The Composting Process

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INTRODUCTION

With a herd of 546,000 cows in 2009, Idaho dairies produce an estimated 15.7 million tons of raw dairy manure (feces and urine) each year. One of the greatest expenses associated with raw manure disposal is the cost of transporting it from dairies to sites where it will be applied as fertilizer. Composting typically reduces manure volume by 30 to 50%, which makes the material significantly more affordable to transport and provides many other benefits.

While many people have a basic understanding of the composting process, few people understand its complexity. Yet the better people understand the composting process, the better the decisions they can make for effective and efficient composting. This publication explains what composting is, how it happens, and how it is affected by various factors.

WHAT IS COMPOST AND WHAT IS COMPOSTING?

Compost is the product of the controlled biological decomposition of organic materials. More specifically, compost is the stable, humus-like product resulting from the biological decomposition of organic matter under controlled conditions. Another commonly accepted compost definition is that of the National Organic Standards Board (see at left: NOSB compost definition).

Human control of the biological decomposition process is what differentiates composting from the natural decomposition of organic matter. Organic materials are recycled regardless of whether or not we compost them, but regulating and optimizing conditions ensures a faster process and the generation of a quality end product.

NATIONAL ORGANIC STANDARDS BOARD DEFINITION OF COMPOST

The product of a managed process through which microorganisms break down plant and animal materials into more available forms suitable for application to the soil. Compost must be produced through a process that combines plant and animal materials with an initial C: N ratio of between 25:1 and 40:1. Producers using an in-vessel or static aerated pile system must maintain the composting materials at a temperature between 131˚F and 170˚F for three days. Producers using a windrow system must maintain the composting materials at a temperature between 131˚F and 170˚F for 15 days, during which time, the materials must be turned a minimum of five times.

HOW DOES COMPOSTING HAPPEN?

Degradation of organic wastes is a natural process and begins almost as soon as the wastes are generated. Under natural conditions, earthworms, nematodes, and soil insects such as mites, sowbugs, springtails, ants, and beetles do most of the initial breakdown of organic materials into smaller particles, thus increasing their exposure to microbial degradation. Under controlled conditions, composting operators break down large waste particles through grinding or chopping.

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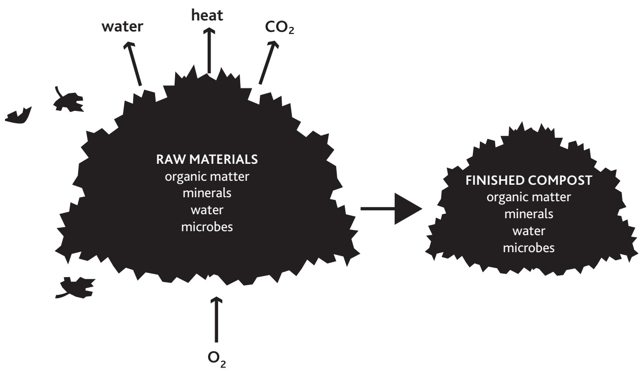

Figure 1. The composting process. (Adapted from Rynk, R. 1992. On-Farm Composting Handbook (NRAES-54). Cooperative Extension, Ithaca, N.Y.)

Once optimal physical conditions are established, microbes colonize the organic material and initiate the composting process (figure 1). Many of the microbes involved in decomposition are present in the wastes themselves. Soil microbes (such as bacteria, actinomycetes, fungi, and protozoa) are introduced when the wastes are mixed with soil or inoculated with finished compost.

Carbon (C) compounds present in the organic materials are used by microorganisms as an energy source, transformed into carbon dioxide (CO_2), and released into the environment. As C is lost from the compost pile, the compost becomes more condensed and air spaces within the pile become smaller. The oxygen (O_2) remaining in the pile is quickly consumed by the resident microorganisms and must be replenished to prevent the system from becoming anaerobic (without oxygen).

The most easily decomposed substances such as sugars and starch are oxidized first. Compounds resistant to degradation such as lignin and cellulose make up the bulk of the finished compost product.

