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Economic feasibility of biogas production from food and leaf waste

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Abstract: This research was focused on the economic feasibility of biogas production from food and leaf waste in the Electricity Generation Authority of Thailand, Bangkrui, Nonthaburi. The research methodology was divided into 1) laboratory scale research was conducted using a 10-liter reactor, filled with 5% of total solid material. The ratio of food waste to leaf waste to microorganisms was 1:1:1. Calcium carbonate was added to the reactor to maintain the pH in the system. Then, pH, methane production, and biogas component data were collected, and 2) economic feasibility analysis consisted of cost, internal rate of return (IRR), net present value (NPV), benefit-cost ratio (BCR), and payback period (PBP). The highest percentage of methane production was 70.19%. The cumulative methane production was 34,417.81 ml. The economic feasibility analysis yielded a net present value of $ 26,527.67, an internal rate of return of 142.24%, a benefit-cost ratio of 20.49, and a payback period of 6 months and 8 days, respectively. Ultimately, this study aligns with Sustainable Development Goal 12.4, which focuses on reducing waste through reuse and recycling, and Sustainable Development Goal 7, which aims to ensure everyone has access to affordable and sustainable energy.

Keywords: Biogas; Food waste; Leaf waste; Economic feasibility

1. Introduction

Food waste (FW) is a type of solid waste that comes from various sources such as households, markets, cafeterias, restaurants, and food waste processing industries [1]. Thailand generates 27-28 million tons of solid waste per year, more than half of which comes from both unconsumed food and materials used in cooking. Therefore, when food waste is not properly managed, it releases greenhouse gases. In addition to food waste, there is also organic leaf waste that, if not properly managed, can also produce pollution. Leaf waste is lignocellulosic material, consisting of cellulose, hemicellulose, and lignin. Cellulose consists of d-glucose units linked together via -1,4 connections and is classified as a polysaccharide [2]. The structure of hemicellulose consists of a heteropolymer made up of pentoses and galactose. The composition of cellulose, hemicellulose, and lignin varies depending on the species of plant or biomass [3]. Therefore, it may utilize materials for the production of biogas. The Electricity Generating Authority of Thailand (EGAT) is an agency that places great importance on the environment. Therefore, it has sought appropriate methods to manage various types of waste within the agency. In addition, EGAT also has a policy on safety, health, and the environment to implement a quality management system, promote good hygiene, and ensure environmental friendliness. Therefore, researcher found suitable ways to manage food and leaf waste in EGAT areas.

There are several ways to transform food waste and leaf waste into resources, such as using them as organic fertilizer, animal feed, and raw materials for biogas production. This is considered an alternative energy source, and biogas can be used to replace cooking gas and as fuel for electricity generation [4]. Additionally, the production of biogas also yields fertilizer that can be utilized. Therefore, researcher is interested in the economic feasibility for biogas production from food and leaf waste in the Electricity Generation Authority of Thailand Bangkrui, Nonthaburi.

2. Materials and Methods

2.1 Substrate and inoculum

This research utilized food and leaf waste (Figures 1A and 1 B) as substrates. Food and leaf waste were collected from the Electricity Generation Authority of Thailand, Bangkrui, Nonthaburi. After the collection process, food and leaf waste were cut to a smaller size for laboratory scale, approximately 1-2 centimetres. The inoculum was collected from the UASB wastewater treatment system. The inoculum was removed from impurities using a test sieve on a laboratory scale.

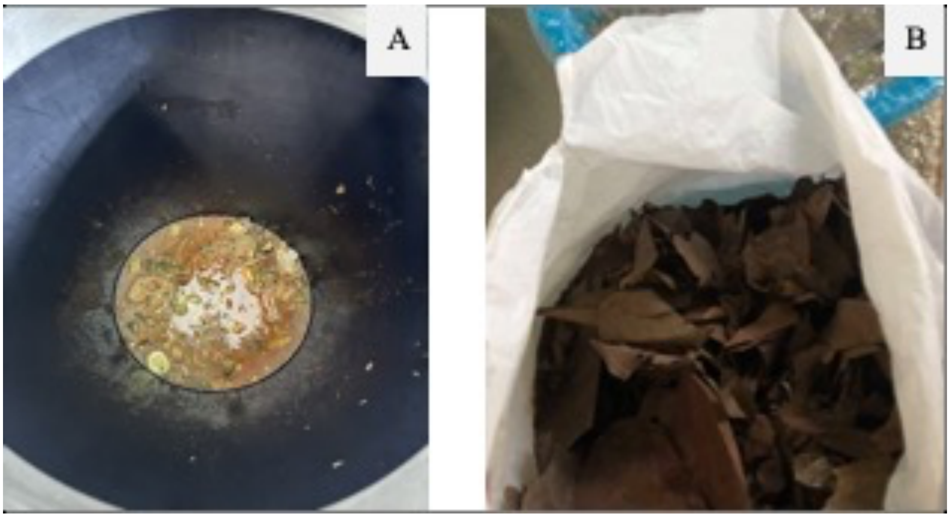

Figure 1. (A) Food waste, (B) Leaf waste.

