Effect of biochar amendment during composting and compost storage on greenhouse gas emissions, N losses and P availability

Vandecasteele Bart[1,*], Mondini Claudio[2], D'Hose Tommy[1], Russo Stefano[3], Sinicco Tania[2], Quero Alba Antonio[4]

(1) Institute for Agricultural and Fisheries Research (ILVO), Plant Sciences Unit, Caritasstraat 21, Melle, BE
(2) Consiglio per la ricerca e la sperimentazione in agricoltura, CRA-RPS, Via Trieste 23, 34170 Gorizia, IT
(3) eEstpiù, Via IX Agosto, 15, 34170 Gorizia, IT
(4) PROININSO, S.A., Carretera Azucarera, 27, 29004 Málaga, SP
*Corresponding author: bart.vandecasteele@ilvo.vlaanderen.be

Abstract
We tested the effect of adding 10% biochar (on a dry weight base) in a mixture of green waste and the organic fraction of municipal solid waste before processing in a composting plant. Focus is on compost quality, fate of nutrients and on the environmental impact during composting (emission of greenhouse gasses). As a consequence of biochar amendment, the <10mm fraction was proportionally higher in the biochar-blended compost. In this full scale experiment, mixing biochar in the feedstock mixture strongly affected the oxygen uptake rate and nutrient availability during the first weeks of the bio-oxidative phase. A higher organic matter decomposition, a higher dry matter content and lower P, SO_4^{2-} and NH_4^+-N concentrations were observed for fraction <10 mm of the biochar-blended compost. After 27 days a clearly lower oxygen uptake rate was detected for the biochar-blended compost.

Introduction
Bio-waste has a great potential for conversion into bio-energy or as an alternative to chemical fertilizers. The FP7 project FERTIPLUS assists the EU in the design and implementation of innovative strategies and technologies for the recycling of waste to both compost and biochar for use in agriculture. The core theme of FERTIPLUS is to ensure that good quality bio-wastes are brought back to the soil in such a way that their nutrients are safely recycled, contributing to soil quality improvement and reducing the use of chemicals in agriculture.
It is generally understood that biochar improves plant nutrition more after its surface has "weathered", or becomes more reactive in the soil [1]. A number of processes over time will make that happen, but mixing char with compost can accelerate the process while biochar can reduce nutrient losses [2-3].
We investigate the effect of biochar on the production of compost in order to understand the influence on compost quality, fate of nutrients (leaching, volatilisation, recycling) and on the environmental impact during composting (emission of the greenhouse gasses CO_2, CH_4 and N_2O and C footprint).

Material and Methods
Full scale composting experiment
The activities of the FP7 project FERTIPLUS include a full scale trial on the effect of biochar on the performance of the composting process. The trial is running at the composting plant of Ambiente Newco s.r.l. (Ronchi dei Legionari, Gorizia, Italy). A mixture of green waste and the organic fraction of municipal solid waste is used as feedstock for the process). The organic fraction is collected separately according to a door to door waste collection scheme. A dry weight (DW) ratio feedstock/biochar of 90/10 is applied. Biochar produced at PROININSO S.A. (Malaga, Spain) is added in the windrow at the beginning of the process. Regular composting of the mixture of green waste and the organic fraction of municipal solid waste is the reference treatment in the trial. Composting is executed in lanes with automated mechanical turning and forced aeration. Greenhouse gas emission is assessed during the composting process. Feedstock materials and composts are sampled and analysed for chemical and physical characterisation. Weight determinations allow for mass balance calculations. The compost trial will be repeated three times in 3 consecutive years.
In the first trial (spring 2013) temperature and GHG emission were measured at regulars intervals during the bio-oxidative phase of the process. Temperature was taken at a depth of 1 m utilizing a

probe. GHG were sampled utilizing a closed chamber and measured by GC. Samples were taken at the start of the experiment (January 31th 2013), and after 14 and 27 days.. Samples were sieved over a 10 mm mesh and the finer fraction was used for determination of water extractable nutrients and oxygen uptake rate. Determination of organic matter (OM) and ash content in the composts was done according to EN 13039, and determination of dry matter content (DM) was performed according to EN 13040. Extraction of water-soluble nutrients and elements was performed according to EN 13652, and elemental concentrations were measured with a Dionex DX-600 IC ion chromatograph (Dionex, Sunnyvale, CA). As an indicator of compost stability, oxygen uptake rate (OUR) at 20 °C was calculated from the oxygen consumption due to microbial activity of 20 g compost (<10 mm fraction) in 200 ml buffered nutrient solution during 5 days of shaking in a closed Oxitop respirometer. OUR is expressed as mmol/kg OM/hour. The composting process is expected to end after 3 months.

