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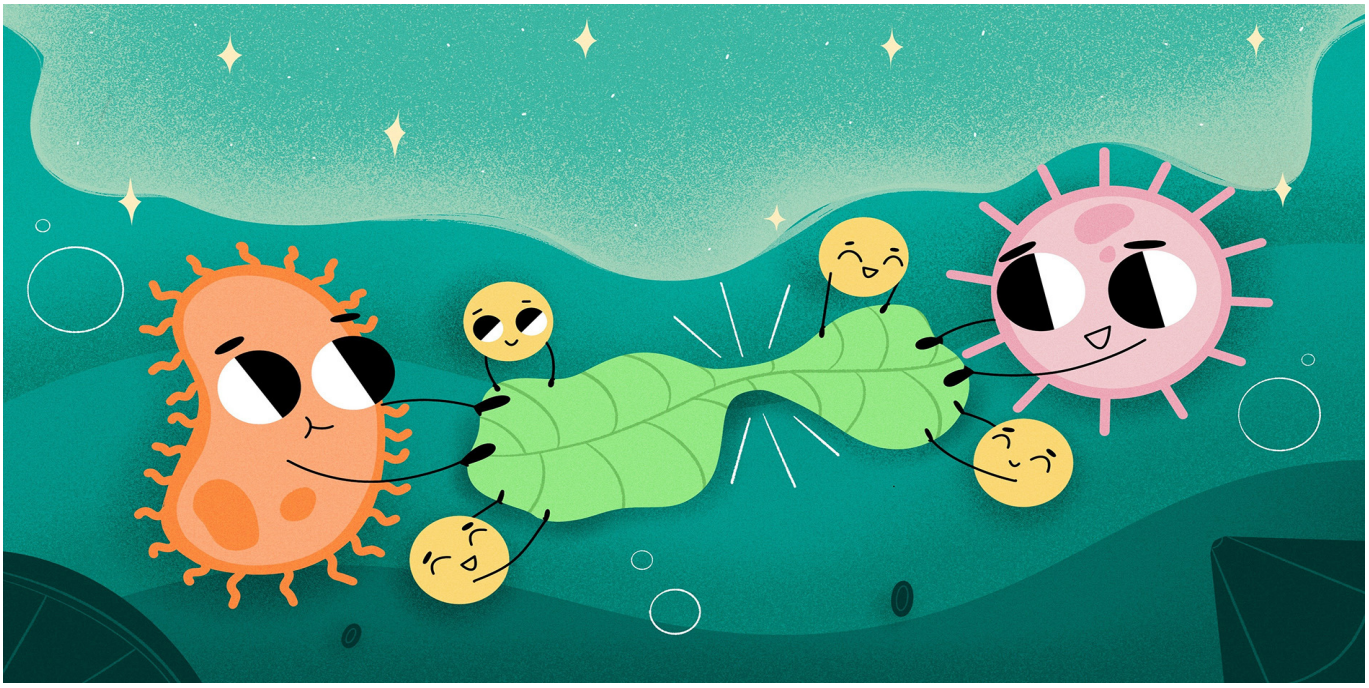

CAN NANOPARTICLES BE USED TO BOOST BIOGAS PRODUCTION?

Ashira Roopnarain [1,2*], ***Haripriya Rama*** [1,3] ***and Busiswa Ndaba*** [4]

[1] *Microbiology and Environmental Biotechnology Research Group, Agricultural Research Council-Natural Resources and Engineering, Pretoria, South Africa*

[2] *Department of Environmental Sciences, College of Agriculture and Environmental Sciences, University of South Africa – Florida Campus, Johannesburg, South Africa*

[3] *Department of Physics, School of Science, College of Science, Engineering and Technology, University of South Africa – Florida Campus, Johannesburg, South Africa*

[4] *Institute for Catalysis and Energy Solutions, College of Science, Engineering and Technology, University of South Africa – Florida Campus, Johannesburg, South Africa*

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KIANA
AGE: 9

OFUNWA
AGE: 9

Biogas is a type of gas that can be burnt to produce energy. It causes less harm to the environment than burning coal or oil, which is why it is called "green energy". Biogas is produced by breaking down a plant or animal resource such as cow dung (poop) in an oxygen-free environment. Biogas is produced by special microorganisms that can survive and multiply without oxygen. Recently, nanoparticles have been used to make more biogas. Nanoparticles have unique features such as their extremely small size and their ability to easily react with substances. During biogas production, microorganisms can get a lot of nutrients from nanoparticles, which helps them to produce more biogas. Nanoparticles may also improve the interactions between biogas-producing microbes, further boosting biogas production.