2.2 Experiment condition

The laboratory experiment was conducted under the optimal conditions identified in prior research With a TS of 5%, materials were introduced into the reactor, which had a capacity of 10 liters (Figure 2). The anaerobic condition was maintained at 35-37 °C, with a pH of 7.00, CaCO3 concentration of 16 g L^{-1}, and mixing at 105 rpm [5 & 6]. The parameters monitored were the percentage of methane production, cumulative methane, and pH, respectively.

Figure 2. Completely mixed 10 liters reactor.

3. Economic analysis

3.1 Benefit Cost ratio (BCR)

The calculation of the benefit cost ratio is a calculation for the economic feasibility of the project, which analyzes and compares the present value of the return with the present value of the investment and expenses in the project. If the BCR is greater than 1, it means that the project provides a return that is worth the investment. If the value is less than 1, it means that the return from the project is not worth the investment [7].

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} \quad (1)$$

Where: Bt is the benefit at the year of calculation
Ct is the cost at the year of calculation
r is the discount rate
n is the project consideration period

3.2 Internal Rate of Return (IRR)

The rate of return equals the present value of the net cash flows over the project's life. If the project's internal rate of return (IRR) is greater than the required rate of return (r), the project is accepted when IRR > r. The IRR method employs two types of money value comparisons: the present value of the net cash flows over the project's life and the net cash flows initially invested at the same point in time [7].

$$IRR = i_L + (i_U - i_L) \times \frac{NPV_L}{(NPV_L - NPV_U)} \quad (2)$$

Where: IRR is internal rate of return
iL is percentage of positive net present value
iU is percentage of negative net present value
NPVL is the positive net present value of project
NPVU is the negative net present value of project

3.3 Net Present Value (NPV)

It is the sum of the net returns that have been adjusted for the time of the project, considering whether the project that is currently underway or has started will provide worthwhile returns or not. If the NPV value obtained is greater than zero, it means that investing is worthwhile. If the NPV value obtained is negative or less than zero, it means that the investment in the project is not worthwhile [7].

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} \quad (3)$$

Where: NPV is net present value of project
B_t is benefit at the year of calculation
C_t is cost at the year of calculation
i is discount rate
t is project's duration in years

3.3 Payback Period (PBP)

Payback period is the time period for the net return from operations to equal the investment cost of the project, or the number of years it takes to receive a return that is worth the investment [7].

4. Economic analysis

4.1 Biogas production

In the context of laboratory-scale anaerobic digestion, the ideal parameters for biogas production were identified as 5% TS, a temperature of 35-37 °C, a pH level of 7.00, and $CaCO_3$ concentrations of 16 g L^{-1}. During the fermentation process of biogas production under mesophilic conditions, the change in pH monitoring is illustrated in Figure 3. In this system, the pH profile began at 7.0 with the co-digestion of food waste and leaf waste. The biogas production system can be operated at optimum pH due to the alkalinity that is controlled with $CaCO_3$ 16 g L^{-1}. In this study, the pH value that was suitable for anaerobic digestion ranged from 6.90 to 7.42. If the pH of the anaerobic digestion system fell below 6.0, both acid-forming bacteria and methane-forming bacteria would be inhibited, leading to an accumulation of volatile fatty acids [8].

