Standard Test Method for Determining the Stability of Compost by Measuring Oxygen Consumption[1]

This standard is issued under the fixed designation D5975; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the stability of a compost sample by measuring oxygen consumption after exposure of the test compost to a well-stabilized compost under controlled-composting conditions on a laboratory scale involving active aeration. This test method is designed to yield reproducible and repeatable results under controlled conditions that resemble the end of the active composting phase. The compost samples are exposed to a well-stabilized compost inoculum that is prepared from municipal solid waste or waste similar to the waste from which the test materials are derived. The aerobic composting takes place in an environment where temperature, aeration, and humidity are monitored closely and controlled.

1.2 This test method yields a cumulative amount of oxygen consumed/g of volatile solids in the samples over a four-day period. The rate of oxygen consumption is monitored as well.

1.3 This test method is applicable to different types of compost samples including composts derived from wastes, such as municipal solid waste, yard waste, source-separated organics, biosolids, and other types of organic wastes that do not have toxicity levels that are inhibitory to the microorganisms present in aerobic composting systems.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 There is no similar or equivalent ISO method.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D515 Test Method for Phosphorus In Water (Withdrawn 1997)[3]
D883 Terminology Relating to Plastics
D1293 Test Methods for pH of Water
D1888 Methods Of Test for Particulate and Dissolved Matter in Water (Withdrawn 1989)[3]
D2908 Practice for Measuring Volatile Organic Matter in Water by Aqueous-Injection Gas Chromatography
D3590 Test Methods for Total Kjeldahl Nitrogen in Water
D4129 Test Method for Total and Organic Carbon in Water by High Temperature Oxidation and by Coulometric Detection
D5338 Test Method for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions, Incorporating Thermophilic Temperatures

2.2 *APHA-AWWA-WPCF Standards:*

2540 D Total Suspended Solids Dried at 103°–105°C[4]
2540 E Fixed and Volatile Solids Ignited at 550°C[4]

3. Terminology

3.1 Definitions of terms in this test method appear in Terminology D883.

4. Summary of Test Method

4.1 This test method consists of the following:

4.1.1 Selecting a compost sample for the determination of the stability.

4.1.2 Producing a fully stabilized compost from a similar waste stream under well-controlled laboratory conditions.

4.1.3 Exposing the compost test samples to the fully stabilized compost under controlled composting conditions.

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[1] This test method is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.03 on Treatment, Recovery and Reuse.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] "Standard Methods for the Examination of Water and Wastewater," 17th Edition, 1989, *American Public Health Association*, 1740 Broadway, New York, NY 19919.

4.1.4 Measuring the oxygen consumption rate and determining the cumulative oxygen consumption.

4.2 Obtaining the level of stability from the cumulative oxygen consumption.

5. Significance and Use

5.1 A measurement of compost stability is needed for several reasons. It aids in assessing whether the composting process has proceeded sufficiently far to allow the finished compost to be used for its intended application. A different compost stability may be required for different applications of the compost.

5.2 A measurement of compost stability also is needed to verify whether a composting plant is processing the waste to previously agreed levels of stability. This measurement is useful in the commissioning of composting plants and the verification of whether plant operators are satisfying permit requirements.

5.3 The level of compost stability also will indicate its potential to cause odors if the compost is stored without aeration, as well as the level to which it has been hygienized and how susceptible the compost is to renewed bacterial and possible pathogenic activity. Compost stability is an important parameter with regard to phytotoxicity and plant tolerance of the compost.

5.4 The determination of compost stability will allow the selection of well performing composting technologies, as well as the safe application of compost in its various markets. The method indicates a degree of stability, but does not necessarily indicate that one level is preferable over another level of stability.

6. Apparatus

6.1 *Stabilized-Compost Inoculum Preparation Bin* (see Fig. 1):

6.1.1 A stabilized-compost inoculum preparation bin with a volume of 100 to 200 L, with insulation sufficient to maintain composting temperatures of 50 to 65°C during a period of at least two weeks when composting similar waste as the waste from which the samples were derived, and equipped with air distribution plate, inlet and outlet, and airtight lid.

6.1.2 *Pressurized Air,* provided to the composting bin at a precise and controllable rate up to 200 L/kg waste/day.

6.1.3 *Thermometer,* with temperature measurement up to 80°C (± 2°C).

