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Bioenergy generation from co-digestion of food waste and rumen fluid: impact of varying quantities of rumen fluid on biogas yields

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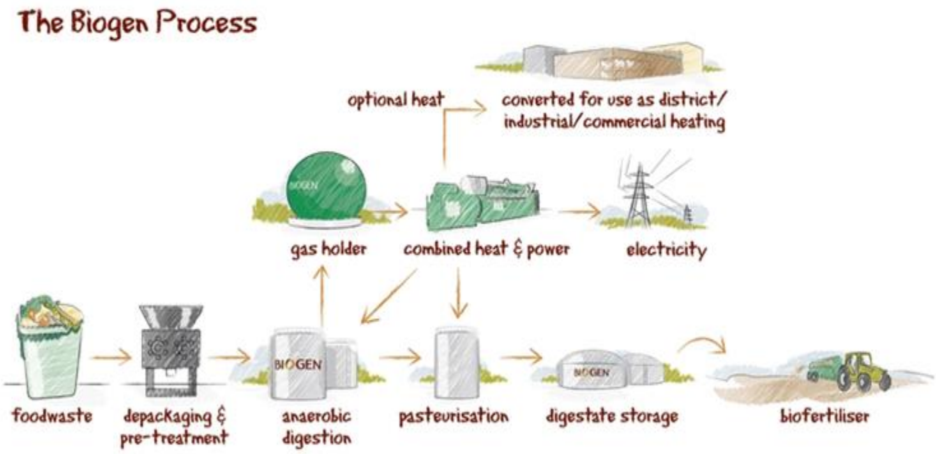
Abstract

This paper examines the effect of mixing varying quantities of rumen fluid with food waste (FW) to generate biogas energy at ambient temperature (37^{o}C) in a batch anaerobic digestion process. The researchers adopted an anaerobic digestion process for the study. Food waste was obtained from selected fast food establishments at Auchi, Edo State, South-South, Nigeria. The rumen fluid was obtained from an abattoir located at Auchi, Nigeria. Anaerobic digestion of food waste without rumen fluid served as control experiment while 4 other digesters contained 20, 40, 60 and 80ml of rumen fluid for co-digestion experiment. The digesters were labelled FW1-FW5 based on their compositions. The laboratory experiment lasted for a retention time of 17 days without pH control and mixing. Cumulative biogas yield was measured daily by water displacement technique. The values were 2220, 2280, 1860, 1600 and 1420ml respectively.

The results obtained showed that addition of rumen fluid did not have any positive impact on biogas yields in digesters FW3-FW5 when compared with the control. Digester FW2 was only 2.70% higher than FW1 which was not a significant increase. Generally, there were antagonistic effects in the co-digestion of food waste with rumen fluid as the quantity added increased. This implied that mono-digestion of food waste could produce significant quantity of biogas with impressive production rate. Co-digestion should be carried out at a lower quantity of rumen fluid to improve biogas yield and the performance of the process. This article contributed to the body of knowledge by bridging the gap of limited literature in the domain of food waste management techniques in Auchi and Nigeria in general.

Keywords: Bioenergy, co-digestion, food waste, rumen fluid, biogas.



Source: http://www.biogen.co.uk/upload/managerImage/Food%20waste/BIOGEN-PROCESSv3.jpg

Introduction

Fast food business is currently enjoying a geometric growth in Nigeria (Esohe, 2012). The reasons for this trend are not far-fetched, hence, include rapid urbanization, and change in lifestyle and dietary pattern of the populace (Nworuh et al., 2011). It has been predicted that fast food phenomenon would be part of Nigerians in the future judging by the frenzies that go with it (Esohe, 2012). In the light of the aforementioned, it is certain that fast food wastes generated in urban areas in Nigeria will continue to increase. The problem essentially is that many fast-food restaurants in Nigeria do not have adequate and effective waste management facilities for their food wastes (Nworuh et al., 2011). This same phenomenon is commonplace in fast food restaurants in Auchi. They often resort to unwholesome practices of waste disposal which include open burning and dumping which are detrimental to the environment, humans and are largely unsustainable (Nworuh et al., 2011). Coker et al., (2008) suggested the use of anaerobic digestion technique for management of food wastes.

