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(photo NDSU Carrington Research Extension Center)

Composting Animal Manures:

A guide to the process and management of animal manure compost

Revised by
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Composting and utilizing compost are advantageous tools in nutrient management plans that, when managed properly, benefit crops and reduce the potential to pollute.

Compost is a mixture of organic residues (manure, animal carcasses, straw, etc.) that have been piled, mixed and moistened to undergo thermophilic [high heat, 113 to 160 degrees Fahrenheit (F)] decomposition (SSSA, 1997).

This publication pertains to composting animal manures. For information on composting animal carcasses, refer to NDSU Extension publications "Animal Carcass Disposal Options" (NM1422) and "4 Easy Steps for Composting Dead Livestock" (AS1781).

Composting requires routine introduction of oxygen, which stimulates aerobic microorganisms that feed on the organic components and convert the piled organic material to a fairly stable nutrient-rich soil amendment (Larney and Blackshaw, 2003). Compost can be applied to agricultural fields as a fertilizer, added to improve soil structure, substituted for peat in horticulture and used as a microbial additive to increase enzyme activities (Steger et al., 2007).

Compost Benefits

The soil benefits greatly from the addition of compost. Fertility, water-holding capacity, bulk density and biological properties are improved (Flavel and Murphy, 2006). Odors are reduced and fly eggs die due to the high temperatures occurring during microbial decomposition (Larney et al., 2006). Manure contains various life stages of internal parasites that can lead to severe health conditions in animals. Parasite eggs are quickly destroyed when temperatures reach 104 F, which reduces the population and potential spread (Nielsen et al., 2007).

Certain weed seeds can pass through livestock and grow in manure applied on cropland. Few weed seeds remain viable in properly composted manure, which can reduce the amount of herbicide or tillage needed for weed control. Larney and Blackshaw (2003) studied weed seed viability in composted livestock manures. After 21 days of composting downy brome, false cleavers, foxtail barley, scentless chamomile, wild mustard and wild oat, weed seeds did not germinate. Some weed seeds were more difficult to kill. Those were green foxtail, redroot pigweed, round-leaved mallow, stinkweed and wild buckwheat. After 42 days of composting, those weeds did not germinate.

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Figure 1. Initial windrows of bedded feedlot manure. The west pile cannot be seen in this picture and note the initial height of the middle pile
(photo NDSU Carrington Research Extension Center)

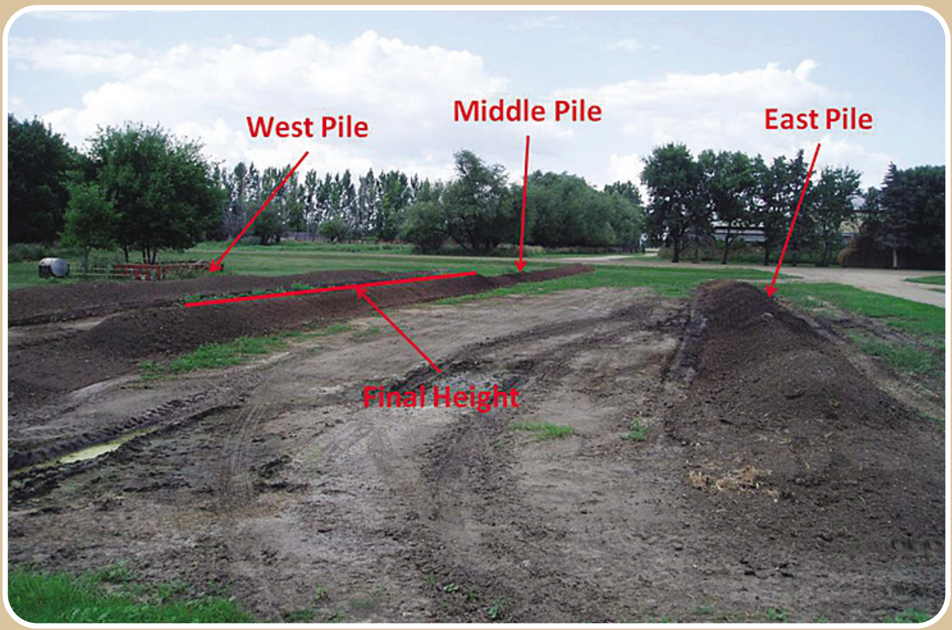

Figure 2. Composted bedded feedlot manure. The west pile can be seen and the final height of the middle pile is greatly reduced.
(photo NDSU Carrington Research Extension Center)

