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RESEARCH ARTICLE

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# Assessment and Optimization of a Decentralized Food-Waste -To-Energy System by using Anaerobic Digestion System: Case study in Beyda City

**Fayzh Thabet , Yousif Hamad, Tarek Hamad**

Libyan Academy- Al-Beyda – Libya

Omar Al Mukhtar University - Department of Sustainable and Renewable Energy
AlBeyda- Libya

(E-Mails:f.alsharef659@lajak,edu.ly; yousif.habib@omu.edu.ly; Tarek.Hamad@omu.edu.ly)

**Abstract.** In this study, anaerobic digestion was used to manufacture biogas from food waste. To improve production digester performance and biogas generation, chicken manure and slaughterhouse waste were added. The Bach feeding system with two digesters was followed by a laboratory fermenter. Bones were put to the second fermenter after the first fermenter was loaded boneless. The anaerobic digestion of food waste was simulated using two steps of Aspen Plus. According to experimental data, the first reactor generated the most gas on the seventh day, with 0.357 liters, while the second digester produced 0.24 liters. Aspen Plus simulation findings showed 42.38% CO2, 5.8% traces, and 50.82% methane. This illustrated how closely the biogas's composition matched that of the traditional

**Keywords:**. Renewable Energy, food waste, biogas, anaerobic digestion, Aspen Plus.

## 1. INTRODUCTION

The amount of solid trash generated by global industrialization and population growth has increased significantly.(Sunil Kumar Srivastava, 2020), Since organic waste makes up about half of all garbage generated, it is believed to be the most important source of municipal solid waste(MSW).
(Zamri et al, 2021). MSW is composed of organic wastes, including food waste (FW), vegetable waste, paper waste, and so forth.

The abundance of organic waste may be detrimental to the soil, water, and air. (Lin et al, 2019), and the substantial greenhouse gas emissions caused on by its inappropriate disposal (Cecchi &Cavinato, 2019). According to the Food and Agriculture Organization (FAO), there are around 1.6 billion tons of food waste produced worldwide each year, which can lead to 3.3 billion tons of CO2 being released into the environment from household garbage. (Chowdhury, 2021), food waste It is simple to manufacture biogas, one of the most promising substrates for use as a renewable resource.

(Cecchi &Cavinato,2019),(Zamri2021) Anaerobic digestion (AD), a biological process that converts food waste into energy, uses four main processes to break down organic materials into digestate and biogas.

(Zhang et al ,2007) It is depicted in the process-flow diagram in Figure 1 below.

Because methane can be used as vehicle fuel and to replace fossil fuels in the generation of heat and power, biogas is a flexible source of renewable energy.

(Weiland, 2010). This study's primary goal is to look into the possibility of using biomass (food waste), as an environmentally friendly way to produce biogas.

Additionally, a simulation model is used with Aspen Plus software to validate experimental findings.

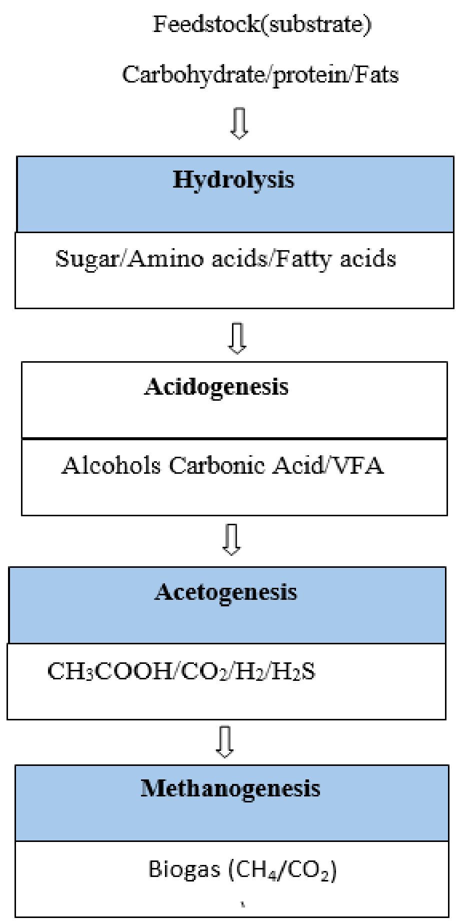


Figure 1: Flow chart of Anaerobic digestion phases

## 2.METHODS

The goal of this study is to turn food waste into biogas., Anaerobic systems' total performance can be predicted and optimized through modeling and simulation, which are also helpful tools for design and control in research.

Process simulation is a more cost-effective method of estimating process output than testing.

## 2.1 . Characterization of Food Waste

The material used in fermentation is a week's worth of kitchen waste from a typical household, which includes the leftovers of cooked food as well as the remnants of fruits and vegetables, the waste was cut and crushed into small pieces. Approximately 70% of total feedstock (food waste), 25% slaughterhouse wastes ,The reason for taking it, It produces a lot of biogas and 5% animal manure (chicken manure) showed the digester performs well if a little percentage of animal manure is added to the mixture. according to ( Rhee, et al, 2021).

