Lab-scale optimization of co-composting agri-industrial effluents with biochar to reduce ammonia emissions and save water and energy

Roberto Altieri, Mirko Cucina, Alessandro Esposito

Institute for Agricultural and Forestry Systems in the Mediterranean, National Research Council (ISAFOM-CNR), Perugia, Italy

Email: roberto.altieri@cnr.it; mirko.cucina@cnr.it; alessandro-esposito@cnr.it

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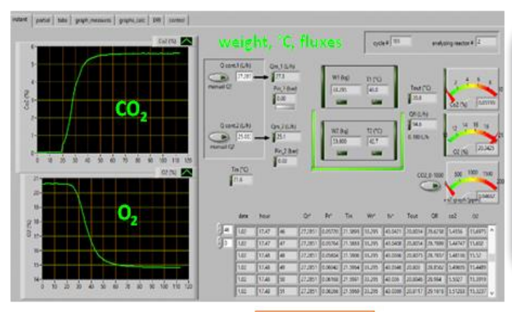
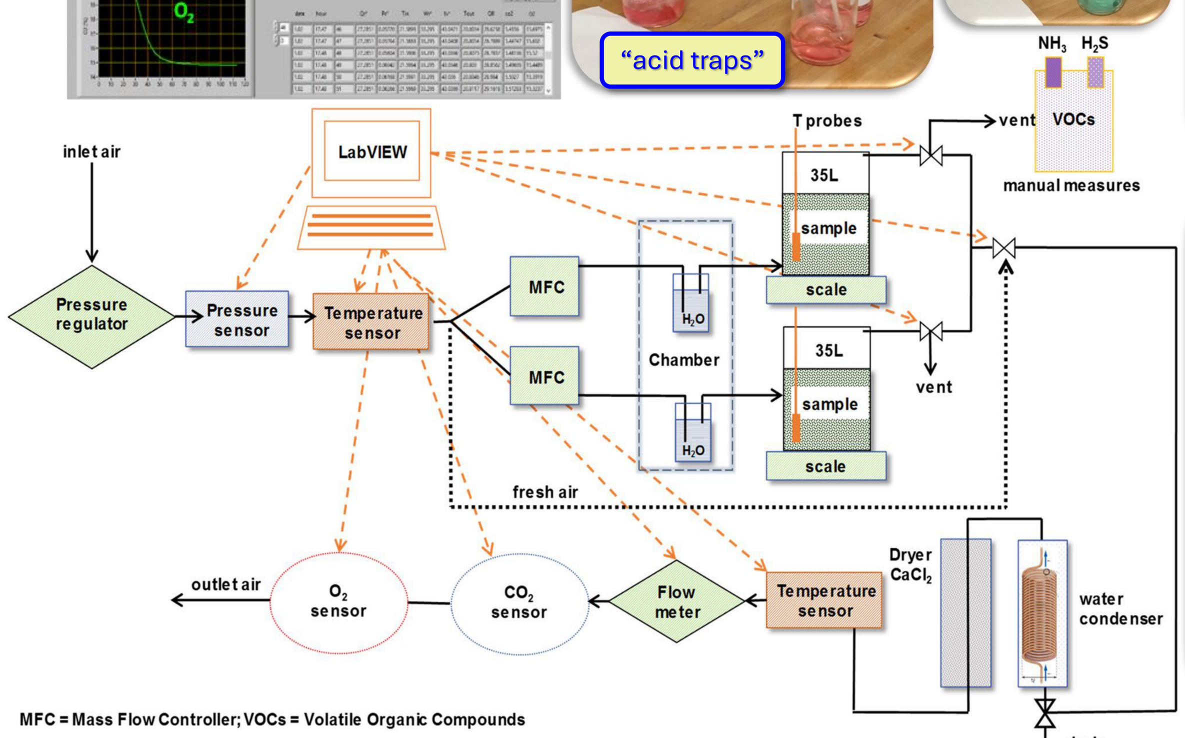
The activity is part of the *Spoke n. 8 - Circular economy in agriculture through waste valorization and recycling*, with reference to *WP n. 8.3 - Nutrient and organic matter recovery from wastes to reduce the use of agrochemicals and closing waste cycle – Task 8.3.2 - Valorisation and biological regeneration of wastes as resource, organic fertilizers, or amendments to improve carbon storage and soil quality.*
AIMS: to develop, test and validate innovative technologies to produce fertilizers, biofertilizers and soil amendment to support soil fertility and mitigate climate change.

The activities focused on studying the process and evaluating the products obtained through "optimized composting" trials of problematic waste, such as livestock effluents, digestates and olive mill waste. Composting was carried out using a lab-scale pilot plant named COMPOSTER. Moreover, the effectiveness of biochar in reducing ammonia emissions was tested: compared to an untreated control, biochar was added (5%) to the initial organic mixtures designed with a low C/N ratio to enhance their emission potential. The ammonia released was captured from the air drain system on a daily base, using tailor-made "acid traps".

