MANURE PROCESSING for Farm Sustainability

Biological Systems Engineering
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Composting Animal Manure

Introduction

Composting is the process in which microorganisms degrade organic feedstocks in a controlled manner to produce a high quality, stable product that can be used as fertilizer. Composting is a process that can be implemented on nearly all sizes and types of animal feeding operations. By composting manure, pathogen concentrations, weed seeds, odor, and overall by-product volume can be reduced. This process renders composted manure more useful and economical for agricultural land applications (Larney et al. 2006). In fact, composting manure and agricultural by-products can increase the feasible hauling distance by more than 2x when compared to hauling fresh manure. Composting can also be used to manage mortalities to minimize disease and odors.

In-depth resources on composting, including how to address common issues with the composting process, can be found through Natural Resource Conservation Service (NRCS) and American Society of Agricultural and Biological Engineers (ASABE) practice standards (ASABE S585.1 2021; NRCS 2007).

Figure 1. Examples of compost windrow (top), a three-bin composting system (middle), and an in-vessel system (bottom).

Technology Basics

A composting system can be implemented on nearly all sizes and types of animal feeding operations. Two of the most popular systems are windrows and bin systems, however there are more sophisticated in-vessel systems (**Figure 1**) as well as aerated piles. All composting systems can be either covered with a roof or uncovered depending upon the climate and budget. If an uncovered system is used, it is important to recognize that precipitation and other weather factors can have a substantial impact on the composting process and can lead to significant differences in compost produced during different seasons. As a result, runoff control and collection strategies need to be considered, especially when the composting process takes place in open areas.

It is important to recognize that composting is a microbially

COMPOSTING 101

For more information see https://youtu.be/JwdCWSORiyo for a video highlighting a dairy manure windrow composting facility in Wisconsin.

mediated process. Thus, conditions within the windrow or pile must be maintained for optimal microbial activity. Factors that must be controlled and monitored include aeration (or oxygen availability), carbon to nitrogen ratio (C:N ratio), temperature, and moisture. The composting process begins with the creation of either a windrow or pile. Optimally, windrows or piles should be approximately 3.3 to 5 feet (1 to 1.5 m) high in size and constructed so that airflow through the pile is not impeded (ASABE S585.1 2021). Thus, plenums (layer of material with high porosity) might be needed in static piles to facilitate aeration, avoiding the need of manual or mechanical turning. Compost piles, in either bins or windrows, need to be turned frequently or aerated with blowers to maintain aerobic conditions and promote microbial activity.

Another important factor that should be managed is the initial C:N ratio of the compost pile. The C:N ratio can be thought of as the number of units of carbon per unit of nitrogen. The C:N ratio should be between 20:1 and 40:1 with an ideal range of 25:1 to 30:1 (Wortmann and Shapiro 2012). The ideal range is based on the C:N ratio needed by microbes to promote activity which accelerates the breakdown of organic matter. The C:N ratios of manure from various livestock species is shown in **Table 1**. In most cases, additional carbon (C) should be added to the manure to ensure an adequate C:N ratio. Some common C sources include straw, wood chips or shavings, and corn stalks.

Temperature and moisture also need to be managed to ensure optimal microbial degradation of manure. Composting is a thermophilic process, meaning temperatures should be maintained between 104–149°F (Wortmann and Shapiro 2012). Temperature is a good indicator for when piles should be aerated through turning. It is recommended that compost reaches 145°F to kill pathogens and destroy weed seeds, but compost should be turned once it reaches this temperature to avoid killing beneficial microbes at higher temperatures. Moreover, overheated compost piles (>160°F) could spontaneously combust if they are not moist and aerated, though this is extremely rare. Temperature should be monitored and recorded daily from several locations per windrow or pile. Moisture content in the pile also needs to be monitored and managed with an optimum range between 50–60%. As shown in **Table 1**, the manure itself can be an important source of moisture for the composting process. Moisture in manure tends to be higher just after winter/spring and lower in summer months in most places, except for tropical and other climates with high rainfall. As the composting process proceeds and piles are aerated, moisture will be lost. Thus, water should be added back into the system when needed. Management of both temperature and moisture will likely differ between seasons due to ambient temperature and precipitation variations.

