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Static, dynamic and inoculum augmented respiration based test assessment for determining in-vessel compost stability

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ABSTRACT

The purpose of this work was to evaluate compost (and related industry) stability tests given recent large-scale changes to feedstock, processing techniques and compost market requirements. Five stability tests (ORG0020, DR4, Dewar self-heating, oxygen update rate (OUR) and static respiration) were evaluated on composts from ten in-vessel composting sites. Spearman rank correlation coefficients were strong for the ORG0020, OUR and DR4 (both CO_2 and O_2 measurement), however, OUR results required data extrapolation for highly active compost samples. By comparison the Dewar self-heating and static respiration tests had weaker correlations, in part the result of under reporting highly active, low pH samples. The findings suggest that despite differences in pre-incubation period both dynamic respiration tests (ORG0020 and DR4) are best suited to deal with the wide range of compost stabilities found.

1. Introduction

Compost stability assessment is used to measure the degree of organic matter decomposition; 'stable' compost can be considered as that which shows resistance to further decomposition (Lasaridi and Stentiford, 1998; Wichuk and McCartney, 2010). Unstable composts are of general concern for a number of reasons including their ability to: (1) self-heat, which may lead to fires, (2) generate nuisance odours, (3) attract disease vectors and (4) generate toxic by-products, especially under anaerobic conditions (Barrena et al., 2014; Brinton, 2000). Such concerns have resulted in compost stability thresholds being adopted by several European countries. For example, in Belgium there is a compost regulatory stability limit for all end uses of either a maximum temperature of 30 °C (self-heating) or both a maximum temperature of 50 °C and <10 mmol O_2/kg OM/h (OUR) (FPS, 2013a,b). In Ireland there is a voluntary limit of <13 mmol O_2/kg OM/h, and in the UK the voluntary PAS100 certification scheme includes a compost stability threshold of 16 mg CO_2/g OM/day (B.S.I. PAS100:2011) assessed using the ORG0020 test. The German Compost Quality Assurance Organisation (BGK) voluntary scheme includes specific stability thresholds (via the self-heating test or respiratory activity) depending on the end use, with Rottegrad II–III or 30.1–80.0 mg O_2/g organic dry matter for agriculture, Rottegrad IV–V or $\leqslant$30.0 mg O_2/g organic dry matter for horticulture and Rottegrad V or $\leqslant$20.0 mg O_2/g organic dry matter for growing media (Kehres and Thelen-Jüngling, 2006). Moreover, the proposed EU-wide End-of-Waste (EoW) criteria for compost includes a stability threshold of OUR 25 mmol O_2/kg organic matter/h or Rottegrad III (self-heating test) (European Commission, 2014). However, current stability tests and thresholds were almost exclusively developed during the period when the majority of composting facilities in the UK (and in Europe) were processing green waste in open air windrows (Slater and Frederickson, 2001). In recent years, the European composting industry has expanded greatly, increasing from an average of 5.5% of municipal waste composted in 2000 to 11% in 2009 (Eurostat, 2013). Europe now includes a significant in-vessel composting (IVC) sector with diverse systems treating a variety of feedstocks. In the UK for example, IVC sites processed nearly 40% of organic waste composted in 2012 compared with just 10% in 2001 (WRAP, 2013). The markets for compost have also diversified to include agriculture, horticulture, turf growers, landscaping, soil blenders and land remediation each with different requirements of compost and, therefore, potentially varying tolerance in terms of compost stability. Given these past and predicted future changes in the bio-treatment sector, this study aimed to address which compost

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(or alternative industry) stability test was most suitable for determining the stability of composts produced by in-vessel composting processes.

Biological stability tests are usually based on respirometric methods, measuring CO_2 production and/or O_2 consumption, or heat production (Komilis and Kletsa, 2012). Although these methods have been extensively reviewed in the literature in recent years (Gómez et al., 2006; Iannotti et al., 1994; Wichuk and McCartney, 2010), individual studies have been either limited to single site with multiple stability tests (Brewer and Sullivan, 2003; Komilis and Kletsa, 2012) or multiple sites with evaluation of a single test (Bernal et al., 1998; Cooperband et al., 2003; Komilis and Tziouvaras, 2009). For example, Brewer and Sullivan (2003) looked at yard trimmings compost stability from a single site using four tests including two static respiration tests (alkaline trap and Dräger tube CO_2 evolution), colorimetric CO_2 (Solvita test®), and Dewar self-heating. On the other hand, Komilis and Tziouvaras (2009) used a static CO_2/O_2 respiration test on six composts derived from specialised feedstocks of cow manure, sea weed, olive pulp, poultry manure or municipal solid waste. Similarly, specialised compost feedstocks were also used in other studies (Bernal et al., 1998; Cooperband et al., 2003). No single study has looked at multiple compost stability tests from multiple IVC sites with varying mixtures of source materials of importance to the majority of composting site operators: (i) municipal source segregated food and garden waste and, (ii) commercial and industrial source segregated food and garden waste.