Various studies have been conducted and reported on the use of anaerobic digestion for food waste management in different parts of the world (Malakahmad et al., 2004; Tembhurkar and Mhaisalkar, 2007; Marin et al., 2010; Bernstad, and Jansen la Cour, 2011).These studies reported different biogas yields due to variation in dietary patterns of regions, thus, the reason food wastes from different localities should be treated on its own merit to determine its biogas (methane) potentials (Chen et al., 2010).

However, limited study had been reported in Auchi, Nigeria on co-digesting of food waste to generate biogas under mesophilic condition. Therefore, the focus of this article is to examine the impact of co-digesting food waste generated in fast food establishment in Auchi, Nigeria with rumen fluid of varying quantities to generate biogas under mesophilic conditions.

Literature Review

Countries such as Spain and Canada have integrated food wastes management programmes using anaerobic digestion technology to handle wastes generated from food industry (Arsova, 2010). Bio-degradable components of FW are generally high in moisture content making them suitable feedstock for anaerobic digestion process (Zhang et al., 2007). Anaerobic digestion (AD) is a multistage process in which microorganisms convert organic matter into methane and carbon dioxide in an oxygen-free environment (Li et al., 2013).This technology has a dual advantage; that is, waste disposal management and generation of useful energy (Kovacs et al., 2013), biogas.

Anaerobic digestion is more efficient and beneficial than composting, incineration or combination of digestion and composting put together, because of the energy generation that accompanies the process (Liabres and Mata-Alvarez, 2000). Besides these, anaerobic treatment of wastes indirectly reduces methane emission from landfills into the atmosphere and thus, mitigating the release of greenhouse gases (Arthurson, 2009). It must be clearly stated that anaerobic treatment can only process bio-degradable components of food industry. For example, bones, polyethylene bottles will not be converted to biogas because of their recalcitrant nature.

Materials and Methods

Food waste used in this study was collected from the selected fast food restaurants at Auchi, Edo State, South-South, Nigeria. The food waste contained mainly, cooked rice, chicken meat, onions, meat pie and salts. A mechanical blender was used to homogenize the food waste and used immediately to prevent decomposition prior anaerobic digestion. The rumen fluid was collected from an abattoir at Auchi, Nigeria. A fixed quantity of the homogenize food waste (200g) was charged into the digesters, and varying quantities of rumen fluid were added to evaluate their effect on biogas yield. Five laboratory digesters labelled FW1-FW5 were used. Digester FW1 served as control without rumen fluid added. About 20ml, 40ml, 60ml and 80ml of rumen fluid was added to the component in digester FW2-FW5 respectively. Each of the 5 digester contained 500ml of water. The digesters were tightly closed with butyl rubber bungs to create anaerobic conditions. The digesters were connected to inverted plastic graduated gas jars filled with salt solution. The biogas was collected by water displacement method. All the digesters were fermented for a retention time of 17 days without agitation or mixing. The pH values of each digester were determined with the aid of a digital pH metre (HANNA Instruments, Italy).

Result and Discussion

The initial and final pH values of the 5 digesters ranged from 1.6 - 4.5 as shown in Figure 1.

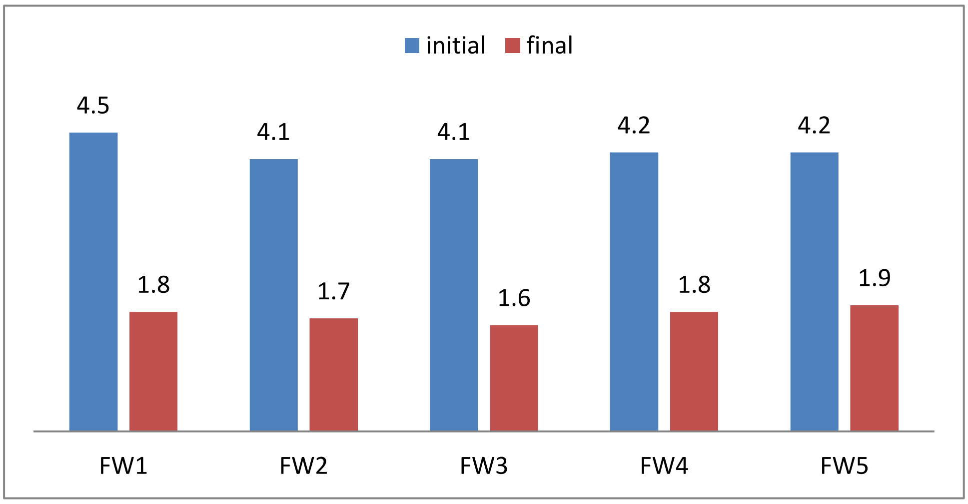


Figure 1: Initial and Final pH Values of Anaerobic Digesters of Food Waste with and Without Rumen Fluid