Table 1. Range of characteristics of manure produced (as excreted) from several livestock species.*

Livestock Species	C:N	Water content (%)
Beef Feedlot, as collected	10:1 – 20:1	20 – 80
Swine, fresh	15:1 – 21:1	70 – 85
Dairy, fresh	8:1 – 30:1	75 – 90
Chicken or Turkey, fresh	4:1 – 18:1	50 – 87
Broiler Litter, fresh	6:1 – 24:1	22 – 29

*Adapted from Wortmann and Shapiro (2012).

Performance

The quality of compost generated depends upon the type of feedstocks used, the level of management implemented, and the intended use of the finished product. In general, compost generated under intense management of its oxygen, C:N ratio, moisture, and temperature will have low odor and also reduce weed seed and pathogens. One measurement used to determine compost quality is its maturity, which can be evaluated using indicators of the senses,

Table 2. Suggested values for compost classes for compost suitable for greenhouses or nurseries (Class A) and compost suitable for row crop production or field applications.*

Measurement	Class A	Class B
pH	6.0 – 7.0	6.0 – 7.5
C:N Ratio	< 25	< 30
Moisture Content, percent	< 50	–
Electrical Conductivity (mmho cm^{-1})	< 2.5	< 5.0

*Adapted from University of Missouri Extension (Accessed October 2021) chemical, stability, or phytotoxicity (Sullivan and Miller 2001). Without intense and thorough management of the components, the quality of the finished product may not be as high (**Table 2**). However, a lower quality compost does not necessarily inhibit its use as a fertilizer. Higher compost quality is typically required when selling packaged compost to a distributer, in facilities requiring a consistent product such as greenhouses, or for use in produce gardens. Lower quality compost still has fertilizer value but may be inconsistent and is better suited for use on-farm or sold locally in bulk. However, most producers must develop the market for their compost product, so it is important to examine your location and potential customer's needs.

Cost

Capital and labor costs required to install and manage a composting system can vary significantly based on the type of system used (e.g., windrow or bin, covered or uncovered), size, and additional technologies used for management of products (i.e., thermocouples, moisture sensors, sprinklers for moisture additions, etc.). Windrow turners can vary in cost, ranging from tens of thousands of dollars for tractor mounted systems (**Figure 2**) to several hundreds of thousands of dollars for crawlers that are self-propelled systems designed specifically for compost turning. Similarly, tractors can be equipped with front end loaders in the case where tractors or skid steers are already available on-farm but will require significantly more labor to turn the compost. In addition to equipment costs, land is needed to house either the composting infrastructure or windrows.

Figure 2. Tractor mounted compost turning systems.

The amount of land needed is generally scalable by the size of the animal operation with bigger operations needing more land for composting. Labor is also needed to support composting for both hauling manure from the production area to the compost site as well as turning windrows or piles, managing moisture, and monitoring temperature regimes. This is also generally scalable by operation size but a higher investment in equipment can offset the time needed (e.g., a windrow turner would take much less time to turn large windrows compared to a front loader or bulldozer). Other cost considerations should include whether water needs to be added to maintain an optimal moisture and whether additional materials are needed to optimize C:N ratio. System profitability is highly dependent upon the market price obtained for the finished compost as well as the cost of the system. If the product can only be sold at a low market value, selecting a low-cost system may still be able to produce a profit if managed effectively. A detailed business plan is recommended before integrating a system.