COMPOSTER



"acid traps"



COMPOSTER diagram

Basic features of the initial organic mixtures

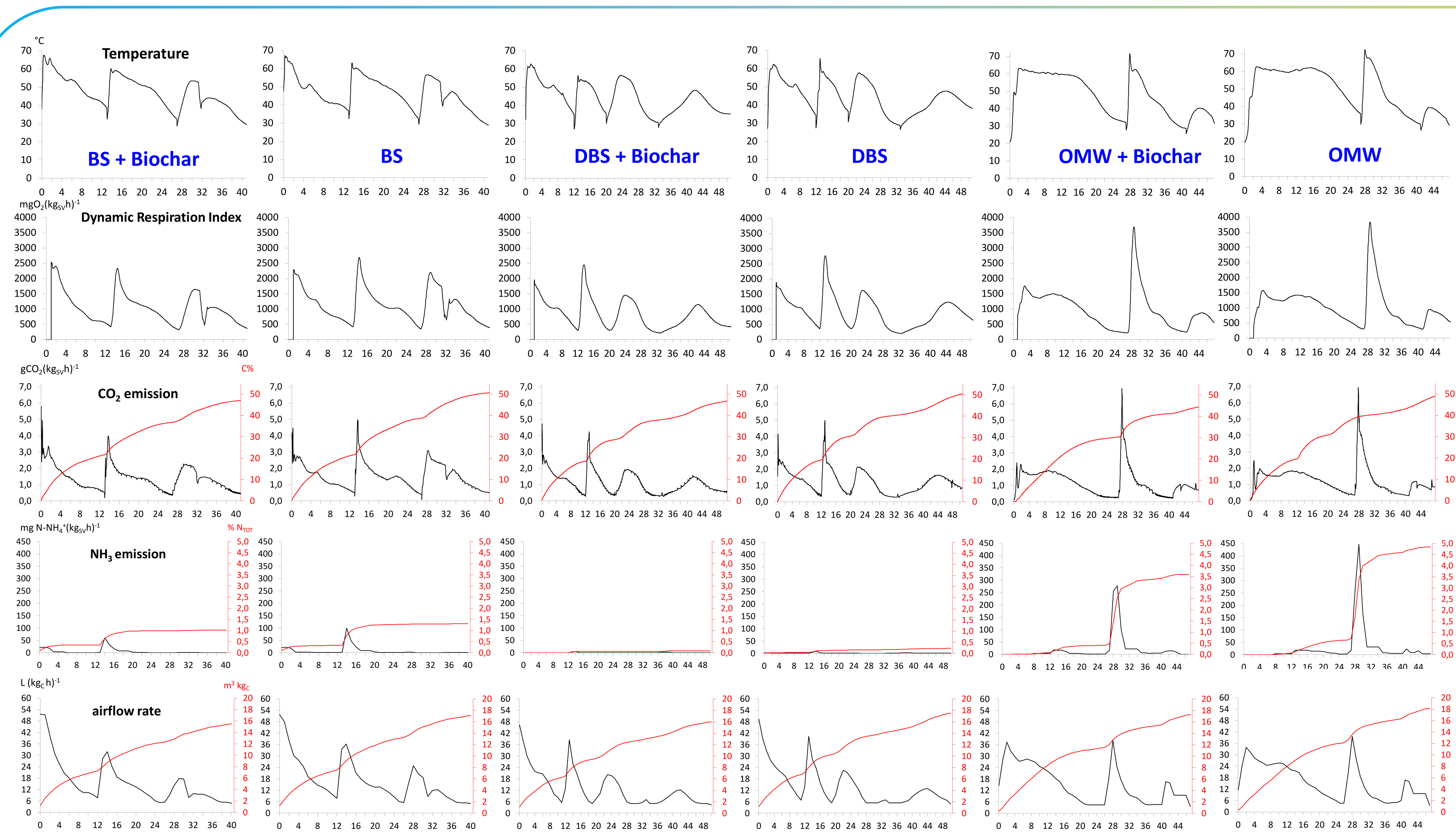
	Trial #1		Trial #2		Trial #3	
	BS + Bio	BS	DBS + Bio	DBS	OMW + Bio	OMW
moisture, %	55,7	53,6	53,0	53,3	53,8	54,0
ash, % dm	10,1	9,1	13,6	12,7	9,0	7,9
total nitrogen, % dm	2,1	2,2	1,9	1,9	2,6	2,7
C/N	22,1	21,0	23,6	22,4	19,0	18,0
bulk density, kg L^{-1}	0,41	0,41	0,39	0,39	0,50	0,50

COMPOSTER optimizes aerobic biodegradation and allows for a comprehensive mass balance assessment. It also prevents leaching, anoxia, and the production of undesirable foul volatile compounds, while assessing the Dynamic Respiration Index (DRI) values which give information on the current biological stability of the compost throughout the trials. COMPOSTER includes two 30-L adiabatic bioreactors able to compost properly and in short time (40-50 days) about 10-15 kg/vessel of any organic mixtures under controlled aerobic condition, performing typical sequences of mesophilic- thermophilic phases. The air flow rate of each bioreactor is managed by separate mass flow controller to keep the oxygen concentration in the exhausted air within optimal aerobic values - [O_2] > 10%.