Mesophilic organisms, which function best at 75˚ to 105˚F, initiate the composting process (figure 2). As microbial activity increases soon after compost piles are formed, temperatures within piles of sufficient volume and density also increase. Thermophilic microorganisms take over at temperatures above 105˚F. The temperature in the compost pile typically increases rapidly to 130˚ to 150˚F within 24 to 72 hours of pile formation, and can stay there for several days to several weeks depending on feedstocks properties, pile size, and environmental conditions. This is called the active phase of composting during which decomposition is the most rapid. It continues until the bulk of the nutrient- and energy-containing materials within the piles have been transformed. Remaining materials continue to decompose but at a much slower rate. As microbial activity decreases, so does pile temperature. This is the curing phase of composting.

In the active, thermophilic, phase, temperatures are high enough to kill pathogens and weed seeds and to break down phytotoxic compounds (organic compounds toxic to plants). During this phase, O_2 must be replenished through passive or forced aeration or by turning the compost pile. Care must be taken that temperatures do not become too elevated (> 160 ˚F), because even thermophilic microbial populations are killed by excessive heat. Excessive heat can also be a fire hazard.

As the active composting phase subsides, temperatures gradually decline to around 100˚F. Mesophilic microorganisms recolonize the pile, and the compost enters the curing phase. The rate of O_2 consumption during curing declines to the point where compost can be stockpiled without turning. Organic materials continue to decompose and are converted to biologically stable humic substances—the mature or finished compost. Potentially toxic organic acids and resistant compounds are also stabilized during curing.

A long curing phase is needed if the compost is unfinished or immature. This can happen if the pile contained too little O_2 or either too little or too much moisture. Immature composts can contain high levels of organic acids, high C:N (nitrogen) ratios, extreme pH values, or high salt contents, all of which can damage or kill plants if the compost is applied to the soil.

There is no clearly defined time for curing. Common practices in commercial composting operations range from 1 to 4 months. However compost piles can cure for as long as 6 to 12 months.

FACTORS INFLUENCING THE COMPOSTING PROCESS

Composting is a microbial-driven process. Like other living creatures, microbes need the right environment to survive and thrive. For successful composting, microbes need nutritious “food”; suitable moisture, pH, and temperature; and oxygen.

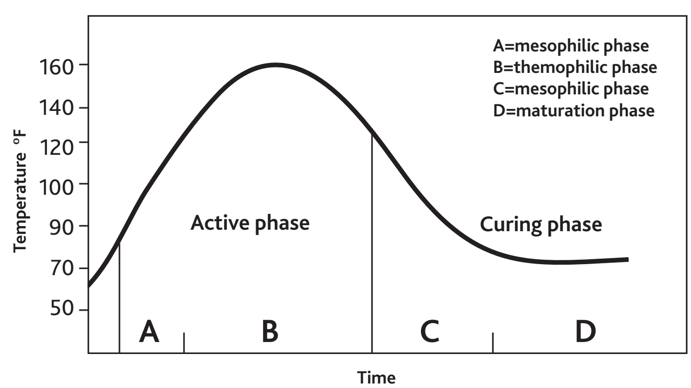

Figure 2. Temperature changes in an average compost pile. (Source: Cooperband, L. 2002. The Art and Science of Composting. Center for Integrated Systems, University of Wisconsin. http://www.cias.wisc.edu/wpcontent/uploads/2008/07/artofcompost.pdf [accessed November 6, 2010])

WHAT IS THE NUTRITIOUS MICROBIAL "FOOD"?

During composting, microbes break down organic compounds to obtain energy to carry on their life processes and acquire nutrients (N, phosphorous, potassium) to sustain their populations. Of the many elements required for microbial decomposition, C and N are the most critical. No trace nutrients have been found to impede the rate of composting.

Carbon provides both an energy source and the basic building block making up about 50% of the mass of microbial cells. Nitrogen is a crucial component of the proteins, nucleic acids, amino acids, enzymes, and co-enzymes necessary for cell growth and function. The ideal C:N ratio for composting is generally considered to be around 30:1, or 30 parts C for each part N by weight. As composting proceeds, the C:N ratio gradually decreases from around 30:1 to 10-15:1 for the finished product. This occurs because each time organic compounds are consumed by microorganisms, two-thirds of the C is given off as CO_2. The remaining third is incorporated along with N into microbial cells and then later released for further use once those cells die.

