# Composting On The Farm

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Composting provides a means to convert plant matter, animal feces, and a variety of other organic materials into a biologically, chemically, and physically beneficial soil amendment. Composting can be a very simple or extremely complicated practice depending on the type of material to be composted, the amount of space available, the amount of time given to generate finished compost, and how the compost is to be used. This handout seeks to provide the basic information needed to develop composting on the farm.

In terms of managing a compost pile, it helps to start with the understanding that composting is nothing more than managing the naturally occurring process of decay. The real workers in composting are microbes. There are several factors that influence how well microbes do their job during composting. Rynk (1992) identified the most critical factors in composting as:

- *Organic materials* mixed to provide a balanced supply of carbon and nitrogen (C:N ratio) needed for microbial activity and growth **(optimal: 25:1 to 30:1)**
- *Oxygen* to support aerobic organisms **(minimum of 5% by volume)**
- *Moisture* to support biological activity without hindering aeration **(optimal: 40-65% by weight, other literature recommend up to 75%)**
- *Temperatures* conducive to high rates of decomposition from thermophilic microorganisms **(optimal - 110-150 °F)**

Temperature is the most commonly measured indicator of composting activity. The temperature trend of a leaf and dairy manure compost mix during the most active phase is shown in Figure 1.

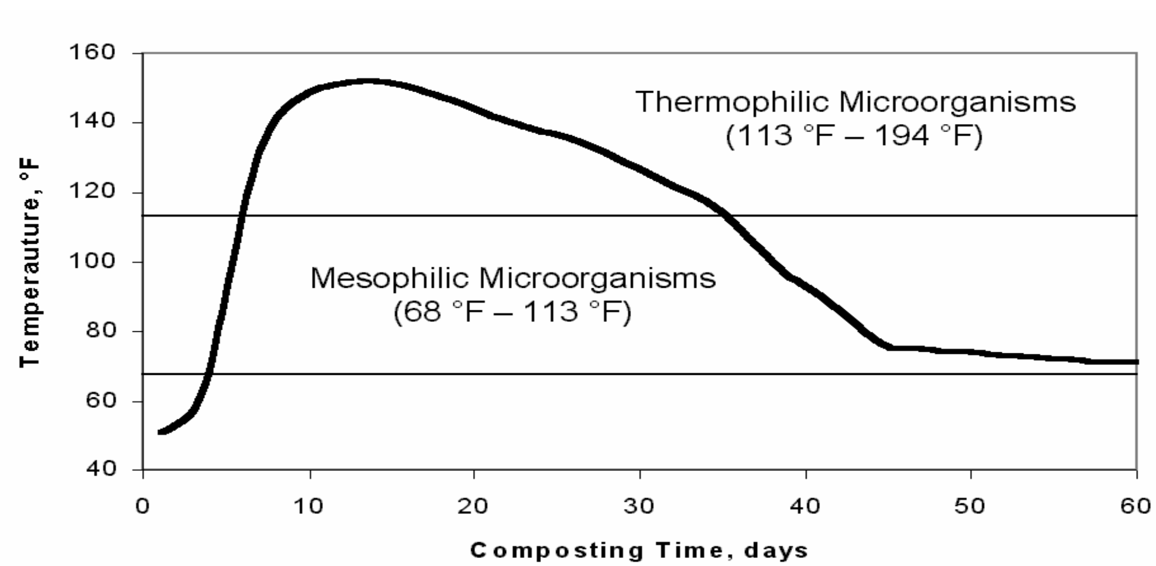


**Figure 1. Temperature trend during most active phase of composting.**

The recently established federal organic standards require that compost be turned 5 times during which compost temperatures of 131-170 °F are maintained for a minimum period of 15 days for windrows and piles, and 3 days in a static pile (methods described in more detail later). These standards were set to assure that human pathogenic bacteria are killed off, and are based on composting of sewage sludge. Farmers that want to sell compost for use in organic production must meet these standards. There are cases, composting of just leaves for instance, where it is unlikely the temperatures will be maintained for that long. Additionally, there is no need to turn leaves that many times.

