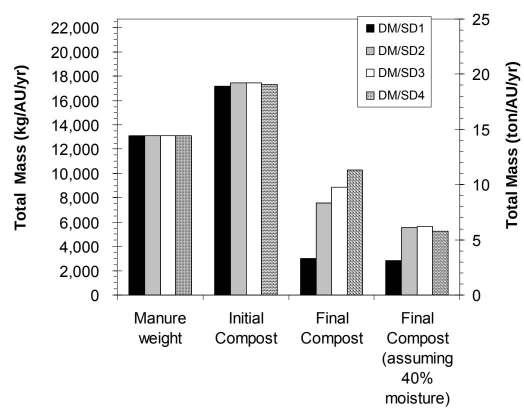
Substantial changes in volume occurred in all of the composts. The sawdust-amended windrows lost 33-79% of their initial volumes, while the straw-amended windrows lost even more (65-93%) of their initial volumes. The sand bedded manure composts lost 8 to 26% of their initial volumes during composting. Dry weight losses ranged from 44 to 72% for sawdust amended and from 54-76% for straw amended windrows (Table 2). Bulk density and free air space changed considerably in the straw amended windrows (DM/ST1 to DM/ST4) but remained relatively constant in the sawdust amended windrows and sand bedded manure composts (DM/SD and DM/S/SD composts). This change contributed to a much greater volume loss observed in the straw amended as compared to comparable sawdust amended windrows made on the same dates (Table 2).

Temperature and Oxygen Concentration

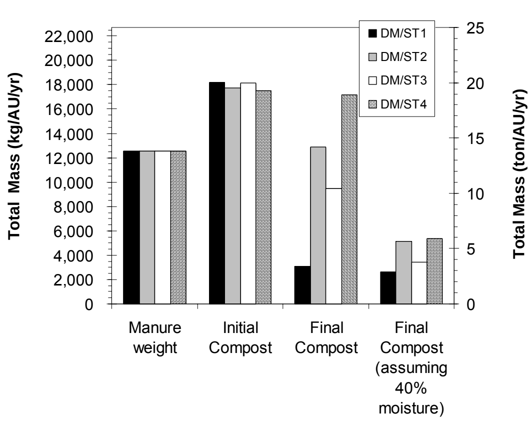
Straw and sawdust amendments and sand had very different effects on compost temperatures (Fig. 2). All of the sawdust-amended manure composts (DM/SD and DM/S/SD) reached temperatures greater than 55°C (131 F) after 3 to 10 days. However temperatures in sand bedded manure composts dropped quickly to below 50° C after 20 days while sawdust bedded manure composts maintained temperatures in a narrow range between 50º and 70°C past day 50 (Fig. 2). By contrast, only two of the straw-amended manure composts (DM/ST1 and DM/ST3) exceeded temperatures of 55º C and this did not occur until after 40 and 70 days of composting (Fig. 1). In addition, in straw amended windrows, temperatures fluctuated greatly (10º - 60°C) throughout the composting period (Fig. 2). The straw-amended composts cooled down rapidly after day 80, and sooner than the sawdust bedded and amended composts which exhibited temperatures greater than 50º C. through day 100 (Fig. 2).

Figure 1. Quantities (wet weight) of manure, initial compost, final dairy manure compost and final compost assuming 40% moisture content generated per 1000 lb animal unit (AU/yr). Compost was made from manure from freestall farms using straw (A), sawdust (B) or sand (C) as bedding. Compost amendments used were straw (A) and sawdust (B and C). Values were calculated based on initial and final compost weights and assuming a manure generation rate (including bedding) of 2134 (straw bedded), 2219 (sawdust bedded) or 4691 (sand bedded) kg dry manure/AU/yr.

