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Effects of bedding type on compost quality of equine stall waste: Implications for small horse farms

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ABSTRACT: Our objective in this study is to compare 4 of the most common bedding materials used by equine operations on the chemical and physical characteristics of composted equine stall waste. Twelve Standardbred horses were adapted to the barn and surrounding environment for 2 wk before the start of the study. Groups of 3 horses were bedded on 1 of 4 different bedding types (wood shavings, pelletized wood materials, long straw, and pelletized straw) for 16 h per day for 18 d. Stalls were cleaned by trained staff daily, and all contents removed were weighed and stored separately by bedding material on a level covered concrete pad for the duration of the study. Compost piles were constructed using 3 replicate piles of each bedding type in a randomized complete block design. Each pile was equipped with a temperature sensor and data logger. Water was added and piles were turned weekly throughout the 100-d compost process. Initial and final samples were taken, dried, and analyzed for DM mass, OM, inorganic nitrogen (nitrate-N and ammonium-N), electrical conductivity, and soluble (plant-available) nutrients. Data were analyzed using the GLM procedure, and means were separated using Fischer's protected LSD test ($P < 0.05$). No significant temperature differences were observed among the bedding materials. The composting process resulted in significant reductions ($P < 0.05$) in DM mass for each of the 4 bedding materials. The composting process resulted in significant reductions ($P < 0.05$) in OM and C:N ratio for all 4 bedding materials. The composted long straw material had greater concentrations of total Kjeldahl nitrogen ($P < 0.05$), nitrate-N ($P < 0.05$), and ammonium-N ($P < 0.05$) than the composted wood shavings. This study demonstrated that incorporating a simple aerobic composting system may greatly reduce the overall volume of manure and yield a material that is beneficial for land application in pasture-based systems. The straw-based materials may be better suited for composting and subsequent land application; however, factors such as suitability of the bedding material for equine use, material cost, labor, and availability must be considered when selecting a bedding material.

Key words: bedding, compost, equine, manure, nitrogen, stall waste

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INTRODUCTION

A typical 455-kg horse produces 0.023 m^3 of manure per day weighing more than 22.7 kg (USDA-NRCS, 2000). In addition to manure, stall waste includes bedding materials, which varies based on individual management, but has been found to range from 2.7 kg per day for wood shavings to 3.1 kg per day for straw (Komar et al., 2010). Thus, caring for a single horse may result in more than 9,400 kg of waste material annually. Composting of this waste material is a handling technique for small equine operations. It provides many benefits including reduced haulage requirements, significant reductions in mass, and increased nutrient concentrations (Larney et al., 2006, 2008).

Research has found that the physical and chemical characteristics of different bedding materials may have an effect on the volume of stall waste generated on-farm. Barley straw and wood shavings contain similar content of cellulose and hemicellulose. However, the greater carbon content present as lignin makes wood bedding materials less biodegradable than straw bedding (Larney et al., 2008). Larney et al. (2008) found significant differences in the initial properties of beef cattle manure bedded on straw and wood shavings including C:N ratio, total nitrogen, and total carbon. Various studies have reported greater volume loss with composted straw bedding compared with wood shavings (Michel et al., 2004; Larney et al., 2008). Compost quality is affected by the chemical composition of the manure and bedding materials (Rynk, 1992; Haug, 1993; Swinker et al., 1998; Airaksinen et al., 2001).

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Much of the research comparing the impact of bedding materials on compost quality has been conducted using beef and dairy waste. Limited research has been conducted using various bedding types on composted equine stall waste. Therefore, our objective of this study was to compare 4 common bedding materials used by equine operations and evaluate the impact that each have on the chemical and physical characteristics of composted equine stall waste.

MATERIALS AND METHODS

Evaluation of the chemical and physical characteristics of 4 equine stall bedding materials following an aerated composting process was conducted at the Rutgers Equine Science Center in New Brunswick, New Jersey. All methods and procedures used in this experiment were approved by the Rutgers University Institutional Animal Care and Use Review Board.