Why start with a C:N ratio around 30:1? At lower ratios, N will be supplied in excess and will be more likely to be lost as ammonia gas, causing undesirable odors. Higher ratios, which are not common at dairy composting sites, means there is insufficient N for optimal growth of the microbial populations, so the compost will remain relatively cool and degradation will proceed at a slow rate. In general, materials that are green and moist tend to be high in N, and those that are brown and dry are high in C.

The complexity of the C compounds also affects the rate at which wastes are broken down. The ease with which compounds degrade generally follows the order: carbohydrate > hemicelluloses > cellulose = chitin > lignin. Fruit and vegetable wastes are easily degraded because they contain mostly simple carbohydrates (sugar and starches). In contrast, leaves, stems, nutshells, bark, and trees decompose more slowly because they contain cellulose, hemicelluloses, and lignin.

Composts can be made from most organic byproducts. Common feedstocks in Idaho include dairy and cattle manures, food processing wastes, straw, leaves, brush, grass clippings, sawdust, and other by-products of wood processing. A common and effective feedstock combination on dairies is manure (high in N and moisture) combined with straw bedding (high in C, low in moisture).

Ideally, several raw materials should be mixed together to create the "ideal" range of conditions:

- C:N ratios of 25 to 35:1
- Moisture contents of 50 to 60% by weight
- Available O_2 concentrations >10%,
- pH of 6.5 to 8.0
- T emperatures of 130˚to 150˚F
- Feedstock particle size <1 inch

However, in the real world this cannot always happen. Fortunately composting is a forgiving process that can occur

Table 1. Common feedstocks and their characteristics.

FEEDSTOCK	MOISTURE CONTENT (% OF WET WEIGHT)	C:N (WEIGHT TO WEIGHT)	BULK DENSITY (POUNDS PER CUBIC YARD)
High in carbon			
Hay	8-10	15-30	
Corn stalks	12	60-70	32
Straw	5-20	40-150	50-400
Corn silage	65-68	40	
Fall leaves		30-80	100-300
Sawdust	20-60	200-700	350-450
Brush, wood chips		100-500	
Bark (paper mill waste)		100-130	
Newspaper	3-8	400-800	200-250
Cardboard	8	500	250
Mixed paper		150-200	
High in nitrogen			
Dairy manure	80	5-25	1400
Poultry manure	20-40	5-15	1500
Hog manure	65-80	10-20	
Cull potatoes	70-80	18	1500
Vegetable wastes		10-20	
Coffee grounds		20	
Grass clippings		15-25	
Sewage sludge		9-25	

Source: Cooperband, L. 2002. The art and science of composting. Center for Integrated Systems, University of Wisconsin. http://www.cias.wisc.edu/wp-content/uploads/2008/07/artofcompost.pdf (accessed November 6, 2010).

over a wide range of conditions, and if you mix materials with an eye to an acceptable moisture content and C:N ratio (table 1), you can produce acceptable compost with good management practices. In general, the combination of feedstock quality and compost management will determine the quality of the finished product.

WHAT ARE THE WATER REQUIREMENTS?

For aerobic composting (taking place in the presence of oxygen), the maximum moisture content should be kept at a level that allows the whole composting process to be aerobic. Materials containing more fibers, like straw and wood chips, can contain a higher moisture content (over 60%) without causing anaerobic conditions, while materials such as paper, grass clippings, soil, and manure with little structural strength should contain less total moisture to prevent anaerobic conditions from developing. Although the ideal moisture content of the compost pile varies with pile materials, it is commonly believed that the optimal moisture content for on-farm composting is between 50 and 60% by weight. When you squeeze a handful of blended materials, it should feel moist.

Too low of a moisture content will deprive microbes of water needed for their metabolism and inhibit their activity, resulting in slower composting. Too high of a moisture content means pore spaces in the compost pile will be filled with water rather than air, leading to anaerobic conditions. Moisture also regulates pile temperature. Drier piles tend to heat up and cool down more rapidly than wetter piles.

Materials with different moisture contents can be blended to achieve an ideal moisture content. Extra water can be added during the blending process if the original materials are too dry to achieve the ideal moisture content.

