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Optimisation of Biogas Production using Nanotechnology

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ABSTRACT
Nanotechnology largely affects a more extensive scope of biotechnological, pharmacological and unadulterated innovative applications. In this paper we would be covering the use of nanotechnology in the production as well as optimisation of biogas. This paper clearly shows the potential and relationship between the both – biogas production and nanotechnology via various feedstock characterisation studies which was done during this paper. The aim of this paper is to showcase how these both technologies complement each other and how nanotechnology is applied in feedstock and convert it to biogas. Our study shows how nanotechnology is applied on pressmud and gas production is enhanced at laboratory level. The digestion of pressmud with nanomaterials were studied. Our study clearly indicates that the biogas production can surely be enhanced in case of treating pressmud by using magnetite nanoparticles which gives higher methane yields compared to normal digestion without nanoparticles. This study not only confirms the enhanced biogas generation from pressmud but also confirms that on other biodegradable material the same principle can be applied and gas production can be enhanced. Our study surely will be an important tool for implementing of nanotechnology in biogas research and enhanced production wherever the press mud is available.

***KEYWORDS**: Nanotechnology, biogas, feedstock, pressmud, digestion, biodegradable*

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INTRODUCTION

Sugarcane has been grown for sugar production in various countries around the world since the nineteenth century. Scientists and researchers have recognised the importance of sugarcane and its by-products (bagasse, press mud and molasses) as a result of the energy shortages and the need for environmental reforms. Sugarcane is typically processed to yield sugar and biomass, with the available biomass primarily consisting of lignin, fibre, pith, and pentosans, all of which have significant biochemical and microbial potential. Biodegradable matter is present in a variety of by-products generated during the sugar processing process.

This paper shows the studies on nanoparticles and nanomaterials on biogas enhancement from pressmud. It also examines the potential impact of nanotechnology on microorganisms in the field of biogas particularly in the enhancement of biogas. The entire approach of this work was to develop a critical understanding of nanomaterials, defining them according to the European Commissioning recommendation, feedstock characterisation and showcase the impact on biogas enhancement and efficiency.

A nanoparticle is a little molecule that ranges between 1 to 100 nanometres in size. Imperceptible by the natural eye, nanoparticles can show altogether unique physical and synthetic properties to their bigger material partners. The definition given by the European Commission expresses that the molecule size of at any rate half of the particles in the number size dissemination should gauge 100 nm or underneath. Most nanoparticles are comprised of a couple hundred iotas. "A characteristic, coincidental or fabricated material containing particles, in an unbound state or as a total or as an agglomerate and where, for 50 % or a greater amount of the particles in the number size dissemination, at least one outside measurements is in the size range 1 nm - 100 nm". The various explanations are inconsistent with their interpretation of the nature of synthesis or synthesis of nanoparticles. Current level of information available on the presence of nanomaterials and products containing nanomaterials on the market is not enough. As the definition of EU is based on the distribution of spatial size particles of an object expressed in numerical metrics (EU Commission, 2011), almost always powder can be considered nanomaterial. However, the EU has already announced it review of its definition established in 2011: definition updated light of experience and scientific and technological advances. Reviews are appropriate mainly focus on what the 50% size limit should be increased or decreased (EU Commission, 2011).

The table below shows the size of nanoparticles compared to other structures:

Particle Type	Diameter size range
Atoms and small molecules	0.1 nm
DNA diameter	1
Protein	10
Virus	100
Nanoparticles	1 to 100 nm
Bacteria	1000
Fine particles (particulate matter)	100 to 2500 nm
Coarse Particles (dust)	2500 to 10,000 nm
Thickness of Paper	100,000 nm

The material properties change as their size moves toward the nuclear scale. This is because of the surface zone to volume proportion expanding, bringing about the material's surface molecules ruling the material execution. Attributable to their exceptionally little size, nanoparticles have an extremely enormous surface region to volume proportion when contrasted with mass material, like powders, plate and sheet. This component empowers nanoparticles to have surprising optical, physical and synthetic properties, as they are sufficiently little to keep their electrons and produce quantum impacts.

