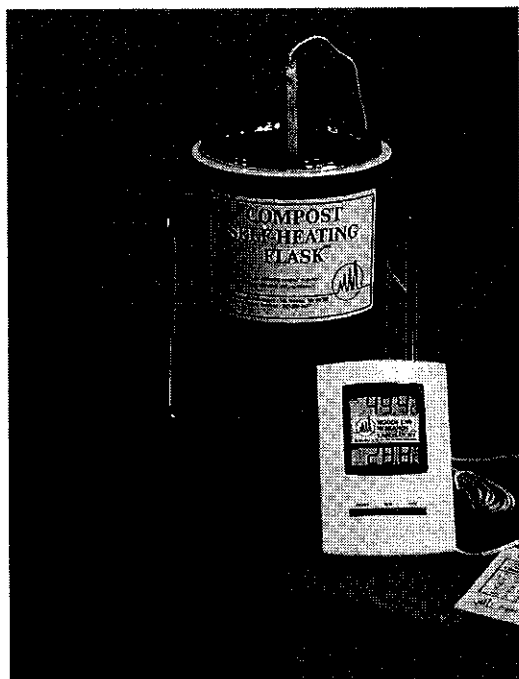


STANDARDIZED TEST FOR EVALUATION OF COMPOST SELF-HEATING



Understanding the stability and maturity of the organic fraction remaining after decomposition is critical for both compost facility management and proper use of the end product.

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COMPOSTING is a means of biologically degrading organic materials while stabilizing a residual organic fraction as humus or forms of it. Theoretically, all the organic matter could break down and escape as CO₂ and water, in which case a finished compost would consist of nothing but the remaining ash. The fact that this does not happen, and that the remaining stable organic fraction is useful to soils and plants, is one of the reasons composting has such value. Understanding the stability and maturation process of the remaining fraction is therefore of great significance. This paper introduces a standardized self-heating procedure that enables producers and users to obtain a reliable measure of compost stability.

It should be pointed out that the words stability and maturity are often used interchangeably, and a strict definition is not possible. The word maturity has occurred frequently and quite early in the literature (Spohn 1978; Jiménez and Garcia 1989). Both expressions have biological overtones

The self-heating test kit consists of a two-liter, steel encased Dewar vessel of 100 mm inner diameter, a dual scale minimum-maximum inside-outside digital thermometer and a 30 cm thermocouple probe on a PVC wand.

relevant to self-heating, however, and persons of different disciplines such as chemistry or microbiology often choose their own interpretations. The Dewar self-heating test described in this paper was intended as a measure of the "degree of decomposition."

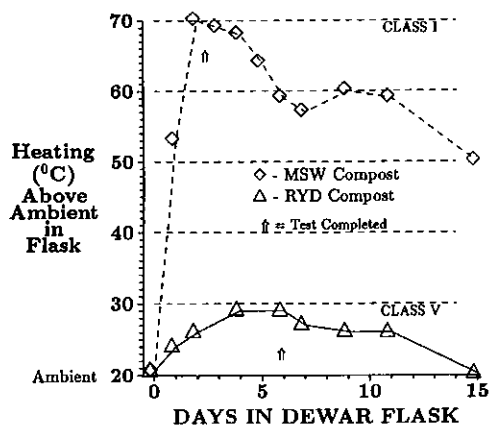
The Dewar self-heating test was first introduced in Europe in 1982 (Jourdan 1982), and recently reevaluated (Becker and Köter 1995). This followed a period of time where numerous workers reported investigations on compost maturity and heating traits of composts (Helmer 1973; Horstman 1961; von Hirscheydt 1977). The Dewar self-heating method was adopted as an official standard for "ripeness" by the German Department of the Environment in 1984 as a follow-up to the 1982 Sewage Sludge Order (LAGA 1984).

A considerable amount of literature discussing the merits of the Dewar test and other similar methods has accumulated in the past 20 years (Niese 1969; Spohn 1969; Harada 1981; Jiménez 1989). In view of this, it is remarkable that no country outside of Germany has made any significant effort to adopt standards that relate to stability or maturity of composts. (The State of Illinois has recently included the Dewar self-heating test in its latest guidelines for finished compost maturity evaluation.) Given the increase of composting activities worldwide, the public and professional horticultural interest in compost products has been aroused. The need for encouraging producers and consumers to adopt general maturity standards is now widely accepted.