Manure Collection

Twelve Standardbred horses (aged 9.8 ± 3.6 yr) were used for this experiment. These horses were adapted to the barn and surrounding environment for 2 wk before the start of the study. Groups of 3 horses were bedded on 1 of 4 different bedding types for 16 h per day for 18 d. The bedding materials included pelletized wheat straw (Streufex, Fex Straw Manufacturing Inc., Lumberton, NC), long rye-straw, pine wood shavings, and pelletized hard wood (Woody Pet, Woody Pet Products Inc., Surrey, British Columbia, Canada). Horses were provided with free choice grass hay and water, and fed 2 meals of pelletized grain (1 kg/d). For the remaining 8-h period, horses were housed in groups of 6 in 0.8-ha dry lots and fed free-choice grass hay. Horse stalls were cleaned by trained staff daily at 0800 h. All manure and soiled bedding were removed by hand using a stall pick fork. All contents removed from stalls were weighed on a calibrated electronic scale and stored separately by bedding material on a level, covered, 15 × 2.3 m, concrete pad for the duration of the collection period.

Compost Management

Compost piles were constructed on May 13, 2009. Three replicate piles of each of the 3 bedding materials were constructed and placed in a randomized complete block design. Initially each pile consisted of 272 kg of manure plus bedding (fresh weight). Piles were formed by placing approximately 1 m^3 of stall waste in 1.2 × 1.8 m stalls constructed on the east side of the pad. Stalls were constructed with 2.54-cm-thick plywood walls separated by a 15-cm void to ensure thermal isolation between piles. Due to density differences between materials, pile volumes varied. Each pile represented approximately 10 d of stall waste generation for an average horse. Each pile was equipped with a Campbell Scientific 108 L Temperature Sensor (Campbell Scientific Inc., Logan, UT) that measured the temperatures in each pile hourly and saved the measurements to a Campbell Scientific CR10X Datalogger. Thermocouples were placed in the center of each pile and were removed before and replaced immediately after each turning. Piles were turned weekly throughout the experiment by completely inverting each pile with a skid steer loader. Water (18.95 L) was added weekly by hand via a measured vessel to maintain approximately 50% moisture in each pile. At each turning event, piles were knocked down and spread horizontally; water was then added to the center of each pile and was mixed thoroughly to ensure complete uniformity. The composting process was terminated on d 100 (August 20, 2009).

Physical Analyses

Stall waste was sampled at the initiation of the composting process and at the termination of the experiment using a modified compost pile sampling procedure similar to Larney et al. (2008). A vertical cut was made in the center of each compost pile with a shovel, exposing 2 vertical faces across the center of each pile. Grab samples were taken from the top, center, and bottom of each exposed surface. These samples were mixed thoroughly, and a 1-kg composite sample was taken for analysis.

Samples were oven-dried at 60°C for 3 d to determine water content. The DM mass reduction during composting was determined by weighing each replicate at the termination of the field study and sampling each pile using pile sampling method described previously. Total DM mass reduction was expressed as a percentage of the initial mass.

Chemical Analyses

Stall waste samples were analyzed at the Rutgers University Soil Testing Laboratory (New Brunswick, NJ). Subsamples were immediately refrigerated before nitrogen analysis. Samples were analyzed for inorganic nitrogen (nitrate-N and ammonium-N), electrical conductivity, and soluble (plant-available) nutrients including phosphorous and potassium. Nitrate and ammonium in solution were analyzed using continuous flow chemistry and photometer detection (Bolleter et al., 1961; Kamphake et al., 1967). A standard electrical conductivity bridge was used to determine conductivity of the solution, a measure of soluble salts. Available nutrients were extracted using a saturated media extraction procedure. Samples were processed by adding deionized water just to the point of saturation. After an equilibration period, the solution was extracted under vacuum from the solid fraction. The solution was analyzed for available plant nutrients, including phosphorus and potassium, using a direct current plasma spectrophotometer (Warnke, 1995). Separate subsamples of each compost sample were dried at 105°C to be used for OM/organic carbon determination and total