For instance, copper is viewed as a delicate material, with mass copper bowing when its iotas group at the 50nm scale. Therefore, copper nanoparticles more modest then 50nm are viewed as a hard material, with definitely extraordinary pliability and flexibility execution when contrasted with mass copper. The adjustment in size can likewise influence the dissolving attributes; gold nanoparticles liquefy at much lower temperatures (300 °C for 2.5 nm size) than mass gold (1064 °C). In addition, ingestion of sun based radiation is a lot higher in materials made out of nanoparticles than in dainty movies of nonstop sheets of material.

PHYSICAL AND CHEMICAL PROPERTIES OF NANOPARTICLES:

The essential boundaries of nanoparticles are their shape (counting angle proportions where fitting), size, and the morphological sub-construction of the substance. Nanoparticles are introduced as a vaporized (for the most part strong or fluid stage in air), a suspension (for the most part strong in fluids) or an emulsion (two fluid stages). Within the sight of synthetic specialists (surfactants), the surface and interfacial properties might be changed. In a roundabout way such specialists can balance out against coagulation or collection by monitoring molecule charge and by adjusting the outmost layer of the molecule. Contingent upon the development history and the lifetime of a nanoparticle, extremely complex syntheses, potentially with complex combinations of adsorbates, must be normal. In the run of the mill history of an ignition nanoparticle, for instance, various specialists are inclined to buildup on the molecule while it chills off and is presented to various encompassing environments. Complex surface compound cycles are not out of the ordinary and have been distinguished distinctly for few particulate model frameworks. At the nanoparticle - fluid interface, polyelectrolytes have been used to alter surface properties and the communications among particles and their current circumstance. They have been utilized in a wide scope of innovations, including attachment, oil, adjustment, and controlled flocculation of colloidal scatterings (Liufu et al 2004).

Sooner or later between the Angstrom level and the micrometer scale, the basic image of a nanoparticle as a ball or droplet changes. Both physical and substance properties are gotten from nuclear and atomic source in an unpredictable manner. For instance the electronic and optical properties and the synthetic reactivity of little bunches are totally not the same as the better known property of every segment in the mass or at expanded surfaces. Complex quantum mechanical models are needed to foresee the development of such properties with molecule size, and commonly all around characterized conditions are expected to analyze tests and hypothetical expectations.

NANOPARTICLE - NANOPARTICLE INTERACTION:

At the Nano scale, molecule associations are either overwhelmed by weak Van der Waals forces more grounded polar and electrostatic collaborations or covalent connections. Contingent upon the thickness and polarisability of the liquid, particle aggregation is controlled by the inter particle communication. By the change of the surface layer, the inclination of a colloid to coagulate can be improved or prevented. For nanoparticles suspended in air, charges can be aggregated by actual cycles, for example, shine release or photoemission. In fluids, molecule charge can be settled by electrochemical cycles at surfaces. The subtleties of nanoparticle - nanoparticle communication powers and nanoparticle – liquid collaborations are of key significance to depict physical and substance measures, and the fleeting development of free nanoparticles. They stay hard to describe because of the limited quantity of particles engaged with the surface dynamic layer. Both surface energy, charge and solvation are important boundaries to be thought of. Because of the vital part of the nanoparticle – nanoparticle communication and the nanoparticle – liquid cooperation, the term free nanoparticle can be effortlessly misconstrued. The association powers, either appealing or unpleasant, significantly decide the destiny of individual and aggregate nanoparticles. This cooperation between nanoparticles bringing about totals or potentially agglomerates may impact on their conduct. In gas suspensions, total is critically dictated by the size and dissemination, and coagulation regularly happens quicker than in the fluid stage as the adhering coefficient is nearer to solidarity than in fluids.