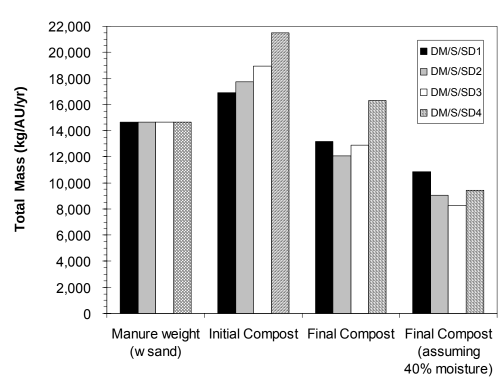
B. Straw bedded



A. Sawdust bedded



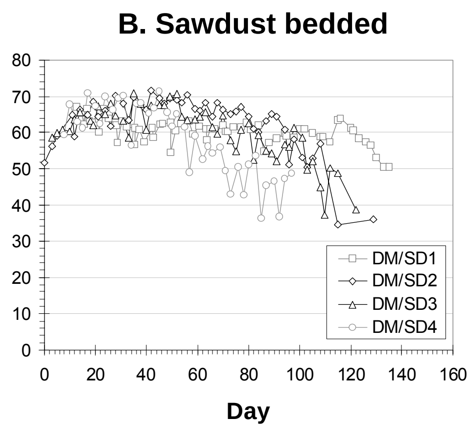
C. Sand bedded + Sawdust

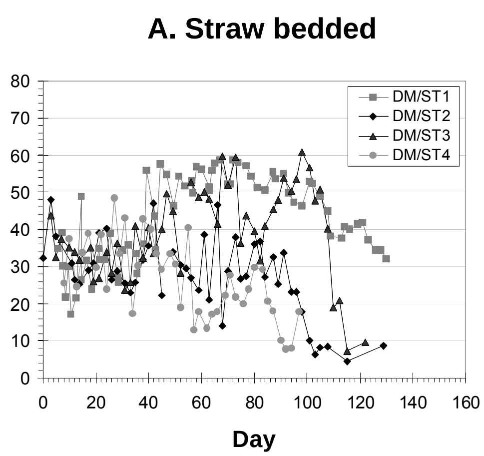


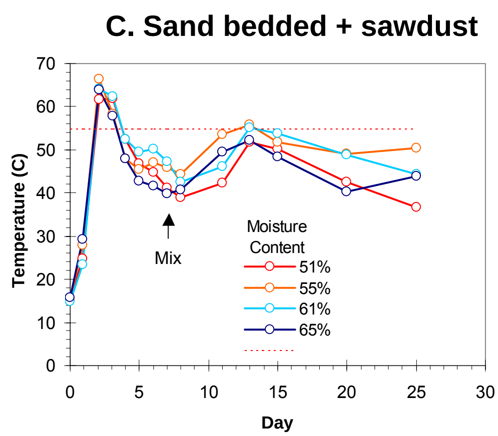
Physical and Biochemical Properties

Composting resulted in increases in nitrogen concentrations and decreases in volatile solids, dry weight and total N (Table 2). Volatile solids losses during composting were substantial. From 46 to 76% of the VS were lost from the sawdust amended and from 58 to 81% from the straw amended windrows (Table 2). Only 24 to 48% VS losses were observed from the sand bedded manure composts. The moisture content increased depending on rainfall and amount of water added during turning. Water losses due to evaporation and leaching were greatest in sawdust amended windrows. A mass balance analysis on nitrogen indicated that the sawdust-amended composts lost 8-26%, straw amended windrows lost 15 to 43% and sand bedded composts lost 1 to 17% of the initial nitrogen (Table 2).

Figure 2. Mean temperatures (ºC.) during composting of dairy manure. Compost was made from manure from freestall farms using straw (A), sawdust (B) or sand (C) as bedding. Compost amendments used were straw (A) and sawdust (B and C). Lines represent replicate experiments.







Discussion

The results of this study demonstrate the changes that occur during composting of dairy manure and provide useful information for the design and sizing of full-scale dairy manure composting facilities. This includes the amount of manure generated, the initial moisture content of the manure, the quantities of amendment required, the extent of bulk density, and volume, wet and dry matter and nitrogen losses during composting.

This information is critical to the sizing and design of composting systems for dairies and is not widely available in the literature.

The results clearly show that overall carbon and nutrient losses during composting were similar for straw and sawdust amendments, the two amendments most commonly used by farmers (Tables 2 and 3). However there were clear differences during composting using the two different amendments and in manure with sand bedding. One difference was that the two amendments and the initial composts made using them had very different bulk densities (Fig. 3). As a result the initial sawdust amended windrows contained on average 935 ±184 (kg manure/m) (and sand bedded dairy manure composts would contain approximately 1000 kg manure/m) while the straw amended windrows contained just 377 ±109 (kg manure/m). These differences resulted in windrows 2.5 times longer on average when straw versus sawdust amendment was used. This difference translated into a significantly increased compost pad size requirement for straw and, ultimately, to an increase in composting capital and operating costs. However, actual pad size requirements also depend on decomposition rates, compost retention times and the ability to build windrows of larger cross-sectional areas. The high free air space of the straw windrows, low initial process temperature, and high observed oxygen concentrations indicate that larger windrows could be built with straw than sawdust. Unfortunately, the dimensions of turning equipment often limit windrow size.

