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Composting Manure and Other Organic Materials

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Composting is becoming more common in Nebraska. This NebGuide provides information on the composting process and related issues.

The Composting Process

Composting is the aerobic decomposition of manure or other organic materials in the thermophilic temperature range (104-149ºF). Composted material is odorless, fine-textured, and low-moisture. It can be bagged and sold for use in gardens or nurseries, or used as fertilizer on cropland with little odor or fly breeding potential. Composting improves the handling characteristics of any organic residue by reducing its volume and weight. Composting can kill pathogens and weed seeds.

Disadvantages of composting organic residues include loss of nitrogen and other nutrients, time for processing, cost for handling equipment, available land for composting, odors, marketing, diversion of manure or residue from cropland, risk of losing farm classification, and slow release of available nutrients. During a three-year Nebraska study as much as 40 percent of total beef feedlot manure nitrogen and 60 percent of total carbon was lost to the atmosphere during composting. Runoff and leaching losses of sodium (Na) and potassium (K) were also high (above 6.5 percent each) during composting periods with high rainfall. Increasing the carbon-to-nitrogen ratio by incorporating high carbon materials (leaves, plant residue, paper, sawdust, etc.) can reduce nitrogen loss. In another study, a 30 percent reduction in nitrogen loss was found during composting of poultry manure in 55-gallon reactors when the C:N ratio increased from 15 to 20. Because of nitrogen, carbon, and potassium losses from manure during composting, it may be more desirable to apply the manure directly as a nutrient source unless there are concerns about improving manure characteristics, killing weed seeds and pathogens, or reducing odor problems.

Temperature, water content, C:N ratio, pH level, aeration rate, and the physical structure of organic materials are important factors influencing the rate and efficiency of composting. Ideal values for these factors are given in *Table I*. Homogeneous manure solids can be composted alone without mixing with bulk materials. Bulking agents are needed to provide structural support when manure solids, or other organic residues, are

Figure 1. Turning of a composting windrow.

too wet to maintain air spaces within the composting pile, and to reduce water content and/or to change the C:N ratio. Dry and fibrous materials, such as sawdust, leaves, finely chopped straw, or peat moss, are good bulking agents for composting wet manure or organic residues.

Temperature is the most common indicator of how composting is progressing. Elevated temperature is necessary to destroy pathogens and weed seeds in manure or other organic materials. Environmental Protection Agency (EPA) regulations for composting municipal waste require that the temperature be maintained at 131ºF or above for at least three days to destroy pathogens. A temperature of 145ºF within the compost pile is needed to destroy weed seeds. Depending on the ambient temperature, a complete composting process may take two to six months. The water content of mature compost should be less than 50 percent and preferably in the range of 30 to 35 percent. The C:N ratio should be less than 20.

Table I. Recommended conditions for rapid composting.

Condition†	*Reasonable range*	*Preferred range*
Carbon to nitrogen ratio	20:1 - 40:1	25:1 - 30:1
Water content	40 - 65%	50 - 60%
Oxygen concentration	> 5%	5 -15 %
Particle size (diameter)	1/8 - 1/2 inch	Depends on the material
pH	5.5 - 9.0	6.5 - 8.0
Temperature	110 -150	130 - 140

Source is *On Farm Composting,* by R. Rynk, M. van de Kamp, G.B. Wilson, M.E. Singley, T.L. Richard, J.J. Kolega, F.R. Gouin, L. Laliberty, Jr., D. Kay, D.W. Murphy, H.A. J. Hoitink, and W.F. Brinton, 1992, Northeast Regional Agricultural Engineering Service, Ithaca, N.Y.
†These conditions are for rapid composting. Conditions outside these ranges can also yield successful composting.

Composting Methods

There are many methods of composting organic materials (*Figures 1* and *2*). These include active windrow (with turning), passive composting piles, passively aerated windrow (supplying air through perforated pipes embedded in the windrow), active aerated windrow (forced air), bins, rectangular agitated beds, silos, rotating drums, containers, anaerobic digestion, and vermicompost (using earthworms).

Because of differences in manure characteristics and handling systems for different livestock species, the composting process for each livestock species will be analyzed separately. Other sections will describe composting of other organic residues.

Figure 2. Composting windrows.

