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BIOGAS PRODUCTION FROM NAPIER GRASS: AN INNOVATIVE APPROACH

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Introduction

Methane is the most dangerous greenhouse gas (GHG). It has an impact on climate change on a worldwide scale. In the global markets for commodities coal, petroleum crude oil, and natural gas are widely used as fuels, energy sources, and chemicals that emit carbon dioxide and carbon monoxide in a large amount and the global formation of fossil fuels takes millions of years, so their sources are finite and can run out rapidly. Malaysia is one country where most electricity is produced from fossil fuels. Therefore, the usage of biogas can be a suitable substitute for fossil fuels in the production of vehicle fuel, heat, and power, reducing emissions of greenhouse gases and mitigating climate change (Annimari, 2006). Products and waste from agriculture are primarily broken down to create biogas. Thailand has an abundance and diversity of agricultural feedstocks for the generation of biogas. Numerous potential crops, such as Napier grass, sorghum, sugarcane, and tree crops, are appropriate for producing biogas (Treedet *et al.,* 2020). This digestion is generally anaerobic. Anaerobic digestion is a biological process that uses microorganisms in an atmosphere of oxygen deprivation to break down organic materials. The usage of biogas replaced fossil fuels to produce power, heat, and fuel, hence it helps in reducing the emission of gases from the greenhouse and mitigating climate change (Annimari, 2006). According to the Ministry of New and Renewable Energy (MNRE) in India, the country had an estimated biogas production capacity of around 5,911.09 MWth (MegaWatt thermal) by the end of 2019. This capacity includes both centralized and decentralized biogas plants by using cow dung, agricultural waste, and other organic waste.

Understanding Napier Grass

Perennial C4 grasses, including Napier grass (*Pennisetum purpureum*) of the Poaceae family originating from Sub-Saharan Africa, have drawn more interest as a possible energy crop in countries like Thailand, and Malaysia (Pandey *et al.,* 2016). Napier Grass is a fast-growing, easy-to-harvest type crop that is low nutrient-demanding, high in lignocellulosic content, and may yield large amounts of biomass (Mehmood *et al.,* 2017). Napier grass is the primary source of Thailand's by producing 221,760,000 tonnes of biomass (Pomdaeng *et al.,* 2022). Napier grass has a high output of 87 tons/ha per year and may absorb up to 42% of CO2. Napier grass is thus appealing for the generation of biogas. Several experts have looked at and analyzed the process of converting Napier grass into biofuel. According to the findings, Napier grass contains three distinct phases that make up its energy source: a solid phase, a liquid phase, and a gas phase (Treedet and Suntivarakorn, 2018). Before utilizing Napier grass solid fuel, the moisture content must be reduced and the fuel must be converted to bulk solid because a lower moisture content and a higher bulk density directly affect the heating value of solid fuel. The optimal moisture content and bulk density for Napier grass are 10-15% wt and 1-1.28 kg/cm3, respectively. This indicates that approximately 50 kWh of power will be required to transform the grass into solid fuel (Divyabbharathi and Venkatachalam, 2015). However, the study result indicated that the thermal combustion of other biomass, such as Pinus or Eucalyptus, must be superior to Napier because Napier has a high content of ash (Rocha *et al.,* 2017). According to the study's findings, there was little output and a high energy conversion efficiency when Napier grass was turned into solid fuel.

Table 1: Yield Potential and Quality Characters

PARTICULARS	CO6	CO(BN)5	CO(CN_4)
Parentage	Interspecific hybrid between Fodder Cumbu CO 7 x Napier Grass FD 459 (Released for North West and Central Zone)	Interspecific hybrid between Fodder Cumbu IP 20594 x Napier grass FD 437	Interspecific hybrid between Cumbu CO 8 x FD 461
Duration (Days)	Perennial	Perennial	Perennial
QUALITY CHARACTERS			
Oxalate (%)	2.4	2.4	2.48
Crude Protein yield (t/ha)	9.6	9.6	8.71
Crude Protein (%)	11.5	14	10.71
Dry Matter yield (t/ha/yr)	83.6	80	79.87
Green fodder yield (t/ha/yr)	380 (7 harvests)	360-400 (7 harvests)	375-400 (7 harvests)

Process of Converting Napier Grass to Biogas

There are various methods of producing Biogas out of Napier Grass:

Anaerobic digestion: It breaks down organic matter without the presence of oxygen and produces biogas as a byproduct, this is the process used to produce biogas from Napier grass (Kongjan *et al.,* 2019).

- **Napier Grass Collection and Preparation:** Napier Grass is often referred to as Elephant grass, Napier grass is best picked while it's still fresh and green. To improve the grass's surface area and facilitate digestion, chop it into small pieces.
- **Loading or Filling the Digester:** A digester is filled with chopped Napier grass. An airtight tank or pit is constructed of concrete, plastic, or any other suitable material that can serve as the digester (Wen *et al.,* 2015).
- **Wetting (Optional):** To create the ideal environment for anaerobic digestion, you might need to add water depending on the grass's moisture level. Generally speaking, at least 80 percent of moisture content is ideal.
- **Inoculation of microbes:** To help the digestive process get underway, the addition of an anaerobic bacterial culture or a slurry made from cow dung if needed. This stage facilitates the quick formation of the microbial colony that produces biogas.