The aim of this work was to compare the relative performance of a suite of standard compost stability tests, alongside other relevant industry tests, using compost from ten commercial IVC sites covering a broad range of compost stabilities. Specifically, five different stability tests were compared: Dewar self-heating, solid static CO_2 evolution, liquid static O_2 consumption (oxygen uptake rate), dynamic CO_2 evolution (ORG0020) and dynamic respiration with a mature compost seed inoculum (DR4) (developed from the original DR4 test for use with fresh compost). For the DR4 test we assessed directly measured CO_2 evolution and O_2 consumption, and calculated respiratory quotient (RQ) (Aspray et al., 2008), parameters. A range of relevant physicochemical determinants, which are typically employed to characterise composts, were also considered.

Table 1
Site feedstock, PAS100 status, in-vessel compost type and process time.

Site code	Feedstock	PAS100 status	IVC type	Approximate process time (IVC + maturation)
A	GW, BMW (including o/s)	Yes	2 barrier	54
B	BMW, cardboard	Yes	2 barrier	62
C	BMW, cardboard, commercial GW	Yes	Other	63
D	GW, BMW, Woodchip	Yes	2 barrier	126
E	BMW, CFW (including o/s)	Yes	Other	108
F	GW, BMW, CFW	Yes	Other	59
G	BMW (including ~10% o/s)	No	1 barrier	29
H	BMW (including ~33% o/s)	No	1 barrier	25
I	BMW (including o/s)	No	Other	60
J	BMW	No	2 barrier	33

GW – green waste; BMW – Biodegradable municipal waste; CFW – commercial food waste; and o/s – oversize. 1 and 2 barrier systems relate to The Animal By-Products Regulations (2005).

2. Materials and methods

2.1. Sites and samples

Samples, representing finished composts, were collected from ten commercial IVC sites across the UK covering both PAS100 and non-PAS100 accredited operations and a range of processing times (Table 1). Finished composts were defined as having completed the typical processing cycle appropriate for each individual site. At least nine sample increments from each compost were combined to form a primary sample pile, which was sub-sampled by cone and quartering. Limited details of the IVC systems are presented in order to protect site and operator identity, however, the spectrum of systems currently being used in Europe were included such as vertical composting units, drum, silo and both one and two barrier systems. The markets for these composts included agriculture, horticulture, landscaping, land restoration and landfill daily cover.

2.2. Physicochemical characterisation of composts

A wide range of physicochemical parameters were measured through a commercial UK accreditation service (UKAS) approved laboratory (Table 2). Dry matter (DM), moisture content, laboratory compacted bulk density and portion of material <20 mm were determined as per BS EN 13040:2007. Water soluble NH_4–N and NO_3–N were determined by colorimetric analysis and ion chromatography, respectively. Total C and N were determined using the Dumas method. Electrical conductivity (EC) and pH were determined following mixing the compost sample with water (EC less than 0.2 mS/m) at a ratio of 1:5 (v/v) following BS EN

Table 2
Physicochemical characterisation of compost samples from ten different commercial sites.

Test	Units	Site									
		A	B	C	D	E	F	G	H	I	J
NH_4–N	mg/kg	146	1117	246	378	2827	2971	2339	3051	2888	1022
NO_3–N	mg/kg	<1	<1	271	258	<1	<1	<1	<1	<1	<1
NH_4:NO_3 ratio	n/a	n/a	n/a	0.9	1.5	n/a	n/a	n/a	n/a	n/a	n/a
Total N	% w/w	2.01	1.94	2.1	1.73	2.41	1.71	2.14	1.62	1.68	1.83
Total C	% w/w	29.06	29.27	22.75	25.39	40.15	29.14	37.93	31.73	34.75	35.2
C:N Ratio	n/a	14.5	15.1	10.8	14.7	16.7	17.0	17.7	19.6	20.7	19.2
DM	% m/m	52.8	39.2	72.3	44.0	36.7	62.0	41.9	44.4	44.2	55.5
OM (LOI)	% m/m	57.7	45.5	43.8	43.7	68.4	52.3	72.6	58.1	62.3	64.9
pH	n/a	8.6	8.9	8.8	8.4	7.3	7.6	4.8	5.6	5.1	7.5
EC	µS/cm@20 °C	1024	1273	1550	1206	2710	2850	2950	1670	2550	1970
Bulk density	g/l	403	524	473	613	672	550	495	316	482	420
Portion < 20 mm	%g/g	90	90	100	95	100	90	97	85	95	97

DM – dry matter; OM (LOI) – Organic Matter (loss on ignition); and EC – electrical conductivity.