Composting reduces the volume and density of manure approximately 50-65% (Figures 1 and 2). The decrease in volume reduces hauling costs. Wiederholt et al., (2009) conducted a case study that compared the energy required of a 180-head feedlot operation that applied raw manure and composted manure to agricultural fields. They concluded that composting and applying livestock compost is more energy efficient than hauling raw manure. The decrease in volume and mass from composting reduced the hauling requirements enough to offset the energy required to compost. The energy ratio of raw manure to composted manure was 1.56-to-1 energy units.

Composting animal manures is an effective way to kill pathogens. Grewal (2006) studied and compared the length of time that pathogens lived in simulated composted dairy manure, a simulated dairy manure pack and a simulated liquid dairy lagoon. Grewal found that after three days of composting at 131 F, *Escherichia coli, Salmonella* and *Listeria monocytogenes* were not detected. However, *Salmonella* still was detected after 28 days in the manure pack and lagoon simulations. *Escherichia coli* and *Listeria monocytogenes* were found in the lagoon after 14 days, and *Listeria* was not found after seven days in the bedded pack simulations.

Site Selection

Composting should take place on an area that drains well but where runoff or leachate will not reach waters of the state. The pad ideally should drain into a containment pond. The site may not be located along surface waters of the state, on soil textures coarser than a sandy loam or within a flood plain. Ideal areas are well-drained, have slopes of 2-4%, consist of concrete or packed soil or gravel and drain into a containment pond. Windrows should be constructed parallel to the slope. This prevents the windrow from blocking runoff and allows implement access to the pad. Slopes exceeding 6% may be prone to erosion and can cause pad issues.

Composting Manure Process

The microorganisms responsible for composting are indigenous to manures. By properly managing compost, the producer facilitates these decomposing microbes. The manure must be piled, the carbon-to-nitrogen (C/N) ratio should be 30-to-1, 50% of the pore space should contain water and the pile must be aerobic (having oxygen) (Rynk et al., 1992).

Manure usually is piled into a windrow. The windrow dimensions are dictated by the length of the pad and size of the turning implement. After a day or two, the pile should reach temperatures in excess of 120 F (Figures 3 and 6).

The C/N ratio in a composting pile needs to range from 20-to-1 (20 parts of carbon for every part of nitrogen) to 40-to-1 (40 parts of carbon for every part of nitrogen).

Decomposing microorganisms typically have a C/N ratio of 5-to-1 to 10-to-1. The C/N ratio needs to be higher because approximately 50% of the metabolized carbon is released as carbon dioxide (Miller, 1996). Nitrogen can be lost when too much (C/N ratio below 20-to-1) is present, and the pile might smell of volatizing ammonia. Adding carbon (straw, corn stalks or woodchips) can help alleviate this. Too much carbon (C/N ratio more than 40-to-1) in a compost pile can immobilize nitrogen and slows the composting process (Coyne and Thompson, 2006).

Composting material's C/N ratio varies greatly. Differences in manure can vary because of differences in species, feeding rations, bedding practices, climate, storage facility, etc. The C/N ratio of bulking materials of plant origin varies greatly as well and for the same reasons as manures. Table 1 outlines C/N ratios that various composting materials possess. Figure 4 and Table 2 illustrate the process of determining the C/N ratio.

Water management is important in compost because 40-65% of the pore space in composting materials should have water. Measuring devices can be used to monitor the moisture, but they can be costly.

One way to test moisture is the simple hand test called the "wet rag test." Squeeze the compost and feel for moisture. If water drips out, then it is too wet. But if the compost feels like a wrung-out wet rag, the compost has sufficient amounts of moisture (Rynk et al., 1992). Remember to wash your hands after working with compost.