- **Sealing the Digester:** To generate anaerobic conditions, securely close the digester after filling it with Napier grass. By doing this, oxygen entry is prohibited, as oxygen might slow down the anaerobic digestion process.
- **Fermentation:** Allow a few weeks for the anaerobic digestion process to occur. The organic content in the Napier grass gets broken down by microbes during this period, creating biogas, which is a combination of carbon dioxide and methane.
- **Gas Collection and Storage:** To collect the biogas generated during fermentation, install a gas collecting system. Typically, this system comprises pipelines that go from the digester to the gas storage tank.
- **Gas Purification:** According to how the biogas will be used, you might need to purify it to get rid of contaminants like moisture and hydrogen sulfide. Desulfurization or filter equipment can be used for this (Wen *et al.,* 2015).

Pyrolysis: It is a type of thermochemical reaction that breaks down organic compounds at high temperatures (usually 400°C - 800°C) without the presence of oxygen. Napier grass is heated in a reactor during the pyrolysis process, which yields three primary products: syngas, biochar, and bio-oil to increase its methane concentration and use it as biogas, the syngas might undergo additional processing (Divyabbharathi and Venkatachalam, 2015).

- **Preparing the feedstock:** Napier grass is first dried until its moisture level is lowered, usually to less than 10%. The drying method can lower the energy needed to heat the biomass, which increases the pyrolysis process' efficiency.
- **Pyrolysis Process:** Next, the dried Napier grass is heated in a reactor a rotary kiln, or a fluidized bed reactor without the presence of oxygen. Generally, the temperature is kept between 400°C and 800°C, though there may be differences based on the pyrolysis method.
- **Product Formation:** Biochar which is a solid carbonaceous material, syngas a mixture of carbon monoxide, hydrogen, methane, and other gases and bio-oil, a liquid mixture of organic compounds, are the three main products that are produced during the thermal degradation of biomass during pyrolysis.
- **Syngas Utilization:** Following the proper conditioning and purification to eliminate contaminants like tar and others, the syngas generated from pyrolysis can be used directly as biogas. As an alternative, the syngas can undergo additional processing using methods like catalytic reforming to raise its methane concentration and enhance its biogas quality (Treedet and Suntivarakorn, 2018).

Gasification: It is a type of thermochemical reaction that transforms biomass at high temperatures (usually 700°C - 1,200°C) into a combustible gas (syngas) in the presence of regulated amounts of oxygen or steam. Napier grass is gasified by reacting the biomass in a gasifier reactor with a gasifying agent (such as steam, oxygen, or air). To make the generated syngas appropriate for use as biogas, it can be refined and purified to get rid of contaminants and raise its methane content (Barman *et al.,* 2012).

- **Feedstock Preparation:** Napier grass is dried to lower its moisture level before gasification, much as pyrolysis.
- **Gasification Process:** The process of gasification involves reacting dried Napier grass at high temperatures (usually between 700°C and 1,200°C) in a gasifier reactor with a gasifying agent such as air, oxygen, or steam. Insufficient oxygen inhibits full combustion, resulting in the creation of syngas, a combination of flammable gases.
- **Syngas Composition:** Several variables, including the type of gasifying agent employed, the temperature and pressure for operation, and the reactor's residence duration, affect the composition of syngas produced during gasification. Hydrogen, methane, carbon monoxide, and other gases are mostly found in syngas.

Figure 1: Process of Converting Napier Grass to Biogas

Challenges and Solutions in Napier Grass Biogas Production

Challenges:

- ✓ **High moisture content:** Napier grass has a high moisture content, which can negatively impact the efficiency of biogas production.
- ✓ **Nutrient imbalance:** Napier grass may have imbalances in its nutrient composition, which can affect the biogas production process.
- ✓ **Low biodegradability:** Napier grass has a high lignin content, which makes it less biodegradable and can hinder the biogas production process.
- ✓ **Inhibitors:** The presence of inhibitors in Napier grass, such as heavy metals and pesticides, can inhibit the activity of anaerobic bacteria and reduce biogas production.

Solutions:

- ✓ **Pre-treatment methods**: Pre-treatments such as alkali, dilute acid, or thermal treatments can be used to reduce the moisture content of Napier grass and increase biogas production efficiency.
- ✓ **Nutrient supplementation:** Balancing the nutrient composition through supplementation with nitrogen, phosphorus, and potassium can improve the biogas production process and enhance methane yield.
- ✓ **Lignin degradation:** Implementing biological and chemical methods to degrade lignin can improve the biodegradability of Napier grass and enhance biogas production efficiency.
- ✓ **Inhibitor:** It is important to implement proper feedstock selection and management practices, including sourcing Napier grass from uncontaminated areas and conducting proper treatment methods such as washing, detoxification, and contamination removal prior to anaerobic digestion.

