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Application Note AN-E02

Assessing the degradation of wood twigs in a compost by isothermal calorimetry

Instruments to which this note applies: I-Cal Flex, Biocal

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Target use: organic decomposition, composting, aerobic biological activity

Introduction

Composting is an important process whereby organic materials of different types are degraded by biological activity. It can be defined as "the controlled aerobic conversion of mixed organic materials into a form that is suitable for addition to soil" [1]. In most cases, the most active microorganisms are bacteria and fungi, but animals of different types (worms, nematodes, insects) may also play a role. Note that composts are aerobic, in contrast to digesters/fermenters that are used to produce e.g. biogas.

One of the more common type of materials to compost are lignocellulosic materials, such as wood, sawdust or straw. These materials are usually high in carbon and low in nitrogen, and are mainly degraded by fungi. In a mixed compost – for example a garden compost of grass cuttings, weeds, leaves and tree cuttings (twigs), the latter are the ones that take the longest time to degrade, as they have low C/N-values (500) and also large dimensions compared to the other materials. Composts with large pieces of wood take several years to mature.

This application note describes how isothermal calorimetry can be used to assess the rate of degradation of wood materials in a compost.

Materials and methods

Wood twigs with diameters of 10-15 mm (Fig. 1) were taken out of a garden compost, cut into 40 mm lengths, and inserted in 20 mL polymer vials for calorimetric measurements in an I-Cal Flex calorimeter. The tests were conducted at two temperatures: 12 and 27 °C.

Three 40 mm twigs were measured at the two above-mentioned temperatures. The masses and dry base moisture contents (MC) are detailed in Table 1.

Table 1: Data on the samples.

	12 °C			27 °C		
Sample	1	2	3	1	2	3
Dry mass / g	1.92	3.06	1.56	2.55	1.30	1.24
MC / %	207	186	339	180	215	235

The samples were loaded into the calorimeters without any pre-thermostating. The calorimeters had been electrically calibrated and 4 mm stainless steel disks were used as references.

Fig. 1 – Wood twigs with diameters of 10-15 mm taken from a garden compost.

Results and discussion

Figure 2 shows the results of the measurements. Note that the thermal powers were normalized per gram dry sample. The thermal power – and thus the rates of degradation are lesser at the lower temperature, as can be expected. There are also some differences between the various samples. For example, sample 2 at 27 °C has significantly higher thermal powers than the other samples, and runs out of oxygen after about 20 hours of degradation (see discussion below). As the measurements were made in closed vials, the result was affected by the changing gas composition in the vials, and therefore the samples at the higher temperature were aerated twice (after 20 hours and 40 hours), which corresponds to the times when the activity of sample 2 had gone down to close to zero.

The main degraders of wood are fungi, and we can assume that most of the heat measured comes from aerobic fungal respiration. As respiration produces 455 kJ of heat per mol oxygen consumed [2], the results in Fig. 2 can be recalculated to oxygen consumption rates. This has two immediate uses in this case: understanding the effect of changes in gas composition in the closed vials, and calculating the rate of wood degradation.

During a respiration measurement in a closed vial, the oxygen concentration decreases and the carbon dioxide concentration

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increases. In most cases it is the increase in carbon dioxide that will influence the activity most. In this experiment the vials have a volume of about 21 mL.

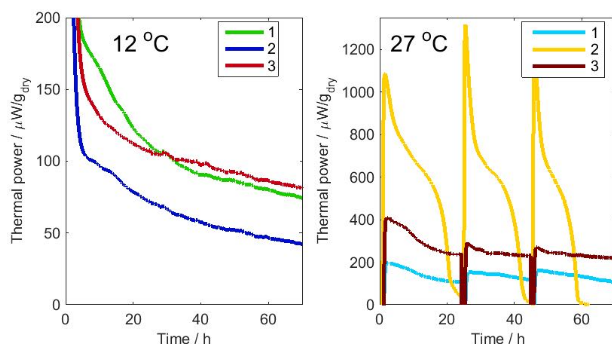


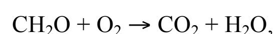
Fig. 2 – The results of the measurements at two temperatures.

