Energetic valorisation of sunflower and maize crops used in phytoremediation of soil contaminated with heavy metals

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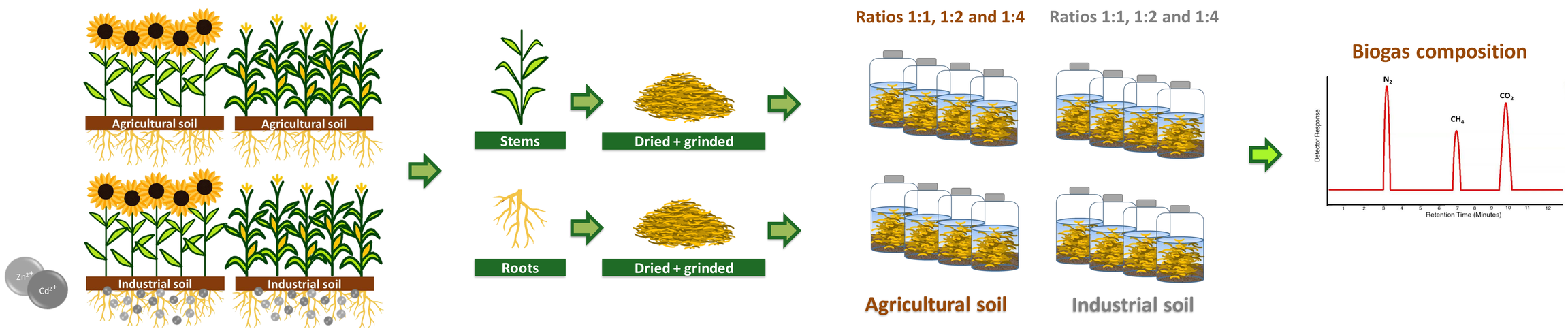
Introduction

Phytoremediation is an attractive low-cost solution for soil requalification which stabilizes the site with a vegetable cover, avoids the dispersion of pollutants and removes contaminants from the brownfield. The use of energetic cultures to perform soil remediation in heavy metal (HM) contaminated sites contributes to the sustainability of phytoremediation strategies. Sunflower and maize are among the most studied species for the remediation of HM-contaminated soils. However, the fate of harvested biomass can be an obstacle for its implementation. One possible solution is to use HM contaminated biomass for generating biogas, using anaerobic digestion (AD). AD is an effective technology for valorisation of crop residues, by producing renewable energy and reducing the agricultural waste. Despite this, the anaerobic processes can be sensitive to the HM present in the crops. In this way, the AD of plants used in phytoremediation must be investigated to understand if HM toxicity could lead to process disturbance. In this study, the main objective was to study the effect of the HM accumulation on the AD of sunflower and maize plants parts, as well as evaluating the potential of each plant for biogas production. For this, maize and sunflower plants were grown in industrial soil, contaminated with HM (e.g., Cd and Zn), and in agricultural soil, used as control soil. Roots and stems were used separately as AD substrates. This work presents an integrated strategy for bioenergy recovery from energetic plants used in phytoremediation.

Methods

1. Maize and sunflower plants were grown (5 months) in contaminated (industrial) and non contaminated soil (agricultural);
2. Stems and roots were separated and dried, grinded and used as substrate (carbon and energy source) for the biomethane assays (BMP);
3. Inoculum → Anaerobic granular sludge from a full scale EGSB (Expanded Granular Sludge Bed) reactor, treating wastewater from a beverage company;
4. Different inoculum to substrate ratios (VS based) were tested → 1:1, 1:2 and 1:4;
5. Biogas composition was measured using gas-chromatography.



