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INVESTIGATION ON BIOGAS GENERATION AND WASTE MINIMISATION USING ORGANIC WASTES AND LIGNOCELLULOSIC BIOMASSES

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ABSTRACT
In the present Paper, characteristics of organic materials and lignocellulosic biomasses are examined separately using Combustion analysis & chemical analysis as per standard test procedure. Cow dung and kitchen waste along with lignocellulosic biomass are assessed separately in an anaerobic digester with the objective of generating biogas from it and reduction in the value of oxygen demand. Thus, the main object of the present study is to analyse and find the optimum proportion of organic waste along with lignocellulosic biomass towards generation of biogas and also investigate reduction of oxygen demand during retention period. To evaluate the ability of ligncellulosic biomasses towards biogas generation, rice straw and rice husk (lignocellulosic biomasses) chosen for present study and gathered from central region of India and characterized. Based on the test results obtained from rice straw & rice husk, rice straw as a lignocellulosic biomass has selected for present study towards generation of biogas. Anaerobic digesters are prepared for the separate investigation on biogas generation using cow dung for different feed ratio. Similarly digesters are prepared for the investigation on biogas production using cow dung and kitchen waste for optimum proportion of feed ratio. Similarly, digesters are prepared for the separate investigation on biogas generation using kitchen waste along with rice straw as lignocellulosic biomass for different feed ratio to find out optimum proportion of feed ratio towards biogas generation. Quantity of biogas generated has measured using volumetric method for mesophilic condition. In present study, effect of various parameters such as temperature, feed ratio, pH and reduction in COD and BOD value on biogas generation is also analyzed and studied for different substrate under mesophilic condition. In the present study, optimum biogas generation is observed at 330c of temperature in mesophilic condition and this temperature is maintained by thermal insulation of digester. In thermal insulation, black/ green surface glazing is done and also solar canopy is provided over the digester. Similarly, from present study it is observed that alkaline nature of slurry found to best for optimum biogas generation. It is observed that 9.75% of total solid contents in cow dung slurry for feed ratio of 1:2 generated maximum volume of biogas than other feed ratio. Similarly, it is observed that 10.87 % of total solid contents in co-substrate of cow dung slurry & kitchen waste slurry for feed ratio of 1:2 generated maximum volume of biogas. It is observed that the biogas produced using cow dung slurry is 10% less than the biogas produced from kitchen waste and biogas produced by co-substrate is 5% less than that of kitchen waste. Reduction in the value of BOD and COD has also measured using standard test procedures and

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it is found that, reduction in BOD & COD value responsible for increment in volume of biogas generation form different substrate. It is observed that percentage COD reduction for cow dung achieved as 42.33% and 45.34% for kitchen waste. Similarly, percentage BOD reduction for cow dung achieved as 58.91% and 67.19 % for kitchen waste

Keyword: Organic waste, lignocellulosic biomass, co-digestion, combustion analysis, chemical analysis, biogas generation, waste minimization

1.0 INTRODUCTION

Reduction in the quantity of fossil fuels and day to day increment in environmental pollution has encouraged and inspired the beginners to think for economical as well as green sources of energy. Solar energy, wind energy & energy generated from hydropower are some of the important source of green & renewable energy. Initial cost of solar system is high and limited. Similarly other source like as wind & hydropower are only related to some fixed location. Hence, use of organic wastes & agricultural wastes to harness the energy is one of the best, economical, green & renewable sources of energy. Huge quantity of organic waste such as cattle manure, kitchen wastes, animal wastes are generated from houses and animal's farms and very much difficult for solid waste management. Similarly, agricultural wastes after harvesting called as lignocellulosic biomasses generated from farms are again difficult to manage and hence proper utilization of these huge quantities of biomass towards energy creation is much needed and because of easy production this technology is best over other types of renewable sources. The current estimated annual quantity of biomass available in India itself is 750 million metric tons [MNRE report, 2021]. Similarly, the surplus biomass availability obtained from agriculture residue is at about 230 million metric tons per annum and this is equivalent to potential of about 28 GW [MNRE report, 2021]. However, generation of biogas from lignocellulosic biomass is at its beginning stage requiring thorough study in the line. Generation of biogas using organic waste along with lignocellulosic biomasses is another eco friendly method to recreate energy and minimize the waste through anaerobic digestion so it helps to decrease emission of oxides of carbon and nitrogen.

