Composting: An Alternative Approach to Manure Management

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■ Take Home Message

Composting is an environmentally viable option for dairy manure management, and may be carried out in a variety of ways ranging from simple, low cost, passive piles to sophisticated, automatically controlled in-vessel systems. Regardless of the system used, if it is managed properly, aerobic thermophilic composting will:

- Reduce the amount of material to be handled and, thereby, reduce transportation and spreading costs.
- Control pathogens and weed seeds.
- Control odours associated with anaerobic management systems.
- Enhance the operator's image of environmental responsibility.
- Result in a readily marketable product.

These advantages do not come for free, however, and must be viewed in relation to the capital and operating costs attached to composting. The economic viability of using composting as a method of manure management will depend on the cost/benefit ratio that applies at any given site.

■ Introduction

In recent years economic pressures have pushed livestock producers in the direction of larger, more intensive, production units. An unavoidable consequence of this trend is that manure production has become concentrated, and producers are confronted with the problem of managing large quantities of manure in environmentally sustainable and acceptable ways. Until quite recently, manure was often viewed as a waste or by-product that was to be disposed of at minimum cost. Now, more and more producers are seeing that manure has significant value, and that management systems which capture and enhance this value make economic and environmental sense. The value of manure stems from its nutrient and organic matter content and, in an ideal sustainable system, these would be recycled to the land where the animal feed was grown. Even when this is not possible, it is important that manure is not spread on land at rates that exceed the ability of subsequent crops to utilize the nutrients. This implies that manure from large production units might need to be hauled significant distances in order to recycle the nutrients in a sustainable manner. Thus any system that can reduce the volume and/or mass of material to be moved is desirable.

Unfortunately, even if a system is sustainable from a nutrient recycling point of view, it might still be unacceptable if it exposes neighbours to health risks, or odour nuisance. In addition, and of increasing importance, there is the question of generation of unacceptable levels of greenhouse gases.

Composting is a process which, if carried out properly, reduces the volume of material, virtually eliminates pathogens, generates an easily handled and odour free product. Greenhouse gas emissions from composting can be at less harmful levels than from alternative systems. For these reasons, it is becoming increasingly popular as a method of manure management.

This paper outlines the principles of composting and how this process can be applied to manure management. The advantages and disadvantages of the process are discussed, as well as available technologies and economic factors that need to be considered in evaluating the applicability of composting to manure management situations.

■ The Composting Process

Composting is a biological process in which thermophilic, aerobic microorganisms convert organic material into a stable, hygienic, humus-like product. Since the process depends on biological organisms, it follows that good process management will aim to provide the best possible environment and diet for the organisms. In this regard three characteristics of the composting material mixture (carbon to nitrogen ratio (C:N), moisture content and porosity) are of key importance and are discussed below.

C:N Ratio

Microbial growth utilizes approximately 25-30 units of carbon for every unit of nitrogen, and so the desirable C:N ratio for a compost mixture is in the range 20 to 40 on a dry matter basis. Manure is rich in nitrogen (the C:N of dairy manure is around 15) and so it should be mixed with carbon-rich material such as straw (C:N 100) or wood shavings (C:N 600).

If the C:N ratio is too low, there will be a surplus of nitrogen and this will likely appear as ammonia and be lost by volatilization. This is undesirable for a number of reasons. Firstly, the more manure nitrogen that can be retained in the compost, the higher the fertilizer value of the product. Secondly, ammonia-laden environments are very corrosive and will reduce the life of buildings and machinery in contact with them. Thirdly, ammonia is an odorous gas that can also compromise respiratory health. Consequently, from the point of view of workers and neighbours, the release of ammonia should be minimized.

If the C:N ratio is too high, not all of the carbon in the mixture will be utilized, and the decomposition of material will be slowed down and, perhaps, will be incomplete.

Moisture Content

Like all life forms, the composting microorganisms require water. The desired range of moisture contents is 50-70%(wet basis). While mixtures with higher moisture contents can be composted, problems can arise if the pore spaces in the mixture become totally filled with water. This creates anaerobic conditions, which are incompatible with the composting process as defined above. Dairy manure typically has a moisture content of around 80% and so some drier, (preferably carbon-rich) material should be mixed with it to lower the moisture content.