6.1.4 Suitable devices for measuring oxygen and CO_2 (optional) concentrations in the exhaust air of the composting bin, such as sensors or appropriate gas chromatography.

6.2 *Composting Apparatus* (see Fig. 2):

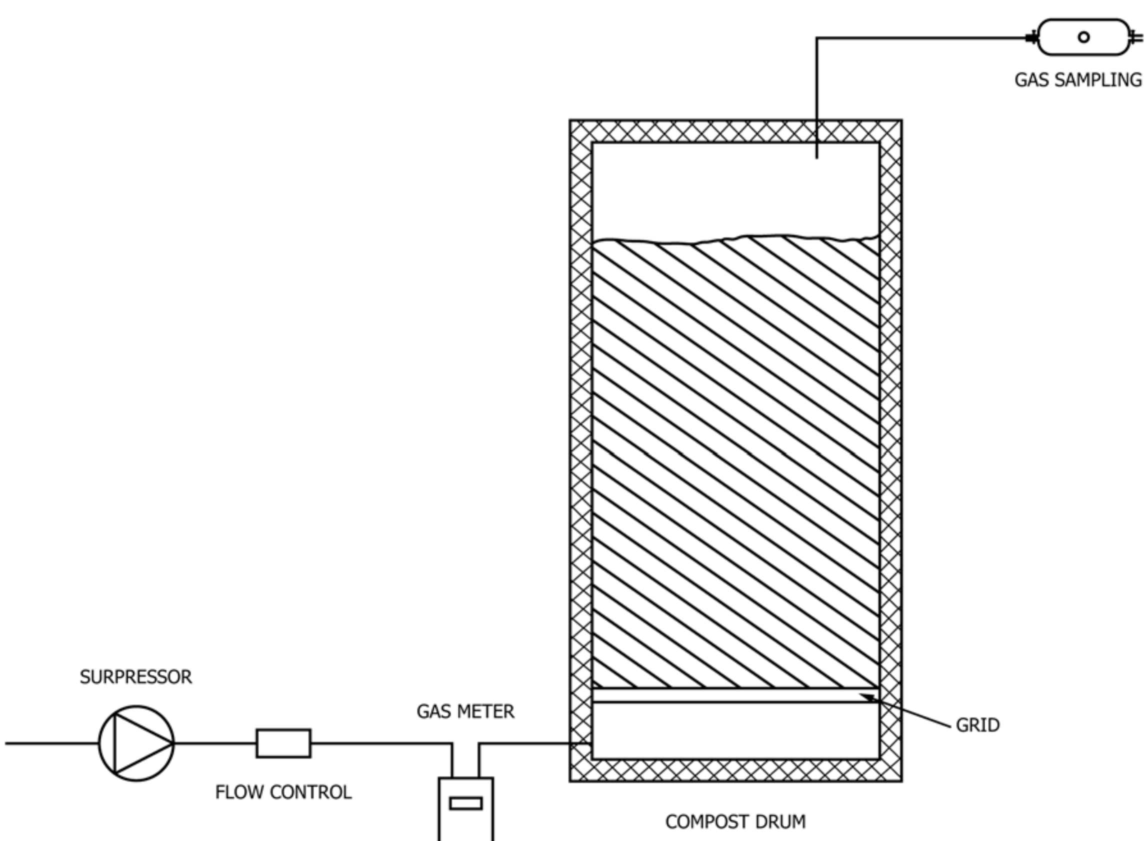

FIG. 1 Optional Set-Up Compost Preparation Bin

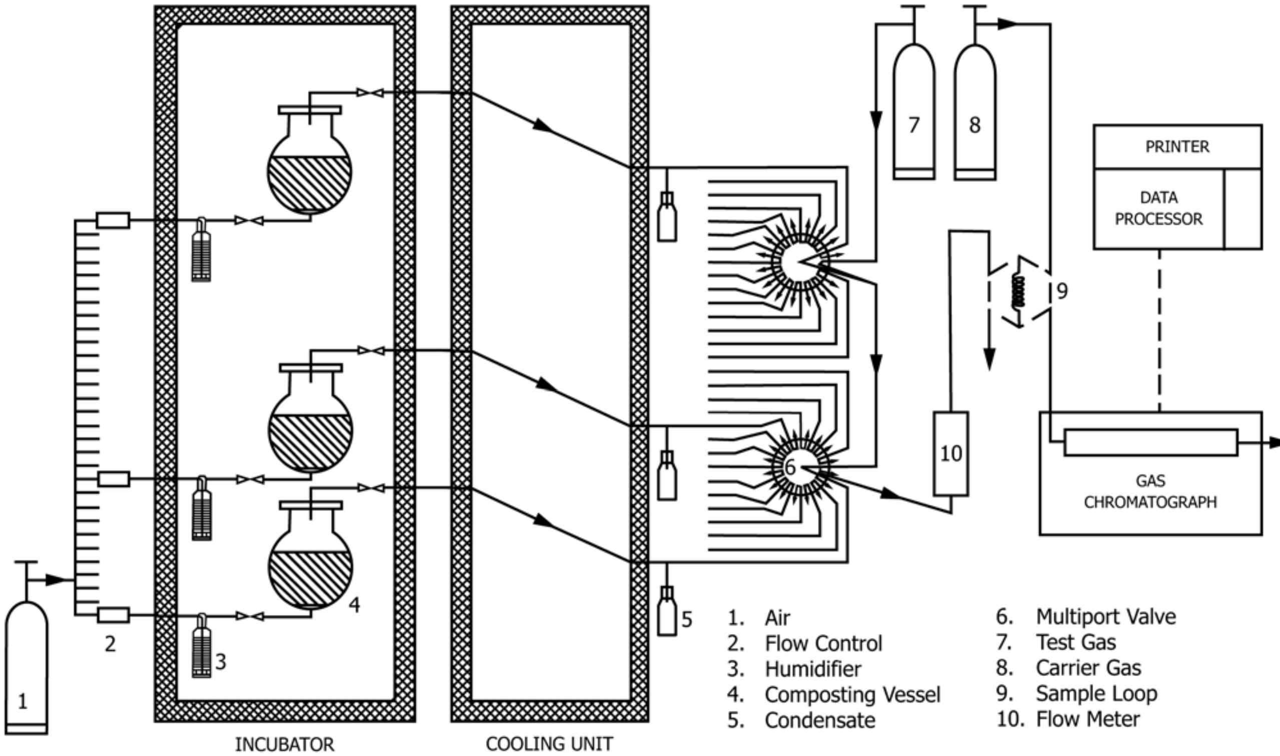

FIG. 2 Optional Set-Up Using Gas Chromatograph (see also Test Method D5338)

6.2.1 A series of at least nine composting vessels (one test substance, one blank, one positive reference, all in three replicates) of 2 to 5 L of volume.

6.2.2 *Incubators,* water baths, or other temperature controlling means capable of maintaining the temperature of the composting vessels at 58°C (± 2°C).

6.2.3 *Pressurized-Air System,* providing H_2O-saturated air to each of the composting vessels at the appropriate aeration rates.

6.2.4 Suitable devices for measuring oxygen concentration in the exhaust air of the composting vessels, such as specific sensors or appropriate gas chromatography.

6.3 *Miscellaneous:*

6.3.1 *Balance* (± 1 mg), to weigh sample and stabilized compost.

6.3.2 *Scales* (± 0.1 kg), to weigh composting waste for stabilized compost production.

6.3.3 Normal laboratory glassware, equipment, and chemicals.

6.3.4 Suitable devices and analytical equipment for measuring dry solids (at 105°C), volatile solids (at 550°C), volatile fatty acids by aqueous-injection chromatography, and total Kjeldahl nitrogen.

7. Reagents and Materials

7.1 Analytical-grade cellulose (microcrystalline, as used in thin-layer chromatography) with a particle size of less than 10 µm, for use as a positive control.

8. Hazards

8.1 This test method requires the use of hazardous chemicals. Avoid contact with the chemicals and follow manufacturer's instructions and Materials Safety Data Sheets (MSDS).

8.2 The waste materials used for the production of stabilized compost, or the compost samples may contain sharp objects. Take care when handling.

8.3 The composting vessels are not designed to withstand high pressures. The system should be operated at close to ambient pressure.