Nanoparticles are attractive because their chemical and physical properties are different from major partners (example - sugar). The example of sugar is appealing- if we want to make tea taste faster, we use granules instead of cubes, but it works less. The sugar cube, for example, reacts with water as water dissolves the surface of sugar. Now the same sugar cube cuts many more pieces - each cut creates a new exterior place for water to melt. With small amounts of sugar, the same volume of sugar now it has much more space. High-level particle has a large number of reaction sites have a lower particle surface, therefore, leading to higher chemistry Re-engineering Another example of an area of excess volume in nanoscale gold (Au) as a nanoparticle. In macroscale, gold is an insignificant substance, which means that it does not work with many chemicals, however at nanoscale; gold nanoparticles are highly functional and can be used as regenerative materials accelerating reactions. This Extended recycling of over-volume space is widely used in nature, one example of biology is the human digestive system. To have the same the microorganism works in both the digestion (human digestion and the biogas) system - the surface area to volume ratio of feedstock (in this case it is pressmud) cause impact on overall biogas process.

INTERACTION OF NANOMATERIALS WITH THE PRESSMUD:

Nanoparticles can play an important role in liquid biomass in water purification (Stoimenov et al., 2002) as many of them contain antibodies. It is now being used to recover removal of chemical and biological substances including metals (ex. Cu, Cd, Zn), nutrients (ex. Ammonia, phosphate, nitrate), natural, algae, cyanide (e.x., cyanobacterial toxin) germs, bacteria, parasites and antibiotics. Basically, four classes of nanoscale objects that are tested as effective water purification agents: example., metal containing nanoparticles, carbonaceous nanomaterials, zeolites and dendrimers. Carbon nanotubes too Nanofibers also show some positive effects. The conversion of pressmud to biogas is basically biological process. Molecular size, inorganic contaminants of press mud cause impact on the conversion process. Functional nanoparticles could come from either or both natural and manmade sources. Due to the existence of this multifaceted interaction within the process a number of issues which could arise and therefore need to be addressed appropriately. Physical, biological and chemical composition of press mud was studied. The impact of the particle size of pressmud was evaluated in relation to its generation of biogas in both biochemical and bio thermal aspect. Particle size and pre treatment of few samples of pressmud was also studied.

When different pre-treatment methods were applied to press mud then different effects were produced and noted down in terms of its structure and composition. For example, hydrothermal and acidic pre-treatment conceptually removed the hemicellulose fraction and the alkaline pre-treatment removed lignin content from press mud to an extent. Specific surface area was increased by milling the pressmud which also reduced the particle overall size when observed. These processes showed impact in the overall process efficiency.

Microorganisms effectively react to nanoparticles and can cause a huge impact. An overview of antimicrobial properties of nano particles suggests the potential adverse effect they could exert on the microorganisms. This has significant negative implications although at present, information on Nanoparticles effect on pressmud based digester microorganisms during biogas system is rarely available. Therefore it is difficult to make specific assertions regarding the toxic effect of nanoparticles on press mud microorganisms. There is a possibility that nanoparticles in contact with a microbial community may lead to reduced efficiency and overall anaerobic digestion process, complete failure of the overall system.