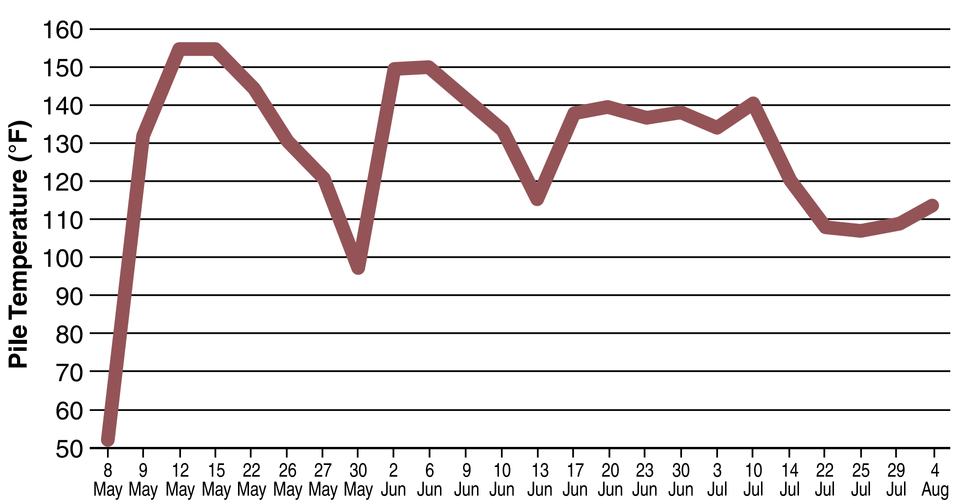

Figure 3. Average temperatures of a straw-bedded beef feedlot manure compost pile. The manure was piled into windrows on May 8. The pile was turned on May 30, June 13, June 23 and July 29. The pile did not pass the wet-rag test on June 11 and was watered the same day. This pile may be piled for curing after Aug. 4.

Moisture usually is not an issue in central and eastern North Dakota. However, water may have to be added in western North Dakota or during prolonged dry events. Some turners have water tanks plumbed into nozzles that add water while turning. Water also may be added by spraying it directly on the windrow (Figure 5).

The microorganisms that transform manure into compost require oxygen for their energy-deriving chemical reactions. Less than 5% of oxygen within the pore space will turn the pile anaerobic (without oxygen), may create a rotten-egg smell and will slow the composting process. Aerobic conditions can be replenished by turning the pile (Rynk et al., 1992).

Table 1. Carbon-to-nitrogen (C/N) ratio of common composting materials.

Material	C/N Ratio	Material	C/N Ratio
Cattle Manure	19:1	Poultry Carcass	4:1
Cattle Carcass	10:1	Sawdust	442:1
Corn Silage	40:1	Sheep Manure	16:1
Corn Stalk	68:1	Swine Carcass	14:1
Dairy Manure	20:1	Swine Manure	12:1
Grass Clippings	17:1	Turkey Litter	16:1
Horse Manure	30:1	Wheat Straw	127:1
Leaves	54:1	Wood Chips	600:1

(Rynk et al., 1992)

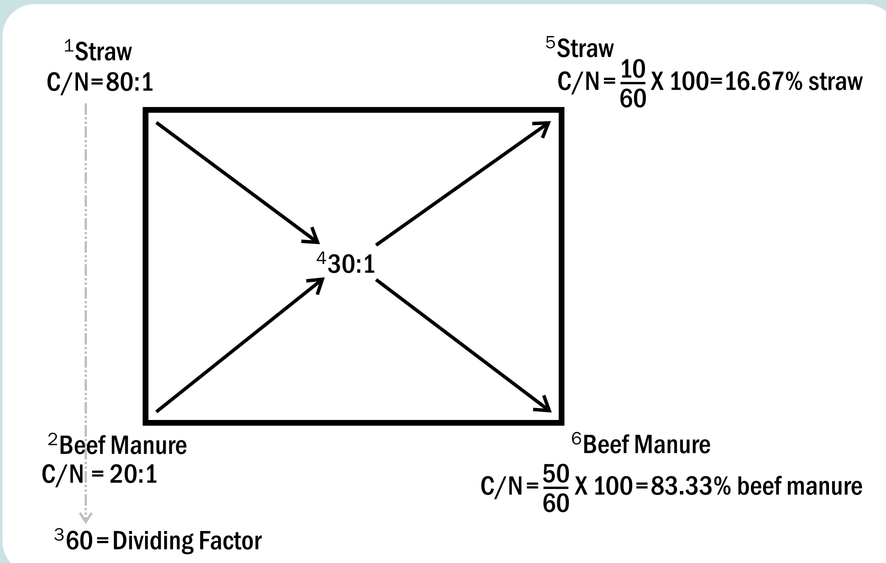

Figure 4. An example of using the Pearson Square method for proper compost mixture determination.