Results

1) Anaerobic digestion of sunflower and maize roots

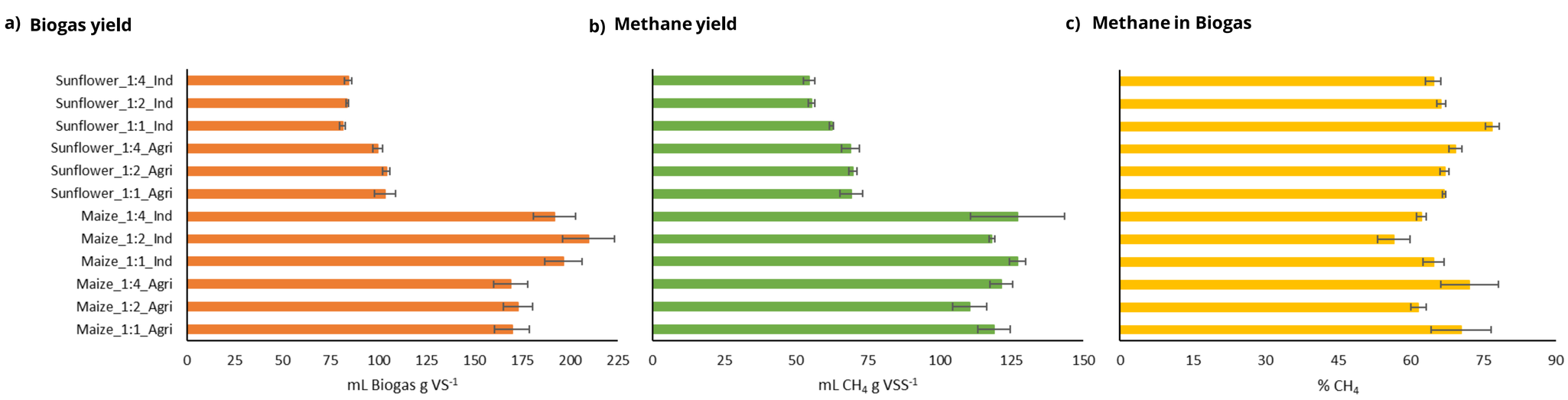


Figure 1. Biogas production yield (a), methane production yield (b) and methane percentage in biogas (c) at the end of the BMP assays using sunflower and maize roots as substrate: comparison between ratios 1:1, 1:2 and 1:4 (inoculum to substrate (g VSS/ g VS)), for both soil conditions (Ind – industrial soil; Agri – agricultural soil).

2) Anaerobic digestion of sunflower and maize roots and stems

Table 1. Average values (± SD) for maximum volume of methane (V_{max}) and methane yield (Y) obtained at the end of the assays, for ratio 1:1 (inoculum to substrate)

Soil	Agricultural		Industrial	
Biomass	V_{max} (mL)	Y (mL g^{-1}VS)	V_{max} (mL)	Y (mL g^{-1}VS)
Maize stems	14,4 ± 0,5	161,3 ± 5,9	14,2 ± 0,4	159,3 ± 3,6
Sunflower stems	5,2 ± 0,3	58,6 ± 3,2	6,6 ± 0,8	74,3 ± 9,2
Maize root	10,6 ± 0,8	119,0 ± 5,6	11,3 ± 0,3	127,2 ± 2,9
Sunflower root	6,2 ± 0,4	69,2 ± 4,0	5,6 ± 0,1	62,4 ± 0,6

1) Anaerobic digestion of sunflower and maize roots

- Biogas and methane yields obtained from maize roots were twice the values obtained for sunflower roots;
- Biogas and methane yields were similar for sunflower roots, independently from soil condition;
- More methane was produced using maize roots grown in industrial soil compared to roots from the agricultural soil;
- The percentage of methane in the biogas was between 60 and 70 % for both plants and soil conditions.

2) Anaerobic digestion of sunflower and maize roots and stems

- Methane production from maize stalks was higher compared to sunflowers stalks;
- More methane was obtained from maize stems compared to the maize roots;
- A similar amount of methane was obtained from sunflower roots and stems;
- Soil condition did not seem to negatively affect methane production, for any of the tested plants.

Conclusions

→ HM soil contamination did not affect sunflower or maize anaerobic digestion process;

→ Maize presented a higher methane production potential compared to sunflower.

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