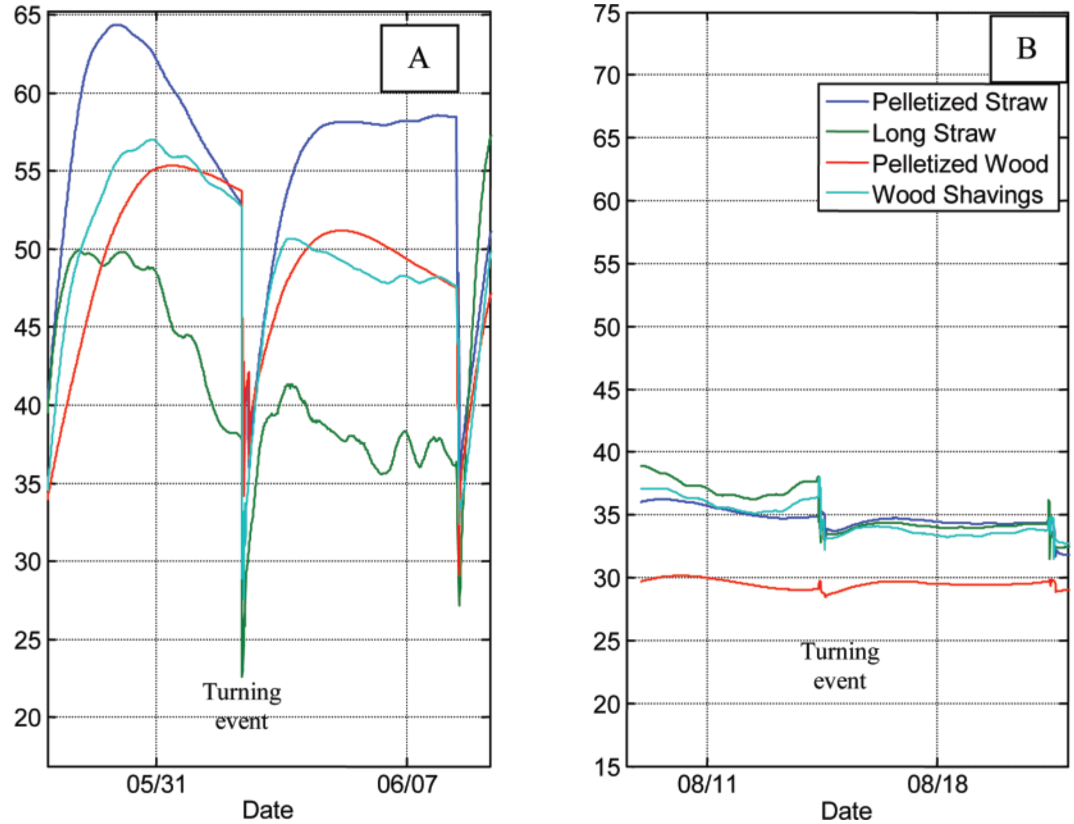

Figure 1. Initial and final average treatment temperature (°C) for 4 different bedding types during the first 2 wk (A) and the last 2 wk (B) of the 100-d compost process.

Kjeldahl nitrogen (**TKN**) analysis. Organic matter was determined by weight loss on ignition at 400°C; organic carbon was calculated assuming OM is 58% organic carbon. A micro-Kjeldahl digestion of each compost sample resulted in solutions that were analyzed for ammonium-N (Bremmer, 1965).

Statistical Analysis

Treatments were arranged in a randomized complete block design with 3 replications of each of the 4 bedding materials. Data were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC) with fixed effects being bedding type and random effects being the replicate sample (initial vs. final). Means were separated using Fisher's protected LSD test ($P < 0.05$).

RESULTS AND DISCUSSION

Temperature

The temperatures of all treatments reached their maximum values between May 29, 2009 (d 16) and June 2, 2009 (d 18; Figure 1). No significant differences were observed among bedding materials. Mean high temperatures for the pelletized straw and long straw reached 65 and 53.9°C, with SD of 3.1 and 2.4°C respectively, whereas the pelletized wood and wood shavings reached 55.4 and 57°C with SD of 3.8 and 3.1°C, respectively. All treatments except pelletized wood remained increased relative to ambient temperature throughout the extent of the study. These maximum temperatures were less than those reported for similar studies in which temperatures reached as high as 73.8°C (Larney et al., 2008). Of the 4 treatments, only the pelletized straw reached the optimum temperature of 55°C for 15 d to meet US Environmental Protection Agency guidelines for microbial degradation (USEPA, 1992).

