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Case Study on Production of Biogas from Paddy Straw

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Abstract: ***India is the second-largest rice producer in the world, accounting for over 20% of global production. Rice is a major crop in India, covering around 43 million hectares of land. Major rice-producing states in India are West Bengal, Uttar Pradesh, Punjab, Andhra Pradesh, and Tamil Nadu. There are different types / Rice varieties, India grows over 6,000 varieties of rice. In which Popular varieties include Basmati, Jasmine, and Non-Basmati. The production seasons are Kharif (June-September): The main rice-growing season and Rabi (October-March): The secondary rice-growing season. Average yield of 2.5-3.5 tons per hectare and a total production of Over 110 million tons per year. There are many initiatives taken by GOI to promote the rice cultivation in India some of then are National Food Security Mission (NFSM) to increase rice production, and Rice Export Policy to promote exports. The increasing demand for rice globally provokes India to cultivate more and more rice and similarly increasing the export potential. Also shifting and trying new varieties or diversification to other rice varieties. GOI must ensure for the sustainable rice cultivation practices. Growing of more and more rice will also increase the agriculture waste called as paddy straws, in India, paddy straw is often burned, causing air pollution, but initiatives promote its use for bioenergy and composting. In China, Japan, and many other countries, uses paddy straw for bioenergy, animal feed, and paper production. Also Globally United Nations Food and Agriculture Organization (FAO) promotes sustainable use of paddy straw for bioenergy, animal feed, and soil amendment, similarly the International Energy Agency (IEA) recognizes paddy straw as a potential feedstock for bioenergy and biofuels.***

Keywords: Paddy Straw, Bio Gas, Compressed Bio Gas (CBG), Green fuel, Agriculture waste

1. Introduction

Paddy straw, abundant agricultural waste, can be converted into biogas, a clean and renewable energy source. Anaerobic digestion of paddy straw produces a mixture of methane (CH4) and carbon dioxide (CO2), which can be used as fuel for cooking, lighting, and power generation. The biogas production process involves feeding paddy straw into a digester, where microorganisms break down the organic matter, releasing biogas. The gas is then collected, stored, and utilized.

Biogas from paddy straw has numerous benefits:
- Renewable energy source
- Reduces greenhouse gas emissions
- Provides energy independence
- Creates additional income for farmers
- Minimizes waste and pollution

The biogas produced can replace fossil fuels, reducing reliance on non-renewable energy sources. Additionally, the digested slurry can be used as organic fertilizer, enriching soil health. With the vast availability of paddy straw, biogas production has immense potential to contribute to a sustainable energy future. By harnessing this energy source, we can reduce our carbon footprint and promote a cleaner environment.

Paddy straw, also known as rice straw, is the biomass left over after harvesting rice. Paddy straw is widely available in rice-producing countries, with an estimated global production of over 700 million tons per year. Paddy straw is primarily composed of:

- Cellulose (35-40%)
- Hemicellulose (20-25%)
- Lignin (10-15%)
- Moisture (5-10%)
- Ash (5-10%)

Paddy straw has a high energy content, with a calorific value of around 14-16 MJ/kg. Paddy straw can be used for:
- Animal bedding and feed
- Composting and soil amendment

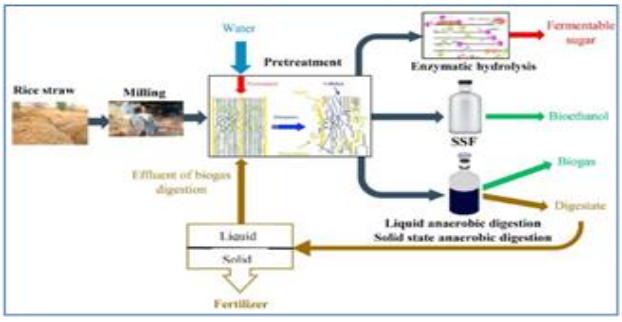

Figure 1: Flowchart showing paddy straw

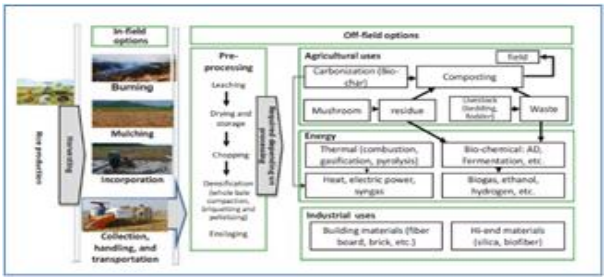

Figure 2: Paddy straw different utilizations

- Bioenergy production (biogas, bioethanol, and bioelectricity)
- Paper and pulp production
- Building materials and insulation

Here's a step-by-step overview of biogas production from paddy straw:

