Closing the circle for urban food waste anaerobic digestion: The use of digestate as fertilizer for tomato plant cultivation

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Introduction

The increasing world population necessitates the production of larger amounts of food in a safe and environmentally sustainable manner. These needs can theoretically be achieved by the recycling of the nutrients in food waste via anaerobic digestion. Apart from the biogas produced for energy recovery, the liquid by-product (digestate) is rich in major nutrients (N, P and K), which can be applied as fertilizer for plant cultivation. Besides, urban farming has been gaining popularity, but the poor urban soil quality has raised concern regarding soil productivity. Amendment with rapidly decomposing organic matter can improve soil structure and porosity, and thus improve water and gas movement for root and tree growth (Somerville *et al.*, 2020). Furthermore, the use of organic matter derived from urban waste streams helps to promote the sustainable use of resources. In this regard, lightweight renewable growing medium such as cocopeat and biochar were proposed as part of the soil amendment. The renewable growing medium was selected due to the global soil degradation, which may embark the shift from soil to soilless substrate culture (Song *et al.*, 2021).

Herein, this study investigated the use of food waste anaerobic digestate (FWAD) as a nutrient source fertilizer, combined with biochar-/ cocopeat-soil amendment growing medium to cultivate tomato (*Solanum lycopersicum L.*) plant. The objective of this study was to investigate the yield of tomato with FWAD application in biochar-/ cocopeat-soil amendment growing medium. Such a waste-to-resource approach offers a shift from soil to soilless substrate culture for crop growers, contributes to waste valorisation, and enhances the growth of plants under renewable FWAD application.

Material and Methods

FWAD was collected from a 10.4 m^3 decentralized anaerobic digester system treating with food waste. The digester was operating stably at an average loading rate of 44.8 ± 21.2 kg, with a production of 56 % methane concentration biogas, in correspond to an average methane specific yield of 0.36 $m^3_{methane}/kg_{VS}$. A portion of the FWAD was subjected to pasteurization at 70°C for 1 h by oven dried, for use as a nutrient fertilizer. Wood-based biochar (Kyungdong Energy, South Korea) was produced using torrefaction at 200–300 ◦C. Garden soil (FERTIPLUS Universal Potting Soil), cocopeat and tomato (*Solanum lycopersicum L.*) seeds were purchased from Far East Flora Pte Ltd, Singapore.

The cultivation of tomato was conducted at NUS Native Plant Nursery, Singapore. For each treatment, 5 replicates of 2 L pots were filled with well-draining cultivation media containing 40% biochar/ cocopeat and 60% soil mixture (v/v). Tap water (0% AD) was applied on garden soil to substitute for the semi-liquid fertilizers as the blank control treatment, while another similar control treatment was added with FWAD. Tomato seeds were germinated in seedling trays with garden soil for two weeks (Day 0-13) before transplanting. On Day 14, respective seedling was randomly transplanted to each 2 L pot containing the biochar + soil/ cocopeat + soil growing medium. FWAD treatments were applied to each pot on Days 16, 26 and 36. An application volume of 250 ml was used as it was pre-determined gravimetrically to be the media saturation volume of a 2 L pot (Cheong *et al.*, 2020). On harvest day (Day 46), plant growth parameter yields, i.e., leaf number, shoot length and chlorophyll control index, were measured accordingly.

Results and discussions

On harvesting day (Day 46), tomato plant grown in biochar and cocopeat-soil growing medium with the added FWAD revealed better yield than those without (**Fig. 1**). These results suggested that biochar/ cocopeat growing medium could be a sustainable substitute for soil. Among these, biochar-soil mixture growing medium showed the best performance yields in terms of chlorophyll content index (CCI), volumetric water content (VWC), as well as

physical characteristics that include shoot length and leaves number. High CCI value (dark leaf colour) recorded in biochar-soil growing medium indicates the FWAD not only served as a N source but also increased the N use efficiency (Möller and Müller, 2012). Meanwhile, this treatment may provide a more stable growing environment due to the higher VWC value. High VWC can reduce the moisture level fluctuations in the soil–water environment and the need for plants to develop more protective tissues, thus enhance faster growth in the soil treatment (Song *et al.*, 2021). Owing to the high CCI and VWC values, the physical growth also consistently showed the highest shoot length and leaves number in biochar-soil growing medium.