MEASUREMENT OPTIONS

Generally speaking, there are three approaches to measuring stability: oxygen uptake rate, carbon dioxide production rate, and heat production rate. More than other procedures, self-heating is a relative test which depends on how it is measured. Surface spread raw compost does not heat in the soil (even though it may release large quantities of energy). On the other hand, a stable compost, if placed in a large enough pile, can heat up considerably. Learning to identify these traits with a self-heating test can be very useful.

Figure 1. Dewar self-heating results for selected composts



The Dewar method is essentially a standardized means to evaluate self-heating. It was inspired from early investigations of self-heating phenomena in nature. Self-heating is important because it drives the compost process, and regardless of other traits, the presence of heat in compost is widely held to be a sign of immaturity (Gallenkamper *et al.* 1993). Self-heating in finished composts can be dangerous after packaging of large volumes of material, because of the tendency of containers or pallets to heat up during shipment.

A compost self-heating test may be compared for illustration purposes to a calorie bomb analysis, used widely to calculate the energy content of food stuffs. In a calorie bomb, organic matter is ignited in the presence of oxygen, and the total temperature rise is precisely recorded. The amount of energy (calories) present in the material is computed from the result. Theoretically, compost could be analyzed this way, but the results would, of course, be impractical.

The name Dewar refers to a super insulated vessel, invented by Sir James Dewar, almost 100 years ago. The vacuum lined vessel was intended to keep cool (or hot) ma-

A compost self-heating test may be compared for illustration purposes to a calorie bomb analysis, used widely to calculate the energy content of food stuffs.

terials in a stable state. It was Bernd Jourdan, working at the Institute of Wastewater Management of the University of Stuttgart, who first applied the vessel to evaluating compost maturity self-heating (Jourdan 1982; 1988).

Theoretically, any type of respiratory method — whether Dewar self-heating, CO₂ respiration or O₂ consumption — should give approximately the same information. The challenge lies in comparing the units involved. Increasingly, efforts are being devoted to correlating the various standards.

The Dewar test may be viewed as a “holistic” procedure, compared to laboratory respirometry techniques. Some workers have described self-heating tests as being dependent on more than one factor, including vessel size, level of moisture and porosity (Spohn 1978; Matthur 1993). Quantitative laboratory techniques, on the other hand, are those where respiration is measured under ideal conditions of air flow and moisture, and the biological succession associated with natural heating is suppressed by the fixed temperature incubation. The Dewar test integrates a number of factors present in normal composts and therefore may provide data that correlates well with field observations about compost behavior. Its use, however, should not be viewed as replacing these more precise laboratory procedures (Becker and Köter 1995).

METHODS AND MATERIALS

The kit presented here consists of three parts, each replaceable separately. The necessary materials may be readily obtained from major scientific supply houses. It is very important that the size of the vessel be correct. The three components are: a two-liter, steel encased Dewar vessel of 100 mm inner diameter (the inner diameter and volume are very important); a dual scale minimum-maximum inside/outside digital thermometer with plus-minus 1°C readability over the range of 10° to 80°C; and a 30 cm thermocouple probe on a PVC wand for insertion into the vessel. The entire kit assembled for this research project is comprised of off the shelf hardware costing less than \$300 and which if cared for will last for years.

Compost is prepared by careful, representative sampling, cooling to room temperature and remoistening, if needed, prior to filling the vessel. Prescreening compost into the 0 to 20 mm range improves uniformity of results — and results in slightly higher temperatures — but it is not essential to performance (Gallenkamper *et al.* 1993).