Table 2. Overall weight, volume, volatile solids, nitrogen losses during dairy manure (DM) composting with sawdust (SD) or straw (ST) amendments and sand bedded dairy manure with sawdust (DM/S/SD).

Windrow ID	Volume Loss	Wet Weight Loss	Dry Weight Loss	Water Loss	Volatile Solids Loss	Total Nitrogen Loss
DM/SD1	79%	83%	72%	89%	76%	26%
DM/SD2	40%	57%	44%	63%	46%	8%
DM/SD3	36%	49%	54%	47%	55%	24%
DM/SD4	33%	41%	46%	38%	48%	7%
DM/ST1	93%	83%	74%	88%	81%	43%
DM/ST2	65%	27%	54%	11%	58%	15%
DM/ST3	86%	48%	76%	22%	80%	38%
DM/ST4	71%	2%	59%	-45%	63%	27%
DM/S/SD1	8%	22%	26%	27%	24%	10%
DM/S/SD2	19%	32%	22%	35%	36%	2%
DM/S/SD3	23%	32%	33%	28%	48%	1%
DM/S/SD4	24%	24%	23%	18%	42%	17%

Values reported are losses as a percent of the initial compost quantity and were calculated using total weight, moisture and nutrient concentrations. All values are on a dry weight basis except wet weight and water.

Substantial differences in windrow temperatures were observed with straw versus sawdust amended windrows (Fig. 2). All of the sawdust but none of the straw amended windrows reached temperatures required to meet guidelines for pathogen destruction during composting (USEPA, 1989; USDA, 2002). Both the EPA and USDA Organic Program rules state that, “producers using a windrow system must maintain the composting materials at a temperature between 131 F and 170 F for 15 days, during which time, the materials must be turned a minimum of five times”.

The differences in temperature profiles may be related to differences in free air space and the initial resistance of straw to biodegradation. The straw-amended windrows all had higher initial free air space values (76-95%) than the sawdust-amended windrows (62-66%) (Fig. 3). The higher free air space in the straw-amended compost may have allowed for greater convective air flow through the windrow leading to greater heat loss and a lower rate of temperature increase (Fig. 1). This increased airflow may also have contributed to greater variations in temperatures recorded in the straw-amended windrows (Fig. 1).

The straw amended windrows DM/ST2, DM/ST3 and DM/ST4 also had low initial moisture contents (53-62%) that may have been suboptimal for organic matter decomposition. As the bulk density of straw-amended windrows DM/ST1 and DM/ST3 began to increase and the straw lost its structure, higher temperatures (> 50º C) were maintained and a decrease in oxygen concentrations was observed (Figs. 2). However, two of the straw amended windrows did not reach temperatures above 50º C during the entire composting process (DM/ST2 and DM/ST4). These straw amended composts also exhibited the smallest changes in volume, bulk density and free air space (Table 2). A contributing factor may have been that these two windrows exhibited high initial C:N ratios (39 and 50, respectively) that decreased the rate of organic matter decomposition as well. It is not known how the sand would affect the temperatures observed in a windrow as opposed to a reactor vessel.

A large reduction (65-93%) was observed in the volumes of the straw-amended windrows (DM/ST1 to DM/ST4) while sawdust showed somewhat less volume losses of 33 to 79% (Table 2). Sand bedded composts (DM/S/SD) showed volume losses of only 8 to 24% (Table 2). Factors contributing to this effect were probably physical chopping of the straw by the windrow turner initially and extensive decomposition of the straw during the process that further reduced windrow free air space and increased bulk density. The small particle size of the sawdust and initially higher bulk densities of the windrows made with sand bedded manure resulted in less volume reduction.

