Biochemical Methane Potential of Food Wastes from Akouedo Landfill, Côte d'Ivoire

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Abstract

The determination of biochemical methane potential (BMP) is very important for the valorization of food wastes. This study is focused on the evaluation of the theoretical methane production from chemical oxygen demand (COD) of some food wastes, coming out Akouedo landfill. Almost all of the considered samples exhibited methane theoretical yields equal to about 402.5 - 507.8 mLCH$_4$/gVS. These results indicate the suitability of all the studied food wastes from Akouedo landfill to be converted into energy.

Keywords

1. Introduction

The food wastes include uneaten food and food preparation leftovers from residences, commercial establishments such as restaurants, institutional sources like school cafeterias, and industrial sources like factory lunchrooms [1]. The food waste is, for the most part, disposed of in landfill [2]. In light of rapidly rising costs associated with energy supply and waste disposal and increasing public concerns with environmental quality degradation, conversion of food wastes to energy is becoming a more economically viable practice [3].

Methane potential also called biochemical methane potential (BMP) is a parameter used in evaluating biogas and methane potential of organic materials [4]. The BMP is often defined as the maximum volume of CH$_4$ produced per g of VS substrate [4]. Several theoretical approaches are available to estimate BMP.

Food waste has often of a complex composition, which is difficult to describe in detail [5].The most common parameters used to describe the concentration of food waste are the chemical oxygen demand (COD) and the volatile solids content (VS) [6]. Theoretical BMP can be estimated from chemical oxygen demand (COD) of a given biomass [7].

In Côte d'Ivoire, the amount of food waste generated was estimated to be 1.624 million tons per year [8]. 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 [9]. The objective of this study is to evaluate the biochemical methane potential (BMP) of food waste collected from Akouedo landfill in Abidjan by a theoretical approach using chemical oxygen demand (COD). This work represents the first determination of biochemical methane potential of food waste from Akouedo landfill in Côte d'Ivoire.

2. Materials and Methods

2.1. Food Wastes

Food waste obtained from Akouedo landfill was composed of vegetables and fruits as well as leftover cooked food, which makes most of the organic fraction of municipal solid waste. The wastes of fish tuna and *kplala* (*Corchorus olitorius L*) used in this study were also collected from Akouedo landfill in Abidjan. Fifteen samples for each group were collected between December 2017 and February 2018. The substrates were individually homogenized and subsequently stored at −4˚C for further use.

2.2. Analytical Methods

Total solid (TS), volatile solids content (VS), pH, Total Kjeldahl nitrogen (TKN), Total organic carbon (TOC) and chemical oxygen demand (COD) analysis were determined in accordance with American Public Health Association (APHA) standard methods [10]. Samples for metals analysis were prepared by acid digestion and analyzed for metals using an air-acetylene flame atomic adsorption spectrometer (Varian SpectrAA 20).

The maximum methane potential was calculated from the COD concentration using Equation (1), assuming that this equation is valid for any substance or product [7]. This equation gives the theoretical value of methane at laboratory conditions:

$$BMP = \frac{n_{CH_4}RT}{pVS_{added}} \tag{1}$$

where BMP is the theoretical production at laboratory conditions, R is the gas

constant (R = 0.082 atm L/mol K). T is the temperature of the glass bottle (310 K), p is the atmospheric pressure (1 atm), VS_{added} (g) are the volatile solids of the substrate and n_{CH_4} is the amount of molecular methane (mol) determined from Equation (2) [7].

$$n_{CH_4} = \frac{COD}{64\,(g/mol)} \qquad (2)$$

3. Results and Discussion

The initial characteristics of food wastes strongly affect the methane yield [11]. Food wastes used in this study were individually analyzed for their initial physicochemical characteristics and the results are presented in **Table 1**. The initial pH of food waste and *kplala* was lower than the optimum pH required for the methane yield. The pH of the food waste has a significant effect on biogas production, because it affects the activity of bacteria to destroy organic matter into methane [12]. A low pH inhibits the activity of microorganisms involved in the digestion process particularly methanogenic bacteria [12]. C/N ratios of individual wastes used in this study were either greater or lesser than that of reported optimum range of C/N ratio for the methane yield. C/N ratio of tuna waste was relatively lower as compared to food waste, which is due to high nitrogen content of tuna waste mainly in organic form like protein [13]. The C/N ratio of substrate in range of 20 - 30 is considered optimum for the methane yield [14].

The heavy metals like iron, nickel and zinc, are also essential for the methanogenic bacteria [15]. The Ni, Zn, and Fe values (mg/L) detected in substrates were in the range of 1.16 - 1.94, 0.01 - 0.54, and 0.94 - 1.15, respectively (**Table 2**). The toxic threshold concentrations of Ni, Zn, and Fe were 10 mg/L, 1 mg/L and 10 mg/L respectively [16]. These concentrations were below the threshold concentrations for each metal. Above threshold, the metal concentration inhibits biogas production and enhances biogas production below threshold [16].

The calculated methane potential values from the COD of substrates are

Table 1. Food wastes characteristics.

	TS (%)	VS (%)	pH	TOC (%)	TKN	C/N
Food waste	24.82 ± 0.03	96.83 ± 0.09	3.94 ± 0.13	55.63 ± 0.01	1.51 ± 0.04	36.76
Kplala	4.44 ± 0.06	86.67 ± 0.03	4.61 ± 0.03	49.81 ± 0.02	2.80 ± 0.04	17.79
Waste of tuna	16.62 ± 0.09	90.72 ± 0.07	7.31 ± 0.09	52.13 ± 0.01	11.83 ± 0.30	4.41

Table 2. Heavy metal content of food wastes.

	Fe (mg/L)	Ni (mg/L)	Zn (mg/L)
Food waste	0.93 ± 0.02	1.17 ± 0.04	0.24 ± 0.02
Kplala	1.16 ± 0.02	1.94 ± 0.03	0.54 ± 0.03
Waste of tuna	1.12 ± 0.03	1.57 ± 0.07	0.01 ± 0.01

Table 3. COD and BMP of food wastes.

	COD g/kg	BMP mLCH$_4$/gVS
Food waste	302.7 ± 0.02	507.8
Kplala	40.63 ± 0.03	402.5
Waste of tuna	175.47 ± 0.04	445.70

summarized in Table 3. The BMP was ranged from 402.5 to 507.8 mLCH$_4$/gVS. Similar results of methane potential have been determined in other studies for organic wastes (400 - 510 mLCH$_4$/gVS) [17] [18]. These values indicated that these wastes have a good energetic capacity. It is also observed that the theoretical productivity of methane increases with the rise of the COD. The calculated methane potential from COD is a useful tool for determining the best substrate. It is a methodology destined to save costs and time by using the theoretical final methane potential of a substrate from it COD concentration [4]. The BMP for all substrates were the descending order food waste > waste of tuna > kplala. In fact, COD is used to quantify the amount of organic matter in feedstocks and predicts the potential for biogas production. Biogas production in relation to COD is about 0.5 L g^{-1} COD removed, corresponding to a methane production of approximately 0.35 L CH$_4$ per g of COD removed [4].

4. Conclusion

In this study, different food wastes from Akouedo landfill were characterized and their theoretical methane yields were calculated from the chemical oxygen demand (COD). The results indicated that food waste was identified as the best substrates among the ones considered, with a methane potential of 507.8 mLCH$_4$/gVS. However, for the others wastes, initial characteristics and BMP show that they constitute also a good substrate for the methanogenic activity of bacteria. Finally, these results indicate the suitability of all the studied food wastes from Akouedo landfill to be utilised in anaerobic conditions for biogas production.

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