Analyzing the Influential Factors Affecting the Efficiency of Floating Drum Systems

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ABSTRACT

This research paper focuses on two key areas of renewable energy solutions in India: biomass-based power generation and the efficiency of floating drum systems for harnessing wave energy. With the continuous increase in energy demand driven by population growth and industrial development, alternative energy sources are imperative. Regarding biomass-based power generation, India's abundant agricultural resources offer a significant stockpile of biomass for energy generation. The study explores various biomass sources, including fruits waste and animal waste. It examines different processes such as slurry-based systems and gasification to extract energy from biomass. These processes provide energy efficiency, environmental cleanliness, and economic viability in producing heat and electricity. The paper also considers the future prospects of biomass-based power generation systems, emphasizing their potential to address cooking challenges and provide energy access in rural areas through distributed systems. The findings highlight biomass as a promising renewable energy source, aligning with India's sustainable development goals. In terms of floating drum systems, which harness wave energy, the research investigates key factors influencing their efficiency. Specifically, the paper focuses on substrate feed, temperature, pH value, organic loading rate, and hydraulic retention time in biogas production systems. Through an analysis of existing literature and case studies, the research provides insights into the factors significantly impacting the efficiency of floating drum alternatives. The findings contribute to a better understanding of the operational characteristics of these systems and inform the development of optimized designs and strategies for enhanced efficiency.

Keywords: *biomass-based power generation, floating drum systems, renewable energy solutions, energy demand, slurry-based systems, gasification*

INTRODUCTION

The demand for energy in India has been experiencing an unprecedented rise due to a combination of factors such as rapid population growth and industrial development. This surge in energy requirements poses significant challenges to the conventional energy sector, primarily reliant on finite resources like coal, oil, and gas[1]. To address this pressing issue, it becomes imperative to explore alternative and sustainable sources of energy that can meet the escalating demand while mitigating the adverse environmental impacts associated with traditional energy production. Biomass-based power generation emerges as a promising solution in India's renewable energy landscape. The country, endowed with vast agricultural resources, possesses a substantial stockpile of biomass materials that can be harnessed to produce renewable energy. This biomass comprises a diverse range of organic waste, including agricultural residues, fruit waste, animal waste, and forestry by-products. The utilization of these resources not only reduces waste disposal challenges but also offers a viable pathway towards achieving energy access for all segments of the population[2]. One of the key areas of focus in this research paper is the efficient extraction of energy from biomass. Different technological processes, such as slurry-based systems and gasification, are explored for their potential to convert biomass into usable heat and electricity. These processes exhibit high energy efficiency, low environmental impact, and economic viability, making them attractive for widespread adoption[3]. Moreover, the paper delves into the future prospects of biomass-based power generation systems, highlighting their capacity to address prevalent cooking challenges in rural areas and facilitate decentralized energy access[4]. In addition to biomass-based power generation, this research also investigates the efficiency of floating drum systems for harnessing wave energy. These innovative devices have garnered considerable attention as a renewable energy solution, capitalizing on the immense potential of ocean waves[5]. By capturing and converting wave energy into usable electricity, floating drum systems offer a sustainable and environmentally friendly approach to meet the surging energy demand. The research delves into various factors influencing the efficiency of these systems, including substrate feed, temperature, pH value, organic loading rate, and hydraulic retention time, to optimize their performance and maximize energy output. The growing demand for renewable energy sources and the need to address environmental concerns have led to increased research and development in the field of biogas production[6]. Biogas, a mixture of methane and carbon dioxide gases, is generated through the anaerobic digestion of organic waste materials such as industrial waste, livestock waste, and agricultural residues. It serves as a clean and sustainable energy alternative to fossil fuels, contributing to energy security and reducing greenhouse gas emissions. In recent studies conducted by Saran Khotmanee and Unnat Pinsopon, the biogas production potential in Thailand was investigated, focusing on industrial plants with high organic content waste, including ethanol, starch, palm oil, rubber, food, and alcoholic beverage plants. These studies aimed to evaluate the status and potential of biogas production in the country, considering waste from industrial plants, livestock, and agricultural sources. The findings were crucial in aligning with the Alternative Energy Development Plan (AEDP2015) of Thailand, which aims to increase the share of renewable energy in the gross energy consumption to 30% by 2036[7]. The plan also targets the replacement of refined petroleum with compressed biogas for daily use and the utilization of biogas for electricity generation. Man Zhou and Zhiyang Zou developed an expert system for rural biogas engineering, integrating renewable energy technologies and efficient eco-agricultural practices. This system consists of various modules, including biogas pretreatment, installation and use of biogas equipment, biogas engineering fault diagnosis, and biogas comprehensive utilization. The system's design and knowledge base management facilitate sustainable and stable operation of rural biogas engineering at different scales, ensuring temperature and pH control, gas yield rate, and methane concentration. Large-scale biogas plants, such as the one studied by Xiaolin Fan and colleagues in Beijing, have proven successful in converting livestock manure into clean electricity, heat, and organic fertilizers[8]. These comprehensive biogas systems contribute to the efficient utilization of resources and serve as models for similar projects worldwide. In India, Giriraj Prasad Sen and his team conducted a feasibility study on generating electricity from biogas at the community level in rural Rajasthan. By implementing a biogas power plant at a gaushala (cattle shelter), they were able to generate a significant amount of electricity from biogas, promoting renewable energy and energy security in rural areas. The study highlights the technical and economic analysis of grid-connected biogas power plants, emphasizing the role of biogas as a reliable and clean energy source. Tresor K. Kumba and his team focused on the design methodology of domestic mechanical anaerobic digesters[9]. Their study emphasized the importance of factors such as organic loading rate, hydraulic retention time, and waste selection in designing continuous digester systems. The research highlights the sustainability and scalability of anaerobic digesters in various countries, discussing key factors influencing their design and implementation. In Indonesia, Ibnu Budiman analyzed the effectiveness of two biogas technologies for energy security: fixed-dome digesters and floating drum digesters. The study found that both designs were equally effective and reliable, although certain regions experienced issues due to a lack of adherence to construction standards[10]. Both designs contribute to the sustainability, availability, and affordability aspects of the country's energy system, particularly in earthquake-prone areas. Pakistan, an agriculture-based developing country, faces energy challenges. Salman Ahmad and his team explored the potential of biogas as a viable energy source in Pakistan, specifically through the use of fixed-dome digesters and the implementation of a gas recovery chamber. The introduction of the gas recovery chamber in fixed dome biogas plants significantly increased gas yield, contributing to the energy sustainability of the country[11]. By combining in-depth analysis, empirical studies, and insights from existing literature, this research paper aims to provide valuable contributions to the understanding and advancement of biomass-based power generation and floating drum systems in India. The findings and recommendations generated from this research will inform policy decisions, technological developments, and strategic planning to accelerate the adoption of sustainable and renewable energy solutions. Ultimately, this research endeavors to pave the way for a greener and more sustainable energy future for India, aligning with the nation's ambitious sustainable development goals. Biogas production through anaerobic digestion is a promising renewable energy solution that relies on the efficient breakdown of organic matter. This research paper focuses on the factors that influence substrate feed, temperature, pH value, organic loading rate, and hydraulic retention time in biogas production systems. Substrate feed refers to the composition and quality of organic materials introduced into the digester. The selection and preparation of substrates significantly impact biogas yield and composition. Factors such as feedstock type, nutrient content, and particle size play crucial roles in the efficiency of the anaerobic digestion process[12]. Temperature is a critical parameter in biogas production, as it affects the activity and diversity of microorganisms responsible for organic matter degradation. Optimal temperature ranges are determined by the specific microbial communities involved in the digestion process. Deviations from the ideal temperature can lead to decreased biogas production and process instability. The pH value of the digester influences microbial activity and fermentation pathways. Maintaining the appropriate pH range is essential for the growth of acidogenic and methanogenic bacteria. Acidification or alkalization can disrupt the microbial balance and hinder biogas production. Organic loading rate (OLR) refers to the quantity of organic matter fed into the digester per unit time. OLR impacts the microbial population dynamics, substrate utilization efficiency, and biogas yield. High OLRs can cause process inhibition and reduced methane production, while low OLRs may result in underutilization of the digester's capacity. Hydraulic retention time (HRT) determines the duration of substrate contact with microorganisms in the digester. Proper HRT management ensures sufficient time for organic matter degradation and methane production. An inadequate HRT can limit the conversion of complex substrates and decrease biogas production. Understanding and optimizing these factors are crucial for maximizing biogas production efficiency. Through a comprehensive analysis of existing literature and case studies, this research paper aims to provide insights into the influence of substrate feed, temperature, pH value, organic loading rate, and hydraulic retention time on biogas production. The findings will contribute to the development of strategies for optimizing biogas production systems and promoting their adoption as sustainable renewable energy solutions.