After the compost "cools" there is still a need to let the compost cure and age. Even though less heat is produced and less oxygen is consumed, there is still biological activity occurring during curing due to remaining fractions of carbon that are harder to decompose. If the compost is applied before being fully cured, the compost could compete with plants for nitrogen and have potentially phytotoxic affects on plants.

It should be noted that most conventional definitions of composting refer to an aerobic (requiring oxygen) biological process. Aerobic composting methods are more commonly practiced in the states because it reduces the risk of generating offensive odors than anaerobic composting methods. There are also quality characteristics of anaerobically produced compost that limit its use with certain plants. For these reasons, this handout focuses on aerobic composting methods, specifically pile and windrow composting.

<u>How Much Material?</u>

The first piece of information a farmer needs to determine or decide on is how much organic material is to be composted. This ultimately determines the amount of space needed, and helps in evaluating what method(s) to use. Farmers tend to have a good idea of the amount of organic materials such as plant or animal residues (they are not wastes!) are generated. For composting recipes, the relative amounts of materials to add to achieve a proper balance of C:N ratio are computed based on the mass or weight of the materials. The mass is converted to volume based on the bulk density of the material. For example:

> The bulk density given by Rynk (1992) for vegetable "wastes" is 1,585 pounds per cubic yard. To convert 2,000 pounds of vegetable produce to cubic yards, divide by the bulk density: 2,000/1,585 = 1.3 cubic yards

A recipe can be based on mixing volumes of feedstocks, such as the number of bucket loads of a front-end loader, or the number of manure spreader loads. If a farmer has access to weighing scale, then the mix can be done on a weight basis, which would provide for the most accuracy. But scales are not typically available, hence using book values, and with time, experience, should be sufficient for developing quality mixes based on volume and number of loads.

A farmer needs to determine the amount of material being generated to estimate the area required for composting. This can be done by simply keeping track the number of bucket loads or manure spreader loads collected either daily, weekly, or monthly. There are always some fluctuations in how much material is generated, especially with plant matter. Fluctuations with manure depend on the type of handling facilities used. There are daily haul systems where manure would be available for composting everyday. There are other systems such as packed bedding where the materials are available every 6-8 weeks. **Always design a compost operation based on peak generation.**

Type of Material

The farmer needs to know some basic characteristics of the materials, primarily the amount of carbon and nitrogen (C:N ratio), moisture content, and physical structure, in order to come up with a good compost mix. Table 1 lists the C:N ratio, moisture content, and bulk density of a variety of Michigan farm-generated organic materials.

The first six materials listed are typically below the desired optimal C:N ratio and are considered *nitrogen* feedstocks. The remaining five materials are well above the desired C:N Ratio and are considered *carbon* feedstocks. Materials like "vegetable produce" itself will have a wide range of variability in terms of the type of vegetables, but vegetable matter in general should be treated as a *nitrogen* feedstock.

**Table 1. C:N Ratio, Moisture Content %, and Bulk Density of Some Common Organic Materials Generated From Michigan Farms (Rynk, 1992)**

| Material | C:N Ratio (weight to weight) | Moisture Content % (wet weight) | Bulk Density (lbs per cubic yard) |
|---|---|---|---|
| Vegetable "wastes" | 19 | 87 | 1,585 |
| Hay - general | 15-32 | 8-10 | - |
| Grass clippings | 9-25 | 82 | 300-800 |
| Dairy cattle manure | 11-30 | 67-87 | 1,323-1,674 |
| Laying hens manure | 3-10 | 62-75 | 1,377-1,620 |
| Turkey litter | 16 | 26 | 783 |
| Apple pomace | 48 | 88 | 1,559 |
| Corn stalks, mature | 60-73 | 12 | 32 |
| Straw - general | 48-150 | 4-27 | 58-378 |
| Sawdust | 200-750 | 19-65 | 350-450 |
| Leaves | 40-80 | 38 (average) | 300-800 |

The properties of feedstocks can vary for a number of reasons. One important factor is how the material is handled prior to composting. High nitrogen feedstocks, especially wet manure and vegetable matter, should immediately be incorporated into a compost mix. If these materials are stockpiled for several days, microbial activity could deplete the available oxygen and create anaerobic conditions. This would create a host of problems including odor, diminished quality to the compost, and attract vectors (flies, rodents).