A mass balance on the manure removed from the dairy barn through the composting process showed that composting reduced the mass of material that must be transported by the farmer even when the addition of amendments is considered (Fig. 1). Dairy cows (one animal unit [AU] = 1000 lbs) usually generate approximately 1986 kg of dry manure per year (James et al., 2004). A small amount of bedding (0.2 ft^3/cow/dy) is kicked into alleyway by the cows. At a moisture content of 83% (Table 1), this translates into 12,555, 13,056 and 14,632 kg wet manure/AU/yr for straw, sawdust and sand bedded cows, respectively. When this manure was composted, the amount of stable compost generated from one dairy animal unit ranged all the way from 2606 to 10,871 kg wet/yr depending on the bedding and amendment used. On a volume basis this equals 9 to 29 m^3/AU/yr for sawdust and from 15 to 42 m^3/AU/yr for straw amended composts. In six of the eight windrows without sand bedded manure, the weight of stabilized compost produced was less than 55% of that of the manure removed from the barn, even when considering the amendments and precipitation inputs (Fig. 1A and B). The decrease in weight during the composting process was caused by loss of moisture and volatile solids. In the best cases for straw and sawdust amendments ((DM/SD1 and DM/ST1) an 83% mass reduction was realized (Table 2). In one case, moisture mismanagement led to an increase in water weight in the compost (DM/ST4) after composting. This could have been avoided by the use of covers (Lufkin et al., 1995) that would have resulted in much lower final moisture contents. This finding illustrates the difficulty of maintaining optimal moisture contents during outdoor composting. Assuming that moisture management was more optimal and that all of the windrows had final moisture contents of 40%, then a weight decrease of more than 60% (compared to the manure removed from the barn) would have been realized in all eight non-sand windrows (Fig. 1A and B). This translates into a 50-80% reduction in the weight of material that must be transported and applied during utilization to provide the same amount of nitrogen as the original manure. This finding is especially important when considering the distances that farmers must transport manure for land application and for comparisons with liquid manure handling systems where water is added to improve flow properties resulting in major increases in the weight of manure as well as transportation costs (NRAES, 2001). By contrast, the weight of the final sand bedded manure composts was nearly as great as that of the manure removed from the barn when sawdust or straw was used as bedding (Fig. 1C). The reduced weight and the stability of composts, as compared to liquid manures, also means that the compost can be stored and transported more easily to distant nursery and residential value-added markets. The costs and availability of amendments and labor costs associated with composting may offset some of these benefits, however.

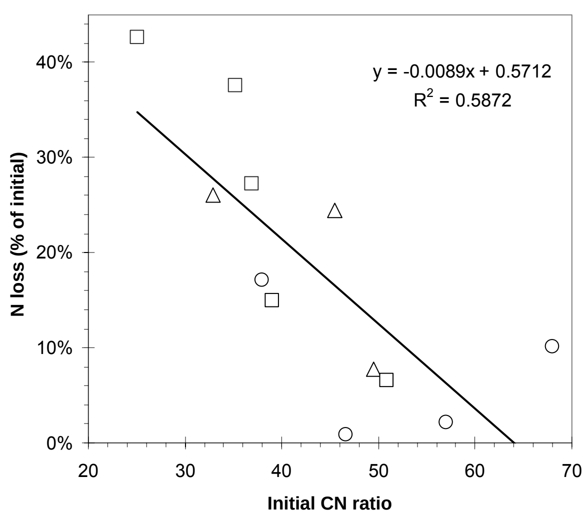


Figure 3. Relationship between initial C:N ratio of dairy manure composts and nitrogen losses during composting. Values are averages for 2 to 6 replicate samples. Symbols: □ -DM/SD, Δ -DM/ST, o -DM/S/SD.