Pile Mass

The fresh weight of each pile was initially 272 kg. Moisture content of each material was used to calculate the DM mass (Table 1). The composting process resulted in significant reductions in DM mass for all 4 bedding materials. Although there were no observed differences in the percent reduction or the initial mass between the bedding materials, significantly decreased ($P < 0.05$) final mass was observed for both straw-based materials compared with the wood-based materials after composting. These results differ from Larney et al. (2008) who reported significantly greater losses for straw bedded beef cattle manure compared with wood shavings after 124 d of composting. Similar results were also reported by Michel et al. (2004) who reported reduced volume loss for sawdust bedded dairy cattle compost compared with straw bedding. Factors such as decreased initial pile mass and sampling vari-

Table 1. Dry matter mass changes and OM during the composting process of 4 different bedding types

Item	Initial, kg	Final, kg	Reduction, %	*P*-value[1]
DM mass				
Pelletized straw	127[a]	65[b]	49[a]	0.001
Long straw	118[a]	65[b]	34[a]	0.04
Pelletized wood	135[a]	88[a]	34[a]	0.01
Wood shavings	135[a]	80[a]	40[a]	0.004
SEM	13.7	7.8	11.5	
OM	Initial, %	Final, %		
Pelletized straw	89[a]	79[ab]	10[ab]	0.0003
Long straw	89[a]	73[a]	16[a]	<0.0001
Pelletized wood	95[c]	88[c]	7[b]	0.006
Wood shavings	92[b]	85[bc]	7[b]	0.003
SEM	0.74	1.91	1.49	

[a–c]Means in each column followed by different superscripts are significantly different according to Fischer's protected LSD ($P < 0.05$).

[1]*P*-values indicate differences between initial and final sampling within bedding types.

ability between the replicated piles may have affected the mass reduction reported in this study.

OM

Initial OM was greater ($P < 0.05$) for the 2 wood products than the straw products, whereas the pelletized wood was greater ($P < 0.05$) than the wood shavings (Table 1). The composting process resulted in significant reductions in OM for all 4 bedding materials. The long straw experienced greater reductions ($P < 0.05$) than the wood products; however, the difference between the pelletized straw and the wood products was not significant. Of the 4 composted materials, the pelletized wood had the greatest final OM, whereas the long straw had the least. This is due, in part, to the hardwood species used to make the wood pellets. Organic matter reduction has been suggested to be indicative of compost stability (Benito et al., 2003). However, other research suggests that the degree of humification and microbiological factors are better suited to evaluate the stability of compost where greater ligno-cellulosic materials are used (Mondini et al., 2006).

Carbon-to-Nitrogen Ratio

Significant differences in C:N ratio were observed at the initiation of the composting process (Table 2). The pelletized straw bedding had a greater ($P < 0.05$) initial C:N ratio than the long straw bedding. Both pelletized materials had greater initial C:N ratios compared with the raw materials. Similar results were reported by Larney et al. (2008), who found greater initial C:N ratios in a wood bedding than in a straw bedding. Composting resulted in significant reductions in final C:N ratio for all bedding materials. At the conclusion of the composting cycle, both the pelletized straw and the long straw material had significantly reduced C:N ratios compared with the wood bedding materials ($P < 0.05$). However, there were no differences in the reductions of C:N ratio between bedding. This is supported by Larney et al. (2008), who found that wood materials had a greater C:N ratio than a straw bedding after composting. The significant reduction in final C:N ratio suggests that composting occurred in all treatments.

Nitrogen

Initial TKN values varied for the 4 bedding materials. No measurable nitrate-N was found for any bedding material at the beginning of the composting cycle. Significant differences in ammonium-N were not observed at the start of the composting process (Table 3). This is similar to Larney et al. (2008), who found initial ammonium-N was similar for both straw and wood bedding materials at the initiation of a similar

Table 2. Carbon-to-nitrogen ratio changes during the composting process for 4 bedding types

Bedding material	Initial	Final	Change	*P*-value[1]
Pelletized straw	74[ab]	28[a]	46[a]	<0.0001
Long straw	55[c]	27[a]	28[a]	<0.0001
Pelletized wood	88[a]	49[c]	39[a]	<0.0001
Wood shavings	69[bc]	40[b]	29[a]	<0.0001
SEM	3.95	2.95	3.32	

[a–c]Means in each column followed by different superscripts are significantly different according to Fischer's protected LSD ($P < 0.05$).