## 2.2. An aerobic Digestion Tests

Composite samples were created by combining the weekly samplings of food waste., and these samples were subjected to digestion tests. After combining all of the food waste samples, representative samples were taken to create the composite samples. After weighing each required amount of substrate with an electronic balance, The combined samples were broken down. in two 2-Lbatch digesters and at a mesospheric temperature (40 °C). The digester's effective volume was 1.5 L, and the pH was measured so it was about 6.42, 6.23 for both digesters respectively. Rubber septa were used to securely shut the digesters. Every day, each digester was carefully blended., see Figure 2.

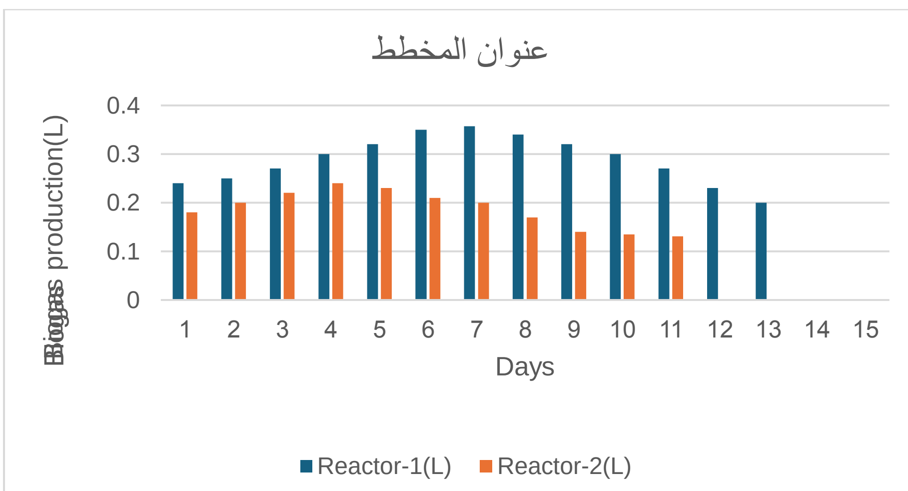


Figure 2: Daily biogas production for both reactors

## 2.3. Biogas Measurements

. A water displacement setup was used to measure each digester's daily biogas production, where the amount of gas produced is equal to the amount of water displaced from the tank, Before calculating the quantity of gas generated, stirring was done by hand and The quantity of gas generated was measured daily. As shown in Table 1.

Table 1 Daily Biogas production at 400C

| Days | Reactor-1(L) | Reactor-2(L) |
|---|---|---|
| 1 | 0.24 | 0.18 |
| 2 | 0.25 | 0.2 |
| 3 | 0.27 | 0.22 |
| 4 | 0.3 | 0.24 |
| 5 | 0.32 | 0.23 |
| 6 | 0.35 | 0.21 |
| 7 | 0.357 | 0.2 |
| 8 | 0.34 | 0.17 |
| 9 | 0.32 | 0.14 |
| 10 | 0.3 | 0.135 |
| 11 | 0.27 | 0.131 |
| 12 | 0.23 | 0 |
| 13 | 0.2 | 0 |
| 14 | 0 | 0 |
| 15 | 0 | 0 |

## 2.4. Model of Aspen plus Simulation

Depending on the kind of substrate, anaerobic digesters can be constructed as single-phase or two-phase reactors to produce biogas. in addition to technical and financial concerns All processes—hydrolysis, acidogenesis, acetogenesis, and methanogenesis—take place in a single reactor in a single-phase digester, and methane is produced. In separate anaerobic reactors, the two-processor, multi-stage process takes place. While methanogenesis is the primary function of the second reactor, hydrolysis, acidogenesis, and acetogenesis are all carried out in the first reactor. Compared to a single-phase reactor, a two-phase reactor works better, particularly with highly biodegradable substrates like food waste. (Pramanik et al, 2019).

Aspen Plus accounted for the two reaction steps of the AD process, which include methanogenesis, acetogenesis, hydrolysis, and acidogenesis. Hydrolysis was the initial process, followed by acidogenesis, acetogenesis, and methanogenesis. The flow diagram for producing biogas from food waste is made up of a collection of blocks and streams. As shown in Figure3 ,the simulation includes:

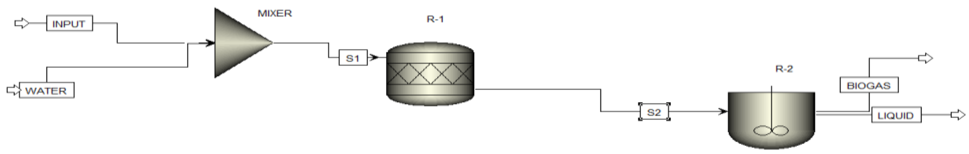


Figure**3** : The process flow diagram of the AD in Aspen Plus

Mixer: used two streams—water and food waste—and combined them at 23 °C and 1 atm of pressure. For 1.5 l/day, the OLR was simulated.