How Much Material to Mix?

Finding the right compost recipe does take knowledge of C:N ratio and moisture content, but it also involves some playing around with the materials. There are circumstances where the organic material is almost at an ideal C:N ratio and moisture content for composting. With packed bedding, some farmers have adjusted how much straw bedding is continually added to stalls so that when it is removed from the stalls, typically every 6-8 weeks, it is ready for composting without the need for additional amendments. The packed bedding cleaned from stalls at the Michigan State University Dairy Teaching and Research Center is typically above the optimal C:N ratio. Manure collected from the tie and free stall dairy units is added to bring the nitrogen levels up. If no additional manure is available, plant materials and vegetables could be added as a nitrogen feedstock instead.

In some cases when the packed bedding is cleaned, there is a faint smell of rotten eggs or fish, an indication that the lower layers of bedding are anaerobic. The bedding is still compostable, but the more anaerobic activity that occurs before or during composting, the lower the quality of compost. The only option would be to increase the amount of bedding, or increase the frequency the stalls are cleaned if the odors are strong.

For livestock operators that use sand for bedding, the manure is compostable, but it is much denser and requires more energy for moving and turning of the material, plus the piles or windrows need to be much smaller. There are technologies that separate the sand from the manure, but the manure comes out almost as a slurry, and slurries are very difficult to handle in composting. To get a well structured pile or windrow made with sand laden manure, the amount of bulky carbon feedstocks like woodchips needed often far exceeds the optimal C:N ratio. While this is not detrimental to quality, it will prolong the composting process. Sand separated manure will require very dry carbon feedstocks, and the amount of carbon material needed may also result in a mix with a C:N ratio well above the optimal ratio.

**It is better to be higher than the optimal C:N ratio than lower.** The higher the carbon levels in the compost mix, the more nitrogen conserved and the less likelihood for the process to go anaerobic thus preventing the occurrence of offensive odors. The drawback in increasing carbon also increases the amount of time to produce finished compost, and this in turn increases the space required.

**Do not exceed the optimal moisture content!** Excessive moisture will lead to anaerobic conditions and the production of foul odors. Sometimes the mix will be a compromise between C:N ratio and moisture content, but often moisture content will be the deciding factor. **Carbon feedstocks such as straw, wood shavings, and leaves, are typically dry unless stored uncovered.** Therefore, if a nitrogen feedstock is very wet, the mix will likely have a C:N ratio above optimal thus prolonging the time it takes to compost. One method composters will use in such cases is to incrementally add the wet nitrogen feedstock to an active compost pile. A hot compost pile losses moisture quite rapidly. **Increasing turning frequency will also help liberate water vapor and thus reduce moisture content.** A well designed passively aerated windrow or pile also loses moisture more rapidly than a naturally aerated pile, which will be discussed later under the "Methods: Building a Compost Pile" section.

Different *carbon* feedstocks decay at different rates. Wood shavings and woodchips in particular are very slow to decompose due in part to the presence of lignin. Leaves are very quick to decompose when mixed with *nitrogen* feedstocks, but there are differences mainly in C:N ratio between freshly raked leaves, and leaves that were stored for several months or years.

The following are ratios of mixes that have been tested at Michigan State University and are representative of mixes used by other livestock facilities:

> 1 skidloader bucket load of dairy manure from tie and free stall (C:N ratio = 18:1, MC = 75-80%) and 1 skidloader bucket load of sawdust horse bedding (C:N ratio = 80:1, MC = 45%). The resulting mix had a C:N ratio of 28:1 to 32:1 and a moisture content of 60-65%.
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> 1 skidloader bucket load of dairy manure from tie and free stall and 2 skidloader bucket loads of 1 year old leaves (C:N ratio = 55:1, MC = 56%). The resulting mix had a C:N ratio of 25:1 to 30:1 and a moisture content of around 60-65%.
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> 1 skidloader bucket load of poultry manure (C:N ratio = 5:1, MC = 65%) and 4 skidloader bucket loads of 1 year old leaves. The resulting mix had a C:N ratio of 25:1 to 30:1 and a moisture content of around 55-60%.