Moisture can be measured by a manure and compost testing laboratory. Moisture meters are also available from equipment dealers. However, a more practical and simple approach is to use the “squeeze test.” With a gloved hand, take a handful of the mixture and squeeze. If more than a few drops of water come out it is too wet. If it appears to be very dry, moisture will need to be incorporated.

WHAT ARE SUITABLE pH LEVELS?

The pH, which is a measure of acidity or alkalinity of the compost pile materials, affects the growth and activities of microorganisms and the fate of N compounds. The optimal pH range is 6.0 to 7.5 for bacteria and 5.5 to 8.0 for fungi. When the compost pH exceeds 7.5, gaseous losses of ammonia are more likely to occur. Certain materials such as dairy manure and paper processing wastes can raise pH, while food processing wastes can lower pH. However, controlling pH within an optimal range is difficult and generally not attempted.

The pH varies throughout the pile and during the composting process. Finished compost generally has a pH within a range of 6.5 to 7.5. Measuring pH can be done by sending samples to a laboratory. A list of certified testing laboratories can be found at http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp. It is important to collect representative samples from the compost piles since pH varies throughout piles.

WHAT ARE SUITABLE TEMPERATURE LEVELS?

Temperatures within compost piles affect microbial growth and activities, and hence the rate at which the raw materials decompose. Higher temperatures result in faster breakdown of organic materials, destroy weed seeds, and kill pathogens. However, excessively high temperatures (>160˚F) can inhibit microbial activity. Thermophilic temperatures (105˚ to 160˚F) are the most effective and efficient for composting. The optimal temperature range is commonly believed to be 130˚ to 150˚F.

Temperature should be frequently monitored using a thermometer and adjusted as needed throughout the composting process. Common methods used for adjusting temperatures are aeration, turning, and changing pile moisture contents and pile sizes.

WHAT IS THE OXYGEN DEMAND?

Composting can occur in both aerobic and anaerobic environments. However, aerobic composting is the most efficient. Although the atmosphere contains 21% O_2, aerobic microbes can survive at O_2 concentration as low as 5%, while O_2 concentrations of more than 10% are considered optimal in compost piles.

As microorganisms oxidize C for energy, they use up O_2 and produce CO_2. As microbial activity increases in the compost pile, more O_2 will be consumed. Without sufficient O_2, the process will become anaerobic and produce undesirable odors.

Composts must be aerated either passively or actively to keep aerobic organisms active. Turning materials is the most common method of aeration for on-farm composting.

Oxygen monitoring equipment is available but expensive. Temperature, odors, and moisture are easy to measure and provide a good indication of active decomposition and adequate aeration. A compost pile is not odor-free, but a distinct foul odor (e.g., rotten eggs) usually means anaerobic conditions have developed.

ADDITIONAL RESOURCES

CalRecycle (www.calrecycle.ca.gov/organics/compostmulch/compostIs.htm)

Cornell Composting (http://www.compost.css.cornell.edu)

Internet Recycling and Composting Resource Page (http://www.recycle.cc/resource.htm)

Oregon Department of Environmental Quality (http://www.deq.state.or.us/lq/sw/compost/)

Rynk, R. 1992. On-Farm Composting Handbook (NRAES-54). Cooperative Extension. Ithaca, N.Y.

Seyedbagheri, M. 2010. Compost: Production, Quality and Use in Commercial Agriculture. CIS 1175. University of Idaho Extension, Moscow. (http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1175.pdf)

U.S. Composting Council (http://compostingcouncil.org)

U.S. EPA's Composting Web Page (http://www.epa.gov/epawaste/conserve/rrr/composting/index.htm)

University of Idaho Extension (http://www.extension.uidaho.edu/idahogardens/gb/comp.htm)

Washington State University Puyallup (http://www.puyallup.wsu.edu/soilmgmt/composts.htm)

Woods End Research Laboratories (http://www.woodsend.org)

Vermicomposting (www.attra.org/attra-pub/PDF/vermicomp.pdf)

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Cover photo courtesy of Mario E. de Haro Marti

This publication is the first in a series on dairy manure compost production and use in Idaho. Find more information on animal waste management at the Idaho Nutrient Management website—*www.extension.uidaho.edu/nutrient*

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