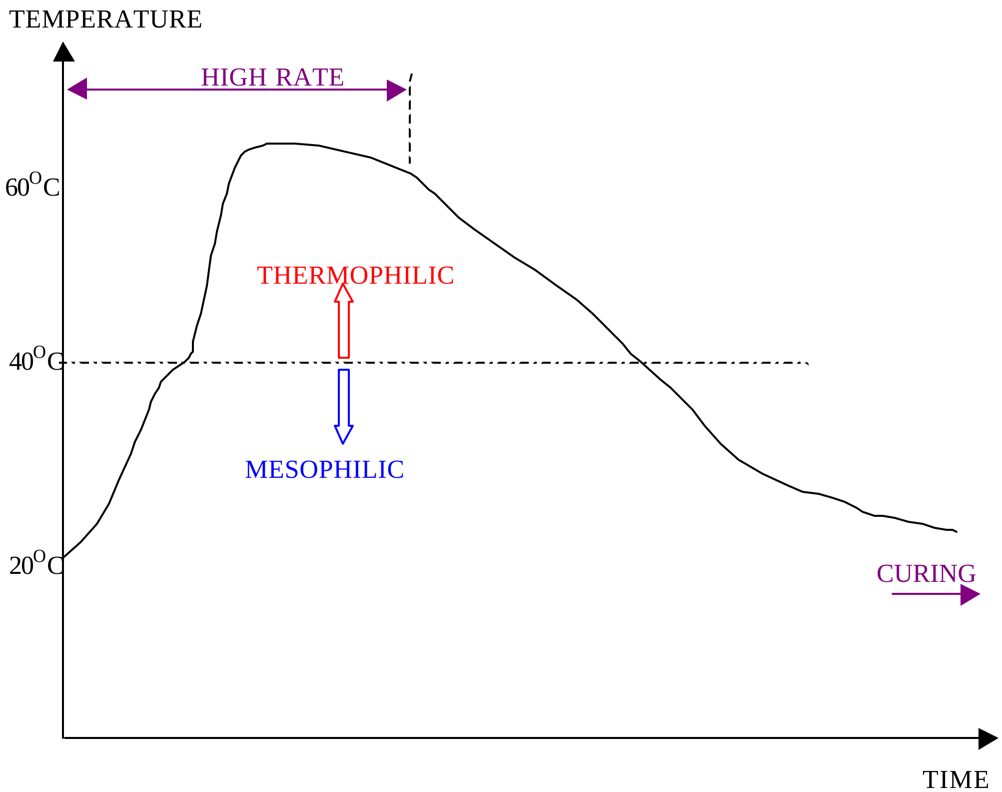
Porosity

In order to keep the process aerobic, the mixture should have a structure that allows air to be retained within, and to pass through it. In general, dairy manure by itself will not satisfy this criterion and, again, it needs to be mixed with a material that will provide a more open and porous structure. If straw is used as the carbon rich additive, it can provide this structure by itself. However, if material such as fine sawdust is used, additional bulking material, such as wood chips, can be appropriate. In such cases the wood chips will not decompose significantly since they have a relatively low surface area and their carbon is not readily available. They can be screened out of the final product and re-used.

A mixture that is insufficiently porous will result in large volumes becoming anaerobic. This does not mean that biological decomposition will not occur, but the organisms doing the decomposing will be different, they will produce some particularly bad smelling compounds in the process, and the rate of decomposition will be slower.

A suitably constituted manure mixture will contain sufficient microorganisms to start composting without any inoculation or external help. The microbial metabolism will result in the production of carbon dioxide, moisture, and heat.

Thus, temperature is a useful indicator of how the process is doing. Figure 1 shows a typical temperature vs. time relationship for a composting process.



]Figure 1. Typical temperatures during the composting process

Initially, mesophilic bacteria attack simple substrates, such as sugars and starches, and their activity drives the temperature up, within a day or two, to thermophilic levels (above approx. 40^{o}C) at these temperatures the mesophiles give way to thermophilic bacteria, which thrive at temperatures as high as 70^{o}C. These high temperatures are conducive to rapid decomposition and are sufficient to kill pathogenic organisms and weed seeds that might be in the manure. Once easily degraded substrates have been exhausted, the rate of decomposition, (and the temperature) decrease. As the temperature falls back below 40^{o}C the less-easily degraded substrates, such as lignin, are attacked by different mesophilic organisms, particularly fungi and actinomycetes.

At this point turning of the compost can redistribute moisture and expose new substrate, so that the process is revitalized and returned to the thermophilic range. When turning or mixing fails to result in thermophilic temperatures the compost enters a curing phase, that may last several months, until it is completely stable and mature.