[1]*P*-values indicate differences between initial and final sampling within bedding types.

Table 3. Nitrogen fraction changes during the composting process of 4 different bedding types

Item	Initial	Final	Change	*P*-value[1]
TKN,[2] %				
Pelletized straw	0.71[bc]	1.72[ba]	1.01[b]	<0.0001
Long straw	0.94[a]	1.55[a]	0.61[ab]	0.0002
Pelletized wood	0.63[c]	1.05[b]	0.42[a]	0.004
Wood shavings	0.78[ba]	1.22[ba]	0.44[a]	0.003
SEM	0.04	0.09	0.09	
Nitrate-N, mg/kg				
Pelletized straw	0.00[a]	0.20[ba]	0.20[ab]	0.03
Long straw	0.00[a]	0.36[a]	0.36[b]	0.0004
Pelletized wood	0.00[a]	0.04[b]	0.04[ab]	0.63
Wood shavings	0.00[a]	0.28[ba]	0.28[a]	0.004
SEM	0	0.05	0.05	
Ammonium-N, mg/kg				
Pelletized straw	10.10[a]	6.55[ba]	−3.55[a]	0.57
Long straw	14.59[a]	8.87[a]	−5.72[a]	0.37
Pelletized wood	13.52[a]	1.58[b]	−11.94[a]	0.07
Wood shavings	17.06[a]	5.10[ba]	−11.96[a]	0.07
SEM	2.65	1.05	2.62	

[a–c]Means in each column followed by different superscripts are significantly different according to Fischer's protected LSD ($P < 0.05$).

[1]*P*-values indicate differences between initial and final sampling within bedding types.

[2]TKN = total Kjeldahl nitrogen.

study. During the composting process TKN concentrations increased ($P < 0.05$) for all of the materials. Nitrate concentration increased ($P < 0.05$) in each of the materials with the exception of the pelletized wood. Increased nitrate-N is often associated with nitrification, which is a step in the degradation of OM during aerobic composting (Fauci et al., 1999). This is supported by this research where significant reductions in OM were also observed. No statistically significant ammonium-N reductions were observed.

On d 100, at the conclusion of the composting cycle, the only significant material difference was between long straw and the pelletized wood product. The composted long straw material had greater concentrations of TKN ($P < 0.05$), nitrate-N ($P < 0.05$), and ammonium-N ($P < 0.05$) than the composted wood shavings. Ammonium-N did not decrease significantly during the composting cycle for any bedding materials, indicating that ammonium-N was not completely converted to nitrate-N via nitrification or that the OM was not completely degraded during the composting process. Although not found to be significant in this study, numerical differences were observed in ammonium-N reduction with both wood materials resulting in greater numerical reduction in ammonium-N. The reduced final ammonium-N concentrations were not accompanied by increased nitrate-N concentrations in the pelletized wood material, suggesting that the losses may be associated with volatization during the thermophillic composting phase. Similar results were reported by Paré et al. (1998), who found a decline in ammonium-N that was not accompanied by an increase in nitrate-N during the initial 33 d of composting. Further research is needed to better quantify nitrogen transformations during composting of equine manure. The relative stability of nitrogen can be an indicator of the suitability of a bedding material for composting and ultimately as a soil amendment for agronomic crop production.

Phosphorus

Phosphorous concentrations measured in each of the bedding materials were similar at the start of the composting cycle (Table 4). Statistically significant changes in concentration were not observed during the composting cycle and the phosphorus concentrations measured in final composted material were similar for all bedding materials. It is however, important to note that a great deal of variation was observed in all of the phosphorus measurements. The lack of any significant impact on phosphorus concentrations from composting is not surprising because most of the changes seen in phosphorus concentrations are attributed to runoff or leaching (Larney et al., 2008), and this study was conducted under a roofed structure and water was provided in small volumes, making runoff losses a minor consideration.