Economic Analysis of Biogas Production from Napier Grass

The following two elements are included in the Cost-Benefit Analysis criteria.

a) Benefit Cost Ratio (B/C ratio): It is the ratio of a project's profit to its corresponding financial expenditures in terms of monetary.

Benefit-Cost ratio = PVC / PVB

Where PVC indicates present value cost and PVB indicates present value benefit

b) Net Present Value: The discrepancy over a certain time between the present value of cash inflows and outflows.

$$NPV = \sum_{n=1}^{N}\left(\frac{B_n}{(1+i)^n}\right) - TIC$$

where;

Bn = expected benefit at the end of year n

TIC = total initial cost (investment)

i = discount rate

n = project's duration in years

N = project's period.

It is possible to produce biogas by growing Napier grass. It took the place of LPG or liquefied petroleum gas. The equipment needed to produce biogas from Napier Grass costs 112.9 US dollars, while in the case of LPG, it costs 282.8 US dollars a year. The annual maintenance cost of Napier Grass was USD 77.4. The growth of Napier grass was 87 tons/ha/year. The calculation known as Net Present Value (NPV) is used to calculate the investment's present value by taking the discounted total of all project cash flows. When the value was positive, the NPV evaluation was approved. In the event of landing, the NPV was 39,216.4. In this instance, the economics of producing biogas were break-even (Mohammed *et al.,* 2019).

Conclusion

Napier grass is a highly promising, sustainable, and economically viable feedstock for biogas production, offering a strong alternative to fossil fuels. Its rapid growth, high yield, and low nutrient needs make it ideal for bioenergy. Conversion through anaerobic digestion and other methods effectively transforms Napier grass into methane-rich biogas, suitable for electricity, heat, and even as a replacement for LPG, while significantly reducing greenhouse gas emissions. Economically, biogas from Napier grass is feasible, with lower operational costs compared to conventional fuels, making it a financially sound investment. Beyond energy, it offers benefits like waste management and reduced reliance on imports. In short, Napier grass for biogas production represents a significant step towards a sustainable and clean energy future.

References

1. Annimari, L. (2006). Biogas production from energy crops and crop residues. *Jyvaskyla Studies in Biological and Environmental Science.* ISSN, 1456-9701.
2. Barman, N.S., Ghosh, S. & De, S. (2012). Gasification of biomass in a fixed bed downdraft gasifier–A realistic model including tar. *Bioresource Technology*, 107, 505-511.
3. Divyabharathi, R. & Venkatachalam, P. (2015). Energy conversion study on cumbu napier CO−4. *International Journal of Agriculture, Environment and Biotechnology*, 8(3), 727-733.
4. Kongjan, P., Reungsang, A., Phasukarratchai, N. & Sittijunda, S. (2019). Biogas production from single digestion of napier grass hydrolysate and co-digestion of solid fraction of microwave acid pretreated napier grass with swine manure. *Chiang Mai Journal of Science*, 46(4), 639-652.

5. Mehmood, M.A., Ibrahim, M., Rashid, U., Nawaz, M., Ali, S., Hussain, A. & Gull, M. (2017). Biomass production for bioenergy using marginal lands. *Sustainable Production and Consumption*, 9, 3-21.
6. Ministry of Energy. (2017). Energy balance of Thailand 2017. Report, Retrieved November 12, 2018.
7. Mohammed, I.Y., Abakr, Y.A. & Mokaya, R. (2019). Biofuel and valuable products recovery from Napier grass pre-processing: Process design and economic analysis. *Journal of Environmental Chemical Engineering*, 7(2), 102962.
8. Pandey, V.C., Bajpai, O. & Singh, N. (2016). Energy crops in sustainable phytoremediation. *Renewable and Sustainable Energy Reviews*, 54, 58-73.
9. Pomdaeng, P., Chu, C.Y., Sripraphaa, K. & Sintuya, H. (2022). An accelerated approach of biogas production through a two-stage BioH2/CH4 continuous anaerobic digestion system from Napier grass. *Bioresource Technology*, 361, 127709.
10. Treedet, W. & Suntivarakorn, R. (2018). Design and operation of a low cost bio-oil fast pyrolysis from sugarcane bagasse on circulating fluidized bed reactor in a pilot plant. *Fuel Processing Technology*, 179, 17-31.
11. Treedet, W., Suntivarakorn, R., Mufandi, I. & Singbua, P. (2020). Bio-oil production from Napier grass using a pyrolysis process: Comparison of energy conversion and production cost between bio-oil and other biofuels. *International Energy Journal*, 20(2), 155-168.
12. Wen, B., Yuan, X., Li, Q.X., Liu, J., Ren, J., Wang, X. & Cui, Z. (2015). Comparison and evaluation of concurrent saccharification and anaerobic digestion of Napier grass after pretreatment by three microbial consortia. *Bioresource Technology, 175, 102-111.*