Cattle Feedlots

About 2.5 million head of cattle and calves are on grain and concentrates in Nebraska. Typically in the central and southern Great Plains, manure scraped from beef feedlots is often 50 percent soil. The quantity of manure produced per animal unit per day is given in *Table II*. About 14.2 lb dry manure/soil mixture is collected per head per day when the feedlot is scraped. Annually there are 5 to 6 million tons of manure (dry weight) available to be applied to the land or to be composted in Nebraska (assuming average weight of each animal is about 800 lb). Characteristics of manure collected from beef cattle feedlots are given in *Table III*. Manure collected from feedlots can be composted as is (with no bulking agents) or with high carbon material *(Table IV)* to increase the C:N ratio and reduce nitrogen loss. Feedlot manure can be composted in 60-120 days depending on the ambient temperature. Windrow composting is the most common method used for beef cattle feedlot manure. The windrows should be 3-6 feet high and 8-12 feet wide. Turn with a windrow-turning machine or with front-end loader.

Table II. Manure production per 1,000 lb live animal weight per day.

Livestock	*Wet mass*†	*Total dry solid*
	-------------------- lb --------------------	
Feeder cattle	52.0	7.1
Dairy	78.0	10.7
Swine (100 lb hog)	88.4	8.1
Poultry		
Broiler	87.9	24.6
Hens	72.7	17.8
Turkey	55.0	12.3
Sheep	39.0	11.3
Horse	54.0	16.5

Source is Livestock Waste Management, Vol. I., by M.R. Overcash, F.J. Humenik, and J.R. Miner, 1983, CRC Press, Boca Raton, Fla.
†Urine and feces.

Table III. Range of manure characteristics from livestock species.

Characteristics	*N*	*P*	*Water content*	*C:N*	*pH*
	-----------------	%	-----------------		
Beef feedlot†	0.2 - 3.0	0.1 - 1.2	20 - 80	10:1 - 20:1	6 - 8
Swine	0.3 - 0.5	0.1 - 0.2	70 - 85	15:1 - 21:1	7 - 8
Dairy	0.3 - 0.6	0.1 - 0.2	75 - 90	8:1 - 30:1	6 - 8
Chicken manure	0.8 - 2.5	0.3 - 0.7	50 -87	4:1 - 18:1	6.0 - 7.5
Broiler litter	1.7 - 6.8	0.8 - 2.6	22 - 29	6:1 - 24:1	6.5 - 8.5
Turkey	1.2 - 1.8	0.3 - 0.9	50 -87‡	4:1 - 18:1‡	6.0 - 7.5‡

†Beef feedlot manure as collected; others fresh manure basis.
‡Assuming similar to chicken.

Table IV. Carbon content and C:N ratio of bulking materials.

Material	*% N (dry weight)*	*C:N*
Corn stalks	0.6-0.8	60-73
Straw	0.3-1.1 (0.7)	48-150 (80)
Bark, hard woods	0.1-0.4 (0.24)	116-436 (223)
Bark, soft woods	0.04-0.39 (0.14)	131-1285 (496)
Newsprint	0.06-0.14	398-852
Sawdust	0.06-0.8	200-750
Wood chips	0.04-0.23 (0.09)	212-1313 (641)
Leaves	0.5-0.13 (0.9)	40-80 (54)

The numbers in parentheses are averages.

Swine

Swine manure production and characteristics are given in *Tables II* and *III*. Swine manure collected from confinement buildings consists of feces, urine, wastewater, and feed. Manure collected by deep pits and shallow pits with mechanical scrapers or gravity drainage gutters has 2-8 percent solid content, while manure collected by flushing systems is more dilute and has less than 2 percent solids.

For composting, manure solids need to be separated from the liquid. Presses and centrifuges have higher separation efficiencies and produce drier solids than screens. Adding flocculants, such as polyelectrolytes and organic polymers, to manure slurries prior to separation can significantly improve the separation efficiencies. Higher water content manure also can be composted if high carbon bulking materials are added to form a composting mound. Characteristics of some bulking materials are given in *Table IV*. After the bulking materials have been added to swine manure, it can be composted in windrows 3 feet high and 10 feet wide. Frequent turning may be needed to dry the material, increase the temperature in the composting pile, and reduce odor.