Although nanoparticles help to produce more biogas, the correct type of nanoparticles and the right amounts must be used to ensure that more biogas is produced.

BIOGAS: GREEN ENERGY GENERATION AND WASTE MANAGEMENT

Around the world, humans need energy to perform their daily activities. This energy is required to power our ovens, microwaves, and computer screens, just to name a few. As more children are born, increasing Earth's population, more and more people will need energy. To date, energy is mostly produced from resources that cannot be produced again, like coal and oil. These energy sources are sometimes called **non-renewable resources** because, as we use them, they are not being replaced. Burning non-renewable resources releases gases into the air, called greenhouse gases, which are harmful to the environment and can cause shifts in normal temperatures and weather patterns. This is called global warming.

Renewable energy resources, which are resources that are continuously created, are a great alternative because they provide "green energy" for human uses. Green energy includes energy from the sun, water, wind, and **biomass** [1]. Biomass energy created from waste material (like cow poop or crop waste) is particularly interesting. It results in green energy production and makes use of waste, which is a win-win situation. If waste is used to produce energy, this means less waste and more energy.

Organic wastes are waste products that can be broken down by microbes—microscopic organisms that cannot be seen by the naked eye, such as bacteria, viruses, and fungi. Organic wastes can be used as a starting material to produce a substance called **biogas**, which can be burned for energy.

So, what is biogas and why is it such a promising green energy source? Biogas is made when organic waste is broken down by special microbes in an oxygen-free (**anaerobic**) environment. The biogas is rich in a gas called methane, which can be burnt for cooking, heating, and lighting purposes. It may even be used to power gas generators for electricity production. In nature, biogas is produced in the stomachs of animals like cows, because their stomachs are oxygen-free. Their stomachs also contain the microbes that can break down the grass that they eat into biogas. Scientists have built **bioreactors**, called anaerobic digesters (Figure 1), that essentially act as cow stomachs. Bioreactors produce biogas from various types of organic waste. The resulting biogas is removed through a pipe. Another outlet releases the leftover broken-down organic waste from the system. The extra waste can be used by farmers as a nutrient-rich fertilizer. Many methods have

NON-RENEWABLE RESOURCES

A substance that is extracted from the Earth, like coal, that cannot be replaced after it is used up.

RENEWABLE ENERGY RESOURCES

A substance that is continuously created and can be replaced naturally over time, like trees.

BIOMASS

A renewable organic material that comes from plants and animals.

ORGANIC WASTES

Any material that can break down in nature and comes from either a plant or an animal.

BIOGAS

A gaseous fuel, primarily made of methane, produced by the breakdown of organic matter by microbes.

ANAEROBIC

An environment that has no oxygen.

BIOREACTOR

A container or vessel where raw materials (such as organic wastes) are converted into products (such as biogas) by microbes or enzymes.

been used to increase the amount of biogas produced in anaerobic digesters. One promising method is adding **nanoparticles** to the system [2].

NANOPARTICLES

Very small particles that range between 1–100 nanometers in size.