9. Stabilized Compost

9.1 The stabilized compost, which serves as an inoculum and the test matrix, should be well-aerated compost two to four months old, coming from the organic fraction of municipal solid waste or source-separated organics, and sieved over a screen of <10 mm. It is recommended that the stabilized compost control consumes 15 to 80 mg of oxygen/g of volatile solids over the four-day test period. The stabilized compost must have a total solids content between 50 and 60 % on wet weight, an ash content of less than 70 % on total solids, a pH between 7 and 8 and be free of volatile fatty acids (less than 100 mg/L as acetic acid). The C/N ratio should be between 10 and 20 and the C/P ratio between 30 and 60.

9.2 The stabilized compost should be as free as possible of larger inert materials (for example, glass, stones, metals). These items should be removed manually to produce a homogeneous material.

10. Test Samples

10.1 The test sample must be representative of the compost that is being assessed for compost quality. Preferably the test sample should be a composite of various grab samples taken throughout the pile. Otherwise, take samples at various depths of a compost pile and analyze these compost samples separately to assess any variations within the compost pile itself.

10.2 When adding the test sample compost to the stabilized compost, all basic composting parameters, such as oxygen in the composting vessel, porosity, and moisture content should be adjusted so as to make a good composting process possible. Oxygen levels in the composting vessel should be at least 6 % at all times and no free-standing water nor clumps of material should be present.

11. Procedure

11.1 *Preparation of the Samples:*

11.1.1 Obtain the stabilized compost inoculum from a properly operating laboratory-scale composting bin processing a waste similar to the waste from which the test samples are derived.

11.1.1.1 Screen the stabilized compost to less than 10 mm and manually remove and discard any large inert items (pieces of glass, stone, wood) that went through the 10 mm screen. Determine on the fraction less than 10 mm the volatile solids, dry solids and carbon, nitrogen and phosphorus contents according to Test Methods D515, D1888, D3590, D4129, and APHA Test Methods 2540 D and 2540 E. Also determine pH and volatile fatty acids as described in 11.4.2. Add ammonium chloride if the C/N ratio is more than 20 and adjust to a C/N ratio of 15. Add NaH_2PO_4 if the C/P is more than 60 and adjust to a C/P ratio of 45.

11.1.1.2 Determine the volatile solids and dry solids of all the test sample composts in accordance with APHA Test Methods 2540 D and 2540 E.

11.1.1.3 Weigh out precise amounts of stabilized compost inoculum and test sample compost (roughly 500 g of each per composting vessel) and mix thoroughly. The relation between the dry weight of the stabilized compost and the dry weight of test material should be about 1:1. Adjust with water the dry solids content of the mixture to approximately 50 %, and add the mixture to three composting vessels. Weigh the vessels with contents.

11.1.1.4 The blank consists of the stabilized compost only, containing about 1000 g wet weight/composting vessel for each of the three replicates. For the positive control, add 50 g of microcrystalline cellulose to 1000 g of stabilized compost for each of the three replicates.

11.2 *Start-Up Procedure*—Initiate aeration of the composting vessels with air-flow rates that are sufficiently high to ensure that oxygen levels do not drop below 6 % in the exhaust air. Oxygen levels should be closely controlled during the first 36 h and measured at least four times daily. Adjust air-flow rates as needed for the remainder of the test.

11.3 *Operating Procedure:*

11.3.1 Incubate the composting vessels in the dark for a period of four days. Keep the temperature at 58°C (± 2°C) for the duration of the test. The incubation time may be extended if the rate of oxygen consumption during the last 24 h is higher than during the previous 24 h in the vessels containing the samples.

11.3.2 Check O_2 concentrations in the outgoing air, four times daily, with a maximum time interval of 5 h.

11.3.3 Check air flow daily at the connections before and after the composting vessels and at the outlets, ensuring that no leaks are present in the complete system. Adjust air flow to maintain an oxygen concentration of at least 6 % v/v in the exhaust air.

11.3.4 Ensure proper composting conditions and shake composting vessels after the first day of testing.

11.4 *End of the Test:*

11.4.1 At the end of the test weigh the vessels with the contents and determine the dry solids content remaining in the compost.

11.4.2 Measure the pH in conformance with Test Methods D1293. Measure the pH by diluting the sample to a 5:1 w/w mixture of distilled water to compost, mix by shaking manually and measure immediately. If the pH is less than 7, measure the volatile fatty acids in accordance with Practice D2908 in the liquid phase after centrifugation of the diluted sample at 3000 G forces. The volatile fatty acids must be below 2000 mg/L as acetic acid.