MATERIALS

The substrate feed for the 200 m3 capacity digester consists of biowaste, which includes fruit waste and cow dung. Biowaste is a combination of organic materials that are suitable for anaerobic digestion and biogas production. Fruit waste constitutes approximately 80% of the biowaste feed. It includes discarded fruit peels, pulp, and other residues obtained from local fruit markets. Fruit waste serves as a rich source of organic matter and contributes to the overall biogas production process. Cow dung makes up the remaining 20% of the biowaste feed. It is sourced from local farms and is known for its high nutrient content and biogas production potential. Cow dung adds additional organic matter to the digester, enhancing the biogas generation process. The power produced from the biogas generated in the digester is measured using a gas generator. The gas generator converts the methane gas produced during anaerobic digestion into electricity, which is measured in kilowatt-hours (kWh).

METHODS

The FD is a low-cost biogas digester that utilizes anaerobic digestion to convert organic matter into valuable energy for electricity generation and cooking purposes (Fig.2). The floating design of the digester serves multiple purposes. Firstly, it prevents flooding by allowing excess liquid to escape. Secondly, it contains the heat produced during the digestion process. Additionally, the floating drum technology has proven to be more reliable in areas with seismic activity, as it is robust against earthquakes (Fig.1).

Figure 1: Floating drum

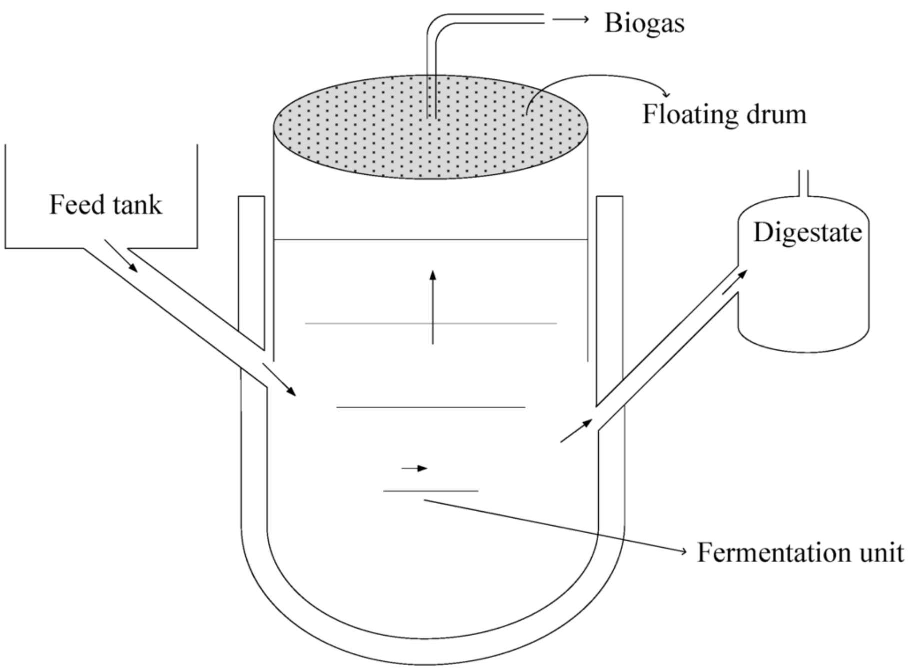


Figure 2: floating drum digester

The floating design of the drum serves multiple purposes. It prevents flooding by allowing excess liquid to escape, while containing the heat produced during the anaerobic digestion process. This design feature helps maintain the efficiency of the biogas production process. The research paper highlights the robustness of the FD against earthquakes, making it more reliable than other biogas technologies in areas prone to seismic activity. The initial construction of the digester involves using brick, concrete, or quarry stone masonry with plaster. However, to overcome maintenance challenges and increase the drum's lifespan, alternative materials such as glass-fiber reinforced polyester and high-density polyethylene are used. These materials reduce maintenance costs and provide a longer lifespan compared to steel drums.

RESULTS AND DISCUSSIONS:

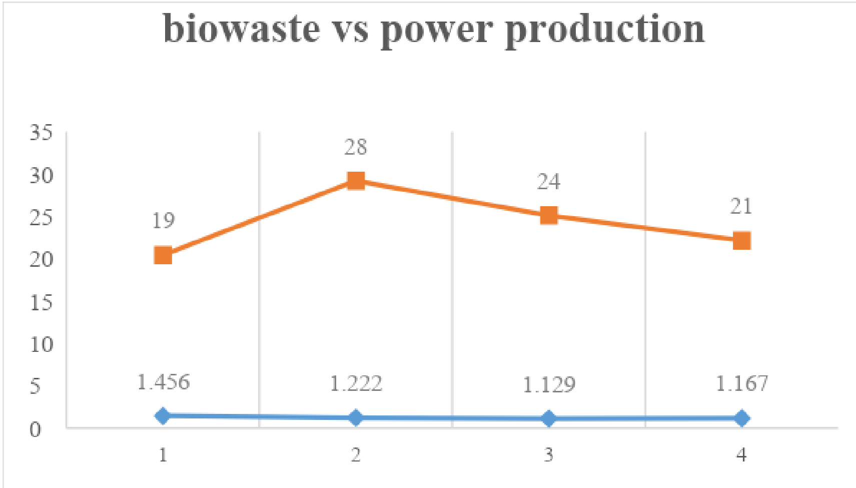
SUBSTRATE FEED

The table1 presents data on the substrate feed and cumulative power produced by the digester during the period from 22nd February 2023 to 27th February 2023.