▪ Benefits of Composting Manure

The use of composting as a method of manure management has a number of advantages. Apart from anything else, the composting process reduces the mass and volume of material that has to be dealt with. Typical volume reduction is in the order of 50%, and so hauling and spreading costs are reduced. Uniformity of spreading is also facilitated by the finer and more uniform particle distribution in compost as compared with untreated manure. The mass reduction comes from the conversion of carbon into carbon dioxide and the loss of water by the evaporation driven by the elevated temperatures in the process.

Because of the reduction of mass and volume, the nutrients in the compost become more concentrated and so the fertilizer value of the material ($/tonne or $\$/m^3$) increases. This implies another important advantage, namely that the compost produced constitutes a value-added product that can be returned to the land or sold to generate additional revenue. More on economics appears below.

One of the major barriers to expansion of livestock facilities in recent years has been the concern with manure odours. As indicated above, most of the objectionable odorous compounds associated with manure are the result of anaerobic processes. If composting is managed well, anaerobic conditions, and resultant odours, are minimized. In very sensitive situations, off-gases from the composting process can be captured and passed through a bio-filter to control odours.

Another concern of the public is the health risk associated with manure – particularly from pathogens such as *E.Coli* and *Salmonella spp*. The thermophilic temperatures achieved in the composting process will kill these pathogens and, as long as every part of the material is exposed to temperatures over $45^{o}C$ for at least three days, the product should not raise any health concerns.

In addition to the tangible benefits outlined above, composting also enjoys the intangible benefit of having a positive environmental image. Adoption of composting tends to reflect well on those using it. The public sees them as making a real attempt to minimize environmental impact and to handle their manure in a responsible way.

■ Problems with Composting Manure

Unfortunately, the advantages outlined above do not come for free! Processing manure by composting involves capital and operating costs that need to be weighed against the benefits. These costs will depend on the level of technology that is used but, even with solid (i.e., scraped floor) manure handling systems, will most likely include the cost of adding additional dry, carbon-rich material. Even so, care needs to be taken to minimize loss of nitrogen in the form of ammonia, particularly during the high rate thermophilic phase of the process.

Another problem that is sometimes associated with manure composting is salinity. Depending on the animals' diet, the manure can have elevated salt concentrations. Just as the composting process concentrates nutrients, so it concentrates these salts. This is not an insurmountable problem, but care may be required in how the product is applied and used.

■ Technology – Ways of Composting

Composting systems range from being very simple and cheap to relatively complex and expensive. Figure 2 provides a schematic overview of the options that are available and their relative advantages and disadvantages.

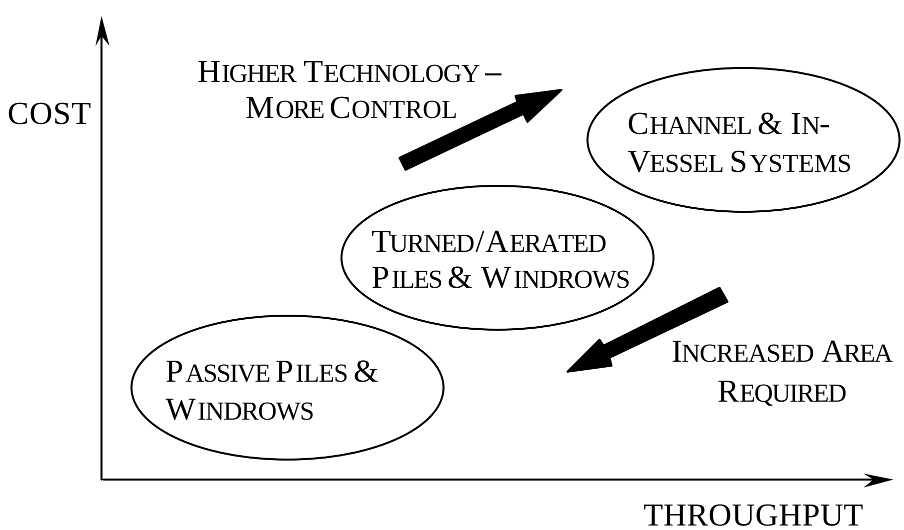


Figure 2. Composting Technologies

With passive pile composting, material is simply piled and left to decompose without any other intervention. While cheap and simple, this method is unlikely to be very successful with dairy manure unless great care is taken in mixing materials so that there is sufficient porosity to maintain aerobic conditions throughout the piles for the duration of the process. Aeration of the pile can be aided by incorporating perforated pipes into the pile when it is built. These provide a means for air to get into the middle of the pile but are inconvenient from a material handling point of view. In any case, passive composting is likely to be slower than other methods and will, therefore, require more area to pile material while it is composted.