This implies that the slurries in the digesters became more acidic as the anaerobic process progressed. This could be the reason for the decline and in other cases no production at all toward the end of the experiment. Also, the growth rates of methanogen could have been impaired at this suboptimal pH range. The optimal recommended pH for anaerobic digestion is between 6.8-7.2 (Mosey and Fernandes, 1989).

In addition, the biogas production rates of the 5 digesters as presented in Figure 2 suggested that there was no lag phase in all the digesters as production began on day one. This indicated that there was no inhibition of microbial activity at the start of the anaerobic digestion in all the digesters. The biogas production rate peak value of 1300ml/d was obtained in FW1while FW2, FW3, FW4 and FW5 recorded 970, 780, 620 and 560ml/d respectively. Interestingly, all the digesters had their peak values of daily biogas production rates on day one.

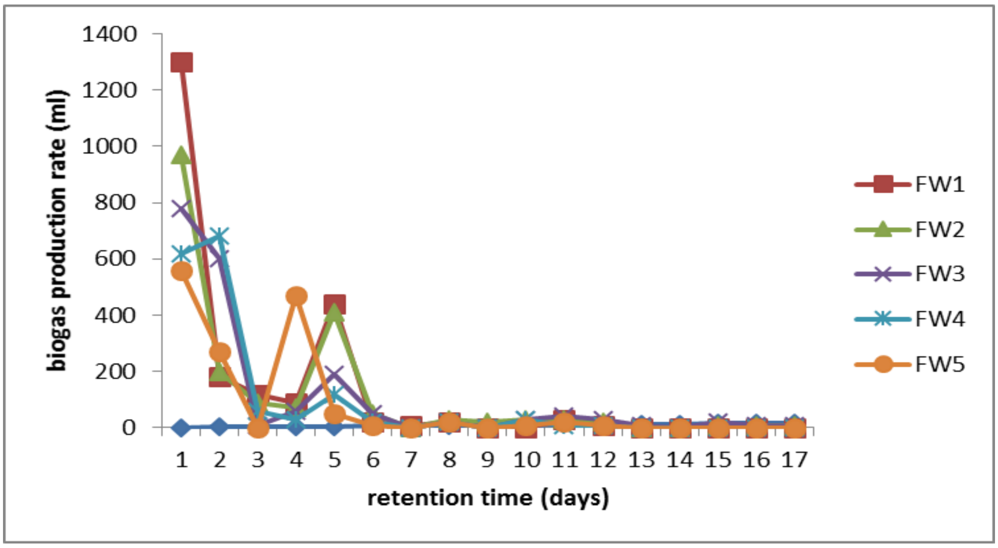


Figure 2: Biogas Production Rates of Co-digestion of Food Waste with Rumen Fluid

Furthermore, the result as shown in Figure 3 indicated that the cumulative biogas yields of the digesters ranged between 1420-2280ml. The highest yield of 2280 was recorded in FW2 followed by FW1.

