Production of Biogas from Coffee Husks Using Rumen Fluid And Mixture of Rumen Fluid and Cow Dung

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Abstract. Coffee husk is a lignocellulosic material that is abundant and can be used to produce biogas. This study compared biogas produced by using coffee husk as a substrate and adding rumen fluid and a mixture of rumen fluid and cow dung. This experiment was conducted for 30 days in an anaerobic batch reactor with a reactor working volume of 3.6 L at mesophilic temperature. The parameters tested in this study were the lignocellulose content of coffee husks, total solids (TS), volatile solids (VS), volatile fatty acids (VFA), chemical oxygen demand (COD), and the content of biogas produced from the two variables. . The values of Total Solids and Volatile Solids for the two variables are CR of 42.47% and 44.49% and CRC of 57.59% and 30.59%, respectively. The VFA values for both variables were 0.96% (v/v) for CR and 1.32% (v/v) for CRC. The COD values for the CR-R and CRC variables were 28.03% and 48.92, respectively. The methane yields for the variables CR and CRC, were 0.01 Nm3/kgCODremoval and 0.06 Nm3/kgCODremoval respectively.

Keywords : coffee husks, cow dung, rumen fluid ,methane, volatile fatty acid.

INTRODUCTION

The increase in world crude oil prices has made many countries found alternative energy sources to replace fossil fuels. Solar energy is considered an effective energy source because it is environmentally friendly. Some of the disadvantages of alternative energy sources such as solar, hydro, and wind are that they require large costs to operate. Biogas is an environmentally friendly alternative renewable energy source that can be utilized such as heating, electricity, or vehicle fuel to replace fossil fuels[1]. The composition of the biogas produced varies and depends on the physical and chemical properties of the substrate used [2].

Methane production from various biomass wastes through anaerobic digester technology is growing worldwide because it is cheap and environmentally friendly[3–9]. The use of agricultural waste for biogas production has increased in recent years. Agricultural biomass waste used is corn, sugar cane, and non-food plant parts such as leaves, stems, and coffee grounds , and husks. Using of waste biomass can help reduce environmental pollution [10,11].

Coffee is the second largest traded commodity in the world and also produces by-products and residues. Lignocellulosic components present in coffee grounds include: cellulose (63%), hemicellulose (2.3%), lignin (17%), protein (11.5%), tannins (1.80-8.56%), pectin (6.5%). , reducing sugar (12.4%), non-reducing sugar (2.0%), caffeine (1.3%), chlorogenic acid (2.6%) and caffeic acid (1.6%) [12-14]. Waste from coffee husks is a source of contamination that can cause serious environmental problems, especially in coffee-producing countries. Not only because of the formation of gases that result from decay, but also because of the high content of caffeine, phenol , and tannins which are toxic in biological processes [15].

Previous studies have explained that the content of toxic substances in coffee skin can be minimized by degrading microbes [16,17]. The use of cow dung for biogas production has been widely carried out [18] however, the cost of a digester for biogas production using cow dung is not profitable because the quantity of biogas is relatively low compared to some other types of organic waste such as food waste [20,21]. Cow dung also contains bacteria and microorganisms such as *Clostridium*, *Bacteroides*, *Bifidobacterium*, *Enterobacteriaceae* (E. Coli), *Ruminococcus*, etc [22].

Rumen fluid and other microorganisms have recently been used to degrade cellulose to volatile fatty acids (VFA) and/or gases [23-25]. The results of previous studies showed that microorganisms contained in the rumen were superior to other microbes in degrading cellulose materials [26]. The Rumen is considered more efficient in utilizing lignocellulosic [27]. The microbial components in the rumen include *Fibrobacter succinogenes*, *Ruminococcus flavefaciens*, and *Ruminococcus albus* [28] , *Clostridium* and *Bacteroides* are also involved in anaerobic digestion [29].

This study aims to compare biogas production using coffee husk as a substrate by adding rumen fluid and a mixture of cow dung and rumen fluid.

MATERIALS & METHODS

The equipment in this research is a batch reactor as shown in Figure 1, then autoclave, hot plate, stirrer, water bath, spectrophotometer, analytical balance, incubator, furnance, oven, vacuum pump (weich), vortex, manometer, gas chromatography (hewlett packard), COD tube, COD reactor, and gas chromatography (GC-2010 Plus-SHIMADZU).

