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Anaerobic bioconversion of food waste into energy: Case study of the food waste from Akouedo landfill, Côte d'Ivoire

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Abstract

Food waste collected in the Akouedo landfill, Côte d'Ivoire, is characterized for its potential for use as a feedstock for anaerobic digestion processes. The biogas yield of the food waste is evaluated using batch anaerobic digestion tests performed at 37°C. It is determined to be 2259 mL (282 mL/g VS) after 45 days of digestion. The results of this study indicate that the food waste from Akouedo landfill is a highly desirable substrate for anaerobic digesters with regards to its high biodegradability and biogas yield.

Key words : Anaerobic digestion, Biogas;Food waste, Akouedo landfill.

1. Introduction

Food waste (FW) is the one of the main types of municipal solid waste (MSW), which is the material resulting from the processing, storage, preparation, cooking, and handling of food and uneaten loss[1]. In the world, every year, between 1.3 and 1.6 billion tons of food, such as fresh vegetables, fruit, and meat, bakery and dairy products, are lost along the food supply chain, and this accounts for one third of the food produced globally for human consumption, affecting several natural resources[2].

In Côte d'Ivoire, the amount of food waste generated was estimated to be 1.624 million tons per year[3]. The food waste is, for the most part, disposed in Akouedo landfill. This landfill is the unique landfill in Abidjan, the economic capital of Côte d'Ivoire. Currently, Côte d'Ivoire experiences energy problem due to dependency on the fossil fuel energy sources. Switching to rely on renewable energy sources will definitely solve the problem in the sustainable way. Food waste is potentially converted to biogas through the fermentation process. Biogas produced from the

anaerobic digestion of food waste can also be used to generate energy[4].The objective of this study is to characterize the food waste collected from Akouedo landfill in Abidjan for assessing their potential as a feedstock for an anaerobic digester. This study is a preliminary approach of anaerobic digestion of food waste collected in the Akouedo landfill.

2. Materials and Methods

2.1. Food waste and inoculum :

Food waste obtained from Akouedo landfill was composed of vegetables, fruits and waste of fish tuna. The cow dung used as inoculum was collected from a livestock farm located in Abidjan. The substrates and inoculum were individually homogenized and subsequently stored at -4°C for further use.

2.2. Analytical techniques :

pH, TS (total solid) and VS(volatile solid) analysis were determined in accordance with American Public Health Association (APHA) standard methods[5]. Total Kjeldahl nitrogen (TKN) was analyzed using a Kjeldahl apparatus (Kjeltec 2100, Foss, Sweden**).** Total organic carbon was determined by following the Walkey-Black method[5], involving oxidation with 1 N potassium dichromate ($K_2Cr_2O_7$) and 96% sulphuric acid (H_2SO_4) solutions for 30 min. The organic carbon content was calculated by back-titration with a solution of 0.5 N $Fe(NH_4\text{-}SO_4)_2{\cdot}6H_2O$ and organic carbon was determined on the basis of an organic matter content to organic carbon ratio of 1.7241[6]. The organic carbon was subsequently divided by the total nitrogen to obtain the C/N ratio. Samples for metals analysis were prepared by acid digestion as described[5]. Nitric acid was used for the digestion. After digestion, the samples were filtered using 0.22 µm filter paper and analyzed for metals using an air-acetylene flame atomic adsorption spectrometer (Varian SpectrAA 20).

2.3 Anaerobic digestion tests :

Anaerobic batch digestion tests were carried out in triplicate at (37±1°C) for 45 days. The composite samples were digested in three 1200 mL batch digesters. The effective volume of digesters was 1000 mL. The initial volatile solid (VS) ratio of substrate to inoculum was kept at 1:1 (8gVS/8gVS) for all the experimental setups. After the inoculum and food waste were added, digester was filled up to 1000 mL with tap water. The digesters were tightly closed with a rubber septa and a screw cap. Two blank digesters that contained inoculum only were also incubated at the same temperature to correct for the biogas produced from the inoculum. The digester was tightly closed with a rubber septa and a screw cap. Each blank digester contained the same amount of inoculum and was filled up to 1000mL with tap water. Each digester was manually mixed for two minutes twice a day. Total biogas volume was measured by water displacement method.