In Dr. John Biernbaum's "Compost Production and Use" handout (2002), he cites one of the best compost mixes made to date at MSU. The mixture was:

> 20% by volume of swine manure and wood shavings
> 20% dairy manure and horse bedding sawdust
> 20% reed-sedge peat
> 10% year old leaves
> 10% chopped corn silage (did not ferment because too dry)
> 10% alfalfa hay
> 10% grass hay

There is growing evidence that the more diverse a mix, the more diversity of beneficial microbes that are ultimately in the compost and subsequently are introduced into the soil, and that this microbial diversity is itself a benefit. The reed-sedge peat was added in order to lower the pH during composting. Depending on the material, **composts tend to have a pH greater than 7.0 (above neutral).** Peat is often blended with finished compost to bring the pH down, but adding peat into the initial compost mix theoretically should conserve more nitrogen and increase the overall quality of the compost. The resulting compost with the peat did have a pH below 7.0, and this means that higher quantities could be used in potting soil blends and with plants that favor lower pH conditions.

A general rule of thumb is to start with 3 parts carbon feedstocks, and 1 part nitrogen feedstocks (MCC, 1995). This is a safe mix in terms of preventing odors, and is a very common ratio to use for composting yard clippings (leaves and brush = carbon feedstocks, grass = nitrogen feedstock). Many yard clippings compost operations will set up piles or windrows of leaves in the fall, and then incrementally add grass during the spring. Early in the spring the C:N ratio of the mix is very high but decreases as more grass clippings are added. This same type of approach can be followed with any carbon and nitrogen feedstocks used in farm compost mixtures.

There are also cases where for instance poultry manure is partially composted without any carbon feedstocks and sold as a fertilizer. Poultry manure is considered a very hot nitrogen feedstock in that it heats up very rapidly, and the heat drives off moisture to the point that it dries the manure out before it has fully composted. While a significant portion of nitrogen is lost as ammonia, the resulting product is still high in nitrogen.

Livestock farmers are often faced with not having enough farm-generated carbon feedstocks to mix with the manure in terms of achieving proper C:N ratios. In such cases the farmer will import carbon sources such as leaves from neighboring communities. Many farmers have found such practices actually serves to connect the farm to the community. However, in some states there are regulatory issues involved if a farm receives and composts materials not generated on the farm. Farmers that intend to include off-farm materials in their compost mixes should investigate the local and state regulations pertaining to farm compost operations first.

## Siting and Space Requirements

There are some basic criteria for locating where to set up compost piles or windrows. The area should be easily accessible, well drained, and as close as possible to the source of material generation. A water source would also be desirable because during draught conditions compost will potentially dry out. If compost is getting too dry and microbial activity declines as indicated by decreasing temperatures, then the material should not be turned until water is added either by irrigation or by rain. Irrigating a compost pile or windrow is difficult. Compost can hold a tremendous amount of water, and simply spraying a pile or windrow will only wet the edges. The City of Ann Arbor will not turn windrows that have dried up but rather wait for a rain and turn during a rain if pad conditions permit. This way the wetted outer edge material is incorporated along with the water, and the drier inner material is then exposed to the rain.

**Never put a compost pile or windrow in the lowest part of a field.** The ideal situation is to have a dedicated area where the surface has been graded to a minimum of 2% slope and topped with packed clay or concrete. Packed clay works well but can limit access during very wet weather. Compost windrows should be set up along the grade, not across it. If no covers are used or the area is unsheltered, provisions should be made to collect the surface runoff and either store it using a retention pond, then either apply it to land, add it to the compost piles/windrows, or apply it to grass infiltration areas.

Some farmers have set up windrows in fallow fields. This is an acceptable practice as long as the field has a minimum of 2% slope, and the windrows should be covered (e.g. fleece blankets) during periods of heavy precipitation to avoid leaching of nutrients into the groundwater. Under these circumstances, space is typically not an issue. When space is not an issue, the time needed to generate usable compost is less critical. When time is not a factor, the farmer should consider mixing the materials and setting up the piles or windrows in ways to minimize the need of turning. This can be accomplished by increasing the C:N ratio of the initial mix, using bulky carbon feedstocks such as woodchips to increase porosity and aeration, and building piles/windrows on a base of porous materials such as straw or woodchips. While it will take a longer period of time to produce a fully matured compost, the farmer will have eliminated one of the most energy-intensive parts of composting, turning.