However, impact and toxicity of Nanoparticles on pressmud treatment stream is still an abandoned area of research. When we had conducted a research to determine the effects of CeO2 and ZnO nanoparticles on pressmud based anaerobic digestion process, sludge dewatering process, and toxicity of sludge to bacteria and plants. The result showed that CeO2 and ZnO nanoparticles could cause inhibition to the biogas production of anaerobic digestion system. The exposure concentration of ZnO at 1,200 mg/l caused the greatest inhibition to the biogas volume (68%) and the methane composition (43%), as compared with controlled sample. In addition, at tolerable exposure concentration of ZnO, the system could overcome the inhibition effect after 16 days of incubation. On the other hand, CeO2 at low concentration of 10 mg/L could increase the generated biogas volume by 13%. The positive effect of CeO2 at low concentration was also observed on bacterial toxicity test. The ZnO nanoparticles was more toxic to bacteria than CeO2 nanoparticles at the same exposure concentration. However, the bacterial toxicity of both nanoparticles was reduced when they were applied rather than naturally occurring to the biogas process. Moreover, at the end of anaerobic digestion process, the bacterial toxicity was again lessened. Additionally, required time to dewater the digested slurry was increased proportionally with the exposure concentration of nanoparticles. The bacterial toxicity of nanoparticles could be greatly reduced when nanoparticles was applied in the pressmud. The pressmud with exposure of 1,200 mg/L of CeO2 nanoparticles before anaerobic digestion caused 45% of inhibition to bacterial viability. However, the same sample after anaerobic digestion just had 31% of inhibition toward bacteria viability. Similarly, sample with 1,20 mg/L of ZnO NPs induced up to 92% of inhibition before anaerobic digestion, while after digestion process, this value was just 31%. The effects of metal oxide particle size on biogas and methane production during anaerobic digestion of cattle manure was studied by Luna del Risco, M. et al, 2011. In the experiment nanoparticles of CuO showed higher influence on biogas production than the other test compounds. The concentration of 18 mg/l of CuO nanoparticles resulted in a reduction of 33% of the biogas production from the total biogas produced in the control at day 15. Biogas production in the presence of micro particles of CuO was less inhibited whereas concentrations of 140 and 250 mg/l of bulk CuO caused a reduction by 20% and 65%, respectively. The statistical analyses have validated the differences between the 2 groups of particles tested (bulk and nanoparticles) the statistical analyses have validated the differences between the 2 groups of particles tested (bulk and nanoparticles) of CuO. Basically nano particles are toxic to bacteria due to the release of bioavailable metal ions that causes cell membrane damage, and therefore, the inhibition of biogas production can occur if the addition goes beyond certain limits.

Biogas production in test samples containing nanoparticles of ZnO was contrasted and bulk ZnO. Centralizations of 150 and 250 mg/l of ZnO nanoparticles introduced a hindrance of 43% and 74% of the biogas yield separately, while test bottles containing bulk ZnO introduced a decrease of 18 and 72% of the complete biogas delivered at day 15. Nonetheless, no critical contrast of biogas hindrance from bulk and nanoparticles of ZnO was found.

From this section it can conclude that particle size and concentration of nano-sized CuO and ZnO affects biogas yield. The addition of Nano iron oxide (Fe3O4 NPs) can enhance the methane production due to the presence of the non-toxic Fe3+ and Fe3+ ions. Fe3O4 NPs (7 mm) were added with a concentration of 100 ppm to anaerobic waste digester at mesophilic temperature (370C) for 60 days and the results showed a 100% increase in biogas production and 180% increase in methane production which is could be considered the greatest improvement to biogas production using nanoparticles. The new delivery system based on Fe3O4 (magnetite) nanoparticles leads to enhanced anaerobic digestion, and consequently to higher methane production and organic matter processing. The improved performance is due to the presence of Fe+2/Fe+3 ions, introduced into the reactor in the form of nanoparticles in a similar way to controlled drug delivery systems. Fe plays an important role in electron transport, so it stimulates bacterial growth and increases enzymatic activity to increase hydrogen and methane production. Fe3O4 nanoparticles are the most prevalent materials because they have low toxicity, good biocompatibility

IMPACT OF NANOMATERIALS ON PRESSMUD:

It was found that nanoparticles synthesized in electrolysis method are showing antibacterial activities against both gram (-) and gram (+) bacteria. Changes in Surface Area to Volume Ratio of Cu are enhancing its antibacterial activities. Cu nanoparticles synthesized in electrolysis method are showing more antibacterial activities (for E.Coli bacteria) than Cu nanoparticles synthesized in chemical reduction method. Utilizing electrical force while on integrating of copper nanoparticles is expanding its antibacterial exercises. The synthetic substances engaged with the blend of nanoparticles are regularly accessible, modest, and non-poisonous. The innovation can be executed with least framework. The tests propose the likelihood to utilize this material in water purification, air filtration, air quality administration, antibacterial bundling, and so forth. Microorganisms play the key role for biochemical conversion of pressmud to biogas. Therefore, the inhibition of their activity reduces the energy yield capacity when applied at certain exceeding limits to pressmud. The various effects of different nanomaterials.