Table 1: Substrate feed vs Power produced

SI.NO.	BIOWASTE in Ton	FRUIT WASTE (80 % of B.W.)	COW DUNG (20% of B.W.)	CUM. POWER in KWh	POWER in kWh
1	1.456	1.1648	0.2912	2211	19
2	1.222	0.9776	0.2444	2230	28
3	1.129	0.9032	0.2258	2258	24
4	1.167	0.9336	0.2334	2282	21
5	1.248	0.9984	0.2496	2303	26

The presented table provides the substrate feed and cumulative power produced by the digester during the period from 22nd February 2023 to 27th February 2023. The substrate feed consists of fruit waste, which accounts for 80% of the total biowaste, and cow dung, which accounts for the remaining 20%. The cumulative power produced is measured in kilowatt-hours (KWh). Throughout the observation period, the substrate feed varied between 1.129 tons and 1.456 tons. The corresponding fruit waste ranged from 0.9032 tons to 1.1648 tons, while the cow dung ranged from 0.2258 tons to 0.2912 tons. These variations reflect the availability and composition of the biowaste during the specified timeframe. The cumulative power produced by the digester increased steadily over the course of the observation period, starting from 2211 KWh and reaching 2303 KWh by the end. The power generated in each individual measurement ranged from 19 kWh to 28 kWh. The results suggest that the substrate feed, primarily consisting of fruit waste and supplemented with cow dung, contributes to the production of biogas and subsequent power generation. The varying amounts of substrate fed to the digester directly impact the cumulative power output, indicating the importance of maintaining a consistent and sufficient feedstock supply for optimal energy production.



Graph 1: Substrate feed Vs Power

The comparison of substrate feed and cumulative power production for the months of March and April provides further insights into the performance of the digester. The table presents the substrate feed and cumulative power produced during a ten-day observation period from 6th March 2023 to 16th March 2023.

Table2: Substrate feed Vs Power production on April

SI.NO.	BIOWASTE in Ton	FRUIT WASTE (80 % of B.W.)	COW DUNG (20% of B.W.)	CUM. POWER in KWh	POWER in kWh
1	1.43	1.144	0.286	2835	17
2	1.080	0.864	0.216	2854	19
3	1.124	0.8992	0.2248	2874	20
4	0.834	0.6672	0.1668	2885	11
5	0.781	0.6248	0.1562	2900	15
6	0.723	0.5784	0.1446	2900	0
7	0.768	0.6144	0.1536	2914	14
8	1.311	1.0488	0.2622	2932	18
9	1.410	1.128	0.282	2945	13
10	1.009	0.8072	0.2018	2958	13

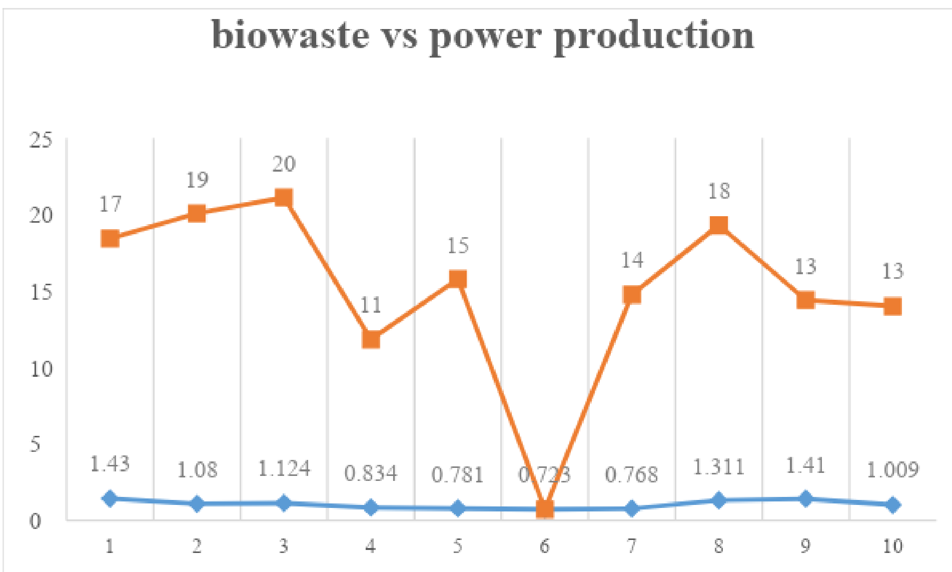
The substrate feed during this period ranged from 0.839 tons to 1.471 tons. As observed in the previous period, fruit waste accounted for approximately 80% of the biowaste, while cow dung constituted the remaining 20%. The specific quantities of fruit waste and cow dung fed to the digester varied for each recorded measurement.

The cumulative power generated by the digester during this period increased gradually, starting at 2426 KWh and reaching 2578 KWh by the end of the observation period. The individual power values ranged from 11 kWh to 25 kWh for the recorded measurements.

Comparing the results from March with the previous period, it is evident that the substrate feed and cumulative power production varied. The substrate feed fluctuated, indicating potential variations in the availability or composition of the biowaste during this period. Despite the variations, the digester continued to generate power, highlighting its resilience and ability to utilize different feedstock compositions.

The power values obtained during this period were generally lower than those recorded in the previous period. However, it is essential to consider that these results represent a short-term analysis, and variations in power production can be influenced by multiple factors, including waste composition, environmental conditions, and digester operation.

These findings emphasize the importance of continuous monitoring and analysis of the digester's performance to optimize its operation and maximize energy production. Long-term studies are necessary to assess the stability, efficiency, and overall performance of the digester over extended periods of operation.



