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Assessment of biofertilizer quality and health implications of anaerobic digestion effluent of cow dung and chicken droppings

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ABSTRACT

Anaerobic digestate have been identified as a rich source of essential plant nutrients. Nevertheless, its safety measured by the concentration of pathogen present is of great concern to end users. This research explored the efficiency of the mesophilic biodigestion process in the stabilization and sanitization of cow dung and chicken droppings. Six (6) kg each of cow dung and chicken droppings were collected fresh and free from impurities, pre-fermented, mixed with water in the ratio 1:1 w/v to form slurry, fed into the respective reactors and digested for 30 days at an average ambient temperature of 30 ± 2 °C. The pH of the medium fluctuated between 6.5 and 8.0. The analysis of the feedstock and effluent of the digesters showed that a total solids reduction of 75.3% and 60.1% were recorded for cow dung and chicken droppings while the reduction in total coliforms was 95% and 70% respectively for the dung and droppings. Microbial analysis of the biofertilizer produced reveals both aerobic and anaerobic organisms which include species of *Pseudomonas*, *Klebsiella*, *Clostridium*, *Bacillus*, *Bacteroides*, *Salmonella*, *Penicillum* and *Aspergillus. Escherichia coli* and *Shigella* spp. were removed while species of *Salmonella* and *Klebsiella* were still present in the digestate. Notwithstanding these results, the digestate still requires further treatment for it to be suitable for application on unrestricted crops either as fertilizer; otherwise a health problem would be created as attempt is made to improve soil fertility.

1. Introduction

Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and in the presence of anaerobic microorganisms [1]. The process generates a product called “biogas” that is primarily composed of methane, carbon dioxide, and compost products suitable as soil conditioners on farmlands [2]. Anaerobic digestion can be seen as a method to treat the organic wastes [3].

The need for adequate sanitation and energy especially in Sub-Saharan Africa where only 36% of the population is served with improved sanitation facilities, and only 58% are served with a safe and clean water supply [4] has made biogas technology a welcomed development. The development of biogas technology will facilitate the achievement of the Millennium Development Goals (MDGs) of the United Nations. The first goal of the MDGs is to eradicate extreme poverty and hunger. Thus, by utilizing the slurry (the digested waste) that is produced from the biogas systems, a community can fertilize its crops and also improve the composition of its soil [5]. There exist abundant evidence that climate change is a severe threat to socio-economic development and can substantially affect a nation’s GDP, as it affects water, forest, sanitation, food security, industrial development, housing, energy, health and the very air we breathe [6]. Thus, development of biogas technology is a suitable alternative energy source that would be affordable and environmentally friendly that would help preserve the green forest thus achieving the 7th mandate of the Millennium Development Goal on environmental sustainability.

Biofertilizers are preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants’ uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil [7]. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants and also mobilizing nutritive elements from non- usable form to usable form through biological processes [8]. Anaerobic digestion draws up carbon, hydrogen and oxygen from the feedstock. Meanwhile, essential plant nutrients (nitrogen (N), phosphorus (P) and potassium (K))

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remain largely in the digestate [9]. The availability of nutrients is higher in digestate than in untreated organic waste. For instance, digestate has 25% more accessible NH_4–N (inorganic nitrogen) and a higher pH value than untreated liquid manure [3].

The quality and composition of the dewatered digestate solid depend on the feedstock and the digestion process [10]. More so, the dewatering separates the digestate into two fractions: the fibre and the liquid effluent. The fibre is bulky and contains a low level of plant nutrients thus can be used as a soil conditioner and as low grade fertilizer although further processing of the fibre such as through composting can produce good quality compost. Whereas, the liquid effluent on the other hand contains a large proportion of nutrients and can be used as a fertilizer. The high water content of the liquor facilitates its application through conventional irrigation methods. Thus, the use of fibre and liquor from anaerobic digestion has led to improved fertilizer utilization and therefore less chemical consumption in cropping systems [3].

Notwithstanding this huge benefit of the anaerobic digestate in the improvement of soil fertility and consequently crop production, the safety of the digestate, measured by the concentration of pathogens present, is of great concern to end users [10]. Pathogens like *Salmonella* spp., *Escherichia coli*, *Shigella spp*., *Klebsiella spp*., etc may contaminate the biogas slurry. Among them, some of the bacteria are hardy and do not get destroyed during the digestion period. Some pathogens survive better in the wet condition and these organisms may still be present in slurry even after digestion [11]. The availability of liquid biofertilizer in the market is on the increase as one of the alternatives to chemical fertilizer and pesticides, one of its benefits is in the population of microorganisms present [12]. Poor farm management techniques and improper use of agrochemicals has resulted in both soil quality and environmental degradation [13]. Therefore, the common objectives of biofertilizer is to provide socioeconomic and ecological benefits among which is soil quality improvement that contributes immensely to food quality and safety, human and animal health as well as environmental quality [14]. Most animal husbandry in Nigeria revolves predominantly around cattle and poultry among others. Thus these materials are more available in most commercial farms and would be more readily available used than other animal substrates for Biogas generation in Nigeria.