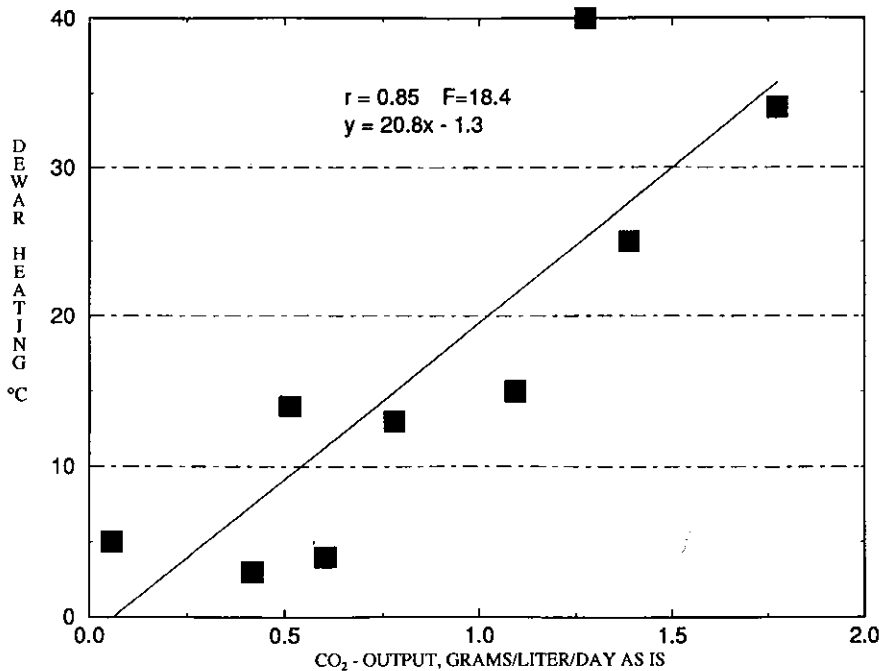
INTERPRETING TEST RESULTS

The principle of the method is to precisely record the highest temperature achieved after placement of compost into the vessel for several days. Interpretation of the results is based on division into five levels of 10°C increments of compost heating (see Table 1). For example, Class I refers to 50°C, II is 30° to 40°C and V, the highest

Table 1. Self-heating increments, rating and description of stability classification based on the European system

Temperature Rise Above Ambient in C°	Official Class of Stability	Descriptors of Class or Group	Major Group
0-10°	V	Very stable, well-aged compost	Finished compost
10-20°	IV	Moderately stable; curing compost	Finished compost
20-30°	III	Material still decomposing; active compost	Active compost
30-40°	II	Immature, young or very active compost	Active compost
40-50° (or more)	I	Fresh, raw compost, just mixed ingredients	Fresh compost

Figure 2. Dewar self-heating vs. CO₂ respiration



grade, is 10°C heating over ambient. Heating past the high point of 50°C can occur, but is unlikely owing to obvious self-limitation around 70°C. The results take about two to nine days to record; fresh composts achieve elevated temperatures sooner than stable composts.

The five categories on the interpretation scale in Table 1 are often grouped by practitioners and European agencies into three major classes, where the lowest grade (I) is called "fresh compost," the middle two (II-III) are referred to as "active compost," and the upper two (IV-V) are termed "finished compost." Compost marketers expect compost to be grade IV or V (Wiemer 1992). The basis of this classification of ripeness is shown in Table 1.

Figure 1 shows the results of using the Dewar vessel to compare two New England composts. These two products were randomly chosen and resulted from a MSW and recycled yard debris (RYD) composting process, respectively. Both samples were advanced in age (65 and 90 days, respectively) and were considered to be approaching "done." The manufacturer of the MSW compost product had observed occasionally that large cure piles sometimes achieved hot temperatures leading to rejection of the material for immediate marketing. The Dewar data shows that the product not only is immature, but is in fact several categories away from being stable (Class V). Later, a similar sample was tracked until it attained a satisfactory endpoint of Class V maturity. The RYD compost was well cured and did not heat past 9°C over ambient. The MSW compost gave a complete Dewar result in three days and the RYD compost in seven days.

Some Dewar runs give inexplicable heat

rise after a week or more in the vessel. Care must be taken to interpret the results of such anomalous samples. The authors' experience shows that heat or moisture damaged composts behave in this manner, appearing to be stable but reheating significantly later, presumably due to reestablishment of indigenous microflora (Rüprich 1990).

DEWAR VALUES VERSUS RESPIRATION TESTS

Compost self-heating in a Dewar vessel is essentially a respiration technique, i.e., it is the respiration of compost materials that produces the heat that drives the test. Therefore, the test will give results similar to CO₂ respirometry measured over a three to seven day period (Jordan 1988; Becker and Köter 1995). Figure 2 shows a correlation between the heating level and CO₂ respiration rate as expressed on a volume basis, giving an excellent correlation.

The difference between tests for O₂ consumption or CO₂ respiration and that of Dewar methods is twofold: 1) the test measures heat output per volume which closely approximates what occurs in the field; and 2) the vessel simulates heat take off simultaneously with the experiment, and may quickly reach a self-limiting temperature. This positive feedback more closely represents field behavior and the potential for continued degradation. This is not the case in current CO₂ or O₂ respirometric methods, which fix the temperature at a single level during measurement (Iannotti *et al.* 1993).

