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COMMENTARY

WHAT'S YOUR COMPOST ENERGY INDEX?

BACK in 1986, when Robert Parnes retired from Woods End Laboratory, he published a book — *Organic And Inorganic Fertilizers (Parnes, 1986)* — in which he proposed the "Energy Index" for carbon in compost and humus. The concept and its simple method of calculation have lain fairly dormant until recently. What about applying the Energy Index to compare inputs and outputs for composting, that is, in terms of carbon equivalents?

Dr. Parnes started with the well-known energy equation for oxidizing organic residues where energy is released, as in aerobic composting: Carbon(C) + 2 Oxygen (O) –> CO2 + energy. The energy expressed here is equivalent to 370 BTU per mole of carbon oxidized. This is rooted in the chemistry term, heat of formation, which for CO_2 is -94,000 gram calories/mole (a BTU of energy is also equivalent to 252 calories).

The next step was to reason as follows: the organic component of compost is roughly 50 percent carbon; therefore in a ton of compost, each one percent of organic matter is roughly equivalent to about 10 lbs of carbon (one pound equals 454 grams). From the table of elements, the formula weight of carbon is 12, so 10 lbs of carbon or 4,540 grams = 378 moles of carbon. Thus, the carbon energy in each one percent of compost organic matter contains 378 moles; at 370 BTU/mole, that equals about 140,000 BTU per ton of residues. Incidentally, this quantity is nearly the same potential energy contained in one U.S. gallon of #2 diesel. So each one percent of organic matter in compost therefore contains the same potential energy as one gallon of diesel oil per ton of residue. That's our starting point.

Clearly, with rising energy costs, all biomass will be viewed increasingly in terms of energy equivalents reducible to carbon. It is, however, the sustainability of the energy transaction that is critical for choosing the right course of action for the future. Using fossil energy — as we do to convert raw organic matter to stable humus-carbon in composting — we have to be concerned not only about the cost of the energy input (which many composters are undoubtedly watching more closely), but in the long run, what the actual energy balance is. This means weighing fossil energy inputs against outputs to derive an index. The idea of doing indices like this began 33 years ago for agriculture when The Center for Biology of Natural Systems (Washington University, St. Louis) published startling studies (Lockeretz *et al.*, 1975) on energy intensiveness of farming by comparing organic to conventional practices (the latter were found to be more energy intense per unit of yield). Compost has a unit of carbon yield, and has measurable inputs, so it seems natural to look at our methods from the perspective of their energy intensiveness.

A primary source of energy input in composting is fossil fuel, or electricity, or both depending on methods, and associated with loading, mixing, turning and aerating. For most operations, this takes the form of diesel used in tractors and turning machines. Tractors consume in the range of 0.05 to 0.1/gphp (gal per horsepower), depending on the particular make, model and load. With self-propelled turning machines the horsepower may be considerably higher than ordinary farm tractors, ranging up to about 400 HP. Fuel consumption of turning machines also depends on pile status (which affects the load), with a capacity ranging from 400 fresh tons/ hour for the initial bulky mix and improving up to 1,500 tons/hour or so after that. With each gallon of fuel worth 140,000 BTU (and costing over $3/gal), energy consumption naturally takes on a new meaning.

GLOBAL WARMING COST OF COMPOSTING

There are several ways to measure the global warming cost of composting. One is the amount of fossil energy consumed per unit of carbon converted; the second is the amount of energy consumed per unit of retained carbon (in stable, sequestered compost carbon). There are, as yet, no standards to calculate these indices. Incidentally, many discussions about the value of sequestered carbon appear to overlook what it costs in fossil energy terms.

To put the equation to the test, I used extensive data collected previously from the 1995 U.S. Department of Agriculture Technical Center Study (Chester, Pennsylvania) that our laboratory performed. We compared four levels of intensity of manure composting, ranging from no-turning (after an initial good mixing), bucket-loader turning twice a week and self-propelled turning at two frequencies. Back in 1995, diesel cost us only $0.95/gal. In revisiting the datasheets from the project, I found several other things have changed as well, driving up costs and carbon tradeoffs. For example, there have been rising costs of bulking agents like sawdust and straw, which now compete in biomass energy markets.

To examine costs of production, we measured all labor and energy inputs and used mass balance to determine the conversion of carbon (e.g. loss of CO_2), which at the time we simply used to decide the endpoint. In approximately 120 days, the dairy manure compost went from 35 down to 17.5 percent relative carbon — in absolute terms an 80 percent conversion of initial carbon — yielding 4.9 million BTU of stable compost carbon. On the energy input side, as expected, there were very large differences depending on the method of handling; with no-turn, clearly the inputs were very low (yet the process took longer, which we also took into account). Depending on intensiveness, the initial mixing plus turning ranged in fuel consumption from 7.5 to 60.6 gallons per each of our 50-ton units. Over the approximately 8-week event, all told from 1.04 to 8.42 million BTU were involved in converting each ton of compost. The ratios of the two yield our energy index (EI).

In the final analysis, we used from 0.2 to 1.72 as much energy input for each stable energy-carbon output. This is also where carbon stability measured as respiration rate is so important, since you must make the calculations at some agreed endpoint. This could mean crediting a process with achieving stability sooner than another, and so on (which accordingly could reduce the carbon footprint, or increase it, if the process is inefficient).

Looked at from the point of view of carbon conversion, when turning twice a week we had invested 8.4 mBTU of energy to stabilize 4.9 mBTU of carbon (EI = 1.72). With no-turn (not always a good idea but it worked fairly well for us) we achieved a low ratio of only 0.21. The in-between conditions were: bucket loader every two weeks (EI = 0.88) and self-powered turner once every two weeks (EI = 0.51). That's quite a range. A positive energy index is less than 1.0.

In the end, several things matter: the carbon stability attained per unit of energy input (the "compost energy index"); the way equipment is used (as opposed to simply the type of equipment); and the quality of the product for growing plants for each unit of energy input. There is a need to design a set of tools to help composters evaluate energy intensiveness in order to determine the best path to the endpoint. If the index is very positive — the energy input/output ratio is less than 1.0 — then you can speak about positive carbon sequestration and even more. If it's negative (energy index > 1.0) then it may be back to the drawing board, revisiting how the technology gets used. So what's your compost energy index? ■

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REFERENCES

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