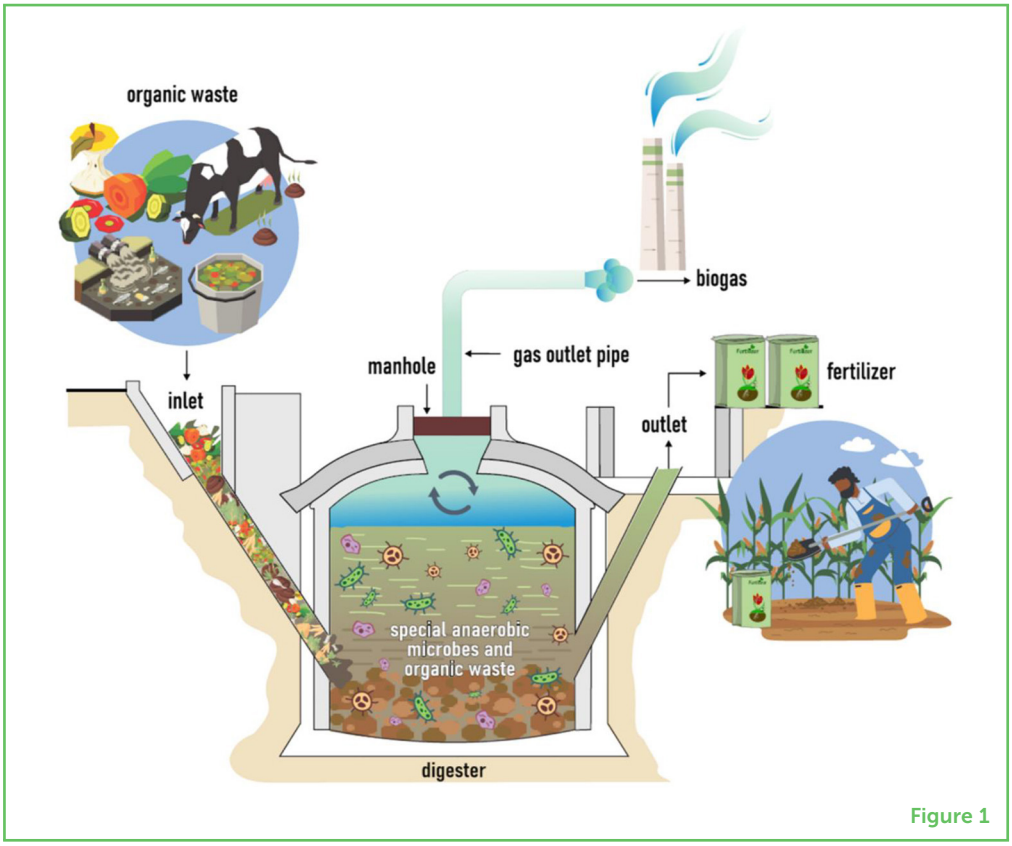

Figure 1

Biogas can be produced in a system called an anaerobic digester. Organic waste, such as cow poop and/or food waste, is added to the digester as a starting material. Microbes break down the organic waste inside the digester, in the absence of oxygen. Biogas is captured through a pipe, and the leftover digested organic waste leaves through an outlet and can then be used by farmers as fertilizer.

NANOPARTICLES CAN IMPROVE BIOGAS PRODUCTION

Nanoparticles are extremely small particles, <100 nanometers in size (Figure 2). Although nanoparticles are very small, they pack a lot of punch. Their small size gives them several special properties, such as high reactivity (ability of nanoparticles to interact with other substances) and high surface area-to-volume ratio (surface on the nanoparticle where reactions take place in relation to their size). These properties make nanoparticles promising candidates for improving biogas production [2].

Since biogas is produced by certain kinds of microbes, its production can be increased by helping these microbes to perform better. This is how some nanoparticles such as those made of iron, carbon, zinc, and nickel can improve biogas production [2]. They also improve microbial growth by acting as a nutrient source. Normally, a large group of microbes work together as a team to produce biogas. Anything that negatively affects any member of the team can slow down biogas production. Some nanoparticles help certain microbes in the group interact with others to speed up the breakdown of organic waste to biogas.

Figure 2

Nanoparticles come in various shapes and range between 1–100 nm in size.

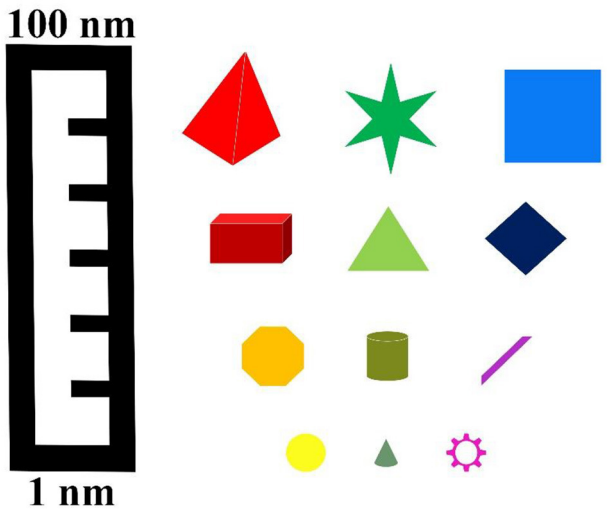

Figure 2

Many studies have shown that certain nanoparticles can improve biogas production. Others have shown negative effects of nanoparticles on biogas production and the microorganisms that drive the process [3]. It is important that studies be conducted to test the effects of different types of nanoparticles on biogas production, to see which ones speed it up and which ones slow it down. The correct number (amount) of nanoparticles to use during biogas production also needs to be studied. It is also important to test whether the selected nanoparticles improve biogas yield no matter what type of organic waste is being digested.

USING NANOPARTICLES IS CHALLENGING

There are some problems related to using nanoparticles for improving biogas yield. The biggest problem is the impact the nanoparticles have on the environment after their use in the digester. In general, the digested waste from the system can be used as a fertilizer. However, can this still happen if the waste contains large amounts of nanoparticles?

