AN EVOLVING DISCUSSION

CHARACTERIZING COMPOST COMPLETENESS

This insightful discussion explores use of Reduction in Organic Matter as a tool to measure the end point of composting, as opposed to — or perhaps with — C:N.

Will Brinton

THERE are a variety of means to define and measure completed or mature composting. One formula found in a recent survey of state agencies that have compost standards is the calculation of *Reduction in Organic Matter* (ROM). Florida and Texas both use ROM to establish expectations for compost. The Florida definition is as follows: "(3) Compost maturity shall be determined as … (a) Mature compost is a highly stabilized compost material that has been exposed to prolonged periods of decomposition ... This level of maturity is indicated by a reduction of organic matter of greater than 60 percent."

Calculating ROM is a little more complicated than may be expected. Determining ROM is not simply comparing start and end organic content of the compost to obtain the desired result. That is a common error, which leads to significantly *underestimating* the real loss of organic matter (OM) that has taken place during composting. If the laboratory test of OM for a fresh compost ("before") is 80 percent by loss-on-ignition test, and the final sample ("after") shows a value of 60 percent OM, this appears to be a 25 percent loss of OM (i.e. 60% divided into 80%). But keep in mind that the final test performed by the laboratory is OM remaining *after* the compost has already lost solids between sampling events over time. This means that the percentage organic matter will appear higher than it actually is since it has become *concentrated* in lesser material during the composting process.

The calculation of ROM from the Florida and Texas protocol is as follows:

$$ROM = [1 - (OM_k\,(100 - OM)/OM(100 - OM_k))]100 \quad \text{. . . . Eq (1)}$$

where:

ROM = percent real reduction of organic matter,

OM = % dry organic matter content *before* decomposition, and

OMk = % dry organic matter content *after* period of decomposition.

This equation considers organic matter in terms of the relationship of OM before and after decomposition in relationship to the ash content (100-OM). The actual solids loss is proportional to the increase in ash content. In this way the formula corrects for losses in the total mass that have occurred along the way. In the example above, what looked like a 25 percent loss of OM is actually a 62 percent loss, or 62 percent ROM. Incidentally, the ROM procedure theoretically will give the exact same results as weighing compost before and after to determine total solids loss. This is, however, rarely practical.

Florida's current rule uses the 60 percent ROM mark as a sign of matured compost, while Texas adopted a slightly more flexible rule (40-60% ROM implies mature and >60% ROM is cured compost). The exact source of the 60 percent ROM requirement used in Florida or Texas is not clear. In the mid-1980s, a method of measuring ROM was reported by our laboratory when composting fish waste for Time & Tide RC&D in Waldoboro, Maine (Brinton and Seekins, 1998) and subsequently in collaboration with Florida Sea Grant College (Cato, 1992) when composting scallops and crab shells. In these projects, ROM was calculated purely to discover the amount of OM loss during composting associated with attaining satisfactory maturity for the noxious fish wastes. It was found this was attained between 40 and 50 percent ROM (maturity was evaluated by loss of fish odor and analyzing ammonia and measuring plant effects in greenhouse trials).

The actual origin of ROM is most likely within the wastewater industry, which, since 1945, has calculated "volatile solids reduction" (VSR) according to the so-called "van Kleeck equation" (WPCA, 1968) or other versions. The U.S. EPA uses this in sludge vector attraction reduction requiring that there be at least 38 percent VSR. The assumptions and method of calculation for VSR is essentially the same as for ROM.

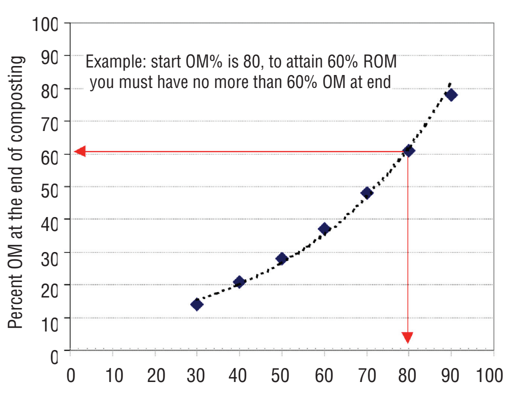
WHY ROM FOR COMPOST?

The premise behind measuring ROM for compost is simple. It is intended to distinguish a material that is sufficiently composted from one that is not, by assuming that an appreciable amount of organic matter must have been decomposed (and lost as CO_2) if it is to be called composted. Setting the bar as high as 60 percent ROM seems very ample protection to validate composting. Attaining this level of ROM, however, does not necessarily guarantee mature compost nor result in the same stability when comparing differing composts. For example, our laboratory tested two final composts, one with 15 percent OM and the other 60 percent OM, and both met the 60 percent ROM criteria (since we also knew the start conditions). The former had completely cooled down, and the latter was still warm, for the OM was high enough to generate heat by volume respiration.