Actively aerated piles and windrows have air supplied by some mechanical means (i.e., fans or blowers). The air can either be blown (positive pressure) or sucked (negative pressure) through the material but, in either case, the piles need to be porous so that air can pass through them without excessive power requirements. With actively aerated systems, there is a tendency for air channels to form within the piles and most of the composting activity occurs around these channels while other regions become anaerobic. Thus, it is usually a good idea to mix up (or turn) the material periodically to break up these channels, re-distribute moisture and expose fresh substrate to microbial attack. Negative pressure systems offer better control of the exhaust air than positive pressure systems and, where odour is a problem, this air can be directed through a bio-filter or other treatment system.

Non-aerated windrows or piles that are simply turned periodically are probably the most widespread form of composting system. Turning can be done with a front-end loader or with specialized tractor-drawn or self-propelled turning machines. The turning process helps to maintain porosity and break up aggregates, as well as redistributing moisture within piles. All of these encourage faster decomposition. However, faster processing needs to be balanced against the cost of turning and the fact that some moisture and heat is lost when the material is disturbed. Turning also results in the release of ammonia, and any odorous gases that have accumulated in anaerobic regions within piles.

An important advantage of turned systems is that the status of the process can be monitored easily during turning. The turning operation provides an opportunity to observe conditions in the inside of the pile. An active pile with a hot, moist interior will steam when it is turned, while anaerobic piles will tend to emit characteristically objectionable odours.

Material in channel composting systems is also turned, but this technology allows more material to be processed in a smaller area than simple turned windrows. In channel systems the compost material is contained in concrete channels and is turned by a machine that runs on tracks along the tops of the channel walls. A transfer carriage allows the turner to be moved from one channel to another, or even to another site if the machine is shared by a number of operations. The turning action moves material along the channel so that fresh material is put in at one end and processed material comes out at the other. Most channel systems also include aeration of at least the first portion of the channel, where composting activity and oxygen demand is the highest. Some systems have a number of aeration zones along the channel so that the first part can be aerated at higher rates than the succeeding zones.

The combination of turning and aeration allows the process to be managed at a higher level than turning or aeration by themselves and, consequently, channel systems can be expected to process material more efficiently. Also, if the channels are enclosed in a building, or if negative pressure aeration is used, odours and off-gases can be controlled to a high degree. However, the advantages of channel systems need to be balanced against the higher initial and operating costs when compared with a simple turned-windrow operation.

The highest level in the composting technology hierarchy is occupied by in-vessel systems. These are batch or continuous-flow systems in which the materials are totally enclosed in a vessel. Tunnels, boxes and rotating drums are some of the different types of vessels that are used. The vessels are insulated to retain heat and are usually supplied with controlled rates of ventilation. Material can be held in the vessel for the entire composting process, or merely for the first few days (i.e., the initial, high-rate part of the process). Because the process is totally enclosed, very good control of the composting environment is possible, together with complete control of aeration, odours and off-gases. The increased control should lead to more rapid processing and in-vessel systems lend themselves to automation. However, these advantages come at the expense of higher capital cost

The choice of system will depend on the economics that prevail at individual sites, and some of the factors that need to be considered are outlined below.

▪ System Management

To work well, composting processes need to be managed carefully. Think of the microorganisms that are responsible for composting as a large herd of small animals whose health and welfare needs to be checked on a regular basis. This involves monitoring of microbial activity, and ensuring that conditions within the composting materials are conducive to maximizing this activity.

The easiest way to monitor activity is by means of temperature. Composting thermometers of up to 2m in length are available for this purpose at quite modest cost. As indicated on the graph in Figure 1, high levels of microbial activity give rise to the desired thermophilic temperatures. If these are not reached, or only last for a short time, the mixture might need to be adjusted, water might need to be added, or turning might be required to increase porosity and oxygen levels within the pile. Dairy manure, particularly if it is mixed with straw, should not require inoculation with microorganisms in order to start composting. However, mixing some mature compost, or even topsoil, with fresh material can help to ‘kick-start’ the process.

In relatively dry climates, such as Alberta’s, moisture can be a limiting factor in composting processes and needs to be monitored as part of the management routine. Unfortunately, there is currently no cheap, convenient and accurate way to monitor moisture content in compost on a continuous basis. The standard method for determining moisture content is to dry a sample in an oven for 24h at 70^oC, and determine the mass of moisture that is lost by weighing. This process can be shortened to a few minutes by using a microwave oven but, with experience, moisture status can be evaluated quite effectively by the look and feel of the mixture.