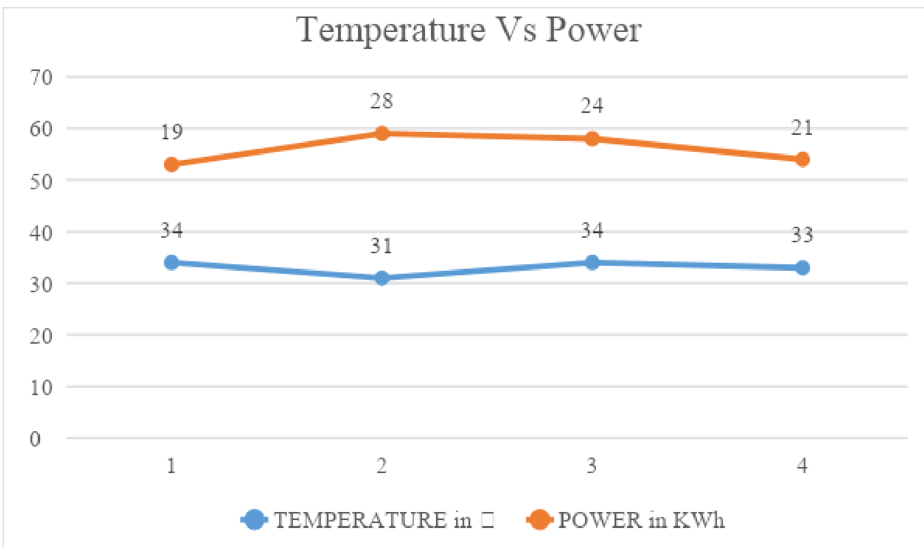
Graph 2.: Substrate feed Vs Power production

TEMPERATURE

Table 3 presents the recorded temperature and corresponding power production data for the floating drum digester during the period from 22nd February 2023 to 27th February 2023. The temperature is an important parameter in biogas digesters, and maintaining an optimal temperature is crucial for efficient methane production. Throughout the observed period, the digester maintained a mesophilic condition, with temperatures ranging from 31°C to 34°C. It is worth noting that mesophilic conditions favor the activity of methanogens, resulting in higher biogas production compared to psychrophilic conditions. The power production values recorded during this period ranged from 19 kWh to 28 kWh for the available data points. The power production values are a reflection of the methane gas produced by the digester during the respective temperature conditions. However, the power production for the last recorded date is

Table 3: Temperature Vs Power

SI.NO.	DATE	DAY	TEMPERATURE in ℃	POWER in KWh
1	22.02.2023	Wednesday	34	19
2	23.02.2023	Thursday	31	28
3	24.02.2023	Friday	34	24
4	25.02.2023	Saturday	33	21
5	27.02.2023	Monday	34	-

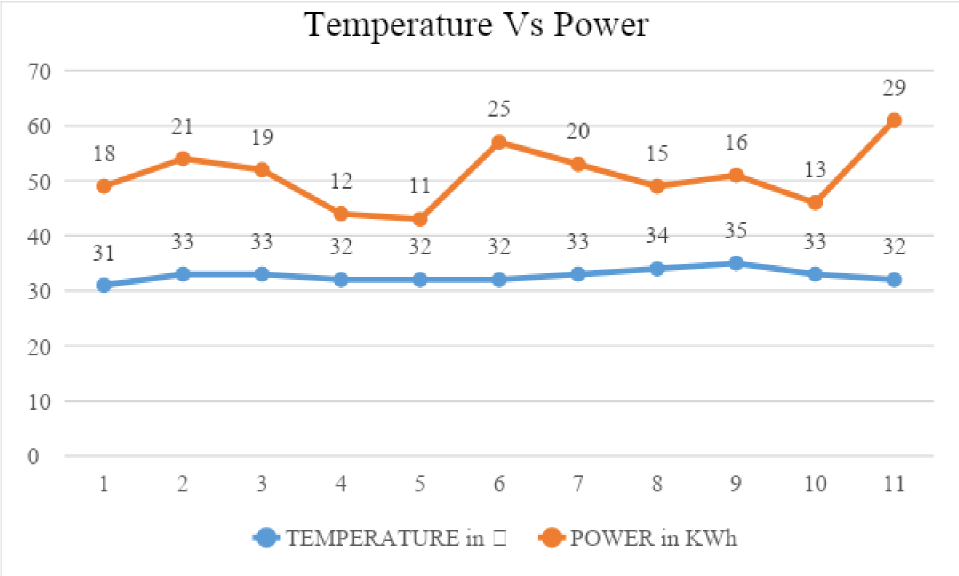


Graph 3: Temperature Vs Power Production on February

not available. The data suggest that the digester was able to produce a significant amount of power even under mesophilic conditions, where temperatures were relatively higher. This highlights the effectiveness of maintaining a mesophilic temperature range for maximizing biogas production and subsequently generating power. It is important to note that the recorded temperature values represent a short-term observation, and further analysis is necessary to evaluate the long-term impact of temperature on power production and overall digester performance. Factors such as substrate composition, HRT (Hydraulic Retention Time), and operational parameters can also influence power production in conjunction with temperature.

Table 5: Temperature Vs Power during March.

SI.NO.	DATE	DAY	TEMPERATURE in °C	POWER in KWh
1	06.03.2023	Monday	31	18
2	07.03.2023	Tuesday	33	21
3	08.03.2023	Wednesday	33	19
4	09.03.2023	Thursday	32	12
5	10.03.2023	Friday	32	11
6	11.03.2023	Saturday	32	25
7	13.03.2023	Monday	33	20
8	14.03.2023	Tuesday	34	15
9	15.03.2023	Wednesday	35	16
10	16.03.2023	Thursday	33	13



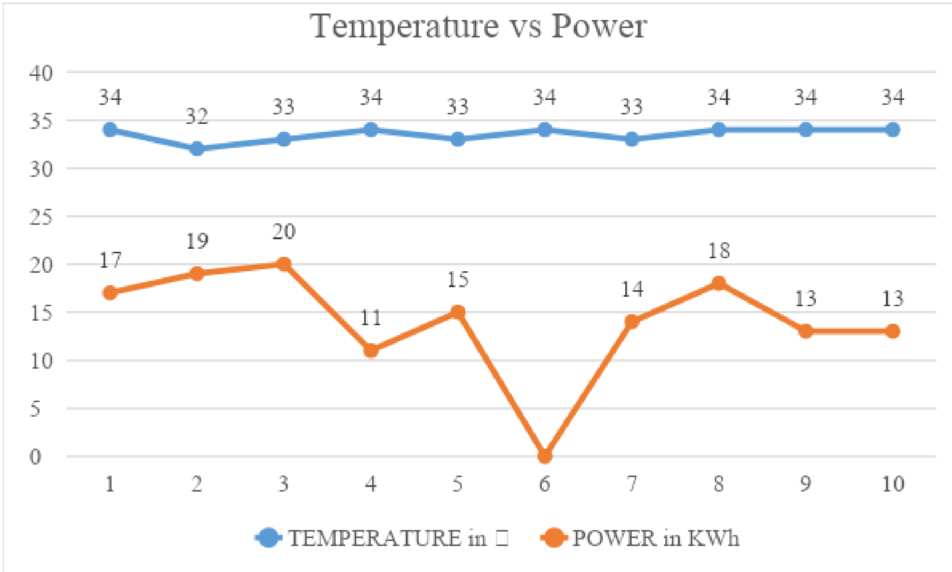
Graph 5: Temperature Vs Power on March

Table 5 provides the recorded temperature and corresponding power production data for the floating drum digester during the month of March. The temperature is an important parameter in biogas digesters, as it affects the activity of methanogens and consequently, the biogas production. Throughout the month of March, the digester maintained temperatures ranging from 31°C to 35°C. The recorded temperature values represent different days of the week, indicating variations in temperature throughout the observation period. The power production values recorded during this month ranged from 11 kWh to 25 kWh for the available data points. The power production values are indicative of the biogas produced by the digester during the respective temperature conditions. To further analyze the relationship between temperature and power production, a graph was plotted using the recorded temperature values against the corresponding power production values. This graph provides a visual representation of the trend and allows for a better understanding of the relationship between these two variables. It is important to note that the recorded temperature and power production data for March provide insights into the short-term performance of the digester. Further analysis and monitoring over an extended period would be necessary to evaluate the long-term impact of temperature on power production and overall digester efficiency.

