ANALYSIS OF EMISSIONS FROM LAB-SCALE COMPOSTING EQUIPMENT: DATA FOR A SUSTAINABILITY CHALLENGE

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ABSTRACT

The increase of global environmental consciousness is pushing more and more towards sustainable systems for the management of cities and agricultural area. Organic waste can be converted into good soil amendments by composting, which is therefore recognized as an eco-friendly process.

Recently, CNR-ISAFOM developed a simplified static composting method easy to be carried out at farm level for olive mill waste recycling; in order to analyze and model the impacts of such a method, a highly air-forced automated apparatus including two 35-liters bioreactors has been designed and developed. The system is able to analyze in real time the emissions derived from the respiration activity of the *in situ* microbiota.

The air flow is managed by means of mass flow controller able to keep the oxygen concentration in the exhausted air within a pre-fixed optimal aerobic value. An accurate monitoring of temperature in the biomass, as well as in the inlet and outlet airflow, is carried out all along the composting trials. In addition, the apparatus records the progressive weight loss of the two bio-reactors while the concentrations of oxygen, carbon dioxide, ammonia and hydrogen sulfide are gathered in the exhausted air by means of separate specific detectors.

The equipment is managed by custom NI LabVIEW software: parameters under control are recorded every fifteen minutes and promptly displayed in tables, graphs and spreadsheets.

The apparatus has been tested by composting olive mill waste with hygroscopic additives, such as straw and waste wool.

Monitoring at a Lab-scale the amount of emissions from composting may led to optimize those parameters which influence the release of greenhouse gases (GHG) emissions. This may help composting companies in comply the even more restrictive rules imposed by Regulators for reducing its environmental impacts.

Keywords: Olive mill waste, Composting, Respirometric system, GHG emissions, CO_2, Ammonia, Environmental sustainability

1. Introduction

Waste management is more and more becoming a critical issue to address for local governments. Among wastes, those derived from the agro-industry are huge in amount and difficult to be managed complying with the European rules. By promoting sustainable recycling strategies, research tries to give answers in terms of innovation which should firstly aim at reducing the amount of waste to be disposed of at the end of life cycle of products; recovery by-products as new raw materials improves the environmental sustainability of the production chain, thus reducing also the fossil carbon dependency.

Composting by-products represents a worthy example of management, adding value to waste; consequently, the use of compost in agriculture may reduce mineral fertilization need thus improving soil fertility.

However, even the innovation must be assessed in terms of environmental sustainability: with this regard, greenhouse gases emissions derived from composting should be monitored for estimating potential impact on the environment and creating a database useful for comparison.

Lab-scale composting, if correctly carried out with controlled systems, allows monitoring several parameters of interest, such as temperature, weight loss and gaseous exchange with atmosphere. Recently, CNR-ISAFOM, Perugia (Italy) set up a simplified static method for olive mill waste composting (OMW) (Altieri *et al*., 2011) and successively, developed an automated system, working at lab-scale, for modeling this method.

The present study aims at briefly describing this lab-scale equipment, providing data on emissions released by the equipment filled with OMW-based organic mixture and put under composting conditions for 39 days.

2. Experimental conditions

The laboratory device (Figure 1) has been designed and developed in order to automatically and continuously analyse and control relevant process parameters in two reactors (composters) containing OMW-based mixture exposed to forced aeration, thus inducing appropriate aerobic static composting.