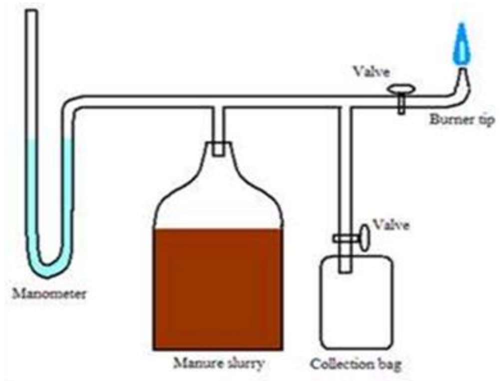

Figure 1. The equipments of anaerobic process from rice straw waste

The materials that will be used in this research are coffee husks, rumen fluid, and cow dung. The Rumen fluid was obtained by squeezing the contents of the rumen, then placed in a thermos that had been preheated at 39 ^{o}C. Next, the rumen fluid was filtered with gauze and collected in a water bath at 39 ^{o}C. 3 kg of cow dung was taken and then put in an airtight container. The cow dung obtained was diluted with aquadest in a ratio of 1:3, then filtered using gauze and then put into the digester in accordance with a predetermined volume of 15% of the working volume of the reactor.

Analysis of Lignocellosic

In this study, the analysis of cellulose, hemicellulose, and lignin used the Chesson method.

Hemicellulose

The hemicellulose content was analyzed by the Chesson method [30], by mixing 1-2 grams of the sample with 150 mL of distilled water, then heated at 100 ^{o}C for 2 hours, then filtered using filter paper, and finally rinsed with distilled water, then the solids part dried in an oven at 105 ^{o}C to constant weight (a). Then the sample was mixed with 150 mL H_2SO_4 1 N, then the sample was heated at 100 ^{o}C for 1 hour, filtered with filter paper and finally rinsed with distilled water. Then the solids were put into the oven at a temperature of 105 ^{o}C to constant weight (b). The hemicellulose content was calculated using equation (1).

Hemicellulose content (%) = (b-c)/a x 100% ....(1)
Noted:
a. Dry weight reduction of lignocellulosic biomass samples
b. Reduction of the dry weight of reflux sample residue using hot water
c. The Reduction dry weight of sample residue after refluxing using 0.5 M H_2SO_4

Cellulose

Cellulose content was analyzed by the Chesson method. The dried sample in hemicellulose analysis (b) was mixed with 10 mL of 72% (v/v) H_2SO_4 solution at room temperature for 4 hours, then H_2SO_4 was diluted to a concentration of 0.5 M. Then the sample was refluxed at 100 ^{o}C for 2 hours. The cellulose content was calculated using equation (2).

Cellulose Content (%) = c−d/a 100% (2)
Noted:
a) The Reduction in dry weight of lignocellulosic biomass samples
c) The Reduction in the dry weight of the sample residue after refluxing using 0.5 M H_2SO_4
d) The Reduction in the dry weight of the sample residue after being mixed using 72% H_2SO_4 after which it was diluted to 4% H_2SO_4

Lignin

Lignin content was analyzed by the Chesson method. The dried sample in the cellulose analysis (c) was filtered and then washed with distilled water. Next, the solids were put into an oven at a temperature of 105 ^{o}C to constant (d). Cellulose content is calculated using equation (3).

Lignin content (%) = d-e/a x 100%
Noted :
a) The Reduction in dry weight of lignocellulosic biomass samples
d) The Reduction in the dry weight of the sample residue after being mixed with 4% H2SO4
e) Ash from sample residue

Biogas Production

This study compared the production by adding rumen fluid (CR) and a mixture of rumen fluid and cow dung (CRC). This study analyzes total solids and volatile solids, chemical oxygen demand (COD), volatile fatty acids (VFA), and biogas composition.

Analysis TS, VS, and COD

Analysis of TS, VS, and COD was carried out every five days for 30 days fermentation process.

Total Solid (TS)

Total Solid (TS) or total solids is the total of dissolved solids and suspended solids, organic and inorganic

Volatile solid (VS)

Volatile Solids analysis was carried out by inserting a 5 mL sample into a porcelain dish that had been weighed previously. The Total Solids were then reheated for 2 hours in a muffle furnace at a temperature of 550 ^oC. After that, the porcelain cup was cooled and then the weight was re-weighed.

