

Sustainable agriculture for the future

March | Maart 2026

No 155

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Boosting Dry Anaerobic Digestion with Size-Reduced Biochar

Dr Ashira Roopnarain and Dr Haripriya Rama
ARC-Natural Resources and Engineering

Every year, millions of tons of agricultural and food waste are generated globally. Crop residues such as stalks and husks as well as food waste and other organic by-products are often burned, dumped in landfills, or just left to rot, releasing copious amounts of greenhouse gases into the atmosphere. However, these materials are rich in stored energy that can be converted into a valuable renewable energy source, biogas. Biogas is a green fuel with several applications including cooking, heating, and even electricity generation. Biogas is generated during the process of anaerobic digestion, where microorganisms break down organic waste such as food and agricultural waste in the absence of oxygen. A more water efficient version of conventional anaerobic digestion is dry anaerobic digestion (DAD), which relies on high-solid waste containing more than 20% total solids and limited water, making it ideal for water-scarce regions.

Problems associated with dry anaerobic digestion

While DAD is water-wise, it is more challenging than conventional anaerobic digestion. High-solid systems have the tendency to become chemically and biologically unstable. Limited water results in the slower breakdown of organic material. In addition, acids known as volatile fatty acids (VFAs) that are produced during the DAD process tend to build up. When these acids accumulate, they lower the

pH of the DAD system, creating conditions that are hostile to the methane-producing microbes. If these microbes are stressed or die off, methane production drops, and the digester can even fail altogether. This instability is one of the main reasons why DAD systems are not yet widely adopted, despite its multitude of advantages.

A small material with massive potential

To solve these problems and make DAD more feasible, scientists are turning to an unusual helper: biochar in the micro and nano size range. Biochar is a carbon-rich material that is

made by heating organic biomass in an oxygen free environment. When it is engineered to a much smaller size, it develops a highly porous structure with an enormous surface area.

This tiny material can serve as a microbial support system or microbial carrier. Its multitude of pores provide safe spaces where microbes can attach and grow, forming stable microbial

communities. This small biochar can also adsorb toxic compounds that are otherwise known inhibitors to microbial activity. In addition, it creates microenvironments that buffer sudden changes in acidity, helping to keep conditions stable inside the digester. Perhaps most importantly, small biochar may even help microbes interact with each other more efficiently thereby boosting methane production.



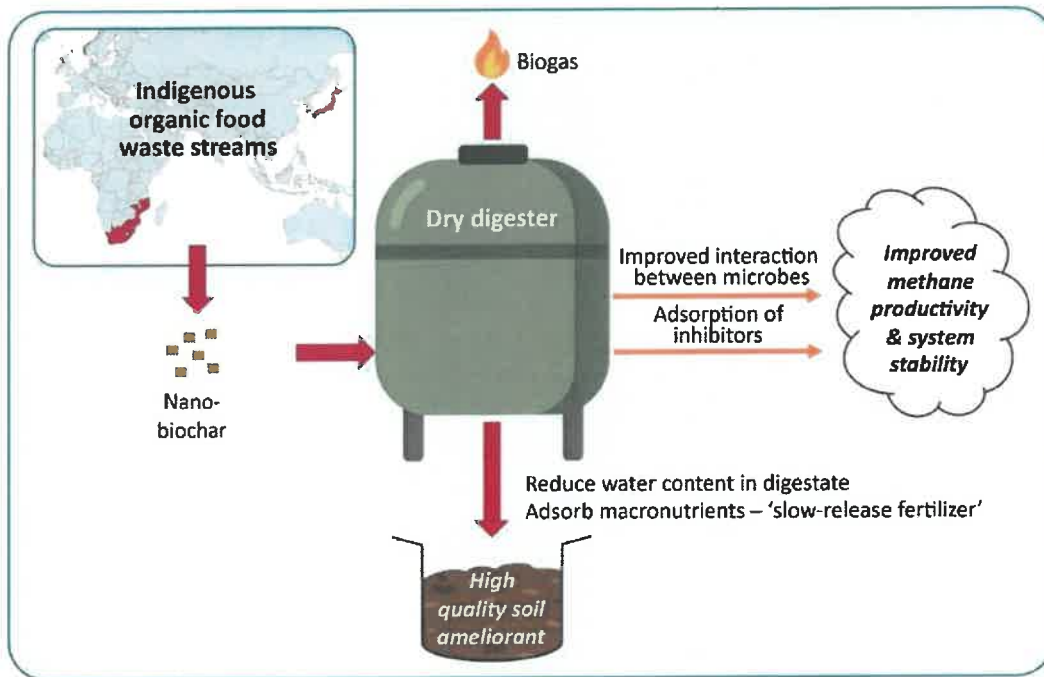


Figure 1: Overview of W3M-Dry AD project

The W3M-Dry AD project

The potential of small biochar on DAD is the basis of the initiation of the W3M-Dry AD project: "Water wise waste management: Two ends of the size scale, macro and nano augmentation for dry anaerobic digestion optimisation". One of the key focus areas of the project is to explore whether small biochar can act as a microbial modulator thereby shaping and stabilising the microbial community inside dry anaerobic digesters and improving the overall process and biogas yield.

The team hypothesises that adding small biochar will not only increase methane production but also make the system more resilient to stress and prevent process failure. To test this, we are running controlled laboratory experiments using high-solid agricultural residues as substrates for DAD in the presence and absence of different small biochar types. By measuring biogas production, acid levels, and pH, and by sequencing microbial DNA, the researchers will track how biochar influences system performance, microbiome dynamics and overall biogas productivity.

Why does this matter for the real world?

More stable and efficient DAD systems could be transformative, especially in regions experiencing water scarcity and limited energy access. Farmers and communities could turn

organic waste such as crop residues into fuel, reduce waste disposal costs, and lower greenhouse gas emissions, all at the same time.

Beyond energy, this research also supports the idea of a circular bioeconomy, where waste is no longer discarded but reused as a valuable resource. By understanding how biochar interacts with microbial communities, scientists can design smarter, more resilient technologies that work with nature rather than against it. By combining materials science, microbiology, and renewable energy research, this work shows that even the smallest materials can have a massive impact.

This research forms part of the W3M-Dry AD project, a collaboration between South Africa, Mozambique, and Japan. It reflects a growing international push toward sustainable, low-water, low-carbon technologies that can meet the needs of both people and the planet. The SA project team is funded by the National Research Foundation (NRF) with team members affiliated to the Agricultural Research Council (ARC), University of South Africa (UNISA) and University of Venda (UNIVEN).

For inquiries and comments:

Dr Ashira Roopnarain RoopnarainA@arc.agric.za
Dr HariPriya Rama RamaH@arc.agric.za