DEWAR METHODS AND MOISTURE LEVELS

The Dewar self-heating procedure is dependent upon the correct amount of moisture being present in the sample. If the moisture is too low or too high, then potentially the Dewar class will be underestimated, distorting the results. A similar problem is encountered in the laboratory work with other procedures for measuring respiration rates. Originally, the European procedure recommended optimizing moisture by par-

Figure 3. Influence of moisture saturation on Dewar self-heating of a biosolids compost

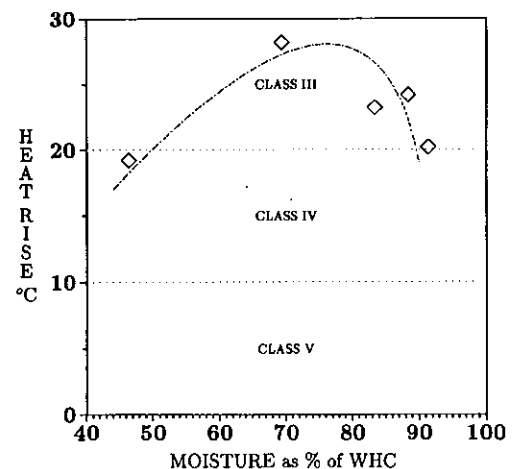


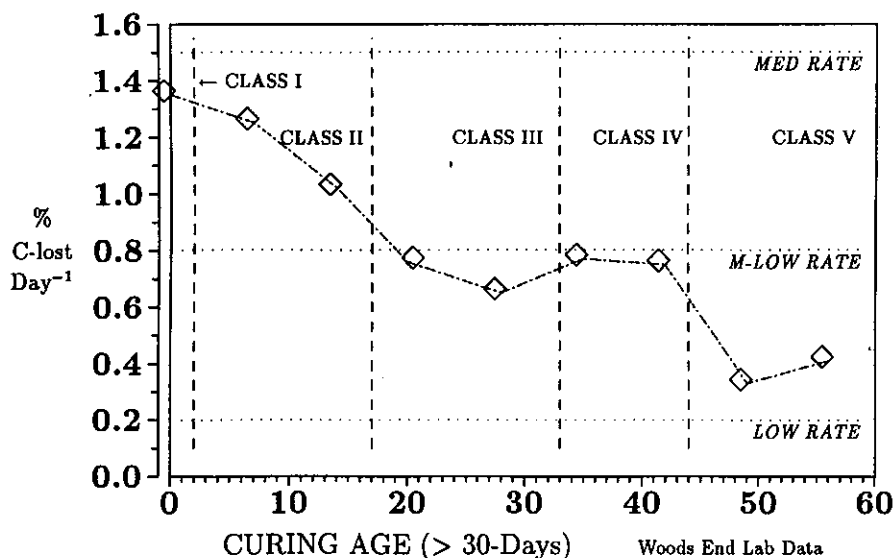
Table 2. Proposed relationship of Dewar class to best use of compost

Class of Stability Based on Dewar Test	Compost Can At Best Be Used For
V	Potting mixes, seedling starters
IV	General purpose gardening, greenhouse cultivation
III	Grapes, fruit, apples
II	Field cultivation <i>e.g.</i> corn, tomatoes, broccoli; greenhouse hotbeds
I	Compost raw feedstock only; fresh mushroom compost

tial predrying and remoistening to a set point of about 30 percent moisture (Jourdan 1982; LAGA10 1984). This moisture level appears low for some composts.

Microbiological evidence indicates that respiration depends on moisture relative to the water holding capacity (WHC), rather than to absolute quantities. With this in mind, the authors investigated various moisture levels in biosolids compost from 45 percent to 92 percent of WHC and determined the Dewar self-heating results (Figure 3). The particular compost used fell into a different class when the moisture was low (<50 percent of WHC) or high (>85 percent of WHC). Different composts are likely to exhibit different relationships to moisture limits. Other recent research supports the view that moistening to just below ideal levels is the best approach (Becker and Kötter 1995). With experience, specific users will develop appropriate methods that give reliable results.

Figure 4. Relation of CO₂ respiration and Dewar maturity class to age of curing MSW compost

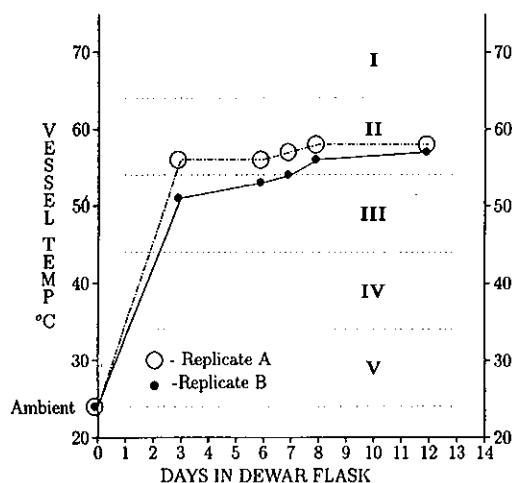


The Dewar self-heating procedure is dependent upon the correct amount of moisture being present in the sample.