Environmental Benefits and Trade-Offs

During the composting process, microbes aerobically consume organic matter and release CO_2 and other gases (Petersen et al. 2013). Most greenhouse gases (GHG), mainly methane (CH_4) and nitrous oxide (N_2O), are produced within the first 60 days (**Figure 3**) (Bernal et al. 2017). Formation of all GHGs during composting is biologically driven. Mismanagement of the composting process can promote the creation of anaerobic conditions in the pile (e.g., lack of oxygen, excess moisture, lack of turning) which will at the same time increase CH_4 and N_2O emissions. The larger the compost pile, the more intensely it must be managed to reduce emissions because anaerobic conditions quickly redevelop after turning (Hellmann et al. 1997). Despite that proper turning of the compost pile reduces N_2O and CH_4 emissions, increased (or excessive) turnings increase loss of ammonia (NH_3) through volatilization. A lower than ideal C:N ratio can also increase NH_3 and CH_4 emissions but does not affect N_2O; an optimal C:N ratio for reducing GHG emissions is 21:1 (Jiang et al. 2011). Emissions of NH_3 are not ideal for compost meant to supply nutrients, including nitrogen, for crop production. Moreover, NH_3 can redeposit in waterbodies and natural terrestrial systems and further transform to particular matter and/or N_2O, negatively impacting human health and air quality (Hristov et al. 2002).

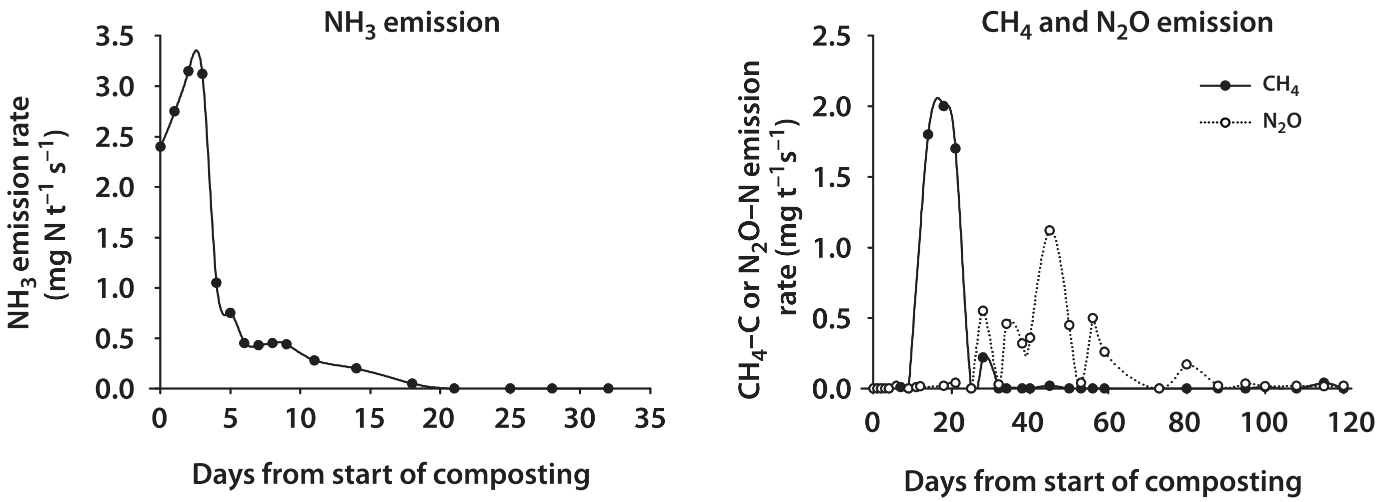

Figure 3. Figure showing ammonia (left) and methane or nitrous oxide (right) emissions for a compost pile over time (Bernal et al. 2017).

Compost is generally used for land application. By composting manure, moisture and overall volume is reduced making it more feasible to haul further distances for application compared with fresh manures. This is a benefit for lands near the animal feeding operation where lands tend to receive over-applications of fresh manure. Due to volume reduction, however, compost will have higher concentrations of nutrients like phosphorus and potassium because they are not lost through emissions or other pathways like nitrogen and carbon. This makes compost a valuable as a fertilizer but also means that nutrient management strategies still need to be utilized to prevent the over-application of phosphorus to cropland. However, due to stabilization of nitrogen and loss by emissions, compost is less likely to leach nitrogen compared to fresh manure.

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