When time and space is not critical, a farmer has significantly greater flexibility in how they use their compost. A batch of compost set up in the spring, even if not fully cured, can be applied to fields in the fall. However, batches set up in the summer and fall may not be mature enough for spring application, hence experienced farmers often wait a full year before using a batch to ensure the compost is fully cured and mature, especially when used on high-valued crops or in transplant soil mixes.

The amount of space needed for a composting area depends on the amount of material to be processed, the type of method used, and as just discussed, the amount of time available to store and cure the compost. Pile composting is fairly straightforward. Piles can be setup one next to the other in order to maximize the space occupied. The only consideration for space is to ensure there is enough room for turning. Some farmers will tumble the pile over which needs more area than a pile that is just mixed in the spot. Windrows turned with a dedicated turner require less area than windrows turned with a front-end loader. Even with a dedicated turner, there should be enough space between windrows to maneuver a front-end loader. If a farmer is serious about setting up a dedicated composting area, a very straightforward design approach is provided in Rynk (1992).

## Methods: Building A Compost Pile

There are several methods used to compost organic material. Pile and windrow composting are among the most commonly used methods. The pile method is just that; place the organic materials in a pile. A windrow is just a long pile. There are two main limitations to how big to make a pile and windrow: aeration, and method of turning. For small quantities of organic materials either composted in piles or bins, turning can be done with a pitchfork and good old-fashioned human muscles. The quantities of organic material from production agriculture would likely be too high to rely on manual labor.

Mechanical turning with a front-end loader is a good option because farmers often already have that equipment on hand. The main drawback with front-end loaders is if the farmer intends to sell the compost. Front-end loaders do not break up and mix the materials as thoroughly as a dedicated turner, which will result in some clumps and a product that does not have the "look" consumers have grown accustomed to with compost.

The height of a compost pile/windrow is critical in ensuring adequate aeration and depends on the organic materials used in the mix. When a dedicated compost turner is used, the height of a windrow is limited to the dimensions of the turner. When a front-end loader is used, compost made from plant materials can generally be piled as high as the front-end loader can reach, while compost made from manure should be piled no more than 4-ft to 6-ft high.

Plant material typically has better structure than manure, which is critical in providing porosity and hence, aeration. For manure compost, bulky materials like straw or woodchips are often used to provide and maintain structure and porosity. They also are a suitable carbon source. These materials, or bulking agents, will allow for manure compost to be piled higher, but the drawback, especially in the case of wood chips, is they decompose much slower than other types of carbon feedstocks. Wood shavings and sawdust are adequate carbon sources but do not provide good structure. Leaves provide structure early in the compost process, but tend to loose their structure later in the process.

The **volume reduction of bulky mixes** can be over 50%. The **volume reduction of denser mixes** tends to be no greater than 40%. Because of the volume reduction, piles and windrows can be combined at some point during the process, which frees up space. It is also a good idea to not let piles or windrows get too small or else they may not be able to retain the heat generated, and they may dry out very quickly.

The importance of aeration during composting cannot be over emphasized. Aeration is one of the most critical factors in producing quality compost. After the organic materials are mixed, the pile or windrow will heat up very rapidly (assuming proper C:N ratio and moisture). As the compost heats up, air is drawn in by what is often termed as the chimney affect (Figure 2).