Chemical Oxygen Demand (COD)

COD was measured by adding a digestion solution ($K_2Cr_2O_7$) with 3.5 mL of H_2SO_4 solution in a COD tube, then homogenized (the solution became hot), allowed to settle, then added 2.5 mL of distilled water as a blank, homogenized, then heated at 148 ^oC for 2 hours using a COD reactor, let it come to room temperature and measure it with a spectrophotometer at a wavelength of 620 nm.

Analysis of VFA and CH_4

For analysis of VFA content, the slurry sample was taken through a sampling valve digester using a syringe and a hose and then accommodated into 1.5 mL eppendoff, then homogenized with a centrifuge to separate the filtrate and precipitate. The resulting filtrate was analyzed using Gas Chromatography (GC) HP-6890 at an oven operating condition with an initial temperature of 170 ^oC for 18.57 minutes. Injector operating conditions using Helium as carrier gas at an initial temperature of 275 oC at a pressure of 17.21 psi. The content biogas such as methane gas (CH_4) using gas chromatography (Hewlett Packard, USA).

RESULT AND DISCUSSION

Cellulosic Contents of Coffee husks

Table 1.Chemical composition of coffee husks

Coffee husk components	Percentage (%)
Cellulose	65.90
Hemicellulose	24.95
Lignin	0.21
Pectin	0.42
Protein	0.81
Tannin	1.05
Caffeine	0.09
Polyphenol	0.81

Based on the results of the analysis of the coffee skin components using the gravimetric method. It was found that the cellulose content was 65.90%, hemicellulose 24.95%, lignin 0.21%, pectin 0.42%, protein 0.81%, tannin 1, 05%, 0.09% caffeine, and 0.81% polyphenols. Based on the lignocellulosic content obtained, the coffee rind has a higher potential to be used as a substrate in making biogas, but coffee rind has a composition of toxic substances such as tannins, pectins, polyphenols, and caffeine so that it interferes with the activity of microorganisms in degrading the coffee rind substrate [31].

Total Solids (TS) and Volatile Solids (VS)

Based on the results of the TS and VS analysis in Figures 2 and 3, it can be seen that the TS and VS values in KK-R and KK-RKS decreased significantly during the 30-day anaerobic fermentation time. The decrease in TS and VS values in KK-RKS was greater than that of KK-R, namely 57.59% and 44.49% and 42.47% and 30.59%, respectively. The values of TS and VS are influenced by the increase in the growth of microorganisms from degraded organic compounds. After the 15th day, the values of TS and VS decreased steadily for both treatments.

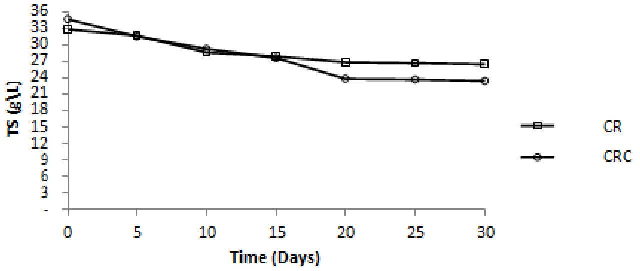

Figure 2. Total Solids profile for anaerobic digestion from CR and CRC

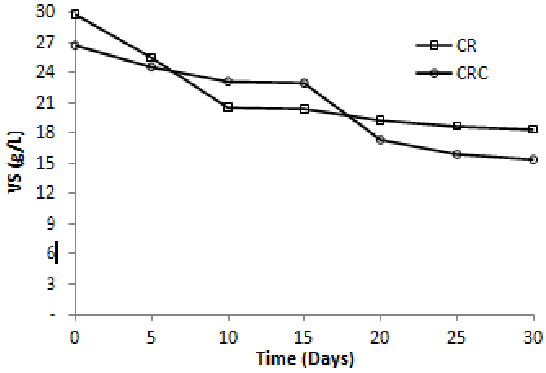

Figure 3. Volatile Solids profile for anaerobic digestion from CR and CRC

Chemical Oxygen Demand (COD)

In Figure 4 shows the results of the COD analysis. The decrease in COD in each treatment was CR by 28.03% and CRC by 48.92%. Based on the results of the analysis, COD decreased every 5 days both CR and CRC. This indicates that methane is produced.