12. Calculation

12.1 Determine the volumetric cumulative oxygen consumption for each composting vessel over the whole test period, using for each reading during the test the following formula:

$$V_1 = \left(O_i - O_e\right) \times F \times \Delta t \tag{1}$$

where:

V_1 = cummulative volumetric oxygen consumption (L),
O_i = oxygen concentration in incoming air (volume %),
O_e = oxygen concentration in exhaust air (volume %),
F = air flow rate (in L/h), and
Δt = period of time.

12.2 The cumulative volumetric oxygen consumption in litres, obtained from the previous calculation, is recalculated to standard conditions of temperature and pressure, using the formula:

$$V_2 = V_1 \times \frac{T_2}{T_1} \times \frac{p_1}{p_2} \tag{2}$$

where:

V_1 = cumulative volumetric oxygen consumption (L),
V_2 = cumulative volumetric oxygen consumption under standard conditions (L),
T_2 = standard temperature (273°K)
T_1 = ambient temperature (in °K),
p_1 = ambient pressure (in atm), and
p_2 = standard pressure (1 atm).

Subsequently, the oxygen consumption is recalculated using the formula:

$$C = V_2 \times \frac{32\ \text{g}}{22.414\ \text{L}} \tag{3}$$

where:

C	=	oxygen consumption in grams,
22.414 L	=	volume of 1 mole of oxygen under standard conditions of temperature and pressure, and
32 g	=	weight of 1 mole of oxygen.

12.3 Determine the net cumulative oxygen consumption of the test compost sample by subtracting the oxygen consumption of the stabilized compost inoculum in the test vessel from the total oxygen consumption of the test vessel, (the oxygen consumption of the inoculum in the test vessel is the consumption per gram of the inoculum in the control vessels multiplied by the weight of inoculum in the test vessel).

12.4 Express the oxygen consumption in mg oxygen/g volatile solids and over four days (mg O_2/g VS.4d).

13. Interpretation of the Results

13.1 Results of other analyses of the test compost sample such as volatile fatty acids, pH, ammonia, nitrate and rotting degree and information on the ecotoxicity of the test substance may be useful in the interpretation of inhibitive effects.

13.2 A reference or control substance known to biodegrade is necessary to check the activity of the stabilized compost, which serves as an inoculum. If sufficient oxygen consumption (a minimum of 20 % of the theoretical oxygen demand for cellulose within the duration of the test) is not observed with the positive reference, the test must be regarded as invalid and should be repeated using new stabilized compost inoculum.

14. Report

14.1 Report the following data and information:

14.1.1 Information on the stabilized compost inoculum, including source, percent dry solids, percent volatile solids, pH, volatile fatty acids, carbon, total Kjeldahl nitrogen, phosphorus, C/N, C/P, activity (oxygen consumption), date of collection, storage and handling.

14.2 Information on the compost sample including source, percent dry solids, percent volatile solids, pH, date of collection, storage and handling.

14.3 Apparatus used for carrying out the test method. Weight of vessels with contents before and at the end of the test.

14.4 Cumulative oxygen consumption over time (display graphically).

14.5 Average oxygen consumption for each test compost in mg oxygen/g volatile solids/four days, along with standard deviation.

14.6 Evolution over four-day test period and final percentage of mineralization of positive reference.

14.7 pH of final residues. Volatile fatty acids concentration for vessels with a final pH of less than 7.

14.8 Ratio of oxygen consumption versus CO_2 consumption (optional).

15. Precision and Bias

15.1 The precision and bias of this test method is being determined.

15.2 Preliminary results of a test with six different composts are given in Table 1. The compost stability through oxygen consumption in mg O_2/g VS.4d is compared with the NO_3/NH_4 ratio and with the rotting degree obtained in a respirometry method without inoculation. The evolution of the oxygen consumption for the six different composts is shown in Fig. 3. Analyses were performed in duplicate.

