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# Evaluation of Waste with High Organic Content in Energy Production

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ABSTRACT

Animal and vegetable wastes are mostly utilized by burning or as fertilizer on agricultural lands. Burning these wastes does not produce a desired level of heat, and the remaining material after heat production cannot be used as fertilizer, either. For this reason, plant and animal wastes are converted into energy by obtaining biogas from biomass, which is one of the most environmentally acceptable methods of solution. This system makes it possible to both produce energy and evaluate the end product as fertilizer. In this study, the efficiency of biogas and methane production from kitchen waste and ovine manure via anaerobic fermentation was evaluated. First of all, the C/N ratio of randomly selected kitchen wastes was determined, and it was found as 34.30. The mixing ratios with ovine manure were determined by considering the C/N ratio that was found. The mixing ratios of kitchen waste and ovine manure by mass were determined as 1:0, 0:1, 1:1, 1:2, and 2:1, respectively, and the C/N values providing optimum biogas production in the mixtures were found. At the end of the 48-day-long anaerobic fermentation process, the highest biogas and methane production was achieved as 525 ml and 332 ml, respectively, in reactor 5 with a mixing ratio of 2:1. This reactor was followed by reactor 2 with 450 ml of biogas and 271 ml of methane production. Accordingly, it was concluded that kitchen waste could be a good mixture with ovine manure in anaerobic fermentation.

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## Introduction

Today, fossil fuels are largely used to meet the energy needs of societies. However, the environmental crises experienced due to the use of fossil fuels lead societies to renewable energies. Environmental crises are the most important deadlocks of human societies. Biogas, one of the main renewable energy sources, is one of the simplest ways to produce a clean fuel and control environmental pollution (Najafi and Faizollahzadeh Ardabili, 2018).

Biogas can be produced from any raw material that includes polymers of biomolecules, especially such as carbohydrates. Raw materials that can be used in biogas production include agricultural wastes (e.g., crop residues), animal wastes (animal manure, etc.), food industry wastes, aquatic biomass, and lignocellulosic biomass. All of the materials used are abundantly and widely available. Most of these raw materials consist of complex molecules and decompose very slowly (Taherzadeh and Karimi, 2008).

Whatever the source, the vast majority of organic matter contains carbon (C), nitrogen (N) and hydrogen (H). Since the metabolic activities of methane bacteria vary by the ratio of C/N, biogas production is significantly affected by the C/N ratio of these three elements. The optimum C/N ratio for biogas production is known as 25-30/1 (Dutta et al., 1994). Therefore, it is necessary to work with a C/N ratio suitable for the organic matter used so that the efficiency of the system can be improved. If the C/N ratio is too high, carbon limits gas production. If the C/N ratio is low, nitrogen plays a limiting role in gas production and also causes the formation of ammonia in the system (Ilkiliç and Deviren, 2011).

### *Kitchen Wastes*

Kitchen waste is one of the various types of solid waste produced by today's society. Accumulation of waste materials without proper disposal is one of the biggest problems in our country. Kitchen waste left without a disposal process will create problems for our environment in the future. Various methods, such as aerobic digestion, composting, or anaerobic digestion, can be used to dispose of biodegradable wastes.

Of these methods, anaerobic digestion is the best way to treat biodegradable waste such as kitchen waste because energy is produced in the form of biogas during this process. As is known, biogas can be used for different purposes, including cooking food, running water pumps, running engines, and generating electricity. Sludge produced in a biogas plant can be a very good fertilizer for our agricultural lands. In addition, it will provide a healthy, clean, and smoke-free environment in rural kitchens (Nehra et al., 2015).

### *Animal Wastes*

Manure of animals such as cows, sheep, chickens, and horses, wastes generated during the processing of animal products, and slaughterhouse wastes can be processed in the anaerobic fermentation process, and therefore they are widely used as raw material. Storage does not decrease the pH value of animal wastes, compared to plant wastes. Besides, they help produce products with high nitrogen content (Kaya and Öztürk, 2012). The biogas yield that can be obtained from animal waste is shown in Table 1 (Gülen and Arslan, 2005).

In our country, animal wastes are generally used in agricultural lands or destroyed without conversion into energy. However, one of the best ways to benefit from waste is the production of biogas energy (Salihoğlu et al., 2019). As seen in Table 1, biogas yields that can be obtained from animal sources are quite high.

Traditionally, animal manure has been used as the sole raw material in most digesters studied worldwide to produce biogas for recycling energy. Although the use of animal manure alone is appropriate and feasible, it does not offer the most efficient way to produce biogas due to natural carbon deficiency (i.e., low carbon/nitrogen ratio) (Wu et al., 2010).