Potassium

Potassium concentrations were similar for all bedding materials at the start of the composting process (Table 4). Among treatments, straw bedding was the only material to significantly increase potassium concentration during composting ($P = 0.03$). No differences were observed between the straw-based bedding materials. The only difference among beddings was that straw was greater ($P < 0.05$) at final than pelletized wood. It is possible that the numerical increase in available

Table 4. Phosphorus and potassium changes during the composting process of 4 bedding types

Item	Initial, mg/kg	Final, mg/kg	Change, mg/kg	P-value[1]
Phosphorus				
Pelletized straw	59.10[a]	42.33[a]	−16.77[a]	0.22
Long straw	66.93[a]	68.33[a]	1.40[a]	0.92
Pelletized wood	56.37[a]	69.07[a]	12.70[a]	0.35
Wood shavings	47.27[a]	73.73[a]	26.47[a]	0.06
SEM	3.89	5.90	7.45	
Potassium				
Pelletized straw	889.93[a]	1,050.03[ab]	160.10[a]	0.20
Long straw	867.47[a]	1,145.00[a]	277.53[a]	0.03
Pelletized wood	728.57[a]	729.97[b]	1.40[a]	0.99
Wood shavings	832.33[a]	1,030.10[ab]	197.77[a]	0.12
SEM	32.8	63.6	65.8	

[a,b]Means in each column followed by different superscripts are significantly different according to Fisher's protected LSD ($P < 0.05$).

[1]P-values indicate differences between initial and final sampling within bedding types.

potassium in the composted long straw may be a result of degradation of the material during composting. We theorize that the greater demand for potassium in cereal crops may result in greater potassium availability in the stem tissues. Because potassium is concentrated in vegetative plant parts, much of the potassium in the straw materials may become available for plant use. Compost with greater potassium concentration may prove beneficial where composted manure is spread on pasture or forage crop due to the greater potassium removal in these crops.

pH

No differences were observed in pH for any of the bedding materials at the initiation of the composting process (Table 5). Although not significant, a slight numerical difference was observed with the straw-based bedding materials having a slightly higher pH. This is similar to Larney et al. (2008), who reported significantly higher pH in straw-bedded beef cattle waste before composting. After composting, pH was reduced for both the long straw and the wood shavings. No significant reductions in pH were observed for either of the pelletized materials after composting. Differences were observed among materials after composting with pH for both straw-based products being significantly greater ($P < 0.05$) than both wood materials. This may be a result of the acidifying nature of the wood materials. The final pH of the composted material can affect the suitability of the product for land applications, particularly if being surface applied to pasture-based systems.

Conclusions

Composting is a viable option for equine stall waste disposal. This study demonstrated that incorporating a simple aerobic composting system may greatly reduce the overall volume of manure and yield a material that is beneficial for land application in pasture-based systems. The pile temperatures observed for all the bedding materials indicate that composting did occur. However, only the temperatures observed in the straw materials remained increased long enough to reduce the persistence of pathogens, parasites, and weed seeds and may make spreading of composted equine waste more practical in situations of limited pasture availability. Large increases in mass reduction demonstrated by composting can result in reduced haulage costs and decreased application rates or reduced acreage requirements. Reduced application requirements are particularly important to many equine operations with limited acres available for spreading. The chemical and physical characteristics of the composted material indicate that straw-based materials may be better suited for composting and subsequent land application. Other

Table 5. The pH changes during the composting process of 4 bedding types

Bedding material	Initial	Final	Change	P-value[1]
Pelletized straw	7.79[a]	7.62[a]	0.17[a]	0.37
Long straw	8.23[a]	7.77[a]	0.47[a]	0.02
Pelletized wood	7.70[a]	7.37[b]	0.33[a]	0.09
Wood shavings	7.87[a]	7.42[b]	0.45[a]	0.03
SEM	0.097	0.050	0.09	

[a,b]Means in each column followed by different letters are significantly different according to Fisher's protected LSD ($P < 0.05$).

[1]P-values indicate differences between initial and final sampling within bedding types.

factors such as suitability of the bedding material for equine use, material costs, labor, and availability must be considered when selecting a bedding material.

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