Figure 1 computes the required 60 percent ROM (dotted line) for any start condition of OM content. All the composts that fall on or below the dotted line have attained the necessary 60 percent ROM to be defined in the case of Florida law, as matured product, or in the case of Texas, on the border between Mature and Cured. Those that lie above the dotted line have not reached a 60 percent ROM. This graph can be used as a guideline if data exists for the start and end OM contents for any compost, as the intersection of the two numbers will indicate how much ROM was achieved.

The hidden factor that plays the all-important role in making ROM calculations work is the nonorganic or inorganic (ash) fraction of compost — the nonvolatile portion that remains constant throughout. This indicates an area of potential problem for the ROM equation, since the ash fraction must be very reliably measured. This problem has been thoroughly discussed in early literature on VSR in wastewater. For example, if composting is conducted on bare ground and soil is inadvertently mixed into compost during the process of turning, then ROM may yield a false positive, since the nonorganic fraction appears to increase more than could be accounted for by carbon respiration. It is a similar problem in wastewater VSR when either settling of solids or accumulation of grit throws off the accurate measurement of volatile solids. ROM also will produce erroneous estimates

Figure 1. Passing end OM% of compost to attain 60% ROM based on starting OM content



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if at any point during composting additional materials are blended into the compost mix, diluting the ash component. In such a case, a full mass balance method will be needed to properly determine ROM.

ROM VS. C:N AS MATURITY GAUGE

The question may be raised about how ROM relates to C:N ratio, a popular test frequently used by itself as the ultimate indicator of composting maturity. Calculating ROM is a very different approach for determining compost completeness than measuring the ratio of carbon to nitrogen (C:N). There are serious limits in using C:N alone as a proper indicator of compost completion, which the architects of ROM regulations are likely to have been aware of and which may explain why ROM rules came into existence.

One of the problems is that the C:N method requires two separate laboratory tests, one for carbon (or volatile solids and using a correction factor to get carbon) and one for total nitrogen. Neither of these tests has any essential bearing on each other, nor does total nitrogen alone have any actual relationship to compost maturity. In fact, if nitrogen is lost during composting — a not uncommon occurrence — the C:N ratio may either not change over time as expected or it may actually go up slightly as the compost is maturing. This severely compromises the usefulness of the C:N index.

The ROM approach does not possess the same inherent error potential. ROM like VSR depends on only one very reliable lab test, EPA 160.4, "Loss on Ignition". This robustness, and the fact that ROM may be used to exactly calculate mass balance for any element in composting, as in wastewater biodegradation, may be why the ROM method is preferable over C:N for such a purpose, and why it should be used more.

ROM LIMITS

ROM — and its limits — can be illustrated by taking two cases of compost: dairy cow manure (DCM) having a start OM of 75 percent and a C:N of 41, and a leaf compost, with a start OM of 95 percent and a C:N of 95. Figure 2 shows the decomposition lines plotted down to an end C:N of 17. The interesting point is *where* these lines intersect the 60 percent ROM line. This reveals that while the DCM compost does attain a stable endpoint C:N of 17 at the same time as meeting 60 percent ROM, the leaf compost, which started at a higher OM and C:N, clearly does not. For this high OM, low N leaf compost to attain a finished C:N, it would require about 85 percent reduction of organic matter. ROM therefore is a method to report a minimum requirement for degradation and not a stability or maturity protocol.

In this example, it can be argued that a C:N of 95 is too high for composting, but the point still stands. (In the author's opinion this is not necessarily the case, since a large enough pile of high C:N material of appro-

Figure 2. Reduction of organic matter for two varying C:N composts

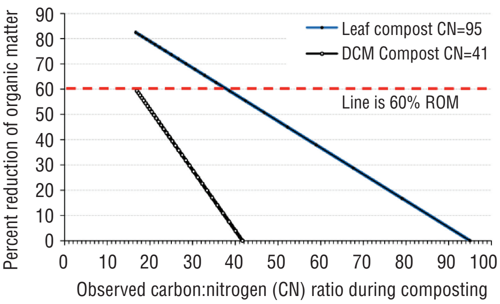
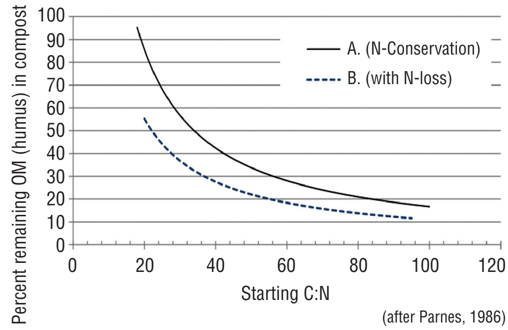


Figure 3. Percent remaining OM after composting to a stable endpoint for any starting C:N



(after Parnes, 1986)

ROM protocol should work well for a fairly narrow range of very normal starting conditions.

priate moisture and texture will conserve nitrogen and most likely will also be able to attain elevated temperatures and eventually fully compost.) Regardless, the example illustrates that there is no underlying principle to ROM, which explains why there is little or no literature showing a relationship to actual stability.