Composition (% of fresh matter) of the initial organic mixtures

ingredients	Trial #1		Trial #2		Trial #3	
	BS + Bio	BS	DBS + Bio	DBS	OMW + Bio	OMW
buffulo slurries - BS	52,5	58,1	-	-	-	-
digestate from BS - DBS	-	-	49,7	52,3	-	-
olive mill waste - OMW	-	-	-	-	66,9	70,5
bulking agents	41,5	40,7	44,2	46,5	22,3	23,5
inoculum - OMW compost	1,0	1,2	1,1	1,2	3,2	3,4
hydrolyzed collagen	-	-	-	-	2,5	2,7
biochar - Bio	5,0	-	5,0	-	5,0	-

Throughout the trial, the temperature of the biomass, the pressure and temperature of the incoming and outgoing air flows are monitored, as well as the weight loss of each bioreactor placed on the scale, while the concentrations of oxygen, carbon dioxide are recorded every hour by means of specific detectors placed online. Ammonia, hydrogen sulfide and VOCs can be monitored on demand, arranging appropriate traps and/or easy sampling. Acquisition of signals, control of actuators, remote software supervision, data elaboration and monitoring are performed by means of fit-for-purpose integration of hardware and software created in NI LabVIEW environment. All detected parameters, except NH_3, H_2S and VOCs, are logged, plotted and instantly displayed in tables, graphs and spreadsheets, showing on real-time video the biodegradation patterns occurring in both bioreactors. During testing, the bioreactors can be easily opened to mix the biomass and collect samples for physicochemical and microbiological analyses.



COMPOSTER, emptying and start of the curing phase

Aeration rate, cumulated O_2 consumption and CO_2 emission recorded during the thermal phase of composting

		Trial #1		Trial #2		Trial #3	
		BS + Bio	BS	DBS + Bio	DBS	OMW + Bio	OMW
aeration rate, hourly mean	$L\ (kg_{DM}\ h)^{-1}$	7,6	8,1	6,1	6,6	7,4	7,7
aeration rate, max		24,5	23,6	21,7	22,8	28,6	28,2
total oxygen consumption	$gO_2\ kg_{DM}^{-1}$	613	649	610	662	667	695
total carbon dioxide emission	$gCO_2\ kg_{DM}^{-1}$	801	852	799	854	790	831

COMPOST		BS + Bio	BS	DBS + Bio	DBS	OMW + Bio	OMW
N		3,90	3,91	3,31	3,55	4,21	4,53
K	%	2,99	2,17	2,26	2,24	2,92	3,09
P		0,92	0,70	0,90	0,85	1,38	1,54
C/N		11,4	11,4	11,9	10,3	9,9	8,7
pH		8,90	8,90	7,84	7,76	7,42	7,58
EC	$dS\ m^{-1}$	1,268	1,424	1,308	1,415	2,810	3,090
GI	%	115,3	125,9	123,2	119,2	75,0	69,0
MASS BALANCE		BS + Bio	BS	DBS + Bio	DBS	DBS + Bio	DBS
weight loss	%	18,7	18,8	18,5	19,8	18,8	15,8
dry matter loss		47,1	51,0	43,9	46,0	41,7	40,0
carbon loss		49,3	52,5	49,8	54,0	44,7	42,4
nitrogen loss		1,0	1,3	0,1	0,2	3,6	4,9

EC = electrical conductivity; GI = germination index

- All composting trials showed optimized thermal phases, resulting in mature and stable composts (high GI and low DRI values) after only 40-50 days of maturation.
- The optimization of the process allows to preserve most (>95%) of the nitrogen present in the biomass, with a carbon loss ranging 42-53%.
- Biochar added during composting affected the ammonia emission, reducing it more (≈ -50%) in the case (DBS trial) there was a lower total emission, while ≈ -30% in the other trials.
- Regardless of the ingredients, optimized composting required about 7-9 $m^3\ kg_{DM}^{-1}$ (≈ 15-18 $m^3\ kg_C^{-1}$) of air consumption, with initial peaks of 21-24 L $(kg_{DM}\ h)^{-1}$.
- All trials confirmed that biochar is "non-biodegradable", even in the highly aggressive context of composting.
- Compost analyses showed high content of nitrogen, potassium, and phosphorus. There was an absence of phytotoxicity, and the Dynamic Respiration Index values were less than 25 mmol $O_2(kg_{VS}\ h)^{-1}$, with pH and electrical conductivity suitable for multiple beneficial agronomic uses.
- **Compost can be profitably used as soil amendment/fertilizer and as ingredient in substrates for potted nursery crops, partially or entirely replacing peat.**

Altieri R., Spaccini R., Pane C., Manganiello G., Cangemi S., Verrillo M., Stanzione V., Esposito A., 2024, *Process and quality evaluation of different improved compost made with a smart laboratory pilot plant*, Heliyon 10: e31059
https://doi.org/10.1016/j.heliyon.2024.e31059

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