1) *Collection and Preparation:* Paddy straw is collected, cleaned, and chopped into smaller pieces to increase its surface area.
2) *Anaerobic Digestion:* The chopped paddy straw is fed into an anaerobic digester, a sealed tank or container, where it is broken down by microorganisms in the absence of oxygen.
3) *Microbial Action:* The microorganisms, such as bacteria and archaea, convert the complex organic matter in paddy straw into simpler compounds, releasing biogas (a mixture of methane and carbon dioxide).
4) *Biogas Production:* The biogas is produced as the microorganisms feed on the paddy straw, typically taking 15-30 days.
5) *Gas Collection:* The biogas is collected and stored in a gas holder or tank.
6) *Scrubbing and Purification:* The biogas may undergo scrubbing and purification to remove impurities, such as hydrogen sulfide (H_2S) and water vapor (H_2O), Carbon di Oxide (CO_2).
7) Utilization: The purified biogas can be then compressed to a pressure of 250 bar and can be bottled known as CBG (Compressed Bio Gas) this CBg is easy to transport and then can be used for:
   - Cooking and heating
   - Electricity generation
   - Fuel for vehicles
   - Industrial processes

Anaerobic Digester Types:

1) Batch Digester: A simple, low-cost design where paddy straw is added in batches.
2) Continuous Digester: A more efficient design where paddy straw is continuously fed into the digester.
3) Fixed Dome Digester: A popular design with a fixed dome-shaped roof.
4) Floating Drum Digester: A design with a floating drum that rises and falls with biogas production.

Factors Affecting Biogas Production:

1) Temperature: Optimal temperature ranges from 25°C to 40°C.
2) pH: Optimal pH ranges from 6.5 to 7.5.
3) Moisture: Optimal moisture content ranges from 80% to 90%.
4) Retention Time: The time paddy straw spends in the digester affects biogas production.

What is the need of Pretreatment of Peddy Straw--

1) *Breakdown of lignin:* Paddy straw contains lignin, a complex polymer that makes it difficult for microorganisms to break down. Pretreatment helps to break down lignin, making the straw more accessible to microorganisms.
2) *Increase in surface area:* Pretreatment can increase the surface area of paddy straw, allowing microorganisms to attack the straw more easily.
3) *Removal of impurities:* Pretreatment can remove impurities like dirt, stones, and other contaminants that can inhibit digestion.

Figure 3: Crushed paddy straw (5mm to 10 mm)

4) *Reduction of cellulose crystallinity:* Pretreatment can reduce the crystallinity of cellulose, making it easier for microorganisms to break down.
5) *Hydrolysis of hemicellulose:* Pretreatment can hydrolyze hemicellulose, a complex carbohydrate that can be difficult for microorganisms to break down.
6) *Improved biogas yield:* Pretreatment can improve biogas yield by making more of the straw's organic matter available to microorganisms.

Common pretreatment methods include:

1) Physical pretreatment: Milling, grinding, or chopping to increase surface area.
2) Chemical pretreatment: Using acids, alkalis, or enzymes to break down lignin and hemicellulose.
3) Biological pretreatment: Using microorganisms or enzymes to break down lignin and hemicellulose.
4) Thermal pretreatment: Heating the straw to break down lignin and hemicellulose.
5) Mechanical pretreatment: Using mechanical forces to break down the straw.

Collection, Storage, Shredding and pre-treatment of paddy for better digestion—

Collection Methods:

Figure 4: Storage system of paddy straw

- Manual Collection: Laborers collect paddy straw from fields, often bundling it into small sheaves.

- Mechanized Collection: Machines like balers, bundlers, or straw harvesters collect and bundle paddy straw.
- Combine Harvester: Some combine harvesters are equipped with straw collection attachments.

Chopping Methods:
- Manual Chopping: Laborers chop paddy straw using sickles, machetes, or knives.
- Mechanical Chopping: Machines like choppers, shredders, or hammer mills chop paddy straw into smaller pieces.
- Baler-Chopper: Some balers come equipped with chopping mechanisms.

Chopping Sizes:
- Coarse Chopping: 5-10 cm (2-4 inches) for anaerobic digestion or composting.
- Fine Chopping: 1-5 cm (0.5-2 inches) for biogas production or biofuel applications.

Equipment Used:
- Tractors: With attached balers, choppers, or straw harvesters.
- Balers: Round or square balers for collecting and bundling paddy straw.

Figure 5: Tractor with baler

- Choppers: Tractor-mounted or standalone choppers for cutting paddy straw.
- Shredders: Used for fine chopping or shredding paddy straw.
- Hammer Mills: Used for fine chopping or grinding paddy straw.