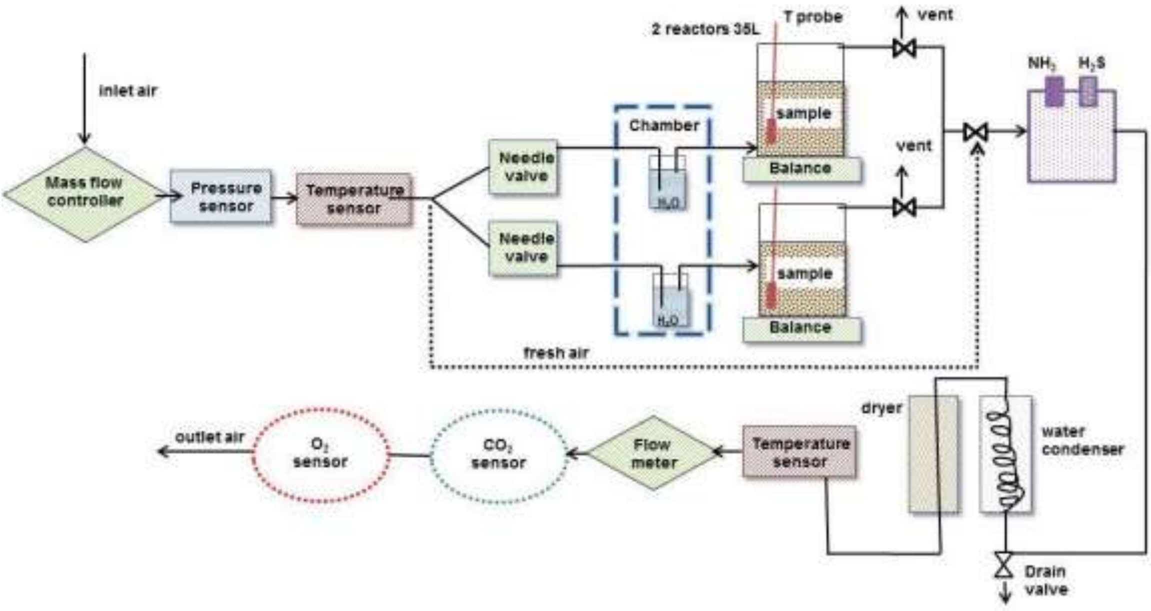


Figure 1: Pneumatic and mechanical scheme of the lab-scale equipment

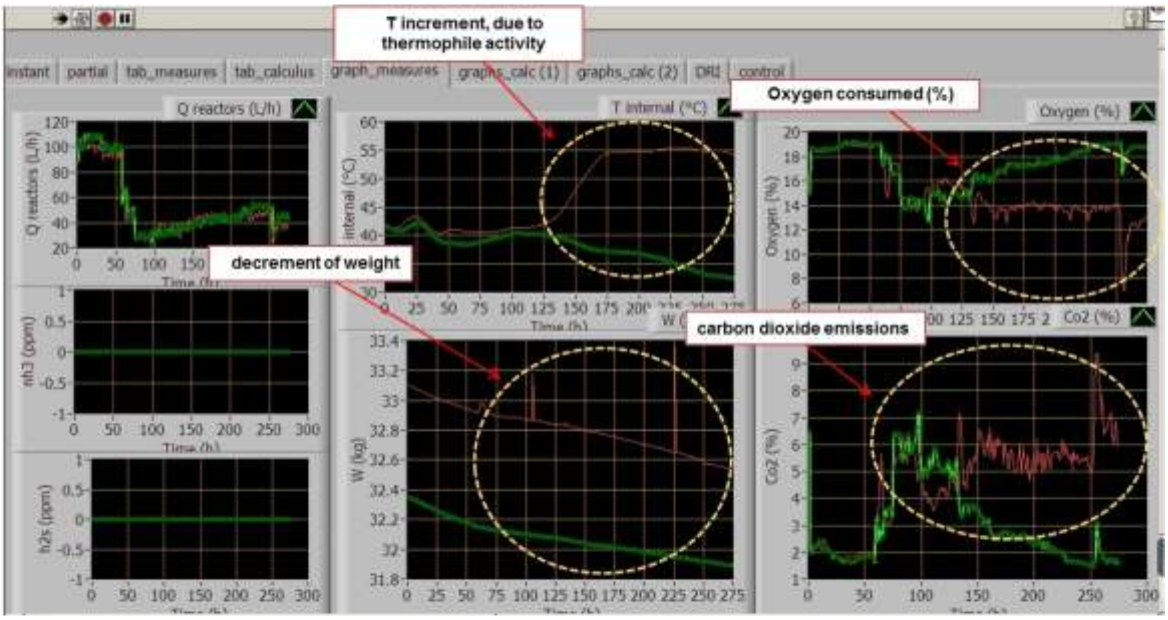
The laboratory device is composed by mass flow controller, pressure sensor, four temperature probes, needle valves, manifold to distribute the air flow, two 35-L insulated reactors, two balances, ammonia and hydrogen sulphide sensors, water condenser and air dryer, flow meter and oxygen and carbon dioxide sensors. The inlet air has been supplied by means of an air pumping system, while the oxygen concentration in the exhausted air has been kept higher than 12% throughout the test by the mass flow controller. By means of relays, the system automatically switches among reactors, thus allowing alternate analysis of the exhausted air flowing out from both reactors.