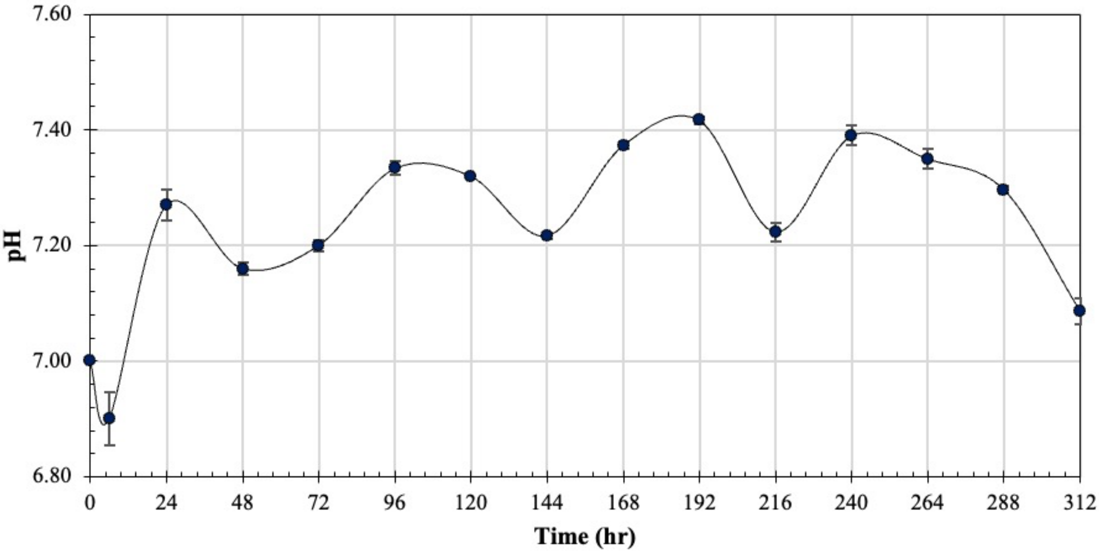

Figure 3. pH in biogas production during the fermentation period.

The highest percentage of methane production was obtained at 70.19% within 312 hours (Figure 4A). The cumulative methane production was obtained as 34,417.81 ml within 312 hours (Figure 7B).

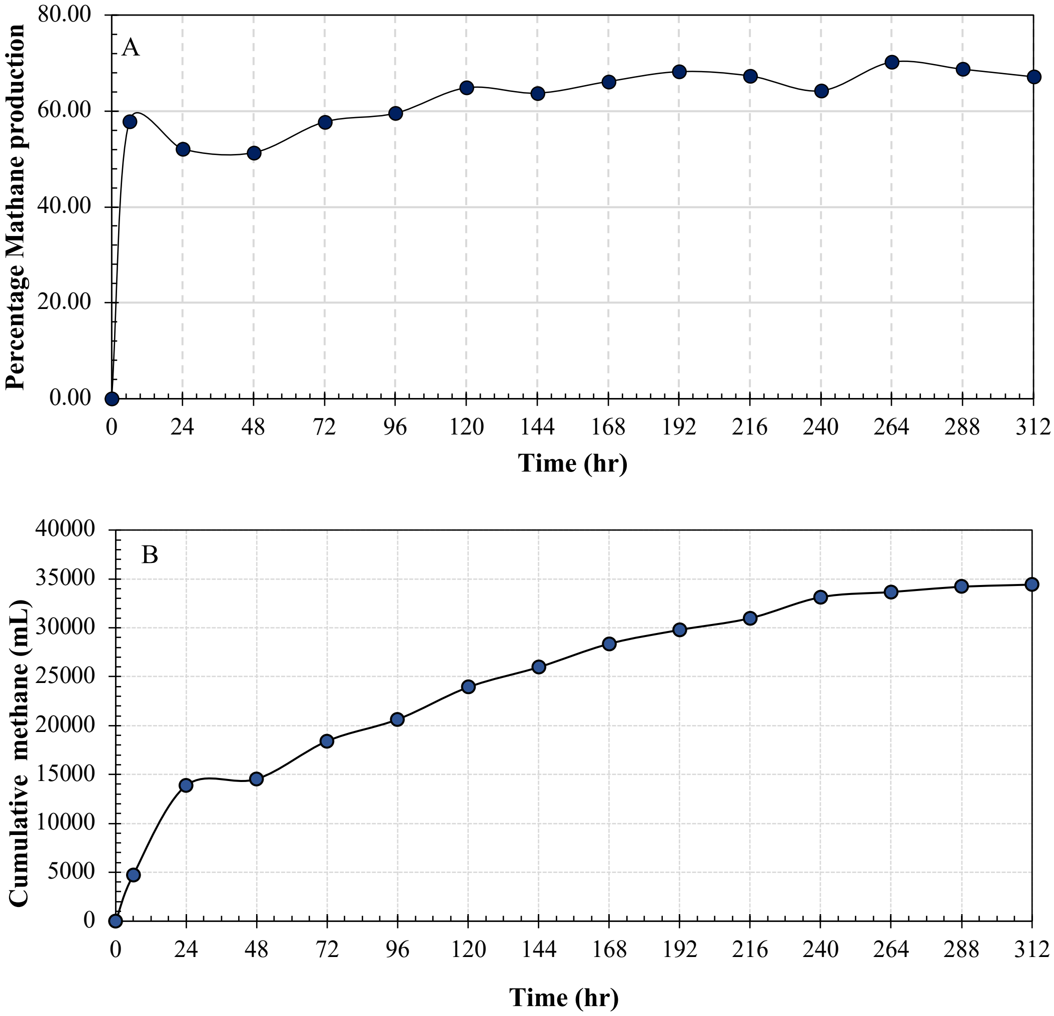

Figure 4. (A) Percentage methane production, and (B) cumulative methane production (ml).

