Preliminary results on food waste valorization into soil organic amendments and their agronomic effects

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Introduction

Food waste (FW) is a big issue across the world. It is estimated that around one-third of the food produced is lost or wasted along the food production and supply chains, with over 58 million tons of FW generated only in the EU ("Food Waste," n.d.). FW is not only an economic and ethical issue – in fact, over 37 million people still cannot afford quality meals – but also a huge environmental issue, considering that food production consumes limited natural resources and that food waste only is responsible for 8-10% of global greenhouse gas (GHG) emissions (Food Waste Index Report 2021, 2021), excluding the huge impact of food production itself. Machinery operations and the manufacturing of synthetic fertilizers, as well as the overexploitation and improper management of arable lands have a huge GHG emission potential. It is estimated that the degradation of one third of the world's soils has released up to 78 Gt of carbon (C) into the atmosphere ("FAO Maps Carbon Stocks in Soil" 2017; "Soil Carbon Sequestration & Climate Change Mitigation," n.d.)

On the other hand, healthy soils and proper management practices can promote C sequestration in plant biomass and soil thus contributing to the reduction of GHG in the atmosphere and helping to reach the "Fit for 55%" goal of reducing GHG emissions by 55% by 2030 and the zero-emission target by 2050 stated by the European Green Deal. Moreover, healthy soils are essential for sustaining life on Earth since they provide numerous fundamental ecosystem services for human beings – e.g., producing food, storing and purifying water, ensuring nutrient cycling for crop productivity, capturing carbon from the atmosphere, preserving and protecting biodiversity ("A Soil Deal for Europe," n.d.) - and they are crucial for the achievement of many Sustainable Development Goals (SDG2, SDG3, SDG6, SDG11, SDG12, SDG13, SDG15) ("Soil and United Nations Sustainable Development Goals," n.d.). Organic amendments – such as compost, anaerobic digestate, and biochar – can contribute to restore soil health and to increase soil organic carbon (SOC) and at the same time they represent a valuable valorization strategy for FW. Thus, the use of organic amendments could be considered among the management practices to maintain and enhance SOC on mineral soils, which is one of the carbon farming practices identified by the European Commission ("Technical Guidance Handbook Setting up and Implementing Result-Based Carbon Farming Mechanisms in the EU" 2021). However, the C sequestration potential of these organic amendments is still controversial, because, considering the whole lifecycle, the net effect is highly uncertain and quality standards are difficult to control with potential drawbacks for soil health and biodiversity (Mcdonald et al. 2021).

The aim of this study is the comparison of different organic amendments, like compost, biochar, digestate, and composted digestate, to evaluate the impact of their productive processes and their agronomic effects and to demonstrate their beneficial contribution to plant growth and their feasible use to replace chemical fertilizers. To make a more reliable comparison, it has been chosen to use the same input biomass for all the treatments, i.e., the Organic Fraction of Municipal Solid Waste (OFMSW) coming from a real collecting and treatment plant.

Materials and Methods

Real Organic Fraction of Municipal Solid Waste (OFMSW) used in this study was supplied by ACSR s.p.a. (Borgo San Dalmazzo, CN, Italy), which collects OFMSW mixed with mowing and pruning wastes. ACSR s.p.a. also provided industrial compost derived from the treatment of the same OFMSW.

The first Anaerobic Digestion (AD) of OFMSW was performed in a 20 L glass Duran® Bottle with a working volume of 80%. AD was designed at 4.8% w/w Total Solids (TS) and with a substrate to inoculum ratio (S:I) equal to 1:1. The inoculum used for the AD came from the farming cooperative "La Speranza" located in Candiolo (TO, Italy) and it is the mesophilic digestate of cow agricultural sludge (CAS). Given the big dimensions of the used reactor, it was not possible to control the temperature, but the hot summer climate ensured an ambient temperature of around 30 °C during all the process, which lasted 21 days during summer 2023.

At the end of the AD process, digestate was centrifuged to separate solid and liquid fractions. About 8 kg of liquid supernatant and 6.5 kg of solid were obtained. The solid fraction was composted in a polystyrene drilled box, to ensure temperature insulation and air circulation. The composting substrate was mixed periodically and watered to guarantee the right humidity during the process.

A second AD of OFMSW was performed to produce the digestate to be used as it is. This time, AD was conducted in a 10 L plastic bin with a working volume of 80% and designed at 6% TS and 1:1 S:I. The reactor was kept at 30 °C in a water bath for the entire duration of the process, which lasted 45-50 days and was stopped when daily production was below 1% of the total gas production. At the end of the process, digestate was stored until analysis and use.

In both AD processes, produced biogas was collected in Tedlar® gas sampling bags, quantitatively measured by bag displacement and qualitatively analyzed with micro-GC.

Two different biochars were produced, one from the dried OFMSW and the other from the dried digestate coming from the OFMSW AD. Both biochars were produced through slow pyrolysis in a fixed bed reactor at 500 °C/min for 1 h as residence time, which were selected as optimal operative conditions in a previous study.

Complete chemical characterization of the amendments will be performed before use and includes elemental analysis CHNSO (Elemental Macro Cube system Vario, Germany), Total and Volatile Solids, pH, Electrical Conductivity (EC), metals content with ICP-MS, nitrates, ammonium and ortho-phosphates with HACH kits, respectively LCK 340, LCK 503, LCK 350 (HACH LANGE GHB, Germany), Total Organic Carbon (TOC).

The obtained amendments will be tested in greenhouse pot experiments to evaluate their different agronomic effects on plant growth through the measurement of the main parameters, e.g., height, number of leaves, Chlorophyll Content Index (CCI), fresh and dry biomass and roots development.

The collected data will allow to evaluate the most valuable process, not only in terms of lower environmental impact, but also in terms of effectiveness for agronomic use and their carbon sequestration potential. The nutrients cycle from the input biomass to the final product will also be evaluated.

Conclusions

To the best of the authors' knowledge, this is the first study that deals with a comprehensive comparison of both the production processes and the agronomic effects of different organic amendments made from the same input biomass and the nutrients cycle along all the chain.

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