Compost storage experiment and incubation trials

A study on the effects of biochar on compost storage is also planned. In this trial biochar is added to stable compost, the end product of the composting treatment without biochar addition in the trial described above. The compost storage trial is executed after the composting trial, since compost from the full scale trial is a necessary input. A DW weight ratio compost/ biochar of 80/20 is applied in this sheltered storage trial. This experiment will start in May 2013. Effects on N and P availability after application of the composts in agricultural soils are assessed in incubation trials.

Results

Temperature and greenhouse gases emission

Temperature in the reference treatment was significantly higher than in the biochar-blended compost throughout the whole bio-oxidative phase (Table 1). Amending biochar in the compost feedstock resulted in a clear reduction in CO_2 and CH_4 emissions. The mean emission rates for the period were 664 and 222 mg CO_2-C m^{-2} min^{-1} and 4.0 and 0.36 mg CH_4-C m^{-2} min^{-1} for the reference and the biochar-blended compost, respectively. In the case of N_2O no significant differences between the two treatments were observed.

Sieve fractions during composting

The initial feedstock for the compost decreased from 22772 kg fresh weight (FW) to 13280 kg FW during the 24 days of the bio-oxidative phase. Bulk density decreased from 660 to 500 kg/m^3. The initial feedstock for the biochar-blended compost decreased from 21614 kg fresh weight (FW) to 10220 kg FW during the 24 days of the bio-oxidative phase. Bulk density decreased from 600 to 380 kg/m^3.The feedstock mixed with biochar initially had a clearly higher fraction <10 mm than the regular feedstock (Fig. 1). This is a logical observation, as the biochar added to the feedstock consists of fine material <10 mm. This trend was also observed for the other two sampling events, but after 14 days the proportional share of the fine fraction had decreased for both feedstock mixtures (Fig. 1). This may indicate a faster decomposition of the finer fraction than for the >10 mm fraction during the first 2 weeks of the process. After 27 days the share of the fine fraction clearly increased (Fig. 1), pointing at decomposition and fragmentation of the >10 mm fraction, hereby moving into the <10 mm fraction.

Chemical analyses and OUR

Clear differences were observed in the evolution of the chemical properties between the feedstock for the compost and the feedstock for the biochar-blended compost (Table 2). The biochar-blended compost initially had a higher OM content due to the addition of biochar, but this composting mixture was characterised by a faster decline in OM during the 27 days, while there was a small increase in the OM content of the compost feedstock. DM content was higher for the biochar-blended compost, and increased for both feedstock mixtures during the bio-oxidative phase (Table 2).

In both mixtures, the NO_3^--N concentrations remained very low, while mixing biochar had a small effect on Cl concentration (Table 2). From the first sampling event during the process, mixing biochar resulted in lower NH_4^+-N, SO_4^{2-} and P concentrations in the <10 mm fraction, and this effect was still measured after 14 and 27 days.

Initially, mixing biochar resulted in a lower OUR, and this effect remained after 14 and 27 days (Table 2). After 14 days a striking difference in the pattern of the oxygen consumption was observed, with a clear lag period for the feedstock without biochar (Fig. 2).

Conclusion and perspectives

Mixing biochar in the compost feedstock clearly affected the process and compost characteristics during the the bio-oxidative phase. Biochar increased OM degradation and dry matter content, and decreased bulk density, CO_2 and CH_4 emissions and the availability of elements.

The effect of mixing biochar in the compost feedstock will be further monitored during the maturation phase of the composting process. Both the compost and the biochar-blended compost will be characterised chemically and physically in order to quantify the effect of biochar on compost quality and nutrient losses during the process. After the composting experiment, a second experiment on the effect of biochar amendment to stable compost will start.

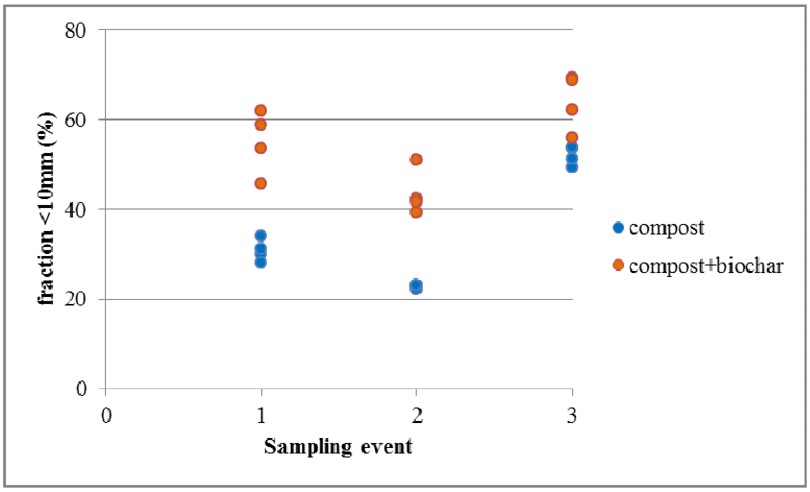

Figure 1. Evolution of the % <10 mm fraction of the compost feedstock without ('Compost') or with biochar amendment ('Compost+biochar') at three times (1: day 0, 2: day 14 and 3: dag 27) of the of the bio-oxidative phase (4 replicates per sampling event)