The objective of this study therefore is to assess the efficiency of the anaerobic digestion at mesophilic temperature range in the treatment of cow dung and chicken droppings in order to establish if the pathogen removal is sufficient to use the effluent as fertilizer.

2. Materials and method

2.1. Materials

Two 25 L-biogas digester tanks each of height 0.5 m and diameter 0.25 m were fabricated from Galvanized steel which is strong enough to withstand the weight and pressures of the contained slurry. The cylindrical shape was adopted to enhance better mixing. The tank is air tight and is clearly placed above the ground level and outside the shed where it is exposed to the sunlight for partial heating. pH meter model pHS-2S, (SHANGHAI JINYKE REX, CHINA) was used for measuring the pH of slurry every week day throughout the retention period, Gallenhamph Weight balance, Mettler P160N was used for measuring the weight of evaporating dish and sample for Total Solid analysis, UNISCOPE SM9053 oven was used to evaporate the sample for total solid analysis to dryness and UNISCOPE 2/1 °C thermometers was used to obtain daily temperature of the digester as well as the ambient temperatures of the environment.

2.2. Method of fabrication of digesters, biomass collection, slurry preparation and digester loading

The design volume of the two identical anaerobic digesters was sized according to the amount of volatile solids that must be treated daily and the period of time the material will remain in each of the digesters (Retention time). The design of the digesters was based on Ajoy Karki's Biogas model [15] incorporating the separate floating gas holder system for ease of measurement of gas volume. The cylindrical shape was adopted to enhance better mixing. The digester is a separate component, with the gas holder in a separate water jacket.

The theory behind the design is simply "downward delivery and upward displacement". The slurry on fermenting in the digester produces gas. This gas is delivered to the bottom of the water jacket via a pipe; the pipe extends above the surface of the water level (water seal) in the water jacket. The gas displaces the gas holder (upward) and gets trapped between the gas holder and the water seal. The displacement of the gas holder is dependent on the pressure and volume of the gas produced. The setup is as shown in Fig. 1.

Cow dung was collected fresh and free from impurities from the Zango abattoir in Zaria, Kaduna state, Nigeria while the chicken droppings were collected fresh and also free from impurities (such as wood shavings and iron filings) from the poultry department of the National Animal Production Research Institute (NAPRI), Shika, Zaria, Kaduna State, Nigeria. They were stuffed into sterile bags and transported to the research laboratory of the Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria where they were subjected to further pre-treatment. The digestion was a batch process. Six (6) kg each of cow dung and chicken droppings were respectively mixed with water in the ratio 1:1 w/v to form slurry and treated in the two purpose-built 25-L anaerobic digesters. Each digester system comprised a pre-fermentation tank, a digester, a gas collection system and a digestate collection tank. The pre-fermented feedstock waste was added to the feed tank together with recycled digestate taken from the collection tank. The slurry was allowed to occupy three quarter of

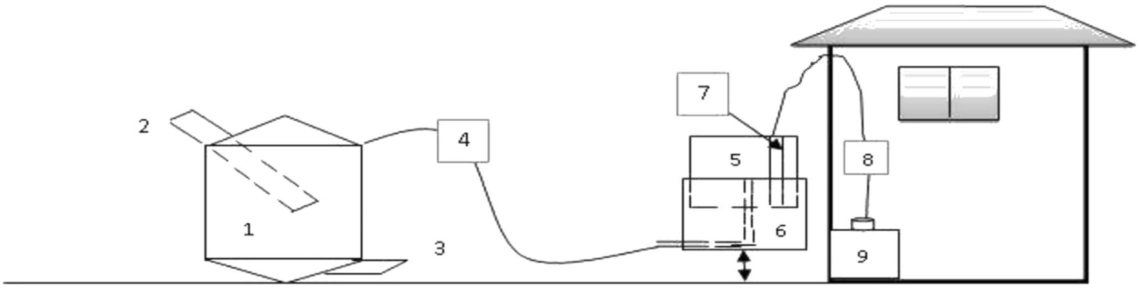

Fig. 1. Schematic view of the plant setup. Key: 1. Digester body, 2. Feedstock inlet pipe, 3. Effluent outlet pipe, 4. Hose from digester to gas holder, 5. Gas holder, 6. Water jacket, 7. Rule, 8. Hose to cooking stove, 9. Cooking stove in the kitchen.