Pearson Square Procedure: 1 is the C/N ratio of a typical straw. 2 is the C/N ratio of typical beef manure. 3 is the difference of straw and beef manure. 4 is the desired C/N ratio. 5 is the difference of beef manure C:N ratio and desired C:N ratio. Multiplying this value by 100 reveals that 16.67% of straw is needed for the desired C/N ratio. 6 is the difference of straw C/N ratio and desired C/N ratio. Multiplying this value by 100 reveals that 83.33% of manure is needed for the desired C/N ratio.

Figure 5. Watering compost at the Carrington Research Extension Center during an extremely dry period.
(photo NDSU Carrington Research Extension Center)

Table 2. A worksheet to determine C/N ratio mixture of composting materials.

Material	C/N Ratio	Minus	Desired C/N Ratio	Equals	Adjusted C/N Ratio (Absolute Value)	Materials C/N Ratio Difference	Equals	Dividing Factor*	Equals	Adjusted C/N Ratio (Absolute Value)	Divide	Dividing Factor*	Equals		Multiply by 100 Equals	Recom-mended Co-product (%)	Minus 100% Equals	Recommended Mixture (%)
Swine Manure	12:1	–	30:1	=	18	127–12	=	115	=	18	÷	115	=	0.157	X 100 =	15.7%	– 100% =	84.3% Swine Manure
Wheat Straw	127:1	–	30:1	=	97	127–12	=	115	=	97	÷	115	=	0.843	X 100 =	84.3%	– 100% =	15.7% Wheat Straw
		–		=			=		=		÷		=		X 100 =		– 100% =	
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*Dividing Factor is the difference of C/N ratios of different composting materials. The value used is the absolute value.

Monitoring the internal temperature with a probe-type thermometer can indicate when to turn the windrow (Figure 6). To efficiently compost manure, turn the windrow when the internal temperature drops below 120 degrees F. After five to six turns, the manure should be composted. Temperatures should be taken at various locations and depths. According to Michel (2009), compost windrows can be turned every 10 days or two weeks. This can minimize labor while creating a good-quality product.

Organic operations must meet certain temperature and turning frequency requirements. The Organic Materials Review Institute (2019) requires compost made from plant and animal materials to reach and maintain temperatures of 131 – 170 F for 15 days, and piles to be turned at least five times during that 15-day period.

Piles may exceed 160 F, which can destroy the beneficial microbes, causing a decline in microbial activity and slowing the process. If this occurs, chances are the piles have too much nitrogen. Adding carbon, making the piles smaller and digging holes in the pile are ways of cooling the pile (Carpenter-Boggs, 1999).

Figure 6. Twenty-four hours after raw straw-bedded feedlot manure was piled in early May, temperatures already have reached 132 F.
(photo NDSU Carrington Research Extension Center)

Compost Aeration

Turning manure is essential to composting manure. Turning compost incorporates oxygen into the system, homogenizes the pile and breaks up clumps. Turning allows more contact of manure with microbes. Producers have various ways to turn the pile. The two most common methods for turning compost are with a windrow turner (Figure 7) or bucket tractor. Turners may be self-propelled or attached to a tractor or skid steer. Turners mix the compost by an auger, rotary drum with flails or an elevating conveyor. Some turners require power from the attached implement, while others are self-powered.

Producers have many factors to consider when selecting a turner. Determining the amount of manure to turn is a good starting point. Bucket tractors or skid steers work well for small operations or testing if compost fits into your operation. However, turner implements work better for larger operations.

Turners range in various sizes from 6 feet wide to as much as 20 feet wide. A 10-foot-wide turner may turn 1,500 yards per hour, while a 14-foot turner may turn as much as 2,600 yards per hour. Implements that run a turner must have a creeper gear and go as slowly as 20 feet per minute.

Turning becomes easier throughout the composting process.

After the heating cycles have subsided, compost usually is piled for storage while awaiting field applications. This month long or longer process is known as curing. Applying immature compost can cause issues that include malodors, insect swarms, nitrogen immobilization and phytotoxicity (Mathur et al., 1993; Francou et al, 2005; Steger et al., 2007).