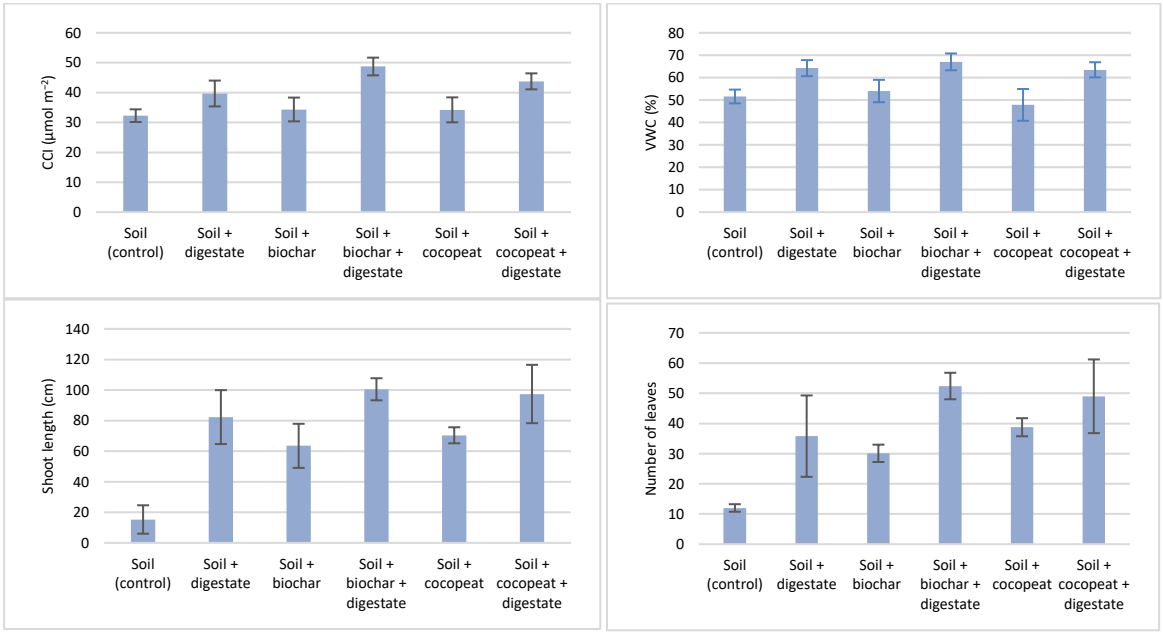

Fig. 1. Various parameter yields conducted on different potting soil treatment conditions on the harvesting day (Day 46). (a) Chlorophyll content index (CCI), (b) Volumetric water content (VWC), (c) Shoot length, and (d) Number of leaves.

Conclusion

This study revealed the sustainable agricultural inputs (AD, biochar, and cocopeat, all of which solely consist of recycled growing materials), can replace the commercial farming method which uses soil and mineral fertilizers. Not only does FWAD improve yield, it also increases chlorophyll content by enriching the soil's fine and dissolved organic matter, providing both quick and sustained release of nutrients. This evaluation of using FWAD generated from anaerobically digested food waste to cultivate tomato plant has yielded promising results and can be applied by urban farmers to reduce food waste and grow more food.

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References

Cheong, J.C. *et al.* (2020) 'Closing the food waste loop: Food waste anaerobic digestate as fertilizer for the cultivation of the leafy vegetable, xiao bai cai (*Brassica rapa*)', *Science of the Total Environment*, 715, p. 136789.

Möller, K. and Müller, T. (2012) 'Effects of anaerobic digestion on digestate nutrient availability and crop growth: A review', *Engineering in Life Sciences*, 12(3), pp. 242–257.

Somerville, P.D. *et al.* (2020) 'Biochar and compost equally improve urban soil physical and biological properties and tree growth, with no added benefit in combination', *Science of the Total Environment*, 706, pp. 1–12.

Song, S. *et al.* (2021) 'Food-waste anaerobic digestate as a fertilizer: The agronomic properties of untreated digestate and biochar-filtered digestate residue', *Waste Management*, 136(October), pp. 143–152.