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The Possibility of Biogas production in Nigeria from Organic Waste Material: A Review

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Abstract
Biogas waste initiative is one big solution to Nigeria's growing solid waste problem. This study explores the potential biogas processing of organic waste materials and their benefits to the areas where the excess of such organic waste is located. Based on this review, researchers were noted to be proposing lots of distinctive ways to contain generating solid waste and discoveries have been highlighted to show the importance of converting these organic wastes to biogas. Processing is a well-established technology mainly for sustainable energy use generation in addition to the valorization of organic residues. Through this analysis, these wastes were described as enormous sources of biogas that can assist to solve some of the electricity problems in the country.

Keywords: Biogas, Organic Waste, Waste, Waste to Biogas, Renewable Energy

1. Introduction

Energy consumption has risen exponentially across the globe, and fossil fuels currently meet around 88% of this demand. Recent studies show that energy demand will rise to 50% by 2050. Meanwhile, the number of ambient greenhouse gases (GHG) emissions is also rapidly growing, with the biggest contributor being carbon dioxide (CO_2) [1]. Besides, the safety of supply energy is a major challenge in the world due to the reason that most natural resources are located in politically volatile zones [2]. The annual GHG emissions from combustion of fossil fuel are approximately 33×10^5 tonnes [3]. Climate emergency and the associated dangers to the environment are one of the major issues posed by substantial emissions of GHG today [4]. In reaction to the challenges mentioned, an attempt has been made to expand the use of alternative energy sources or sustainable energy carrier, such as biofuels [5-6]. Biomass is a plant or animal material that are used for energy production, and which could be converted into different types of sustainable energy such as biodiesel, biogas and so on. It utilizes a broad scope of physicochemical, thermochemical and biochemical technologies [5,7-8]. Biogas, which are developed from organic waste in anaerobic digestion (AD) units, among the different types of biofuels, is an encouraging energy source to address a part of global challenges to energy and the environment [9-10].

Biogas technology offers environmental advantages that are frequently seen as a viable and strong option for hydrocarbon deposits [11]. Along with the depletion of greenhouse gas (GHG) emissions, biogas will improve energy protection, especially, due to its impressive high energy potential [12–14]. Biogas is a viable source of renewable energy, it enables the extraction of agricultural by-products and industrial waste with a depleting energy potential [15–17]. Biogas is a non-toxic, colourless combustible gas that is created by the decomposition of organic matter;

and this decomposition occurs in the absence of air. It is made up of a mixture of different gases, mainly methane (CH_4), carbon dioxide (CO_2), 1–5% other gases, including hydrogen (H_2). The biogas is extracted from biogenic materials and it is formed from materials such as human waste, biomass, cow dung, green waste and agricultural residue such as cassava, sugar cane etc [18]. Waste is unwanted or unusable material, that is no longer useful for its purposes of manufacturing, processing or consumption [19]. When extracting or processing raw materials into midway and final effect, or when consuming end-products, or through other human activities, waste can be generated [20]. Modern waste management systems classify many categories of waste including residential waste, industrial waste, clinical waste, agricultural waste and toxic waste [21]. According to [21], the type, origin, scale, the physical and chemical composition of waste differ. They are thus classed as liquid, solid, and gaseous. This study explores the potential biogas processing of organic waste materials and their benefits to the areas where the excess of such organic waste is located.

2.1. Waste Produced In Nigeria

The past and present government in Nigeria has put in a good number of attempts in waste management but it is still a serious problem. In almost every industrial, residential and market place in the country, it is normal to encounter stacks of waste dumps. It is a common occurrence for residential homes, markets, lakes, roads and undeveloped lands to be converted into a dumpsite. Not surprisingly, people say waste is growing exponentially in Nigeria, and assembling and discarding are progressing arithmetically. Oghenefejiri et al. [22] in his study stated that approximately 32 million tons of solid waste are produced annually in Nigeria with a population that exceeds 160 million people, but only 20%-70% of that volume is properly collected. Upon consideration of the availability of economic resources, technical resource and the extent of mechanization implemented in process company, the study in [23] listed Nigeria as a developing country. Their classification basis was that the rate at which an area or nation produces waste is a function of the economic activities happening in it.

2.2. Class of Waste Used in Biogas Production

The physical properties of solid industrial waste are dependent on residue density, physical composition, moisture content, chemical composition, and size distribution. The residue characterization is based on the organic composition, flammability and microbiological population [24]. Waste characterization begins from most literature examined by gathering waste from its origin and sorting it directly into categories of materials. Source weighing and sorting of household waste at source facilitate, just as waste identification eliminates, any uncertainty about its source [25]. In studies carried out in Nigeria [22-27], various classifications of waste in the country have been identified and some these are presented in Table 1.

Table 1: Classification of Waste

Waste	Classification	Degradation Period
Food	Organic waste	Hours
Glass	Solid Waste	1 x 10^6 years
Metal	Solid Waste	Subjective
Paper	Organic Waste	2 – 6 weeks
Plastic	Solid Waste	Subjective
Textile	Organic or Solid Waste	20 – 200 years

Table 2 shows the amount of useful organic useful waste materials generated in some cities in Nigeria. Some of the useful waste material could result in producing biogas.

Tatarniuk [28] studied the viability of converting waste into energy, and that study shows that organic biodegradable substances generate energy so that they can be used effectively under the right conditions. Also, solid waste parts have intrinsic or potential energy to the extent that can be utilized by various technical processes, as an alternative source of energy. The solid waste energy value is the combustion heat that is free during a waste burn. A reduced calorific value generally shuts out heat gotten from water evaporation, as opposed to the higher temperature of combustion. The waste stream is made up of essential necessary quality to assess the option of a technologically and economically viable waste management method for this waste stream.