Dairy

Manure collected from feeding, lounging, and milking barns can be composted. Manure collected in dairy operations contains 75-95 percent water and needs dewatering or addition of bulking material for proper composting. The techniques used for dewatering swine manure also can be used for dairy manure. Straw or sawdust bedding are good sources of carbon and drying materials for composting. Dairy manure contains 3-4 percent nitrogen and subsequently benefits from adding high carbon bulking materials to reduce nitrogen loss during composting. Similar to swine manure, dairy manure can be composted after adding bulking material to form a composting windrow.

Poultry

Chicken and turkey manure production and characteristics are given in *Tables II* and *III*. Manure from broiler operations, laying hens and pullets, and turkeys are the primary wastes generated by poultry operations. Chicken manure, broiler litter, and turkey manure contain about 60, 25, and 75 percent water, respectively. When composting broiler litter, water should be added to the material to achieve a water content of at least 40 percent. Nitrogen loss during composting is a major concern if manure or litter are not mixed with high carbon materials because broiler litter contains about 3 percent nitrogen and manure contains about 4 percent nitrogen. Poultry manure can be composted in windrows or in bins. The simplest form of in-vessel composting is bin composting, which is readily adaptable to poultry operations. Bins may be plain structures with wood slatted floors and a roof, conventional grain bins, or bulk storage buildings.

Animal Mortality

Carcass composting can be used for all types of animals. Mortality composting can be accomplished in backyard type bins, indicator composter bins, temporary open bins fashioned from large bales of hay or straw, and in windrows or piles on a paved or well drained soil surface. For bin composting of poultry carcasses, a volumetric proportion of 2:1:1 of poultry litter, straw, and dead birds is used. The composting layers are litter, straw, dead birds, and litter from the bottom of the bin. Carcasses of other animals can be composted in bins using layers of sawdust or chopped straw and dead animals. About 1.5 feet of straw or sawdust is placed under the carcass and 2 feet is needed above the carcass. The biological process of composting animal carcasses is identical to composting any other organic material. The parameters of air, water, nutrient, carbon, and temperature need to be regulated. Water content is an important factor to consider when composting dead animals and should be maintained at about 40 to 50 percent. Lower water content promotes dehydration, which preserves the carcass while too much water (more than 60 percent) will cause foul odor and may cause runoff from composting piles. Dead animals are composted in static piles, which may be turned once or twice in the active composting period. The pile is then allowed to cure until the pile's internal temperature is close to the ambient temperature.

Manure from Minor Classes of Livestock and Other Organic Residues

Manure from sheep, goats, horses, ducks, and others also can be composted by considering their manure characteristics and important factors *(Table I)* for proper composting. Other organic residues that can be composted include yard wastes, grass clippings, peat moss, sea weeds, fruit and vegetable wastes, food processing wastes, municipal garbage, sewage sludge, etc. When composting any of these materials, consider factors such as air, water content, particle size, C:N ratio, pH, and temperature *(Table I)*. Characteristics of some of these organic materials are given in *Table V*. For composting a mixture of grass and leaves collected from municipalities, piles 15 feet wide, 300 feet long, and 10 feet high may be used. The pile is turned as necessary starting on one side and going back and forth with a mechanical turner. Windrows also can be used for composting grass and leaves.

Table V. Nitrogen and water contents and C:N ratios of some organic residues.

Organic Residue	*N content*	*Water content*	*C:N*
	-------------------	%	-------------------
Fruit waste	0.9-2.6	62-88	20-49
Vegetable waste	2.5-4	30-85	11-13
Slaughterhouse waste	13-14	10-78	3-3.5
Fish waste	6.5-14.2	50-80	2.6-5.0
Refuse (mixed food, paper etc.)	0.6-1.3	10-70	34-80
Sewage sludge	2-6.9	72-84	5-16
Grass clippings	2.0-6.0	30-70	9-25

Source is *On Farm Composting,* by R. Rynk, M. van de Kamp, G.B. Wilson, M.E. Singley, T.L. Richard, J.J. Kolega, F.R. Gouin, L. Laliberty, Jr., D. Kay, D.W. Murphy, H.A. J. Hoitink, and W.F. Brinton, 1992, Northeast Regional Agricultural Engineering Service, Ithaca, N.Y.