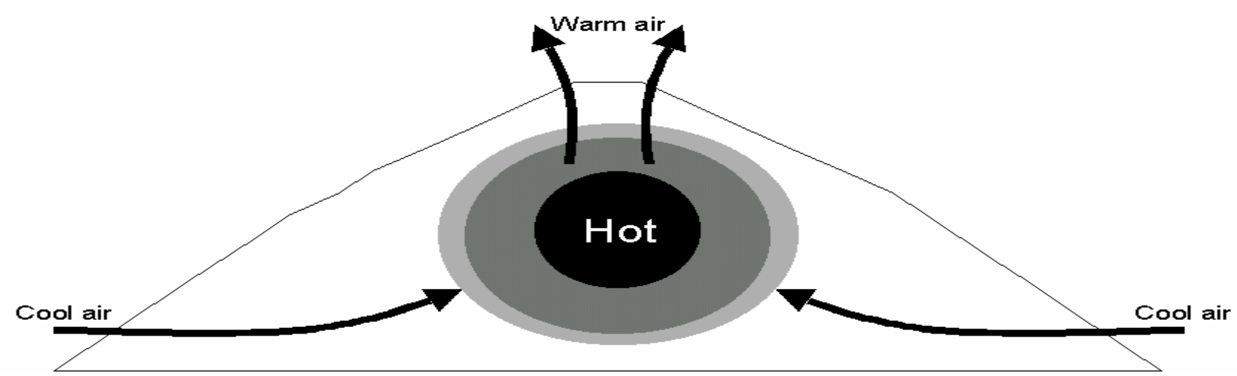


**Figure 2. Natural air movement into a composting pile or windrow.**

The physical structure of the pile affects overall porosity and determines how well or how poorly a compost mix aerates during composting. **Poorly aerated compost requires the most management in order to prevent potential build-up and release of offensive odors and a decrease in compost quality.** Referring again to the dairy cow packed bedding, the straw provides very good structure to the compost mix for aeration, in fact a little too good. **Well-aerated compost will reduce the amount of turning and improve compost quality, but can also lead to rapid drying of the compost before it has fully decomposed.**

In the case of heavier, denser, and less porous mixtures such as wet manure and sawdust, aeration can be enhanced by building the piles/windrows on a base of porous material like woodchips at the base, and further enhanced by placing perforated pipes in the base, as shown in Figure 3. In this type of system, known as passively aerated composting, the compost is not turned. This requires very thorough initial mixing of the materials. This can be accomplished by passing the mixture through a manure spreader. Some farmers use a feed mixing wagon to mix compost. If the mixture contains manure, either power wash the mixer wagon before using it to mix feed, or dedicate the wagon for just mixing compost. After the mixture has been piled, cover the entire pile/windrow with a layer of finished compost, peat, mulch, or woodchips. This layer acts as insulation, which is needed to ensure uniform heating and decomposition throughout the whole pile/windrow. Using finished compost or peat as a cover is preferable because it can be incorporated with the compost pile/windrow without diminishing quality. Mulch and woodchips are not fully decomposed and would either need to be screened out or, if left in the mixture, the compost would need to be cured for a longer period of time.

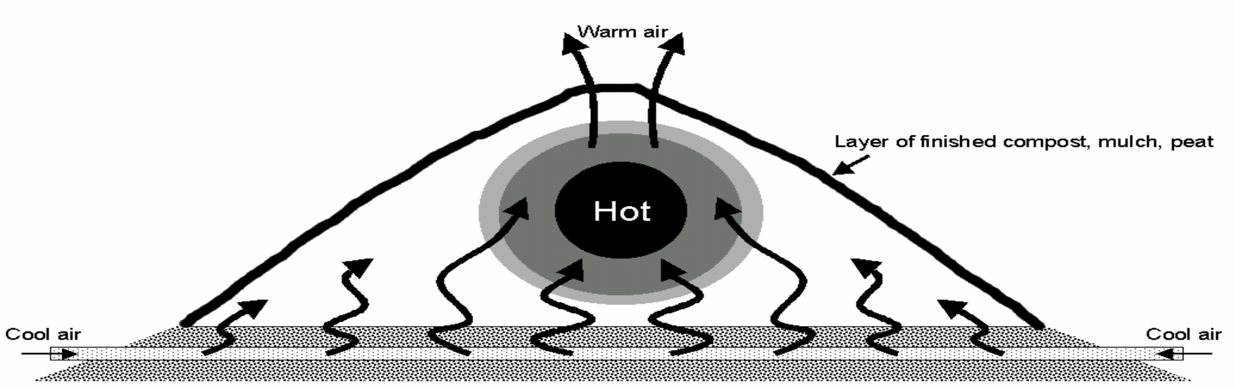


**Figure 3. Passively aerated composting pile or windrow.**

Managing The Compost Pile

The extent a compost pile or windrow needs to be managed depends on several factors. Turning is probably the most demanding part of composting in terms of time and energy. If the mix has good structure in terms of porosity, then the pile or windrow will only need to be turned 2-3 times during the entire process. The main reason to turn is to incorporate the material that are on the edges of the pile or windrow into the inner regions where composting happens at a much more accelerated rate.