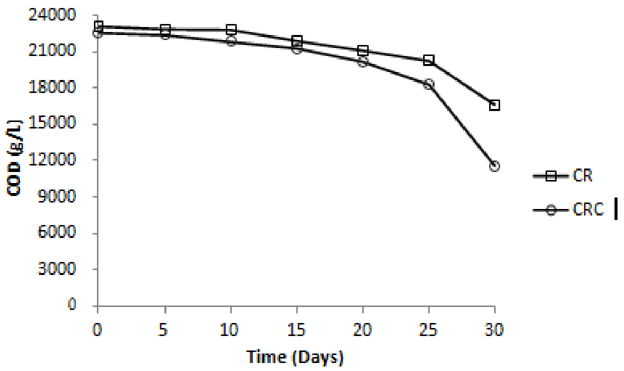

Figure 4. COD profile for anaerobic digestion from CR and CRC

Volatile fatty acids (VFA)

In this study, volatile fatty found in acetic, propionic, and butyric acids were obtained from gas chromatography (GC) results can be seen in Figures 5 and 6. The acetic, propionic, and butyric acids are the main product for biogas production. The results of the analysis of total VFA (acetic, propionic, and butyric acids) can be shown in Figure 5.

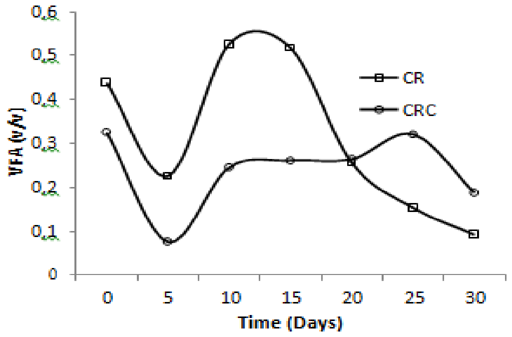

Figure 5. Total VFA for anaerobic digestion from CR and CRC

The resulting VFA was obtained from the total acetic acid, propionic acid, and butyric acid produced. The increase in the production of volatile acids (acetic acid, propionic acid, and butyric acid) in each treatment indicated an increase in the growth of acetogenic bacteria, while the decrease in volatile acids on certain days indicated the process of methane formation. The concentration of these volatile acids indicates the resulting biogas production [32]. Based on the calculation results, the largest concentration of volatile acids (acetic, propionic, and butyric in CRC was 1.32% (v/v), while in CR it was 0.96% (v/v). The rumen has a higher ability to degrade lignocellulosic biomass than other anaerobic microorganisms [33,34].

The results of the analysis of methane, it was found that the highest concentration of methane produced in the CRC was 31085 ppm. This value is higher than the concentration of methane produced in CR, which is 11077 ppm. The production of VFA in CRC is proportional to the production of methane produced. In the methanogenesis stage, methanogenic archaea bacteria such as Methanosarcina Sp and Methanothrix Sp convert H2 and acetic acid into CO_2, CH4 and water, and convert H_2 and propionic acid into CH_4 with Methanobacterium bacteria, Methanococcuss). Acetic acid and propionic acid are the main products in anaerobic biogas production [30].

Biogas Composition

The composition of biogas (CH_4, CO_2, H_2) was analyzed for 30 days of anaerobic fermentation. Table 2 shows the comparison of biogas composition between CR and CRC.

Table 2**.** Comparison of biogas composition in CR and CRC

Compounds	CR(%)	CRC (%)
CH_4	18.4	22.3
CO_2	14.11	13.75
H_2	0.59	0.36

Methane Yield

The highest methane yield was produced in CRC of 0.06 Nm^3/kgCODremoval, while CR produced methane yields of 0.01 Nm^3/kgCODremoval.

CONCLUSION

The use of a mixture of rumen and cow dung in the production of biogas from coffee husks is more effective than the rumen liquid. In the mixture of the rumen and cow dung, the methane composition produced was 22.30% CH_4 with CO_2 impurities of 13.75%, while in therumen fluid the methane composition produced was 18.40% CH_4 with CO_2 impurities of 14.11%.

ACKNOWLEDGEMENTS

The authors would like to thank University of Lampung for funding (contract number: 1572/UN26.21/PN/2021) and the Department of Biology for facilitating this research.

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