Nitrogen loss is an important consideration during composting for two reasons: nitrogen is a valuable nutrient that improves compost fertility and atmospheric nitrogen emissions, in the form of ammonia and nitrous oxides, are linked to a variety of adverse environmental and health effects. Future clean air rules may limit ammonia and greenhouse gas emissions from farms (Bicudo et al. 2002). Manures contain high levels of ammonia (Table 1) and nitrogen loss is usually attributed to ammonia volatilization and leaching (Dewes, 1999; Barrington et al., 2002; Gibbs et al., 2002; Eghball et al., 1997) and to nitrous oxide and nitrogen volatilization (He et al, 2002: Veeken et al., 2002). Nitrogen losses occur during many phases of manure handling including during accumulation and storage in the barn, during removal, mixing, processing and finally during and after land application. It is difficult to compare overall nitrogen losses from different manure handling systems to minimize ammonia losses (Gibbs et al., 2002) since in some systems the majority of the losses occur during land application (liquid manure and anaerobic digests) while for others it occurs during processing and storage (solid storage and composting). Some aspects of the composting process such as high temperatures, convective aeration (Michel et al., 1996), high porosity (Veeken et al., 2002; Lopez-Real and Baptista, 1996), and pH values (>8.0) as compared to liquid manures, would be expected to facilitate ammonia volatilization from composts (Dewes, 1999). For example, nitrogen losses ranging from 35 to 75% have been reported during composting of hog manure (Veeken et al., 2002; Michel et al., 2001; Barrington et al. 2002) and from 9 to 68% during the composting of cattle manure (Gibbs et al., 2002; Eghball et al., 1997). However, Dewes (1999) showed that lower overall emission of ammonia occurs over long periods when manure is composted than when it is stored as a liquid due to biological immobilization of nitrogen. In addition, denitrification can result in substantial quantities of nitrogen loss via nitrous oxides and/or nitrogen gas from oxygen-limited areas of a compost pile (Veeken et al., 2002 and He et al 2002).

Results of this study indicate that as little as 2% and as much as 43% of the total initial nitrogen was lost during dairy manure composting using two different amendments (Table 2). The initial C:N ratio of the composts, which varied from 25:1 to 51:1, correlated significantly and linearly (R^2=0.59) with the loss of total Nitrogen (Fig. 3). For example, compost with a starting C:N ratio of 25 (DM/ST1) lost 32% of its initial nitrogen, while two windrows with starting C:N ratios of 50 (DM/SD2 and DM/SD4) lost only 8% and 7%, respectively (Fig. 3). The C:N ratio has also been shown to be an important factor for minimizing nitrogen loss during the composting of poultry manure (Hansen et al., 1993; Ekinci et al., 1997; Ekinci et al., 2002) yard trimmings (Michel and Reddy, 1998) and cattle manure (Eghball et al., 1997). However, in studies where large percentages of nitrogen were lost, initial C:N ratios were relatively low (Tiquia et al., 2002; Gibbs et al, 2001; Michel et al., 2001). This indicates that there may be a potential to manipulate windrow C:N ratios to substantially reduce nitrogen volatilization during manure composting. To minimize nitrogen loss during dairy manure composting, it may be advisable to prepare composts with initial C:N ratios of 40:1 to 50:1.

Conclusions

- Dairy manure composting with sawdust and straw led to extensive reductions in manure volume and weight even after considering the weight of the added amendments. Sand bedded manure composting resulted in more modest weight and volume reductions. Many farmers haul manures up to 10 km (6 miles) from their farm to avoid over-applying nutrients and reduce water pollution. By using organic bedding and composting, farmers could reduce the volume and weights to be hauled by 50 to 80%, based on equivalent nitrogen values as compared to unamended raw dairy manure.

- The initial sawdust amended windrows (with and without sand) contained 935 to 1000 (kg manure/m) while the straw amended windrows contained 377 (kg manure/m). This difference resulted in windrows 2.5 times longer on average when straw versus sawdust amendment was used. Straw amendment resulted in greater volume decreases than sawdust due to greater changes in bulk density and free air space and higher oxygen concentrations in the windrow which meant that larger windrows could potentially have been used.
- None of the straw amended or sand bedded composts reached pathogen guidelines of >55º C for 15 days despite exhibiting extensive volume and volatile solids losses as well as physical changes. Increasing windrow size may solve this problem.
- All sawdust-amended composts reached temperatures >55 C in less than 10 days and maintained these temperatures for more than 60 days thereby meeting pathogen and weed seed destruction guidelines for windrow composting.
- Moisture management is critical to attaining manure weight reductions during composting. Rainfall and moisture adjustments can result in composts with moisture contents greater than the starting material (Fig. 1). Once the compost is stable, self-heating is not available to fuel evaporation of this excess moisture. Therefore, covers, larger curing piles or barn storage should be used as composts become stable to assure that excess moisture does not accumulate in stabilized composts and that final composts have moisture contents of 40% or lower.
- From 2% to 43% of the initial total nitrogen was lost during composting. There was a significant negative correlation between initial C:N ratio and nitrogen loss (R^2=0.59) during composting. To minimize nitrogen loss during dairy manure composting with sawdust or straw amendments, a C:N ratio of 40:1 to 50:1 is recommended.

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