The data collected during March contribute to the understanding of the digester's performance under different temperature conditions. By observing the power production at varying temperatures, it is possible to assess the optimal temperature range for maximizing biogas production and power generation in the floating drum digester. Additionally, the temperature and power production data for the month of April, as well as any subsequent data, would provide a comprehensive analysis of the digester's performance over a longer period, allowing for more robust conclusions regarding the influence of temperature on power production.

Table 6: Temperature Vs Power during April

SI.NO.	DATE	DAY	TEMPERATURE in ℃	POWER in KWh
1	03.04.2023	Monday	34	17
2	04.04.2023	Tuesday	32	19
3	05.04.2023	Wednesday	33	20
4	06.04.2023	Thursday	34	11
5	07.04.2023	Friday	33	15
6	08.04.2023	Saturday	34	0
7	10.04.2023	Monday	33	14
8	11.04.2023	Tuesday	34	18
9	12.04.2023	Wednesday	34	13
10	13.04.2023	Thursday	34	13



Graph 6: Temperature Vs Power on April

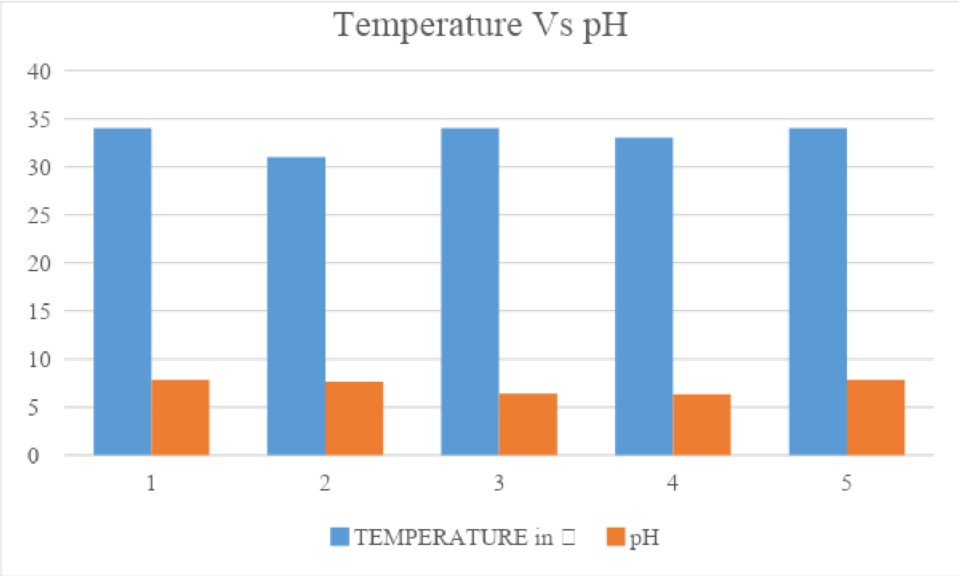
Table 6 presents the temperature and corresponding power production data for the floating drum digester during the month of April. These values provide further insights into the relationship between temperature and power production in the digester. Throughout April, the digester maintained temperatures ranging from 32°C to 34°C. The recorded temperature values represent different days of the week, indicating variations in temperature throughout the observation period. The power production values recorded during this month ranged from 0 kWh to 20 kWh for the available data points. The power production values reflect the biogas produced by the digester at different temperature conditions. To visualize the relationship between temperature and power production, Graph 6 plots the recorded temperature values against the corresponding power production values. This graph helps identify any trends or patterns in the power production as the temperature changes. Analyzing the temperature and power production data for April, in conjunction with the data from previous months, allows for a comprehensive understanding of the digester's performance under different temperature conditions. It provides valuable information for optimizing biogas production and power generation in the floating drum digester. It is important to note that further analysis and monitoring over an extended period would be necessary to draw conclusive insights and make informed decisions regarding the impact of temperature on power production and overall digester efficiency.

pH value

The pH value, plays a crucial role in the process of anaerobic decomposition and biogas production. This research focuses on studying the effect of pH on biogas production and methane gas generation. The results indicate that pH has a significant impact on the production of biogas and methane gas.

Table 7: Temperature Vs pH in last week of February

SI. NO.	DAY	TEMPERATURE in °C	pH	POWER in KWh
1	22.02.2023	34	7.82	19
2	23.02.2023	31	7.64	28
3	24.02.2023	34	6.43	24
4	25.02.2023	33	6.32	21
5	27.02.2023	34	7.83	



Graph 7: Temperature Vs Power on February

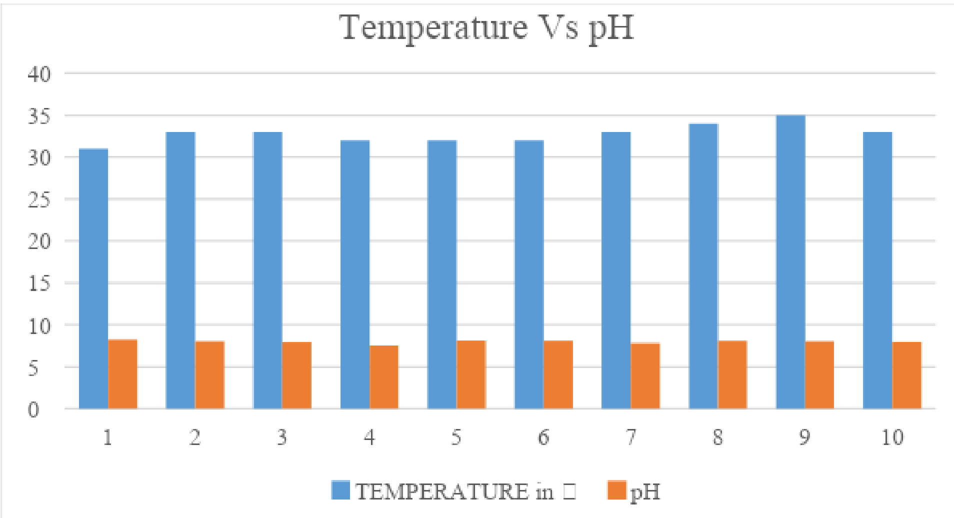
Table 7 provides data on temperature, pH, and power production during the last week of February. The temperature ranged from 31°C to 34°C, while the pH values ranged from 6.32 to 7.83. The highest power production was observed at a pH of 7, followed by pH values of 6.5, 5.5, and 4.5, respectively.