This research was on the co-digestion of food waste and leaf waste. Methane production in this system can be maximized through co-digestion, as food waste is an organic material with a high calorific and nutritive value for microorganisms, leading to an increase in methane production efficiency by several orders of magnitude [9]. In terms of leaf waste, lignocellulose material must be pretreated before being fed into a biogas production process [10]. The most significant physical pretreatment is a decrease in particle size, which leads to an increase in available surface area, and the microorganism can be easily degraded [11]. Therefore, the biogas production from food waste and leaf waste was effective.

4.2 Economic Feasibility

The biogas production system operates in a 10-liter, completely stirred reactor. The data obtained are used to calculate the biogas equivalent to liquid petroleum gas (LPG) and the project's economic value as a guideline for investment. The calculation of the economic value of the project is based on the volume of a 200-liter fermentation tank, with materials and equipment as the cost, at an average total price of 3,500 baht.

A 200-liter fermentation tank can produce biogas to replace cooking gas by converting food waste, leaf waste, and microorganisms into biogas. It can produce 0.66 cubic meters of methane per day and 240.9 cubic meters per year. Biogas 1.0 m3 equals LPG 0.46 Kg. Therefore, biogas can be converted to LPG 110.81 Kg LPG/Year. The project lifespan is calculated to be 10 years (based on the age of the equipment).

4.3 Benefit Cost ratio (BCR)

The calculation of the cost-benefit ratio is an analysis of the value of returns, investment and expenses in the project. Since the discount rate is the rate of return that the project investor expects to receive from the investment, taking into account the risk of the operation, the current interest rate calculation, and the investment opportunity, the discount rate is 10% with a project life of 10 years. The calculation of the BCR value, it was found to be 20.49, which, when considered according to the specified criteria, was found to be more than 1, indicating that this project provides returns that are worth the investment.

4.4 Net Present Value (NPV)

Calculating the net present value to consider whether the project will provide worthwhile returns can be calculated from the project life of 10 years, a discount rate of 10%, an initial cost of 3,500 baht, a maintenance cost of equipment every 2 years of 500 baht, and a return calculated from replacing cooking gas of 5,124.96 baht. The calculation found that the total net present value was positive, which is 26,527.67, indicating that the project is worthwhile investing.

4.5 Internal Rate of Return (IRR) and Payback Period (PBP)

The calculation of the project return rate, which considers the present value of net cash received throughout the project's life, is equal to the net cash paid for the initial investment. The project return rate must be greater than the investor's desired return rate. The calculation determined that the return rate is 142.24, indicating that the project is a worthwhile investment. The payback period of the project was 6 months and 8 days.

Table 1. Findings of microplastics concentration in plant**.**

Economic parameters	Results
NPV	26,527.67
IRR	142.24
PBP	6 months 8 days
B/C Ratio	20.49

The economic feasibility analysis of biogas production concludes that producing biogas from food waste, leaf waste, and microorganisms in an anaerobic wastewater treatment system can pay back within 6 months and 8 days, which can be used to adjust biogas production in various agencies.

5. Conclusion

The research demonstrates the economic feasibility of biogas production from food and leaf waste as a management tool for mitigating global warming impacts. The highest percentage of methane and cumulative methane production at laboratory scale were 70.19% and 34,417.81 ml, respectively. The economic feasibility analysis yielded a net present value of $ 26,527.67, an internal rate of return of 142.24%, a benefit-cost ratio of 20.49, and a payback period of 6 months and 8 days, respectively. Ultimately, this study can be aligned with Sustainable Development Goal 12.4, which focuses on reducing waste through reuse and recycling, and Sustainable Development Goal 7, which aims to ensure everyone has access to affordable, sustainable energy.

6. Patents

Author Contributions: A.S. Conceptualized the study, data curation and formal analysis. The original draft was prepared by A.S.

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Conflicts of Interest: The authors declare no conflicts of financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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