BIOCHAR AND ORGANIC MATTER CO-COMPOSTING: A CRITICAL REVIEW

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BIOCHAR, COMPOST & CO-COMPOSTING

Combining a stable recalcitrant material as biochar with organic matter, as manure or from AD or OFMSW can be a win-win solution.
It can be done either by blending or co-composting

SOME DEFINITIONS AND KEY PARAMETERS FOR COMPOST MATURITY

Degree of compost maturity

Stable: microbiological processes slow down and nearly cease
Mature: toxicity of phytotoxins is reduced
Finished: compost is stable & mature

Compost status indicators

Temperature, C/N ratio, content of soluble organic carbon (DOC), NH4+/NO3− ratio, germination capacity (GI), Humic Acids to Fulvic Acids (HA/FA) ratio, oxygen uptake rate (OUR) and biochemical composition

Mature compost:

- T = ambient
- C/N < 21 or < 15
- NH_4^+/NO_3^- ratio < 0.16
- GI > 50 or > 100
- HA/FA > 1.6 or > 1.9
- OUR < 480 mg O_2 kg_{OM}^{-1} h^{-1} (for compost used as growing media)

In Compost + Biochar, C/N can be > 21 in spite of the compost having attained maturity

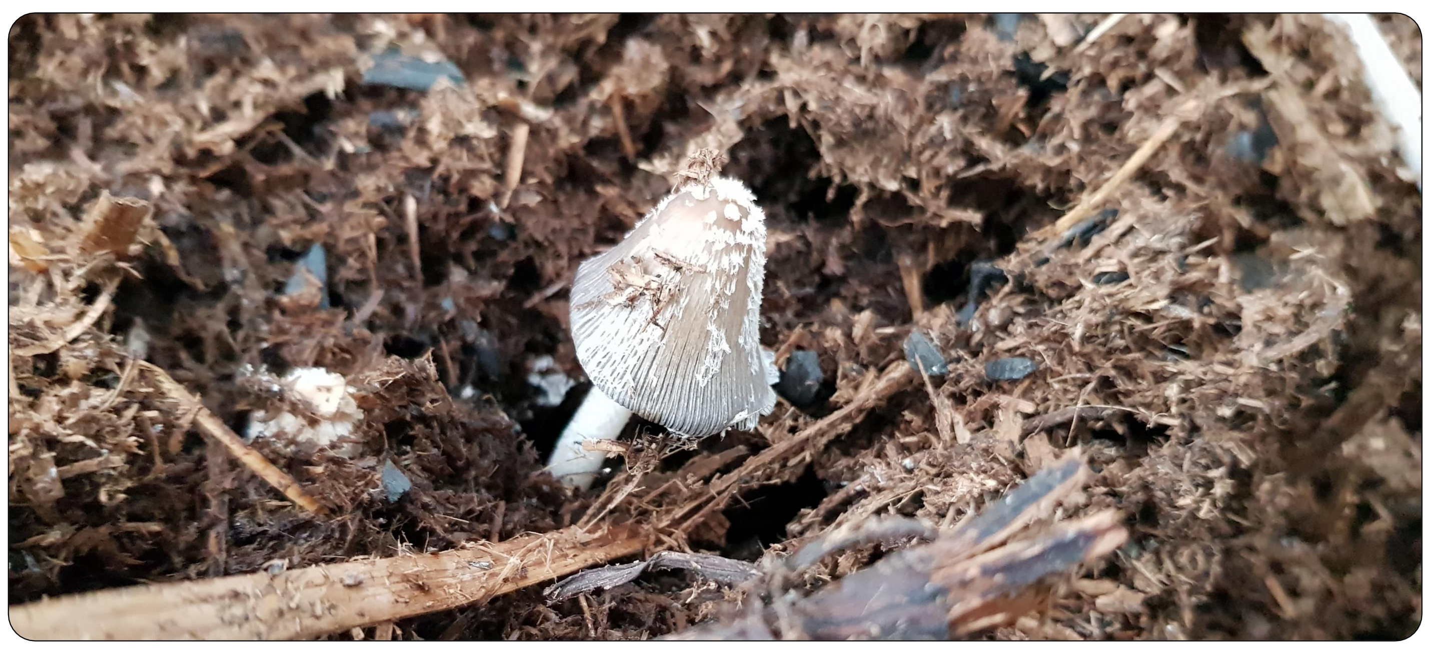
Optimum pH for plants: 6.5-7.

Also Heavy Metals mobility linked to pH (the higher pH, the lower metal mobility, the safer the material).