Co-digestion of various bio-solid wastes, which is a process that uses nutrients and bacterial diversity available in these wastes to optimize the digestive process, is an attractive approach to boost the efficiency of bioconversion (Wang et al., 2012). Thus, it is possible to enhance methane production by efficiently balancing the carbon and nitrogen in the raw material with co-digestion (Wang et al., 2014).

In recent studies, it was determined that the evaluation of kitchen wastes and animal manures with high organic content together in anaerobic fermentation gave very good results in biogas production (Glivin et al., 2022; Rahman et al., 2021; Singh and Sankarlal, 2015; Haider et al., 2015; Ziauddin and Rajesh, 2015; Iqbal et al., 2014; Li et al., 2009; Ojolo et al., 2007).

The review of studies on the topic indicated that biogas production efficiencies of mixtures of various animal manures and kitchen wastes had been evaluated, but no study on the evaluation of mixtures of ovine manure and kitchen wastes was found.

This study was conducted to find out the optimum mixture ratio to achieve biogas and methane production as a result of anaerobic fermentation of ovine manure and kitchen wastes at different mixing ratios. For this purpose, biogas and methane production were monitored in 5 reactors with different ratios of mixtures, and the results were interpreted.

Table 1. The biogas yield that can be obtained from animal waste

| Source | Biogas yield (L/kg) | Methane ratio (Volume %) |
|---|---|---|
| Cattle Manure | 90-310 | 65 |
| Sheep Manure | 180-450 | 60 |
| Poultry Manure | 310-620 | 60 |
| Pig Manure | 340-550 | 65-70 |

Table 2. Description of reactors

| Reactor | Kitchen waste: Ovine manure |
|---|---|
| R1 | 1:0 |
| R2 | 0:1 |
| R3 | 1:1 |
| R4 | 1:2 |
| R5 | 2:1 |

Table 3. Analysis results of raw materials

| Parameters | Kitchen waste | Ovine manure |
|---|---|---|
| C/N | 33.07 | 21.34 |
| % Solids | 25.12 | 30.2 |
| % Volatile matter (in solid matter) | 87.36 | 79.7 |
| pH | 6.9 | 7.8 |
| % Moisture | 74.88 | 69.8 |

## Materials and Methods

### *Raw Materials Used in The Study and Analyses Applied*

The raw materials used in the study included kitchen waste and ovine manure. Kitchen waste was obtained from Tokat Gaziosmanpaşa University, Almus Vocational Higher School kitchen, and ovine manure was obtained from Tokat Taşlıçiftlik village.

In the study, first, the kitchen wastes were divided into small pieces in the blender and mixed homogeneously. Then, the processed kitchen wastes and fresh ovine manure were analyzed for dry matter and organic matter content.

For solid matter analysis, 3 grams of each sample was weighed and dried in an oven at 105°C. After drying, the samples were weighed again and the ratio of solids was determined. After solid matter analysis, the dried samples were incinerated in a muffle furnace at 550°C.

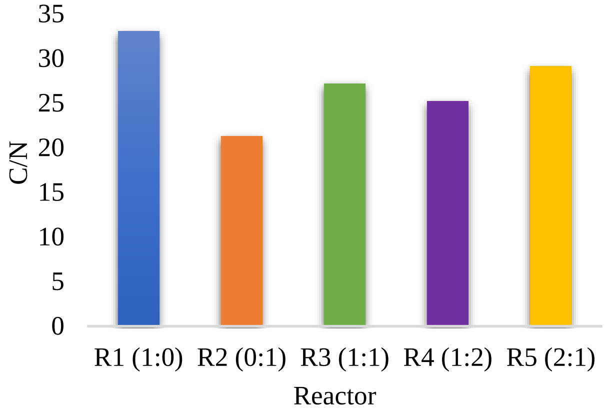


Chart 1. C/N ratios of reactors

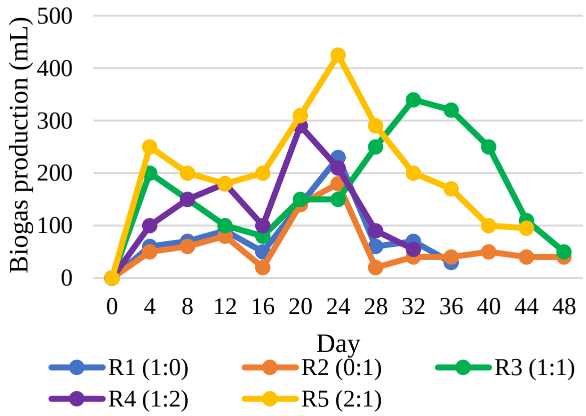


Chart 2. Biogas production in reactors

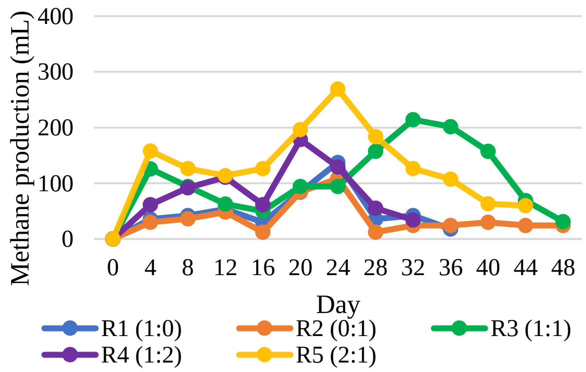


Chart 3. Methane production in reactors

The weight of the volatile part released after the completion of the combustion process was calculated as the quantity of volatile solids.