"Biogas produced from paddy straw, or rice straw, is a mixture of gases that includes methane (CH4), carbon dioxide (CO2), hydrogen (H2), nitrogen (N2), and hydrogen sulfide (HS). The composition of biogas can vary, but methane is usually the major component, making up 50–75% of the gas. Other components may include small amounts of moisture and siloxanes." [4]

"Biogas is produced through a biological process called anaerobic digestion (AD) that breaks down organic matter in the absence of oxygen. AD of rice straw involves four phases, including hydrolysis and acid-producing. During hydrolysis, enzymes and anaerobic bacteria decompose insoluble organic compounds. In the acid-producing phase, simple organic compounds are converted into volatile fatty acids, long chain fatty acids, propionate, and butyrate." [4]

"Biogas can be used as a renewable energy source in a variety of ways. It can be combusted or oxidized with oxygen to release energy, which can be used for heating, in fuel cells, or to convert the gas into electricity and heat in a gas engine. Biogas can also be cleaned and upgraded to natural gas standards, which is known as biomethane. Once carbon dioxide and hydrogen sulfide are removed, biomethane can be compressed and used to power vehicles, similar to natural gas." [5]

There are many benefits of producing biogas from Paddy straw like:
- Renewable and sustainable resource
- Can help reduce greenhouse gas emissions
- Can provide additional income for farmers
- Can help reduce waste and pollution

Table 1: CBG generation by different feedstock as per SATAT data

The type of feedstock to be used for CBG production and financial viability of a plant depends on many factors like cost of input feedstock, location of plant, etc. As per SATAT scheme, the responsibility of setting up of CBG plant lies with the entrepreneur and therefore applicant is requested to assess CBG production and financial viability of its plant by itself.

The following tentative yield of various feedstocks are normally considered as per discussion with various existing and proposed CBG Plants and various technology providers. However these are only directional in nature and actual yield may vary substantially depending on quality of feed stock.

Feedstock	CBG Production(Ton)	Feedstock requirement (Tentative)
Agriculture Residue	1	10 Ton
Press Mud	1	25 Ton
Spent Wash	1	10 KL
Bagasse	1	10 Ton
Municipal Solid waste	1	20 Ton
Cow Dung	1	50 Ton
Chicken Litter	1	25 Ton
Forest Residue	1	15 Ton
Napier Grass	1	10 Ton
Sewage Waste	1	15 MLD

2. Suggestions

1) Feedstock Management: Ensure a consistent supply of paddy straw, and implement a feedstock management system to handle variations in quality and quantity.
2) Pretreatment: Implement a suitable pretreatment method to break down lignin and increase the surface area of
3) Digester Design: Opt for a digester design that suits the local climate and paddy straw characteristics, such as a fixed dome or floating drum digester.
4) Co-Digestion: Consider co-digesting paddy straw with other organic materials to optimize biogas production and reduce inhibitory effects.
5) Microbial Management: Monitor and manage microbial populations to ensure optimal biogas production and minimize pathogens.
6) Gas Purification: Implement a gas purification system to remove impurities and increase the methane content of the biogas.
7) Energy Generation: Utilize the biogas for energy generation through a combined heat and power (CHP) system or a biogas genset.
8) Slurry Management: Develop a plan for managing the digested slurry, such as using it as organic fertilizer or animal feed.
9) Monitoring and Control: Install monitoring systems to track biogas production, temperature, pH, and other parameters to ensure optimal plant performance.
10) Training and Capacity Building: Provide training and capacity-building programs for operators and maintenance staff to ensure smooth plant operation.
11) Scalability: Design the plant with scalability in mind, allowing for future expansion or upgrading.

12) Environmental Impact Assessment: Conduct an environmental impact assessment to identify potential risks and develop strategies for mitigation.

Paddy straw can be converted into various forms of energy using technologies like:

- Anaerobic digestion (biogas)
- Gasification (syngas)
- Pyrolysis (biooil)
- Combustion (heat and electricity)

3. Conclusion

Paddy straw is considered an excellent feedstock for biogas production due to its high organic matter content that is ideal for biogas production. Also the Paddy straw has a relatively low lignin content compared to other agricultural residues, making it easier for microorganisms to break down. The Paddy straw contains a high amount of cellulose and hemicellulose, which are easily convertible into biogas. It also has a C:N ratio of around 50-60, which is close to the optimal range for biogas production. It is also widely available as a by-product of rice cultivation, making it a readily available feedstock. The paddy straw is often considered a waste material, making it a low-cost feedstock for biogas production. The biogas produced from paddy straw contains a high percentage of methane (around 60-70%), making it suitable for energy production. Paddy straw can be co-digested with other organic materials, allowing for flexibility in biogas production. Utilizing paddy straw for biogas production reduces waste, mitigates greenhouse gas emissions, and promotes sustainable agriculture practices, as the economical out put will also aware the farmers not to burn it and instead sell it for energy production and help in green house emission reduction.

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