The combination of **compost/digestate & biochar (COMBI)** can bring **short-term** and **long-term benefits** to the **soil** and to **agriculture**

ROLE OF COMBI IN PLANT GROWTH

- ❑ Quantitative review on COMBI (14 papers, 2007-2018), response-ratio as effect size.
- ❑ COMBI significantly increased grain yields of cereal grasses (39.7%).
- ❑ Best: < 20 t/ha (+48.3%) or >30 t/ha (+15.7%)
- ❑ Greatest increase in productivity observed at 4-5 soil pH
- ❑ COMBI application rate, but no details on biochar content in co-composting as the attainment of compost maturity,



USE OF BIOCHAR & BIOCHAR/COMPOST MIX

Biochar-compost application are more effective in improving soil properties and crop yields (field and horticulture crops) than biochar alone

i) majority of published works in developed countries where soils are less impaired in terms of food production capacity than in developing countries;
ii) studies on biochar produced in small kilns more common than biochars produced at commercial scale in developed countries, whereas biochars from traditional techniques are more common than biochars produced in modern pyrolysis units in developing countries;
iii) laboratory and greenhouse studies more common than field studies
iv) wood and municipal wastes were the major feedstock for the preparation of biochar compared to crop residues and manures
v) fertility benefits from incorporation of biochars: manure and legume-derived biochars are far superior to wood derived biochars.

Lack of long-term, well-designed field studies on biochar & biochar-compost mixtures efficacy on different soils & agro-climatic zones

BIOCHAR AS ADDITIVE IN COMPOSTING

- Low dose (3-5 % on dry weight base) recommended
- Clean wood, T=500-600 °C, particles < 2 mm up to >16 mm normally tested. No recommendation yet on particle size!
- Biochar CEC during composting: "oxidative ageing" or "weathering" (development of more oxygenated functional groups on biochar surface due to oxidative process) as well as adsorption of dissolved organic matter & microbial residues
- Increased CEC → increased ability to retain nutrients
- Modification of pores (increase of micropores), larger surface area
- Microbial colonization, thanks to water & nutrient retention by biochar

BIOCHAR MAIN EFFECTS DURING COMPOSTING

- ❑ usually biochar increases pH,
- ❑ reduction of nutrient losses (Ca, Mg, N etc.),
- ❑ increase of nitrification,
- ❑ formation of stable humic like substances,
- ❑ immobilization of heavy metals (reduction of their bioavailability),
- ❑ reduction of emission of greenhouse gases.

SCHEME OF COMBI PRODUCTION IN ANAEROBIC DIGESTION PLANT

OPEN ISSUES

(1) How different biochars influence the composting process?
(2) To what extent the properties of raw material for composting will determine the interaction of biochar with pollutants?
(3) Which optimum dose of biochar during composting (to achieve best run of the process, immobilisation of pollutants and reduction of toxicity)?
(4) How sorption of heavy metals from compost rich in those ions (e.g. sewage sludge) will affect loss of macroelements (ions of Ca, Mg, etc.) from compost – does biochar prefer the sorption of heavy metals or macroelements?
(5) What kinds of biochar and compost for which soil and plants?
(6) Will the degradation of humic like substances formed in the presence of biochar be slowed down relative to their equivalent formed without biochar addition, when the compost is applied to soil?
(7) How does biochar affect the fate of various organic pollutants, and first of all will the ageing of biochar during composting affect in any way the bioavailability of contaminants contained in biochar or in the compost mass?

ADDITIONAL ELEMENTS THAT NEED FURTHER INVESTIGATION

- Biochar particle size, doses & feedstock etc.
- Interaction of biochar with microorganisms and correlation with composting (humification, biodegradation, greenhouse gas emissions, etc)
- Identification of non-biochar carbon species adsorbed onto biochar surface for better understanding the interaction of biochar with key processes such as humification and the reduction of GHG emissions and volatile compounds.
- Development of optimal microscopic techniques and the use of advanced spectroscopic (e.g., NMR) and isotope labelling (e.g., 13C and 15N) techniques.
- Impact on the growth promoting substances when biochar blended compost used as soil amendment or as component for growing media in soil-less cultivation.
- Determination of soluble and extractable C and N compounds involved in the calculation of conventional compost maturation indices (methodological challenge, given the strong sorption capacity of biochar).
- Re-evaluation of some maturity indices (e.g., C/N, dissolved organic C, humification indices, NH4+/NO3−, etc.) for biochar blended composts.

CONCLUSIONS

IS CO-COMPOSTING WORTH?

- If the amount (tons) of biochar in co-composting or blend is the same → no major difference in sequestered fixed C, no large motivations for co-composting form the C monetary value point of view.

Therefore: Does co-composting pay off, or is instead blending sufficient and a better economic choice?

- Answering this question is **site- and policy-dependent**, and requires extensive further work.
- AD plants (especially OFMSW AD) largely implement **pasteurization step** → thus **composting not strictly needed** from the sanitary point of view.
- If thus digestate can be directly spread on soil, avoiding composting save CAPEX and OPEX. **Blend will most likely be the preferred choice**
- **If composting process acceleration is instead required, adding Biochar could be an option**. This could be the case of some OFMSW composting units.
- If **biochar deployment (dust)** is an issue, **co-composting will help** (but other options are possible)
- **Detailed analysis of local (soil) benefits from collected nutrients favor co-composting**, but customer must pay for this (market to be developed). The deployment of biochar, biochar & compost and COMBI will necessarily be a policy-driven issue
- Multiple policies could interact impact. Studies needed to provide policy makers with recommendations.