Let's take a closer look at sample 2. This sample occupied about 4 mL of vial space, leaving about 17 mL of air (with 21% oxygen) at the start of the measurements. Using the ideal gas law, we can calculate that the quantity of O_2 in moles present at the onset of the experiment..

$$n = \frac{pV}{RT} = \frac{0.21 \cdot 10^5 \cdot 17 \cdot 10^{-6}}{8.314 \cdot 293} = 147 \cdot 10^{-6} \text{ mol}(O_2).$$

We used a temperature of 20 °C as a mean temperature of the two measurements. If we multiply this amount of oxygen by the enthalpy 455 kJ/mol(O_2), we get 67 J. We can thus get a maximum of 67 J from the respiration of the sample with the amount of oxygen present in the head-space of the vial. To validate this, we have plotted in Fig. 3 the heat produced as a function of time for sample 2 at 27 °C. The graph shows that the heat actually peaks at about 50 J, a value 25% lower than 67 J. Possible reasons for this are that more oxygen is consumed during the first hour than is measured because of the initial disturbance in the calorimeter signal, or that the activity goes to lower levels as a result of the combined effect of decreasing oxygen and increasing carbon dioxide concentrations. In any case, we can infer that the decrease in the signal seen in the results is an effect of the change in gas composition in the closed vials. Another interesting point is that sample 2 at 27 °C immediately recovers its activity after aeration, which suggests that it is not harmed or inhibited by the changes in gas concentrations. Also note the decreasing amplitude of the successive peaks in Fig. 3 gets lower, which may be because the aerations were too short and therefore did not completely refresh the atmosphere in the vials.

Now let's calculate the rate of degradation. If we assume that carbohydrate is what is consumed, the overall reaction is (with CH_2O being a carbohydrate repeating unit):



$$CH_2O + O_2 \rightarrow CO_2 + H_2O,$$

and since we know the oxygen consumption rate we can calculate the carbohydrate degradation rate. Taking sample 2 at 12 °C as an example, and using the initial 100 μW thermal power per gram dry mass, this can be recalculated to about 0.2 nmol/s carbohydrate consumed (using the 455 kJ/mol(O_2) enthalpy).

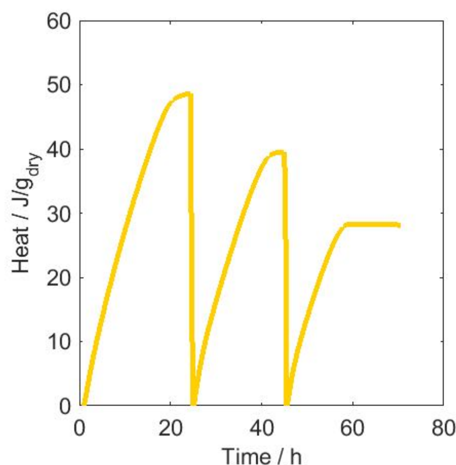


Fig. 3 – The heat produced by sample 2 at 27 °C. The heat has been set to zero at each aeration.

As the molar mass of the carbohydrate repeat unit is 30 g/mol, this value corresponds to 6 ng degradation per s per g of material, or about 1.5% degradation per month.

The simple calculations above highlight some of the uses of isothermal calorimetry as an interesting technique to study biological processes such as composting.

References

1. Hubbe, M.A., M. Nazhad, and C. Sánchez, Composting as a way to convert cellulosic biomass and organic waste into high-value soil amendments: A review. BioResources, 2010 5(4) 2808-2854.
2. Criddle, R.S., A.J. Fontana, D.R. Rank, D. Paige, L.D. Hansen, and R.W. Breidenbach, Simultaneous measurement of metabolic heat rate, CO_2 production and O_2 consumption by microcalorimetry. Anal. Biochem., 1991 194 413-417.

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