The automated control is performed with custom NI LabVIEW program which is able to analyse analogue signals, collect data, switch the electrical system, and show results on screen in real time (an example of the front panel is presented in Figure 2).

Trial supervision has been also performed through specific web platform for remote controlling.

The laboratory devise was tested in a composting trial conducted on an organic mixture composed by 76.2% de-stoned olive mill husk, 4.8% waste wool, 4.8% straw, 14.3% olive leaves and twigs (on wet weight base).

All parameters under control have been recorded every 15 minutes. The equipment showed to be also able to measure in real time the Dynamic Respiration Index (DRI) (Adani *et al*., 2004), thus assessing, during composting, the biological stability of the mixture which is strictly related to own respiration activity.



T increment, due to thermophile activity

Oxygen consumed (%)

decrement of weight

carbon dioxide emissions

Figure 2: LabVIEW front panel screenshot: ongoing trial with captions.

3. Results and discussion

Data on parameters under control (Table 1) have been collected until a steady state of composting was reached: this occurred after 39 days from the start of the trial. Even though filled with the same organic mixture, reactors showed different patterns for DRI; however, at the end of experiment, DRI values were similar each other, with values lower than 500 which is typical of mature compost (Adani *et al*., 2004); this outcome corroborates previous findings achieved at farm scale in composting OMW-based mixture (Altieri *et al*., 2011).

Cumulated oxygen consumption and carbon dioxide emission showed to be comparable to those reported in literature for pilot-scale agro-industrial waste composting (Fernández *et al*., 2010).

Table 1: Parameters recorded during the trial for both reactors (Q = air flow; DRI = dynamic respiration index; VS = volatile solids; * = cumulated consumption/emission; #1, #2 = reactor number)

	weight		Q		temperature		DRI		O_2		CO_2	
days	kg		L/h		°C		$mgCO_2kg^{-1}VS^{-1}h^{-1}$		gO_2*		gCO_2*	
	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
0	9.52	9.44	175.0	175.8	26.0	25.4	-	-	-	-	-	-
4	9.27	9.26	67.3	46.2	38.4	40.7	743	810	262.9	258.4	282.4	293.8
13	8.25	8.13	36.7	29.2	47.4	52.2	525	1628	699.6	1034.6	766.4	1140.2
26	7.44	7.17	20.1	20.3	23.9	25.3	181	150	1035.2	1542.5	1118.6	1721.5
39	7.14	6.93	22.3	21.6	30.4	29.1	421	494	1570.3	2099.0	1754.7	2355.4

At the end of trial, reactors showed similar weight loss, both accounting at about 10÷12 % of the initial weight (Figure 3); most of the weight loss was due to carbon loss, as revealed by the cumulated CO_2 emissions recorded during the trial (Table 1); these values agree (CV < 5%) with those that can be derived from the mass balance data: in fact, Figure 3 clearly depicts that most of the weight loss was due to volatile solids loss. According to standard lab procedure, volatile solids have been determined on samples collected from both reactors during the trials.
The total ash content resulted constant in both reactors, as expected, as well as the total water content, thus signifying that composting proceeded under proper moisture content throughout the trial. Dryness of compost, which could have lowered the ongoing microbiological activity and respiration, was mostly prevented from the lid of the reactors which worked as condensers; in fact, being colder than compost, most of the water present in the exhausted air flowing out from reactors collects as droplets on the internal lid surface, falling back on the compost; to prevent any dryness, the system has been set up in order to be able also to moisten the inlet air, as explained in Figure 1.