Management of Composting

Adjusting C:N Ratio and Water Content

The C:N ratio is the weight of the carbon (C) divided by the weight of nitrogen (N) in the composting material. When adjusting the C:N ratio of a mixture for composting, the C:N ratio of each added material needs to be considered. For example, sawdust may be added to manure to have a targeted C:N ratio ($C{:}N_T$) of 25. Assume that the manure is 40% dry matter (DM_M), 1% N (N_M), and 15% C, giving a C:N ratio ($C{:}N_M$) of 15. Assume that the sawdust is 90% dry matter (DM_A), 0.5% N (N_A), and 50% C, giving a C:N ratio ($C{:}N_A$) of 100. Calculate the quantity of sawdust to add (Q_A) for each ton of manure as follows.

$$Q_A = \frac{2000 \text{ lb x } N_M \text{ x } (C{:}N_T - C{:}N_M) \text{ x } DM_M}{N_A \text{ x } (C{:}N_A - C{:}N_T) \text{ x } DM_A}$$

or

$$Q_A \text{ (lb sawdust per ton of manure)} = \frac{2000 \text{ lb x } 0.01 \text{ x } (25 - 15) \text{ x } 0.40}{0.005 \text{ x } (100 - 25) \text{ x } 0.90} = \frac{800}{3.375} = 237 \text{ lb}$$

The dry matter content of the mixture (DM_{Mix}) is the weight of dry matter in the components divided by the weight of mix.

$$DM_{Mix} (\%) = \frac{(2000 \text{ x } DM_M) + (Q_A \text{ x } DM_A)}{(2000 + Q_A)} = \frac{(2000 \text{ x } 0.40) + (237 \text{ x } 0.90)}{(2000 + 237)} = 45\% \text{ dry matter.}$$

Turning

The composting material should be turned whenever its temperature rises above 145°F to prevent overheating, which kills the composting organisms. A temperature below 104°F may indicate lack of adequate oxygen and a need for turning. If the temperature does not rise above 104°F after turning, the compost should no longer be turned and left for at least one month of curing to complete the composting process. If the composting material is dry (water content is less than 40 percent), add water to activate the composting process. In some cases, water content lower than 40 percent may result in overheating and a need for watering. If adding water is not an option, regulate the temperature by turning. The composting period may take longer if water content is not maintained at a proper level.

Land Application of Compost

The composted material is an odorless, fine-textured, low-moisture material that can be used in gardens, potting, and nurseries, or used as fertilizer on cropland with little odor or fly breeding potential. Compost can be an excellent source of organic matter, nitrogen, and other nutrients. A representative sample should be sent to an agricultural soil testing laboratory to determine nutrient content. Compost should have very low ammonium or nitrate values, so the organic nitrogen will be the only source of available nitrogen. Use an availability factor of 0.15 or less to determine nitrogen availability the first year after application. Availability of phosphorus, potassium, and micronutrients from compost should be similar or higher than manure or other organic residues used for composting. Since compost is fine textured and has less water than the raw material, it can be applied more uniformly and with better control. The composted material also can be stored and applied when convenient. Weed seeds or pathogens that can create problems with application of manure or other organic residues should not be a concern when properly made compost is used.

Issues and Options

When composting an organic residue, advantages, disadvantages, and feasibility of the composting process need to be considered. Composting has benefits and drawbacks, and producers need to decide if it is a good option for their operation. Advantages of composting include killing pathogens, fly larva, and weed seeds, and improving the handling characteristics of manure and other residues by reducing their volume and weight. Most manure and other organic residues usually contain high nitrogen content and therefore are subject to nitrogen loss during composting. Weed seed destruction, although theoretically possible, needs to be evaluated under field conditions. Manure and other residues may contain significant amounts of water and need to be either dewatered, or high carbon bulking agents need to be included for proper composting. Other considerations for composting include having enough land area, composting odors, economic considerations, and environmental consequences. The market for the composted material needs to be developed so composting is a successful venture. For example, manure collected from a cattle feedlot in central Nebraska is composted and sold to nearby farmers, generating a profit from the manure. Composting can be a good option in a number of situations and may make the generated waste more desirable to crop, fruit, or vegetable producers.

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Index: Waste Management
Livestock Waste Systems
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