The digested waste may be good or bad to the environment, depending on the types and amounts of nanoparticles that are added to the digester. Certain nanoparticles may be useful to the soil and plant growth and may even help maintain the nutrient levels of the soil. But other nanoparticles, in large amounts, may pollute the environment and may even result in the pollution of underground water reserves. Moreover, nanoparticles may be costly to produce, and producing them may also be harmful to the environment [1]. Like with any new technology, it is important that several studies be conducted in a controlled environment such as a laboratory.

These studies can ensure the safety of the product and improve production processes.

TAKE HOME MESSAGE

Overall, the world needs renewable energy sources due to the negative impacts of burning non-renewable fuels like coal, oil, and gas. Biogas is a promising renewable energy source that has two benefits—energy generation and waste management. However, the biogas production process needs to be improved, and nanoparticles show great potential for boosting its generation. While several studies have shown that more biogas is produced when nanoparticles are added to the system, other studies have shown negative effects on the process. Such findings are expected because the microbes involved in biogas production behave differently in response to different types and quantities of nanoparticles. Using nanoparticles to improve biogas production is still new and more studies are required to determine the effects of different nanoparticles on the microbes and biogas production. These studies will identify the ideal nanoparticles and amounts that need to be used to improve the process. Studies are also required to make sure that the nanoparticles do not negatively impact the environment when the digested organic matter from the system is used as a fertilizer. Finally, an environmentally friendly, cost-effective method of making nanoparticles is also needed. All in all, the potential for nanoparticles to improve biogas production cannot be questioned; however, as with any new technology, working out the details is key.

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REFERENCES

1. Khan, S. Z., Zaidi, A. A., Naseer, M. N., and Al Mohamadi, H. 2022. Nanomaterials for biogas augmentation towards renewable and sustainable energy production: a critical review. *Front. Bioeng. Biotechnol.* 10:868454. doi: 10.3389/fbioe.2022.868454
2. Roopnarain, A., Rama, H., Ndaba, B., Bello-Akinosho, M., Bamuza-Pemu, E., and Adeleke, R. 2021. Unravelling the anaerobic digestion 'black box': biotechnological approaches for process optimization. *Renew. Sust. Energ. Rev.* 152:111717. doi: 10.1016/j.rser.2021.111717

3. Manikandan, S., Krishnan, R. Y., Vickram, S., Subbaiya, R., Kim, W., Govarthanan, M., et al. 2023. Emerging nanotechnology in renewable biogas production from biowastes: impact and optimization strategies–a review. *Renew. Sust. Energ. Rev.* 181:113345. doi: 10.1016/j.rser.2023.113345

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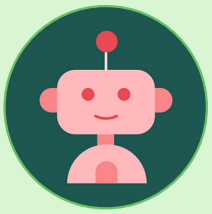

KIANA, AGE: 9
Kiana is 9 years old. Kiana likes to do ballet as well as netball and hockey. Her favorite subject is maths.

OFUNWA, AGE: 9
Ofunwa is a curious young mind, who loves to learn new things and know more about our solar systems, history, and technology. He is currently in Grade 4 and would like to either be a web designer or musician. He loves playing Roblox and Fortnite on the Xbox or watch YouTube educational/entertaining videos. He loves researching new places that he travels to with his family and adores his family of 4.

AUTHORS

ASHIRA ROOPNARAIN

Ashira Roopnarain is a microbiologist whose research focuses on renewable energy generation from organic wastes. She is particularly interested in how to improve biogas production in low-cost anaerobic digesters using cost-effective and environmentally friendly methods. Ashira is a senior researcher at the Agricultural Research Council of South Africa. Outside work, Ashira enjoys spending time with her family, reading, gardening, and traveling. *roopnaraina@arc.agric.za

HARIPRIYA RAMA

Haripriya Rama is a researcher at the Agricultural Research Council-Natural Resources and Engineering, South Africa. Her research focuses on the effect of two nanoparticles produced via green methods on biogas production and digester microbial communities. Her research interests are in developing sustainable solutions to clean the environment via anaerobic digestion, and exploring the potential capabilities of microorganisms. Haripriya enjoys reading, hiking, and spending time with family and friends.

BUSISWA NDABA

Busiswa Ndaba is a senior lecturer at the University of South Africa, College of Science, Engineering and Technology, South Africa. Her research focuses on producing nanoparticles in the laboratory for their use in the production of renewable energy (biogas, bioethanol, and biobutanol) as well as in agriculture as fertilizers. Her interests are on developing methods that are sustainable for the energy and agricultural sectors. Busiswa likes hiking, reading, watching movies, and having a good time with family.