3.Results and Discussion

3.1. Characteristics of food waste :

The results of characterization of food waste from Akouedo landfill are shown in Table 1. The C/N ratio is an important parameter to take into account when investigating different substrates and substrate mixtures for anaerobic digestion. The C/N ratio of substrate in range of 20–30 is considered optimum for anaerobic digestion[7]. In this study, C/N ratio of Food waste was determined below 20. High C/N ratio of inoculum was used to adjust the C/N ratio of food waste. The TS content of food waste influences anaerobic digestion performance, especially biogas production efficiency[8]. The TS content of food wastewas19.86%. This percentage of TS is conventional for anaerobic digestion[8].Biogas yield is affected by VS content[9]. The VS content of food waste was 93.72. In fact, Biogas yield increases with increasing content of VS[9]. The pH is another important parameter that must be monitored in an anaerobic digestion process[10]. The pH of food waste was 6.25. The desirable pH range for an anaerobic digestion process is 6.5–8.0[11]. The initial pH of food waste was lower than the optimum pH required for anaerobic digestion, while the pH of inoculum used for experiment was comparatively high. When inoculum was mixed with food waste mixtures, pH of the inoculated mixtures increased. The pH of digestion mixtures after mixing with inoculum was 6.63.The heavy

Table 1. Characteristics of food waste and inoculum

	C/N	TS(%)	VS (%)	pH	Fe (mg/L)	Ni (mg/L)	Zn (mg/L)
Food waste	8	19.86	93.72	6.25	0.94	1.16	0.24
Inoculum	21.33	20.69	80.91	7.29	1.82	2.36	<LD

LD: Limit of Detection

metals like iron, nickel and zinc, are also essential for the anaerobic process microorganisms[12]. The iron concentration in the food waste was 0.94 mg/L. According to *Takashima et al.*[13], the toxic threshold of iron concentration is 10 mg/L. The nickel concentration in the food waste was 1.16 mg/L. It improves biogas yield and maintains process stability. The toxic threshold of nickel is reported to be 10 mg/L[14]. Nickel was below the threshold to stimulate biogas production. The zinc concentration the food waste was 0.24 mg/L. It was below the toxic threshold of 1 mg/L. Above threshold, zinc inhibits biogas production and enhance biogas production below threshold[14].

3.2. Biogas yield :

The biogas yield (mL/day) during the digestion of food waste is shown in Figure 1. The biogas yield remained almost constant at a low level until day15 and then increased until day 42. The average biogas production from the digesters after 45 days of digestion was approximately 2259 mL corresponding at 282 mL/g VS. More than 50% of the biogas yield (1370 mL) was obtained after the first 28 days of digestion. The biogas yield obtained in this study was higher than the values reported by *Zou etal.*[15], who obtained 141.65 and 240.32 mL/g VS at 37 °C and 42 days. The biogas yield was lowest until day 15 because the particle disintegration and hydrolysis steps that are rate determining in the anaerobic digestion process were highly affected by microbial growth retardation[16]. After day 15, the rapid increase in biogas yield, which reached a peak in day 42is due to the nutrient contents of food waste indicating that food waste contained the required nutrients for anaerobic microorganisms[17]. In fact, the food waste characteristics from the Akouedo landfill and inoculum (C/N) indicate that they contained the necessary nutrients for the anaerobic microorganisms. This may suggest that the cow dung used as inoculum in the experiments had high methanogenic activity[18].

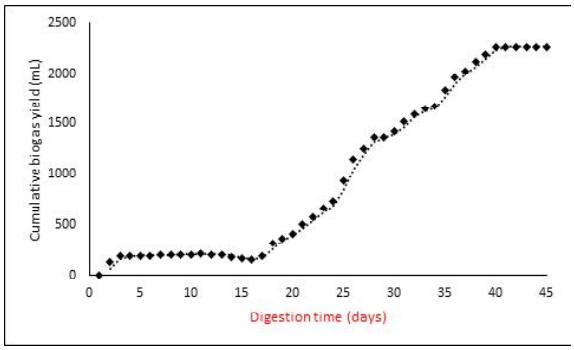

Figure 1: Biogas yield of food waste from Akouedo landfill.

4. Conclusions

The results of the anaerobic digestion tests showed that food waste had average methane yields of 2259 mL (282 mL/g VS) after 45 days of digestion at 37 °C. The nutrient contents of food waste indicate that food waste contained the required nutrients for anaerobic microorganisms. The concentrations of trace elements investigated were within permissible limits suitable for biogas production. Finally, the food waste from Akouedo landfill was a highly desirable feedstock for anaerobic digestion. Thus, the food waste from Akouedo landfill in biogas production can offer an alternative source of energy generation.

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