Graph 7 illustrates the relationship between temperature and power production during February, showing any trends or patterns that may exist between these variables.

Table 8: Temperature Vs pH on March

SI. NO.	DAY	TEMPERATURE in °C	pH	POWER in KWh
1	06.03.2023	31	8.23	18
2	07.03.2023	33	8.02	21
3	08.03.2023	33	7.92	19
4	09.03.2023	32	7.55	12
5	10.03.2023	32	8.11	11
6	11.03.2023	32	8.09	25
7	13.03.2023	33	7.81	20
8	14.03.2023	34	8.08	15
9	15.03.2023	35	8.02	16
10	16.03.2023	33	7.94	13

Table 8 presents data on temperature, pH, and power production for the month of March. The temperature values ranged from 31°C to 35°C, while the pH values ranged from 7.55 to 8.23. Similar to the February data, the highest power production was observed at a pH of 7.92, followed by pH values ranging from 7.81 to 8.23.

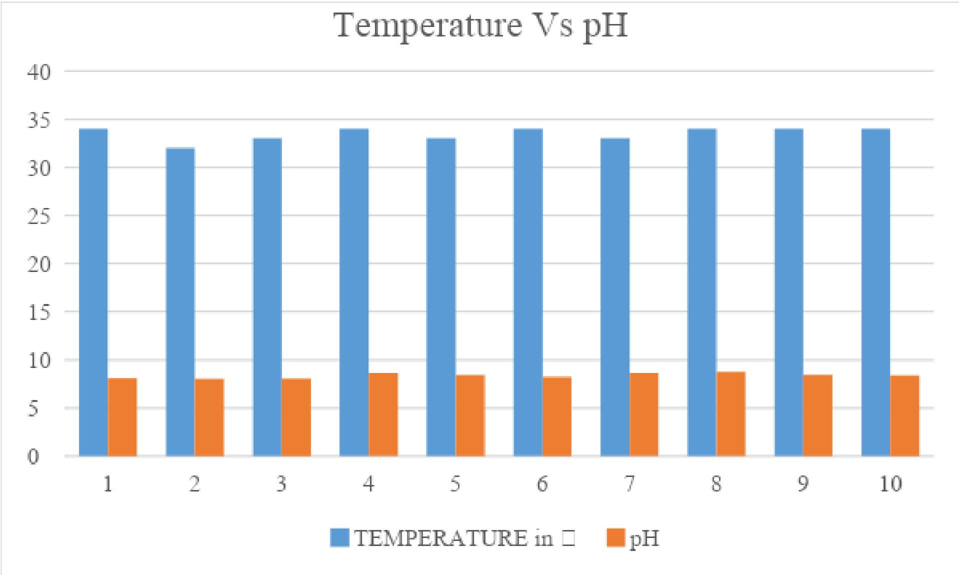


Graph 8: Temerature Vs pH on March

Graph 8 provides a visual representation of the temperature and pH relationship in March, aiding in identifying any trends or patterns in the data. Table 9 provides data on temperature, pH, and power production for the month of April. The temperature values ranged from 32°C to 34°C, while the pH values ranged from 8.03 to 8.77. The highest power production was observed at a pH of 8.77, followed by pH values ranging from 8.06 to 8.63. The data from these tables and corresponding graphs highlight the importance of pH in biogas production. The highest power production was consistently observed at pH values close to neutral or slightly alkaline. It is important to note that maintaining the optimal pH range is crucial for maximizing biogas production. The data presented here indicate that a pH close to 7 results in the highest power production. Regular monitoring and adjustment of pH levels can help optimize biogas production in the floating drum digester. The pH value has a significant impact on biogas production and power generation. The data provided for February, March, and April demonstrate that pH values close to 7 or slightly higher result in higher power production. These findings emphasize the importance of pH control and management in anaerobic digestion systems to enhance biogas production efficiency.

Table 9: Temperature Vs pH on April

SI. NO.	DAY	TEMPERATURE in °C	pH	POWER in KWh
1	03.04.2023	34	8.10	17
2	04.04.2023	32	8.03	19
3	05.04.2023	33	8.06	20
4	06.04.2023	34	8.63	11
5	07.04.2023	33	8.40	15
6	08.04.2023	34	8.22	0
7	10.04.2023	33	8.63	14
8	11.04.2023	34	8.77	18
9	12.04.2023	34	8.42	13
10	13.04.2023	34	8.36	13



Graph 9: Temperature vs pH on April

ORGANIC LOADING RATE

Table 10 provides data on the organic loading rate (OLR) for the month of February. The OLR is calculated as the amount of raw materials fed per day per unit volume of the digester capacity. It is an important parameter that determines the biogas recovery from waste. The table includes the date, day, OLR per day, power production in kWh, and the slurry produced in tons. For example, on 22nd February 2023 (Wednesday), the OLR was 1.456, resulting in a power production of 19 kWh and a slurry production of 2.912 tons. Similarly, data for the other days of February are provided in the table. The organic loading rate is a crucial parameter in determining the efficiency and productivity of the biogas digester. It helps in optimizing the feedstock input and ensuring the appropriate balance between organic waste and biogas production. By monitoring the OLR, operators can adjust the feedstock input to maximize biogas generation while maintaining stable digester conditions.

Table 10: Organic loading rate on February

SI.NO.	DATE	DAY	OLR/DAY	POWER in kWh	SLURRY PRODUCED in Ton
1	22.02.2023	Wednesday	1.456	19	2.912
2	23.02.2023	Thursday	1.222	28	2.444
3	24.02.2023	Friday	1.129	24	2.258
4	25.02.2023	Saturday	1.167	21	2.334
5	27.02.2023	Monday	1.248	-	2.496

The table below presents the organic loading rate (OLR) for the month of March. The OLR indicates the amount of raw materials fed per day per unit volume of the digester capacity. This parameter plays a crucial role in determining the biogas production and overall system performance.

Table 11: Organic loading rate on March

SI.NO.	DATE	DAY	OLR/DAY	POWER in kWh	SLURRY PRODUCED in Ton
1	06.03.2023	Monday	1.471	18	2.942
2	07.03.2023	Tuesday	1.187	21	2.374
3	08.03.2023	Wednesday	0.886	19	1.772
4	09.03.2023	Thursday	0.839	12	1.678
5	10.03.2023	Friday	0.916	11	1.832
6	11.03.2023	Saturday	0.976	25	1.952
7	13.03.2023	Monday	1.390	20	2.78
8	14.03.2023	Tuesday	0.911	15	1.822
9	15.03.2023	Wednesday	1.355	16	2.71
10	16.03.2023	Thursday	1.111	13	2.222

During the month of March, the organic loading rates varied across the observed days. The OLR values ranged from 0.839 to 1.471. These rates reflect the amount of raw materials, such as biowaste, fruit waste, and cow dung that were fed into the digester on a daily basis relative to the digester's capacity. The corresponding power production varied between 11 kWh and 25 kWh, indicating the biogas production efficiency associated with each OLR. The slurry produced during this period ranged from 1.678 tons to 2.942 tons, providing insights into the decomposition and waste breakdown within the digester. It is important to note that the power production and slurry production are influenced by various factors, including organic loading rate, temperature, pH, and substrate composition. Optimizing these parameters can enhance the overall efficiency and biogas yield of the digester. By monitoring and analyzing the OLR, power production, and slurry production data, it is possible to assess the performance of the digester and make informed decisions regarding waste management and biogas utilization.