The C and N values of raw materials were determined with an elemental analyzer (VELP CN 802 Carbon Nitrogen Elemental Analyzer).

Volumetric measurements of methane gas in biogas were made with Honeywell Neotronics Impact Pro model portable gas measuring instrument.

TFA brand Combi-Tester model device was used for pH measurement in the experiments.

***Anaerobic Fermentation Process***

In this process, the mixing ratios of kitchen waste and ovine manure by mass were determined as 1:0, 0:1, 1:1, 1:2, and 2:1, respectively, for each reactor, and 5 bio-reactors were created for anaerobic fermentation experiments (Table 2).

In these bioreactors, nuche erlens of 500 mL were used, and gas collection bags of 0.5 L were attached to their outlet pipe with the help of a hose. The solids ratio of the mixtures in the reactor was 10% by mass, and the bottles were filled at a ratio of ¾. For anaerobic degradation to take place, the reactors were wrapped with aluminum foil to prevent light from passing through. Since the pH values in the reactors were desired to be 6.6-7.6 for optimum biogas production, the pH values of the mixtures outside these values were brought to the desired range with $HNO_3$ and KOH chemicals. During the 48-day-long study, the materials were mixed twice a day. The amount of biogas formed during this period was measured using 0.5 L gas collection bags. This process continued until the formation of gas stabilized or stopped.

## Findings and Discussion

***Results of Analysis of Raw Materials Used***

Before the anaerobic fermentation experiments, analyses were conducted to determine the components in the structure of raw materials. The results of the analyses are given in Table 3.

Kitchen wastes, containing high moisture, carbohydrates, lipids, and proteins, are easily biodegradable organic materials. The use of kitchen waste only in anaerobic digestion reduces the activity of methanogenic bacteria as a result of the rapid accumulation of volatile fatty acids and subsequent drop of pH value in the reactor. Thus, C/N adjustment with the use of some additives and methane formation is required to accelerate the growth of methanogens (Mostafa et al., 2019). This was why kitchen waste and ovine manure were mixed in different proportions in the study. The C/N ratios of the mixtures are given in Chart 1.

In the study, the C/N ratio was tried to be brought to the optimum range by adding ovine manure to the kitchen waste raw material. It was aimed to increase biogas production by controlling the C/N ratio with the mixture of raw materials. In line with this target, biogas production amounts generated by 5 different mixture ratios by mass for 48 days are given in Chart 2, and methane production amounts are given in Chart 3.

As seen in Chart 2, the highest biogas production was observed in reactor 5 with 425 mL on the 24$^{th}$ day. The lowest biogas production value was recorded in reactor 2 as 180 mL on the 24$^{th}$ day. The most important reason for the difference in production amounts can be shown as the consumption of C and N nutrients by anaerobic bacteria at different rates. The reason for getting higher efficiency from the mixing ratios can be due to bringing the C/N ratio of the mixtures to the desired range.

As seen in Chart 3, the highest methane product was obtained as 269.03 mL in reactor 5, where the highest biogas production was achieved. The excess amount of kitchen waste used in reactor 5 is thought to be the reason for the high efficiency.

In general, methane production was observed to be 59-64% of the biogas produced in all rectors. This methane range demonstrates that the biogas produced is usable in terms of energy.

## Conclusion and Recommendations

With the increase in the world population, kitchen waste is increasing every other day. This situation leads to many negative environmental consequences. The same problem applies to animal manure, the amount of which is increasing every other day. For this reason, these raw materials, which come to the fore as a problem, should be evaluated with a determined method. It is known that one of the most suitable methods for the evaluation of such wastes is biogas production.

In this context, it was aimed to use kitchen waste, which is produced in large quantities today, in the production of biogas with ovine manure. In the study, biogas and methane productions were observed for 48 days.

As a result of the experiments done in the study, the comparison of biogas and methane production in the reactors indicated that the highest amount of biogas was obtained as 425 mL and the methane as 269.03 mL at a 2:1 mixture ratio.

The values obtained indicated that the anaerobic digestion of kitchen waste and ovine manure together increased biogas and methane production and that this method was also suitable for environmental protection and energy saving.

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