As indicated above, the other key factor contributing to a suitable environment for the aerobic composting organisms is the oxygen content in pore spaces within the material. Electronic probes, usually combined with a temperature measurement function, are available for monitoring this at a cost of a few hundred dollars. Ideally, the oxygen content should be kept above 10% to maintain aerobic conditions, and values below this are an indication that the material has insufficient porosity or that the pile is too large to allow sufficient airflow. Turning of the pile will increase porosity, and will incorporate fresh air into the pile. However, an active pile will soon use up this new oxygen, and turning should not be relied on, by itself, as a means of supplying air to the process.

Failure of the composting material to reheat after turning, and if lack of moisture and/or oxygen are not limiting the process, indicates that all of the degradable material has been metabolized and that the compost is becoming mature and stable. Laboratory methods such as respirometry and bioassays are also available to assess maturity, or the compost can simply be left to cure for a few months to ensure that the process is complete. Immature compost can have negative effects on plant growth, and its sale or use should be avoided.

Cold Weather Composting

Since composting involves the achievement of high temperatures within the material being processed, a frequently-asked question is ‘Can composting be carried out at temperatures typical of an Alberta winter (e.g., -30^oC)?’ The answer is yes, as long as the piles are large enough to retain heat. There are numerous anecdotal and documented examples of successful composting under quite severe winter conditions. Some heat is lost from piles when they are turned, but this is soon made up by microbial activity and, apart from the surface layer (a few centimeters thick), a suitable environment is maintained within the main body of the pile. One factor that needs to be kept in mind, however, is that very cold air is also very dry, and can result in drying out of the compost. At higher temperatures it is relatively easy to add water, but this process is not as straightforward when the ambient temperature is -30^{o}C!

▪ Economics

While composting is undoubtedly an environmentally sustainable method of manure management, the economic sustainability of composting depends on the circumstances of individual operations. Regardless of the method that is used, effective composting requires some capital investment and a commitment of operating funds to ensure that the process is managed adequately. Return on this investment can be sought in the various forms listed as follows (in no particular order of importance):

a. Lower manure-hauling costs. The reduction in mass and volume that results from composting means that fewer truckloads of material need to be hauled and/or spread. If current haulage distances and costs are high, composting could be quite attractive from an economic point of view.

b. Improved long term response of crops. Because the nutrients in compost are less readily available than those in unprocessed manure, compost acts as an organic, 'slow release' fertilizer and compost nutrients are less likely to be leached out of the soil profile. Also, compost has well-documented non-nutrient benefits such as improvement of soil structure, and suppression of fungal diseases. Thus, if compost is applied to crops with a high enough value, the resulting yield increase can help to justify the processing cost.

c. Public acceptance. The long-term viability of intensive livestock operations depends on having manure management systems that are acceptable to neighbours and the surrounding community. Composting not only enjoys an image of environmental responsibility, but it can also reduce the odour emissions that are the cause of a high proportion of objections to the establishment, or expansion, of intensive livestock operations. In the most extreme case, if the alternative to not composting manure is to go out of business, there is a fairly strong economic incentive to compost.

d. Sale of the product. If the compost produced from manure is not used on-site, or if there is insufficient area to use it all on site in a sustainable way, it can be marketed off site. The price obtainable per tonne will be lower for bulk sales (for agricultural and horticultural use as well as for municipal and recreational facilities) than if the compost is bagged for the retail market. Highest prices can be obtained for value-added products such as granulated or pelleted compost, or compost blended with chemical fertilizer.

However, these products require additional processing and dependable markets must be available to justify the additional processing cost.

■ Further Reading and Resources

There are a number of excellent printed and electronic sources of information available on composting in general, and composting of manure in particular. Perhaps the most widely used book on the subject is 'The On-Farm Composting Handbook', edited by Robert Rynk, and published by the Natural Resource, Agriculture, and Engineering Service (NRAES), Ithaca, NY. Although providing a very comprehensive treatment of composting, this is a very easy to read and reasonably-priced publication which can be ordered on line from NRAES at http://www.nraes.org/publications/composting.html . A number of other, related publications are available from the same source

There are numerous web sites devoted to compost and composting (a recent search for 'compost' indicated about 290,000) but a lot of these are oriented to backyard domestic or municipal composting. One excellent site, dealing specifically with agricultural composting, is maintained by Appropriate Technology Transfer for Rural Areas (ATTRA) and can be found at http://www.attra.org/attra-pub/farmcompost.html. This site provides a comprehensive bibliography on composting, together with links to other relevant sites.

General information on composting in Canada, including relevant standards and guidelines, can be found on The Composting Council of Canada's site at http://www.compost.org/ .