Stoichiometric Reactor (R-1): Reactor that simulated hydrolysis reactions and was used when the stoichiometry and reaction extension were known. The temperature was set at 55 °C (thermophilic), the pressure at 1 atm, and the phases were set at vapor–liquid.

Continuous Stirred Tank Reactor (R-2): When the reaction kinetics were known, a reactor was utilized. simulates the reactions of methanogenesis, acetogenesis, and acidogenesis. The temperature was set at 55 °C (thermophilic), the pressure at 1 atm, and the phases were set at vapor–liquid. Table2 gives a biogas's normal makeup.

Table2 Typical Composition of Biogas

| Compound | Formula | Percentage |
|---|---|---|
| Methane | $CH_4$ | 50-75 |
| Carbon Dioxide | $CO_2$ | 25-50 |
| Nitrogen | $N_2$ | 0-10 |
| Hydrogen | $H_2$ | 0-1 |
| Hydrogen Sulphide | $H_2S$ | 0-3 |
| Oxygen | $O_2$ | 0-0.5 |

## 3. RESULT AND DISCUSSION

From reading the previous chart, we note that the largest amount of gas produced in the first reactor on seventh day is about 0.357L, knowing that gas production did not stop in the first digester until the thirteenth day, while the amount of gas in the second digester was about 0.24 L and gas production stopped in the second digester on the eleventh day. The reason for the difference in the amount of biogas production in both fermenters under the same environmental conditions is that when slaughterhouse waste was added to the second fermenter it was added with bones unlike the first fermenter in which it was placed without it. The reason is due to C/N ration different between both digester .The first digester which have slaughterhouse waste type of (large intestine) the higher lipid content enhancing the potential of methane yield. However, the second digester with bone may result in an inhibition of the methanogenic activity in AD due to the release and accumulation of ammonia. Aspen Plus's simulation results were noted, and the biogas generated is shown in the Table 3.

Table 3 The outcome of the biogas production simulation

| **Component** | **Percentage** |
|---|---|
| Methane ($CH_4$) | 50.82 |
| Carbon dioxide($CO_2$) | 42.38 |
| Hydrogen($H_2$) | 0.07 |
| Hydrogen sulfide($H_2S$) | 0.33 |
| Oxygen($O_2$) | 0 |
| Water | 0.57 |

The findings show that the biogas composition closely matches the usual biogas composition that has been published (Bhardwaj& Das, 2017), 50.82 percent methane and 42.38% carbon dioxide made up the product's main constituents in the biogas stream. Around 6.8 % This simulation project includes traces of hydrogen sulfide, acetic acid, ammonia, and hydrogen, see Figure 4..

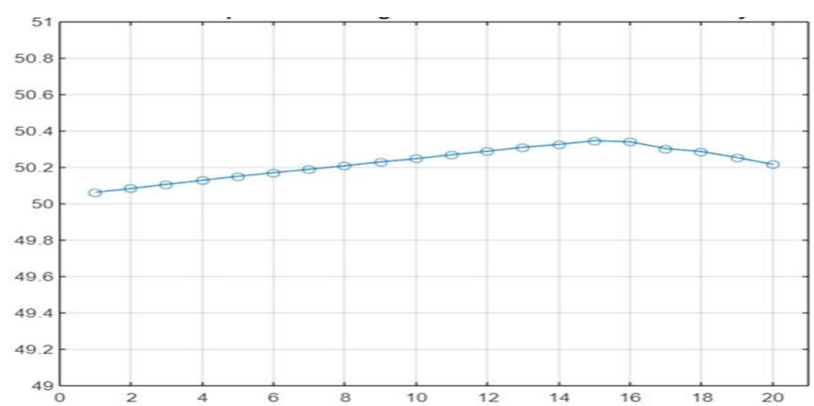

Figure 4: Methane composition % vol at 20 Days.

## 4. CONCLUSION

One of the alternative sustainable technologies that turn food wastes into biogas is the anaerobic digestion method. The food waste was an extremely beneficial anaerobic digestion feedstock. According to the biogas experiment results, the use of mesophilic system by adding slaughterhouse waste and chicken manure to the feedstock is suggested to enhance biogas production, modelling and Simulations are helpful tools for study. helping for design and control purposes, as well as to forecast and maximize the overall performance of anaerobic systems., Compared to testing, process simulation is a more economical way to estimate process output, Aspen Plus software was used to simulate AD. The pressure was 1 atm, and the temperature was thermophilic at 55°C.Was found to be50.82%methane,42.38%$CO_2$,and around6.8 % traces. Given that the data is within the usual range of biogas composition, it can be accepted. The created model may be used to calculate biogas generation in a variety of operational scenarios.

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