COMPOST AGING EFFECT

For any compost which scores low in a Dewar test (*e.g.*, categories I or II), there is a unique and finite amount of conditioning required to eventually bring it to a suitable stability class. The amount of time necessary is dependent on curing conditions, and will be enhanced by proper aeration and moisture conditions existing during curing. A fresh MSW compost was tracked through to completion with Dewar and respirometry methods. Initially, the compost was Class I (immature). It was followed through to final stability or until achieving Class V (finished compost). Figure 4 gives the Dewar class as division lines imposed over the respiration results obtained during the process. Information on this particular MSW compost also

Figure 5. Reproducibility of tests for Dewar self-heating: replicate food compost test



has been reported elsewhere (Stilwell 1993; Maynard 1993; Droffner and Brinton 1995).

The data for this sample indicated that it required approximately 45 days of curing (after in-vessel composting) to attain the desired Class V grade as represented by the Dewar method. The CO₂ respiration rate (performed in duplicate) showed a large drop between day 42 and day 49 into the range where the Woods End test would have classified it as moderately low respiration. This result was consistent with other testing information obtained by field measurement and laboratory microbiology. In other words, either set of data would yield similar interpretive information about the compost. Kehres (1990) produced a similar study showing corroboration of various stability methods with the Dewar test for a variety of compost sites.

REPRODUCIBILITY OF RESULTS

The reproducibility of Dewar results, as with any test, is critical to its acceptance as a general stability method. The stability of a food compost mix was examined by running duplicate tests (Figure 5). The replicate A achieved a high point of 58°C and replicate B achieved a high point of 57°C or

a rise of 34°C and 33°C over ambient, respectively. The two sets of data are statistically identical with a coefficient of correlation of $r^2 = 0.98$. The grid lines on the graph give the demarcation between grades I through V, respectively. Replicate A passed into Grade II by the third day but Replicate B did not achieve it until day seven. Grade II implies a fairly fresh, active compost (which it was). Both tests give the same information if read at the time of highest temperature.

CONCLUSIONS

The self-heating test based on Dewar flask measurement has merit as a general technique to evaluate compost stability, provided the general conditions of the test and the specific equipment are applied. The method may be utilized by producers under field conditions where a relatively stable room temperature of 20° to 25°C (but no more than 25°C) can be maintained around the vessel. In the laboratory, the Dewar method aids researchers in understanding the differences in idealized laboratory technique versus field observations.

As with other lab methods, the self-heating test can yield distorted results under abnormal compost conditions, such as dryness, low pH or heat damage. Our data, however, show a wide latitude of tolerance for moisture variations within the compost, and a fair degree of reproducibility, clearly within the margin of error expected for a procedure of this nature.

The range of values (I-V) suggested to rate stability in five grades are taken unmodified from European data. Some argument exists for using a broader range of classification for non-compost materials and where other laboratory procedures such as CO₂ respirometry are used. However, until such time as new research shows otherwise, there appears to be little merit to proposing a Dewar classification scheme essentially different from the European system.

To better understand how self-heating data relate to compost marketing and applications, European field data for biowaste composts was analyzed (Wiemer and Kerns 1991, 1992). Using the field data and travel by Woods End staff to sites in Europe which sell compost to end users based on Dewar classification, Table 2 was constructed (relating the results to best use). Since the proposed use categories are developed from experience with composted source separated residential food residues blended with yard trimmings, a different and more conservative use guideline may be required with other composts.

The Dewar method also may be useful for assessing pathogen reduction. In one study, preliminary findings with biosolids compost suggest consistent pathogen removal by EPA Part 503 standards after the compost achieves Dewar class IV (Mecklenberg and Reed, 1995). Dewar determination for compost self-heating, therefore, if utilized

For compost that scores low in a test, there is a unique and finite amount of conditioning required to eventually bring it to a suitable stability class.

on a broader scale in North America, could provide an important focus to composters and scientists in drawing useful comparisons where formerly no field system has been in place. ■

Dr. William Brinton is President, Dr. Mary Droffner is Director of Microbiology, and Eric Evans is Laboratory Director at Woods End Research Laboratory, Inc. in Mt. Vernon, Maine. Richard Brinton is director of the Woods End UK, Stroud, England office.

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