16. Keywords

16.1 compost; oxygen consumption; stability

TABLE 1 Results of NO_3/NH_4 Ratio, Rotting Degree and Compost Stability for Six Different Composts

	NO_3/NH_4 Ratio	Rotting Degree	Stability mg O_2/g VS.4d
Compost 1	0	II	258
Compost 2	0	III	109
Compost 3	0	IV	35
Compost 4	∞	IV	23
Compost 5	∞	IV	20
Compost 6	53	IV	8

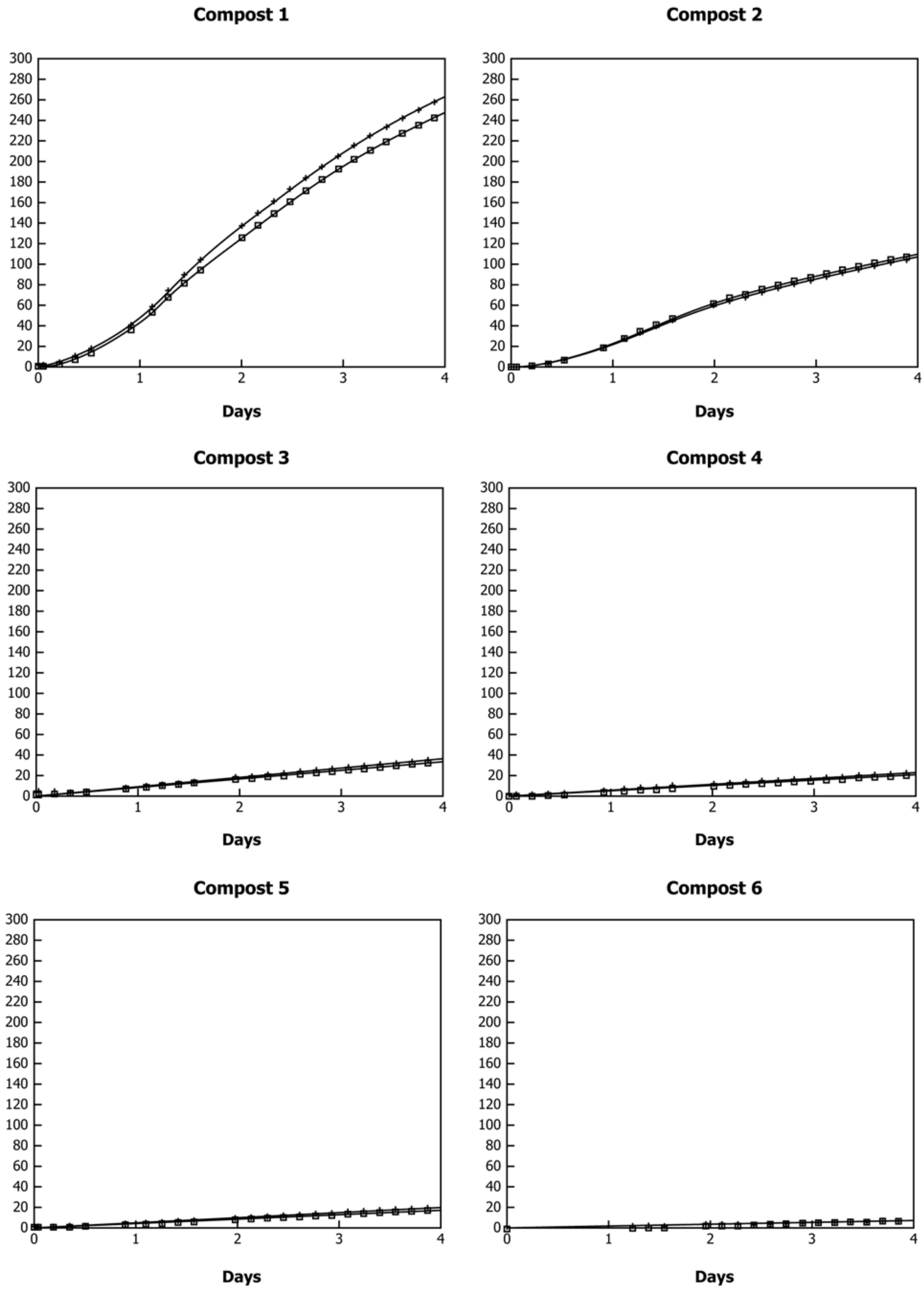

FIG. 3 Oxygen Consumption of Six Different Composts Over Time