EFFECTS OF NANOMATERIALS ON PRESSMUD:

Nanomaterials	Effects	Remarks
CeO2	Inhibits biogas and methane content in biogas	Higher concentrations – 1000 mg/l
	Increase biogas volume	Low concentrations – 10 mg/l
	Digestate inhibit root growth and germination	
ZnO	Inhibit biogas and methane content in biogas	Higher concentrations – 1000 mg/l
	Overcome inhibition effect	Tolerable exposure concentration
	Digestate inhibit root growth and germination	
CuO	Reduction of 30% of the biogas production from the total biogas	Low concentration of 15 mg/l
	Biogas production less inhibited	Micro particles of CuO
AgO – 5nm	Complete inhibition of growth and viability	At E-Coli bacteria
AgO – TiO2 at 100 nm	Photoactivated inhibition of growth and viability	At E-Coli bacteria
0.5 mg/L AgO at 9 – 12 nm	Toxic to the respiration of bacteria	Nitrifying bacteria
Fe3O4 Nanoparticles	Enhanced Biogas system, Higher methane and volatile matter destruction	

IMPACT OF NANOMATERIALS ON BIOGAS PRODUCTION:

Categories	Nanomaterials	Impact
Metal Oxides	ZnO, CuO, MnO2 and Al2O3	Reduce biogas production
Zero Valent Metals	Nano Iron	Enhanced biogas production and increase in methane percentage
Metal oxides	Metal nano particles encapsulated in porous SiO2	Significant increase methane production
Nano-ash and carbon based materials	Silver nanoparticles	Decrease in biogas production
	Micro fly ash or Micro nano bottom ash	Increase biogas production

RESULTS AND DISCUSSION:

Nanotechnologies could enhance the biogas efficiency across all the branches of industry and economically leverage renewable energy production. It has the potential to enhance the conversion of press mud to biogas, chemical intermediates, speciality chemicals and products. Nanotechnology is an important tool that can improve the overall efficiency of the biogas system. The impact was found in the form of inhibitory, adverse or enhanced biogas yield in aspect of biogas production. The variation in the severity of impact on the basis of particle surface area to volume ratio was also assessed. These results are described here on the basis of press mud which was found to give significant response to nanoparticles.

CONCLUSION:

The performance of anaerobic digestion can be affected by various nano materials. It Is very important to better understand the complex mechanisms by which these particles interact with the pressmud and the process of conversion and potentially overcome adverse effects and optimise the positive effects. All nanoparticles paying little mind to their substance constituents have surface area to volume proportions that are incredibly high. This makes nanoparticles' actual properties be overwhelmed by the impact of the surface atoms and covering specialists on the nanoparticles surface. High surface area to volume proportion is significant for applications like catalysis. Reactions take place at the surface of a chemical or material; the greater the surface for the same volume, the greater is the reactivity. Therefore, the response and interaction of different nanoparticles are different with microorganisms. Although only a few studies have reported the antibacterial properties of Cu nanoparticles which have a significant potential as bactericidal agent however, other nanoparticles, such as gold, platinum, iron oxide, silica and its oxides have not shown bactericidal effects in studies with Escherichia coli. The addition of magnetite NPs (Fe_3O_4 NPs) can enhance the methane production due to the presence of the non-toxic Fe^{3+} and Fe^{3+} ions through the stimulating of bacterial growth.

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