Perhaps we need to look back to the early sludge studies, which showed that a minimum of 38 percent VSR correlated to an apparent loss of vector attraction. Based on what we know about composting, the ROM protocol should work well for a fairly narrow range of very normal starting conditions. So, if meeting a ROM of 40 to 60 percent is taken as fact, as required in the Florida and Texas rules, then meeting ROM will also obtain a mature endpoint (C:N=17), but only for composts that are initiated between a C:N of 30 and 40. Outside of this range, lower or higher, requires less or more ROM, to meet the same stable end point, but we don't know how to interpret this, i.e., over-composting one and under-composting the other.

ROM IN RESEARCH PERSPECTIVE

There is an unfortunate absence of research literature relating the change of properties and especially C:N during composting, relative to attaining ROM, yet this is an interesting if not very essential question. Robert Parnes, who first presented the carbon energy index in 1986 (Brinton, 2008), evaluated this requirement of compost mathematically. Parnes published an early graph (Parnes, 1986) using the principle of ROM and the assumption that a C:N of 17 must be attained to reach proper maturity in compost. Parnes wrote a computer program (before PCs were widely available) which used iterative differential equations to draw a graph solving for residual organic matter (the inverse of ROM) as dependent on the starting C:N and factoring in a fixed end point target of C:N 17.

To obtain an even more conservative result, in conversation our lab agreed Parnes would factor in modest nitrogen losses, which would tend to upsize the ROM required. From this, Parnes demonstrated that the requisite ROM for composting any material to the same end point could be precisely known. Figure 3 reproduces Parnes original equation plus an additional curve calculated to show theoretical 100 percent N-conservation during composting (rare but possible). These calculations were made reporting "remaining organic matter" instead of reduction in organic matter to help emphasize the product (humus) instead of what was decomposed — the two are simply the inverse of each other. To obtain ROM on the Y-axis, use 100-Y.

Figure 3 may illustrate several important points about proper use of ROM. One is that if you are losing nitrogen during composting, a lot more composting — i.e. reduction of organic matter — is required to attain the same end point. This is seen by comparing the dotted to the solid line. For example, if a compost is started at a C:N of 40, and no nitrogen is lost, then 60 percent ROM will also represent a stable ending C:N ratio. If the same compost loses any appreciable nitrogen during the composting process, then the ROM requirement to attain the same stability may increase to as much as 75 percent as shown in looking to the dotted line. Composters should probably shoot somewhere in between.

The opposite circumstance is also important, i.e., composting at low initial C:N conditions, frequently encountered with manure ingredients. At a start C:N of 20 and assuming some nitrogen losses (very likely), a ROM of 35 percent (but as little as 5% with no N-losses) is all that is needed to get down to a C:N of 17. From this it can be concluded that while it is possible to write more comprehensive rules for completed composting, the question remains what end stability really means beyond C:N ratio. Composting this low C:N material to a 60 percent ROM would invariably produce a nice looking humus, but at considerable loss of nitrogen.

These various points may shed light on reasons that ROM is not applied more widely in setting standards for composting. Proper use of ROM requires that you diligently obtain accurate beginning /end test results for loss-on-ignition. A lab carbon test converted to OM would not be appropriate since the essential factor is to accurately measuring ash content. Without precisely knowing start conditions, ROM cannot be reliably calculated. As many know, sampling and testing very fresh compost for organic con-

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tent at the beginning when the material is not homogenous, is very challenging. This may be the principal reason why C:N testing has become more popular, since a start test is not required at all. It appears that all that is needed for C:N interpretation is one test result at the end, when it is significantly less challenging to obtain a representative sample and for the lab, to obtain an accurate test result.

COMBO APPROACH

Perhaps it would make the most sense to combine the two approaches. The example used when teaching compost maturity at the University of Maine Extension Compost School and at the Rocky Mountain Compost School, Colorado, is that of trying to find your location on a map. If you have only one reference point available, you may get a longitude or latitude but no point on the line. By introducing triangulation, using two or more different points of reference, you can pinpoint a location very precisely. This particularly applies to compost maturity testing.

What this means is that any single test protocol to obtain a compost end point conclusion is likely to have its limits. ROM performed carefully is excellent for mass balance, and is essential in engineering facilities where solids loss must be properly accounted for. C:N is convenient for mix ratio targeting and estimating the end point. But, if a compost is started with too much nitrogen (or not enough carbon), it is possible to observe a low C:N all the way through composting, which proves very little. Or, if compost loses nitrogen in the process, the C:N ratio can lead to misinterpretation of the quality. This makes the ROM approach seem very useful, since the objective is to find how much solids have actually been transformed. ROM alone may not get you to stability, however, if you are starting your composting between a C:N of 30 to 40, it will be quite close.

At least one more test would be required to add to ROM and C:N before concluding you have validated composting fully, and have reached a stable end-point. Combining expected ROM with a target C:N as illustrated in this article, and then adding a factor that relates to the nature of the remaining organic matter fraction itself, such as CO_2 respiration, should result in a more foolproof gauge of compost completion. The tests described, whether ROM or C:N, are important individual steps in this direction. The somewhat quiet discussion of ROM has been going on for over 25 years. And it's likely to go on longer. ■

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