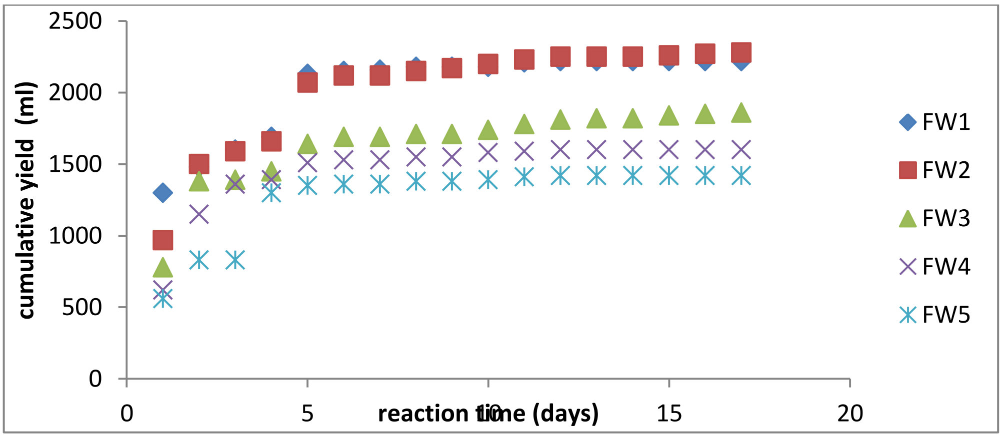


Figure 3: Cumulative Biogas Yields from Digesters FW1-FW5

The study shows further that as the quantity of rumen fluid increased, cumulative biogas yield decreased and in all cases lower than the control. The percentage reduction in biogas yields with respect to the control for FW3-FW5 is shown in Figure 4.

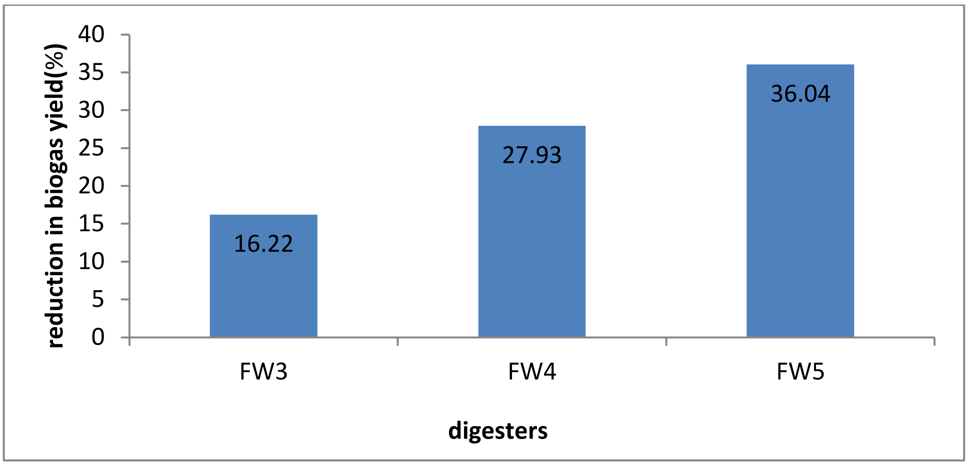


Figure 4: Percentage Biogas Reduction in Digesters FW3-FW5 in Comparison to FW1

This significant reduction in biogas yield further attested to the fact that generally there was no synergistic effect in co-digesting food waste with rumen fluid. This trend was contrary to the results obtained in Budiyono et al., (2009) in which there was increase in biogas production after adding rumen fluid. This could be as a result of formation of inhibitors such as volatile fatty acids, hydrogen sulphide and ammonia which are toxic to methanogens that is responsible for biogas production (Lay et al., 1997). These results implied that addition of rumen fluid did not improve biogas production rate though, it improved biogas yield marginally in FW2 when compared to FW1.

However, it was observed at the expiration of the experiment that there was reduction in odour compared to the offensive smell of the substrate before the commencement of anaerobic digestion; hence, the odour was tolerable. This is in agreement with the work in Wilkie (2000) which reported that anaerobic digestion, besides producing usable energy can help in odour control. Furthermore, the spent slurry produced could be used as organic fertilizer for growing crops, thereby reducing the need for inorganic fertilizers that are quite expensive to produce (Arthurson, 2009).

Conclusion and Recommendations

The socio-economic benefits derived from fast-food business may cloud our sense of judgment to the imminent dangers inherent in improper handling of food wastes generated in various restaurants in South-South, Nigeria, especially, the organic components. An unhealthy environment is a breeding ground for diseases and will not encourage healthy living, hence, could lead to waste of valuable economic resources. Fortunately, application of anaerobic digestion process can convert food wastes into renewable energy, thus, providing both economic and sustainable solutions to the problem. The results obtained in this article showed that food waste was a suitable substrate for biogas generation with or without addition of rumen fluid. Generally, the performances of the digesters were impressive going by the fact that the AD process was done at suboptimal conditions such as no mixing and pH adjustment. Further research is needs to be done to ascertain the effects of mixing and pH adjustment on biogas yields in the co-digestion of FW and RF. It is therefore suggested that waste segregation should be encouraged in fast-food restaurants in order to separate recalcitrant components from the organic ones; thereby making readily available feedstock for anaerobic digestion from the waste streams.

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