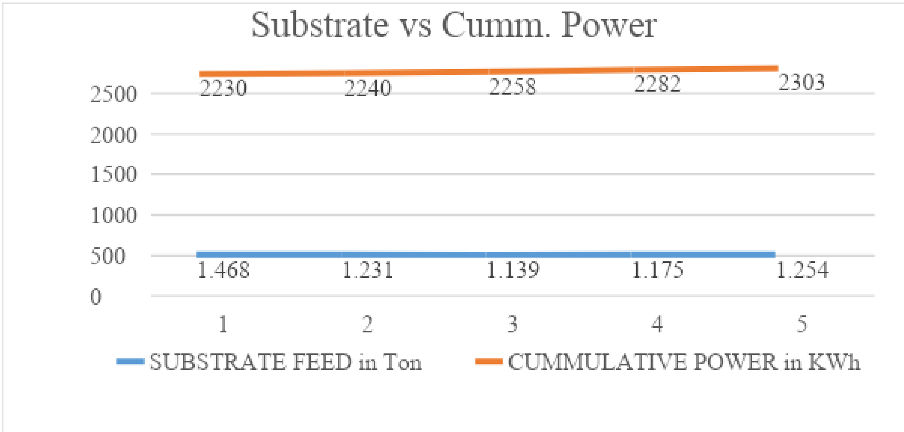
HYDRAULIC RETENTION TIME

HRT (Hydraulic Retention Time) is a crucial parameter in continuous mode for the production of Hydrogen and methane. It represents the average time that cells and substrates stay inside the reactor. The HRT value is determined by the ratio between the reactor volume and the feed flow rate. In the context of hydrogen production, a low HRT is beneficial as it promotes the washout of methanogens, ensuring the survival of hydrogen producers. Additionally, maintaining a slightly acidic pH range of 6.0 to 6.5 is considered optimal for hydrogen production. On the other hand, an increased HRT can shift the ermentation pattern from hydrogenogenic to methanogenic. For methane production, a constant HRT of 16 hours and a pH range of 6.85 to 7.05 are maintained in the plants.

Table 13: Generating running hours Vs Cumulative Power Produced

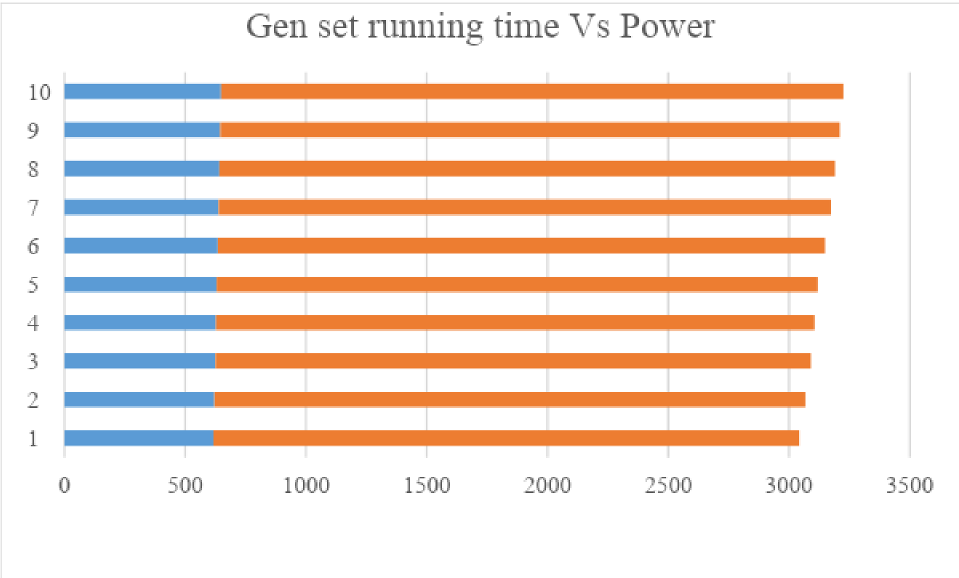
SI.NO.	DATE	GENSET RUN Hrs.	GAS FLOW RATE in m^3/sec	SUBSTRATE FEED in Ton	CUMMULATIVE POWER in KWh
1	22.02.2023	569	0.3474	1.468	2230
2	23.02.2023	574	0.3499	1.231	2240
3	24.02.2023	579	0.3514	1.139	2258
4	25.02.2023	584	0.3540	1.175	2282
5	27.02.2023	588	0.3560	1.254	2303

Table 13 presents data on generating running hours, gas flow rate, substrate feed, and cumulative power produced during February. The cumulative power increases over time, indicating an efficient power generation process.



Graph 10: Substrate feed Vs Cumulative Power

Graph 10 illustrates the relationship between substrate feed and cumulative power. It provides a visual representation of the increasing trend in power production with an increase in substrate feed. These findings emphasize the importance of HRT and pH control in optimizing hydrogen and methane roduction. By monitoring and adjusting these parameters, it is possible to enhance the efficiency an yield of the biogas production process.



Graph 11: Gen set running time Vs cumulative Power

Graph 11 illustrates the relationship between generator set running time and cumulative power produced. It provides insights into the performance of the generator set over time and its contribution to the overall power generation.

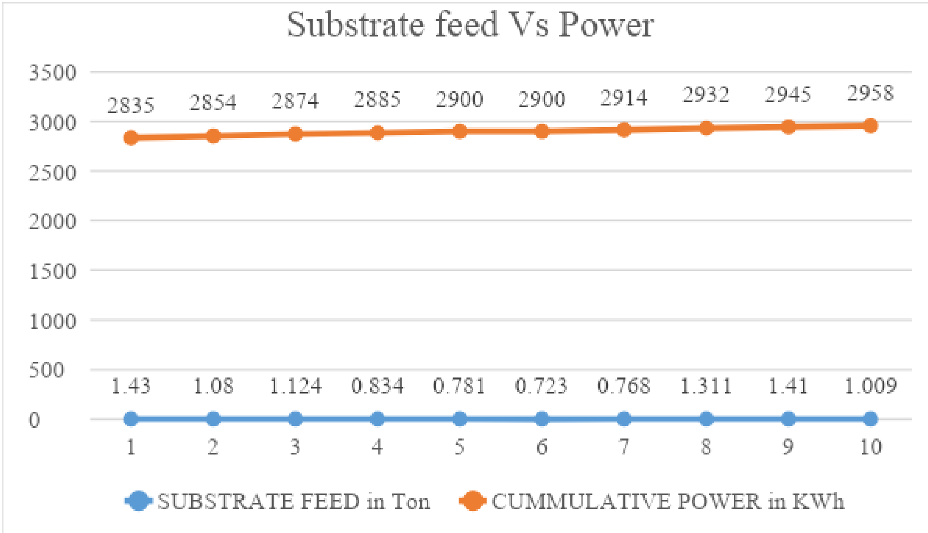
Table 14: Generating running hours Vs Cumulative Power Produced