Denser compost mixes need to be turned more frequently for a number of reasons. Turning will fluff up the pile to allow for better airflow, but the mix tends to settle within 2-3 days of turning, so it's a short lived benefit. It was commonly believed that turning introduces air into the pile, but several researchers have found that the microbes consume the air introduced into a compost mix from turning in a matter of hours.

If anaerobic conditions develop even slightly in compost, turning will releases the odors that built up in the inner regions of the compost. One may think, "If I don't turn the compost, I won't release the odors." Not turning the compost may actually be worse than turning more frequently because the longer a pile sits unturned the more odors build up, and these odors can eventually escape even if the compost is not turned. Quality is also significantly diminished in compost that has been subjected to prolonged anaerobic conditions. Frequent turning to minimize odors then simply becomes the dilution solution for controlling odors, and it is strongly recommended to take preventative measures such as adjusting the mix by adding bulkier carbon feedstocks.

There are several ways to approach when to turn and how frequently. As stated earlier, temperature is the main way to monitor the progress of a compost mix. A compost mixture that exceeds 160 °F should be turned to release heat. At such temperatures the beneficial microbes needed for decomposition begin to be killed off. For compost mixtures that have a moisture content in excess of 75%, turning can help release water vapor. Turing too often can result in too much moisture being released. The lack of adequate moisture will slow and even stop the decomposition process.

When mixing and turning piles/windrows with a front-end loader, dig into the bottom of the pile, lift the bucket, and drop the material. As discussed previously, front-end loaders do not break up the material and mix as thoroughly as a dedicated compost turner. But if the compost is to go onto agricultural fields or vegetable beds, "clumpy" compost is acceptable. It's when a farmer wants to market the compost that the clumps and overall appearance of the compost become an issue. Passing the compost through a spreader can break up these clumps. Any compost producer considering marketing the compost will likely need to screen the compost, so the clumps could be removed and added to new compost piles/windrows.

In closing, there are several other factors that can be controlled to a certain extent in order to optimize composting while minimizing odors. They include:

- Feedstock - what organic materials are used. Do not let raw manure sit for more than 2-3 days (prevent odor and quality problems). Carbon feedstocks can be stockpiled for several months without creating odors, but should be covered to prevent increase in moisture content from rain or snow infiltration.
- C:N ratio - properly balancing the initial mix of feedstocks.
- Moisture Content (MC) – the best way to control MC during composting is to use covers (fleece blankets for piles and windrows) to prevent rain infiltration when MC is high. The author's experience is to cover when compost MC is above 50%, and remove the covers when the compost MC is below 50%. Sheltered areas assure compost will not get too wet, but water must be added if compost dries out before process is complete. Adding a dry feedstock, typically a carbon feedstock such as straw, wood shavings, or leaves that are covered when stockpiled, will bring moisture down. Increased turning frequency will reduce moisture levels more rapidly.
- pH – tends to be above 7.0, can be adjusted with peat (sphagnum or reed-sedge), finely ground agriculture sulfur, or prolonged curing.
- Porosity, bulk density, particle size – controlled by what feedstocks are used. The bulkier materials, such as wood chips, provide better porosity, but take longer to decompose.
- Aeration – partially controlled by what feedstocks are used and also by how the pile/windrow is built and maintained.
- Pile configuration – relates to maintaining good temperatures, moisture levels, and providing adequate aeration. Pile configuration and dimensions often determined by the turning equipment used.

**Private Compost Testing Laboratories**

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Fax : 706-548-4891
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Website: mmilabs.com
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Soil & Plant Nutrient Laboratory
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Fax: 517-355-1732

University of Wisconsin - Madison/Extension
Soil & Plant Analysis Laboratory
Soil Science Department
5711 Mineral Point Rd.
Madison, MI 53705-4453
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Fax: 608-263-3327
Website: uwlab.soils.wisc.edu
(Note: Lab does not have specific tests dedicated to compost, analysis must be prearranged)

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Columbia, MO 65211
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Website: aasl.psu.edu

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