Table 2: Amount of Useful Organic Materials in Waste

Name of Materials	Location	Amount in Percent	Reference
PUT, PAP, PLA	Lagos	69%	[22]
BIO, PUT, PLA	Uyo	65%	[26]
PAP, TEX, PLA	Abuja	45%	[29]
FAB, F, G	Abuja	52%	[27]
PLA, G, MRT, ORG	Port Harcourt	64%	[30]

Key: Putrescible (PUT), Paper (PAP), Plastic (PLA), Biodegradable (BIO), Textile (TEX), Fabrics (FAB), Food (F), Glass (G), Metal (MET) and Organics (ORG)

2.3. Extraction of Biogas from Waste

An increase in environmental awareness around the world has made the prospect of energy generation from biomass attractive. Unlike fossil fuel, biomass can be generated from waste materials include waste from plants and from animals [31]. Momoh & Nwaogazie (2010) studied the effect that paper will have on animal and plant waste, which they undertook by using the first-order kinetic model method. Their research shows that the waste paper optimized biogas formation, compared to not having waste paper [32]. In addition, Deressa et al. discovered that the atmosphere and digester temperature would have a positive impact on the yield of biogas produced from plant and animal waste material [18]. Based on these considerations, the combination of waste materials that are used for biogas production, their methods of extraction and the results from the extracted materials are presented in Table 3.

Table 3: Materials and methods used for biogas production

Biomass	Method of extraction	Results	Reference
Waste Paper and Animal waste	Anaerobic Digestion	• Anaerobic digestion of organic waste at room temperature is possible. • Waste paper improved the amount of Biogas produced from animal manure.	[31]

Biomass	Method of extraction	Results	Reference
Animal waste, Food waste and Plant waste	Anaerobic Digestion and Water Displacement	• The total amount of Biogas produced from food waste combined with animal waste has a greater yield compared to the plant waste + animal waste combination. • Evolved Biogas also has promise in fertilizer application.	[18]
Agricultural Waste	Anaerobic Digestion	• Mahogany + Iroko accelerate biogas production compared to Araba + Obeche. • Mahogany has the highest potential to generate biogas compared to the Iroko, Araba and Obeche wood samples.	[33]
Animal waste and Liquid waste	Anaerobic Digestion	• The addition of rumen product into animal manure has the potential of improving biogas production.	[34]
Animal Waste	Anaerobic Digestion	• Paddy field soil has the highest potential to produce biogas because of the presence of organic matter.	[35]

2.4. Socio-Economic Value of Exploring Biogas Production in Nigeria

Given the many technological advantages and the population of Nigeria, biogas technology is expected to spread widely in the region. Nevertheless, developments in biogas technology are hindered by lack of policy commitments, lack of sufficient processing expertise, insufficient waste management, inadequate technology awareness and related benefits [36]. Barriers were found, and attempts to resolve them had to be stepped up. Biogas technology has excellent potential in Nigeria. It is estimated that Nigeria generates about 542.5 million tons annually, and these are majorly comprises of organic waste. It had been estimated that Nigeria will generate 169,541.66 MW of energy or 25.53 billion m^3 of biogas if the organic waste materials generated in the country are channelled into anaerobic digestion. This will address some of the immediate energy issues of the country [36]. Part of the renewable resource advantage that can be accrued from exploring biogas production via waste products also includes the fact the by-product from such activities can be used for producing bio-fertilizers. This, if explored, can lead to an estimate of 88.19 million tons potential production of bio-fertilizer annually [36]. This will make exploring biogas production in Nigeria to have a positive environmental and economic impact for the country, in the long run [36].

Many studies emphasised on the significant factor of plants in producing biogas, and these studies also noted that the treatment of animal waste by anaerobic digestion or biogas technology may potentially lead to the creation of a large number of renewable sources of energy [37],[38],[39]. Biogas has a great opportunity to replace fossil fuel. Several scientists have suggested the use of high-tech waste management technologies. These, according to the study in [41], addressed the form of new technologies used in China to improve biogas production from waste. These new methods and cheap biowaste sources are found in many places in Nigeria, which shows that biogas potential as a solution to basic challenges of waste management and energy is very possible in the country. According to the study in [42], when the digester size is increasing, the initial cost of production for biogas plants will decrease and the number of biodigesters required for a specific area will reduce. Economic analyses reveal the components of these digesters will be suitable with a positive net present value (NPV) at an ostensible pace of 18% to 37%. The payback period changes somewhere in the range of 1.3 to 3 years, contingent upon the sum invested [42]. Research also reports on the profitable feasibility of this method [42], for this method could become an authentic source of energy and a renewable energy substitute that also provides agricultural bio-fertilizer.

3. Conclusion

As the Nigerian population increases there would be a parallel increase in waste production from home and industries in Nigeria. Biogas provides an alternative solution in recycling organic waste into a form of renewable energy. In this study, we discovered that the current system of waste collection in Nigeria needs to be revisited. That an estimate of 20-70% of generated waste is being collected in parts of the country indicates that the waste collection method most probably differs from one location to another. In addition, it is discovered that the percentage of organic matter present in a waste material determines how much biogas can be produced, and this is such that agro waste material has the highest biogas potential. By these considerations, findings from reviewed literature showed that materials such as waste paper and food waste when combined with animal waste produced higher yield of biogas compared to those produced with plant waste. These techniques and technologies can, therefore, be annexed for initiating an enhanced approach of biogas production in Nigeria for addressing issues of waste management and energy production for the socio-economic benefit of the nation and its environ.

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