SI.NO.	DATE	GENSET RUN Hrs.	GAS FLOW RATE in m^3/sec	SUBSTRATE FEED in Ton	CUMMULATIVE POWER in KWh
1	06.03.2023	616	0.3636	1.471	2426
2	07.03.2023	620	0.3643	1.187	2447
3	08.03.2023	625	0.3656	0.886	2466
4	09.03.2023	627	0.3673	0.839	2478
5	10.03.2023	630	0.3673	0.916	2489
6	11.03.2023	635	0.3687	0.976	2514
7	13.03.2023	639	0.3698	1.390	2534
8	14.03.2023	642	0.3703	0.911	2549
9	15.03.2023	645	0.3716	1.355	2565
10	16.03.2023	648	0.3728	1.111	2578

Table 14 presents data on generating running hours, gas flow rate, substrate feed, and cumulative power produced during March. The generator set running hours gradually increase with each date, indicating continuous operation. The gas flow rate, substrate feed, and cumulative power produced values are also provided for each date. The cumulative power produced shows an increasing trend, indicating the effectiveness of the power generation process. The data suggests that as the generator set runs for more hours and the substrate feed increases, the cumulative power output also rises. By analyzing the relationship between generator set running time, substrate feed, and cumulative power produced, it is possible to evaluate the performance of the power generation system and identify any potential areas for optimization or improvement.

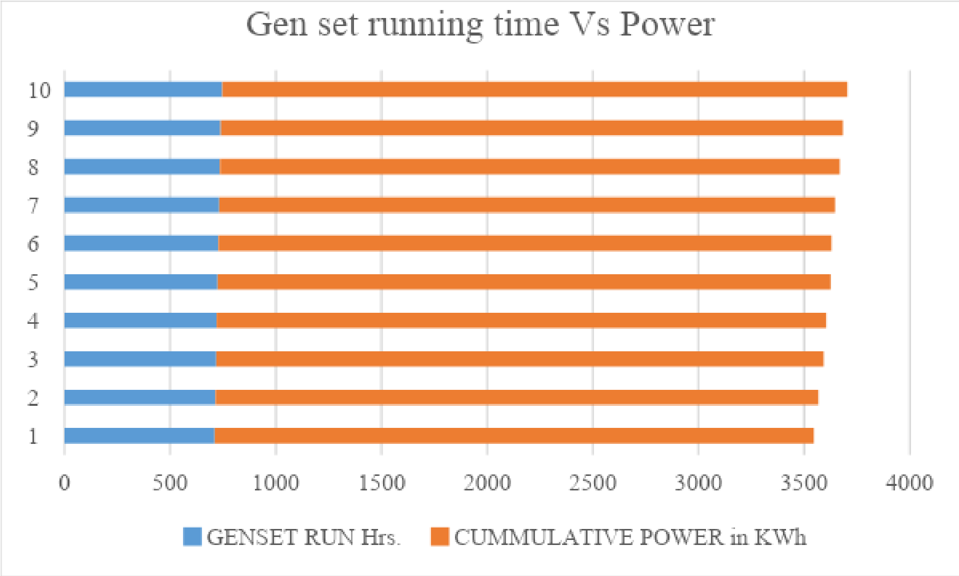
Table 15: Generating running hours Vs Cumulative Power Produced

SI.NO.	DATE	GENSET RUN Hrs.	GAS FLOW RATE in m^3/sec	SUBSTRATE FEED in Ton	CUMMULATIVE POWER in KWh
1	03.04.2023	710	0.4165	1.43	2835
2	04.04.2023	714	0.4198	1.080	2854
3	05.04.2023	718	0.4229	1.124	2874
4	06.04.2023	720	0.4261	0.834	2885
5	07.04.2023	725	0.4273	0.781	2900
6	08.04.2023	729	0.4314	0.723	2900
7	10.04.2023	733	0.4314	0.768	2914
8	11.04.2023	736	0.4340	1.311	2932
9	12.04.2023	739	0.4371	1.410	2945
10	13.04.2023	746	0.4392	1.009	2958



Graph 14: Substrate feed Vs Cumulative Power

Table 15 provides data on generating running hours, gas flow rate, substrate feed, and cumulative power produced during April. The generator set running hours, gas flow rate, substrate feed, and cumulative power produced values are presented for each date. Graph 14 depicts the relationship between substrate feed and cumulative power produced. It illustrates how the amount of substrate feed influences the cumulative power output. Graph 15 shows the correlation between generator set running time and cumulative power produced. It provides insights into the relationship between the operating time of the generator set and the cumulative power generated. Analyzing the data from Table 15 and the corresponding graphs allows for the evaluation of the power generation system's performance during April. It enables the identification of trends, patterns, and any potential optimization opportunities to enhance power production efficiency.



Graph 15: Gen set running time Vs cumulative Power

CONCLUSION:

The data and information provided offer valuable insights into the performance and operation of a power generation system based on biogas production from organic waste. Key parameters such as organic loading rate (OLR), hydraulic retention time (HRT), pH, gas flow rate, substrate feed, and cumulative power production were monitored and analyzed to evaluate the system's efficiency and productivity. The organic loading rate (OLR) plays a crucial role in determining the biogas recovery from waste. The observed OLR values varied over the observed periods, indicating the amount of raw materials fed per day per unit volume of the digester. These rates have a direct impact on the power production and slurry production within the system. Additionally, the hydraulic retention time (HRT) is an important factor for hydrogen and methane production. Low HRT, combined with a slightly acidic pH range, was found to be favorable for hydrogen production, while an increased HRT shifted the fermentation pattern towards methanogenic for methane production. In the studied system, a constant HRT of 16 hours and a pH range of 6.85-7.05 were maintained for methane production. The cumulative power produced was determined based on the generator set running hours, gas flow rate, and substrate feed. The data showcased the relationship between these variables and the power generation output. Graphs depicting the substrate feed versus cumulative power and generator set running time versus cumulative power provided visual representations of these relationships. Overall, the analysis of the data allows for the assessment of the system's performance, identification of trends, and potential areas for optimization. By monitoring and optimizing parameters such as OLR, HRT, pH, and substrate composition, the efficiency and biogas yield of the power generation system can be enhanced, leading to more sustainable and effective waste management practices and increased renewable energy production.

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