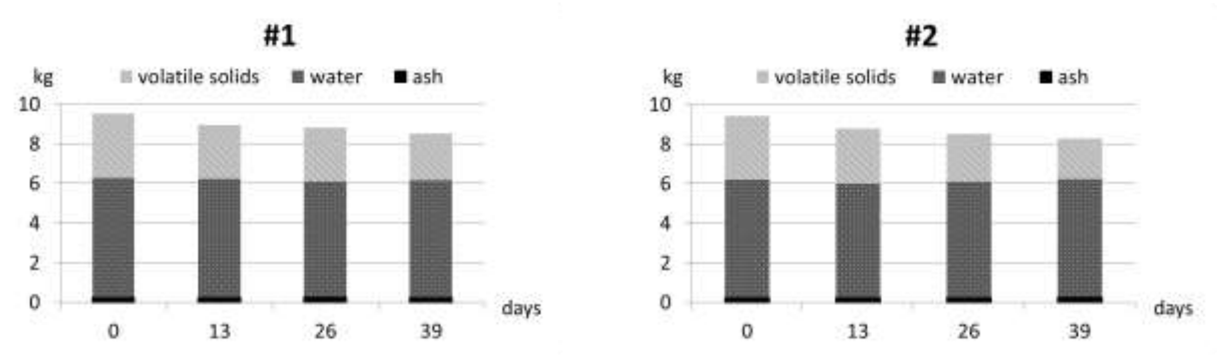


Figure 3: Mass balance for both reactors.

As regards NH_3 and H_2S emissions, they were only sporadically monitored with the inline paramagnetic sensors (Figure 1) because they required a very long purging time, if compared to that required for cleaning oxygen and carbon dioxide sensors, thus inducing inappropriate delay in recording of the other relevant parameters under study.

Ammonia as well as hydrogen sulphide are highly reactive and readily soluble in water and it is likely that they adsorb and/or desorb irregularly from the measurement enclosure and tubing walls, thus causing ambiguity of results, as explained in Harper (2005).

For overcoming this issue, ammonia and hydrogen sulphide, along with VOCs emissions have been regularly monitored with another external monitor (MX6, Industrial Scientific, USA), intercepting the exhausted air of both reactors from the vent lines; measurement were performed once per day for a very short time: in the first ten days of the trial, both reactors showed concentration lower than 5÷8 ppm for both NH_3 and H_2S emissions while VOCs resulted absent.

4. Conclusions and outlook

Cumulated CO_2 emissions, O_2 consumption and mass balance of OMW mixture put under composting have been assessed in a 39 days trial conducted at Lab-scale with an innovative automatic equipment.

CO_2 emissions mostly contributed to the weight loss registered, while VOCs resulted absent, thus signifying that the system ensured optimal composting condition.

Negligible loss of nitrogen as ammonia was assessed throughout the trial.
About 30% (w/w) of the initial carbon content was transformed into CO_2 by the *in situ* microbiota which drove the aerobic biodegradation, thus saving up to 70% of carbon which can be usefully recycled in agriculture for improving soil fertility.

At the end of the trial, OMW mixture was considered as mature compost, therefore being ready to use for safe agronomic applications, even at plant nursery as peat substitute in the preparation of growth media.

Further trials will be soon performed in order to quantify other possible GHG emissions, such as methane and nitrous oxide, by using GC analyses.
Such analyses may be adapted to up-scaling findings and assess the environmental impact of composting.

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