Compost maturity is strongly related to microbial activity during the composting process. Producers have many options to assess compost maturity. Options include sending samples to laboratories, checking pile temperatures to ensure that the pile is near the ambient temperature and kits that give colormetric readings of carbon dioxide and ammonia emissions.

Nutrient Management of Compost

Manure composts not only improve soil physical and chemical characteristics; they also are a good source of fertilizer for crop production. However, much of the nitrogen is tied up in complex organic compounds (immobilized) and is not immediately ready for plant uptake, whereas commercial fertilizers are predominantly plant-available. Cropland soils and compost should be tested for nutrients. Nitrogen, phosphorus and potassium tend to be the most limiting nutrients required by crops (Coyne and Thompson, 2006).

Applications of compost must be based on crop needs. Manure applications should be based on crop nutrient needs (North Dakota Department of Environmental Quality, 2021). Most crops have a nitrogen-to-phosphorus (N:P) ratio of 7-to-1 to 10-to-1, whereas composted manure commonly has an N:P ratio of 1-to-2. Because of this, nutrient management plans may need to be based upon phosphorus management. This change in management can prevent nutrient loading and high levels of phosphorus that can accumulate when not properly managed and monitored (Spargo et al., 2006).

Figure 7. A pull-type compost turner that is turning windrowed bedded feedlot manure for the first time.
(photo NDSU Carrington Research Extension Center)

Sampling and testing soil for nutrients can alleviate nutrient loading. Refer to NDSU Extension publications "North Dakota Fertilizer Recommendation Tables and Equations" (SF882) and "Soil Sampling as a Basis for Fertilizer Application" (SF990) for more information on soil sampling and nutrient requirements.

Crop and environmental benefits may not occur if the finished composted product is not tested and properly applied. Once cured, compost samples should be taken within the pile at various points and mixed thoroughly to account for variability. Samples should be tested as soon as possible or kept in cold storage until they can be sent to a laboratory for analysis. Refer to NDSU Extension publication "Solid Manure Sampling for Nutrient Management Planning" (NM1259) for more sampling methods and interpretation of test results.

Keep in mind that many testing labs treat compost nutrient availability as if it were raw manure (approximately 50% nitrogen, 80% phosphorus and 90% potassium of the total nutrients are plant-available the first growing season). Compost nutrient availability is different and producers need to account for the differences. This difference is due to the increased stability of compost. Eghball and Power (1999) found in a four-year study that 15% of the total nitrogen in beef feedlot compost was plant-available the first year and 8% of the nitrogen was mineralized the second year. Wen et al. (1997) found in a two-year study that 30% and 70% of the total phosphorus in composted livestock manure was mineralized the first and second year, respectively. A greenhouse study conducted by Bar-Tall et al. (2004) showed that 31% of the total potassium in compost is mineralized.

Because of immobilization and the possibility of nutrient loading, compost fertilizer applications may need to be supplemented with conventional fertilizers. Eghball and Power (1999) tested different management strategies (compost applications based on nitrogen or phosphorus and conventional fertilizer). They found that managing composts based on phosphorus and supplementing the other nutrient requirements with conventional fertilizers yielded equal or greater corn yields.

Compost should be applied with a calibrated spreader. This ensures that the proper amount of nutrients is applied and also lessens the chance of polluting. Manure spreaders can be calibrated various ways. Refer to NDSU Extension publication "Manure Spreader Calibration for Nutrient Management Planning" (NM1418) for spreader calibration procedures.

Summary

Manure needs to be managed properly to be composted properly. Carbon/nitrogen ratios should be about 30-to-1, moisture content should be around 50% and oxygen needs to be incorporated routinely by turning. This ensures that the pile will heat and convert to compost effectively.

Surface and ground water proximity are important for compost site selection. The compost site needs to be in an area not prone to contamination of groundwater by leaching or where leachate can run off to surface water.

instead of viewing manure as a waste, producers can begin to view it as a product that can be substituted for commercial fertilizer and as an economic resource.

Composting is an effective manure management tool that reduces volume, kills pathogens, kills parasites and reduces weed seeds, and also improves soil health and fertility. However, soil and compost should be tested for nutrients. Applying compost with a calibrated spreader ensures that crop yield goals will be met and reduces the chance of pollution. The volume reduction of composting manure can save livestock owners money and provide crop producers with a more uniform fertilizer than fresh manure.

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