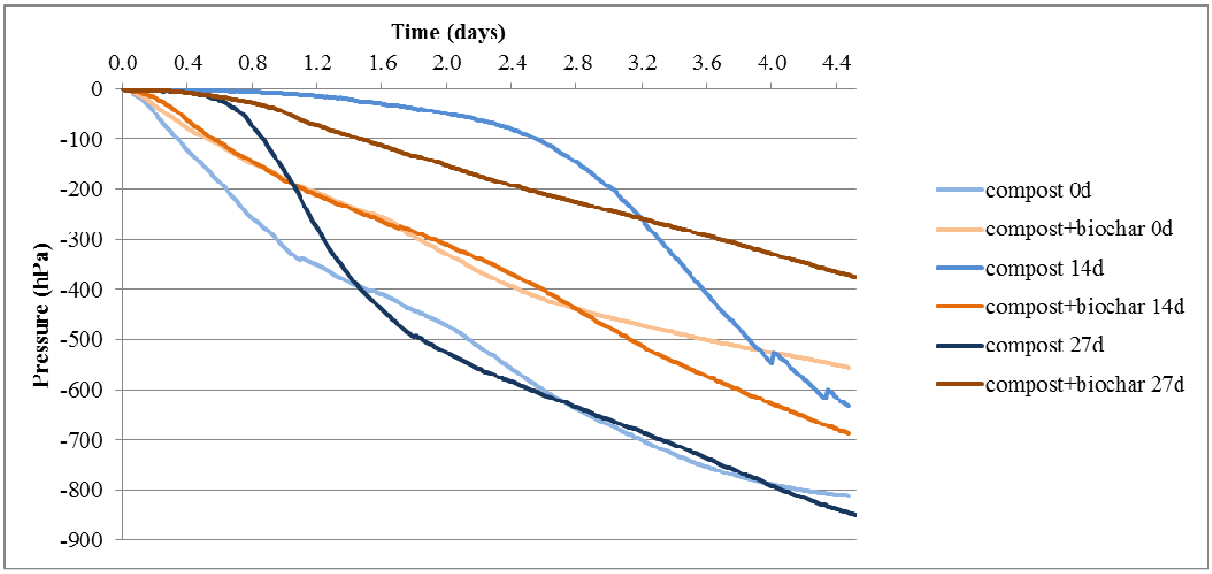

Figure 2. Evolution of the pressure decline during Oxygen Uptake Rate determination of the <10 mm fraction of the compost feedstock without ('Compost') or with biochar amendment ('Compost+biochar') at day 0, 14 and 27 of the of the bio-oxidative phase. Values are averages of 4 replicates per sampling event.

Table 1. Temperature (°C) measured at the composting plant for the compost feedstock without ('Compost') or with biochar amendment ('Compost+biochar') at several times during the bio-oxidative phase. Values are averages of at least 5 measurements per sampling event (st.dev: standard deviation).

Date	Compost		Compost+biochar	
	average	st.dev	average	st.dev
31/01/2013	41.4	1.0	33.1	1.8
6/02/2013	47.2	3.7	38.0	8.1
13/02/2013	37.2	1.9	21.9	1.1
21/02/2013	46.2	12.6	31.7	0.9
26/02/2013	54.2	3.1	60.0	11.4

Table 2. Characteristics of the <10 mm fraction of the compost feedstock without ('Compost') or with biochar amendment ('Compost+biochar') at day 0, 14 and 27 of the of the bio-oxidative phase. Values are averages of 4 replicates per sampling event (OUR: oxygen uptake rate, DM: dry matter, OM: organic matter)

	OM %/DM			DM %/fresh			OUR mmol/kg OM/hr			NO_3^--N mg/l compost		
Day	**0**	**14**	**27**	**0**	**14**	**27**	**0**	**14**	**27**	**0**	**14**	**27**
Compost	61.6	64.6	63.3	36.9	38.1	46.2	73	66	57	<5	<5	<5
Compost+biochar	69.9	62.9	58.3	47.5	49.9	71.3	33	41	16	<5	<5	<5

	$NH4^+$-N mg/l compost			$SO4^{2-}$ mg/l compost			Cl mg/l compost			P mg/l compost		
Day	**0**	**14**	**27**	**0**	**14**	**27**	**0**	**14**	**27**	**0**	**14**	**27**
Compost	8.1	416	337	116	314	292	590	1051	889	102	149	38
Compost+biochar	<5	100	207	72	52	58	452	1221	1334	48	10	17

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