1.1ANAEROBIC DECOMPOSITION PROCESS

In anaerobic decomposition process organic waste & biomass resources are disintegrated by anaerobic bacteria in the absence of oxygen. In anaerobic decomposition process biomass resources are kept in sealed reactor called as anaerobic digester. A chemical reaction between substrate & microorganisms within the digester produces biogas in following stages as shown in fig 1.1. Anaerobic digestion produces biogas without any harmful gas and odor and also enhance the nitrogen and phosphate of digested slurry which resulting into rich quality of fertilizer to nourish the soil. [K.M. Mittal, 1996].

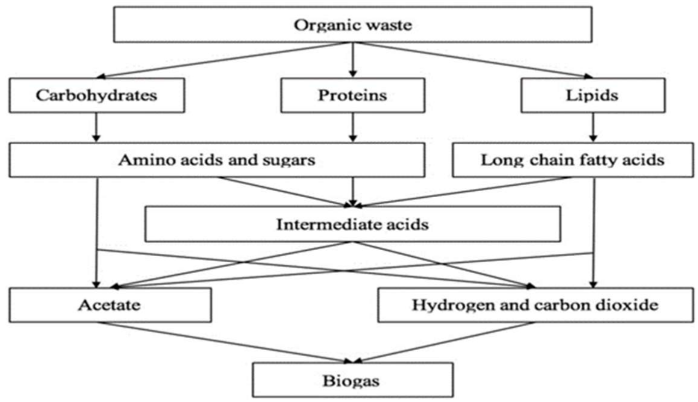

Fig 1.1 Anaerobic Decomposition Process [Gujer et al., 1983]

1.2 BIOGAS AND CONSTITUENTS OF BIOGAS

Biogas is non toxic gas and harmless in nature, has no objectionable odor and smell and it burns completely without smoke and burns without leaving any residue. Constituents of biogas presented in table 1.1

Table 1.1 Constituents of Biogas [Kolumbus FI; 2007]

Constituents	**Chemical formula**	**Percentage**
Methane	CH_4	50-75
Carbon Dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydogen Sulphide	H_2S	0-3
Hydrogen	H_2	0-1

1.3 SUBSTRATE MATERIALS FOR BIOGAS PRODUCTION

Biogas production from various feed materials varies and not same for all feed materials. Various factors such as carbon to nitrogen ratio, retention time, temperature and pH of slurry affects the generation of biogas. Table 1.2 shows different types of Cattle wastes, Kitchen wastes and Lignocellulosic biomasses used for Biogas Production.

Table 1.2 Substrate Materials used for Biogas Production

Cattle Wastes [Jarwar et al., 2021; Mukumba et al., 2017; Gaworski et al., 2017; Rode et al., 2017; Alfa et al., 2014; Zhang et al.,2013; Okoroigwe et al.,2009]	**Kitchen Wastes** [Szilagyi et al.,2021; Rahim et al.,2019; Rode et al., 2017; Yang Yang Li, et al., 2016; Sharada et al.,2016; phetyim et al.,2015; Deressa et al., 2015]	**Lignocellulosic Biomasses** [Rode et al.,2022; Kaur et al., 2020; Ngan et al., 2019; Gaworski et al.,2017; Sawasdee et al.,2014; Li sun et al., 2013., Illaboya el., 2010]
Buffalo Dung	Tomato waste	Rice Straw
Horse Manure	Banana peel waste	Sugarcane Bagasse

Pig Manure	Kitchen waste	Rice Straw
Cow dung	Kitchen waste	Corn Silage
Poultry Droppings	Kitchen waste	Napier Grass
Goat Manure	Vegetable waste	Wheat Straw
Dog waste	Fruit and vegetablewaste	Agricultural wastes

2.0 ANALYSIS OF ORGANIC WASTES AND LIGNOCELLULOSIC BIOMASSES

In the present study the analysis of organic waste such as Cow dung, kitchen waste and analysis of lignocellulosic biomasses (rice husk and rice straw) is done by Combustion analysis using ASTM methods of combustion analysis and Chemical analysis is done by EDXA using Scanning Electron Microscope (SEM), LEO 1430VP, [Zeiss, Germany.]. Chemical oxygen demand of fresh slurry of feed materials is determined using standard procedure according to IS: 3025 (Part 44) reaffirmed 2006. Similarly calorific value and fiber analysis of organic wastes (cow dung & Kitchen waste) and lignocellulosic biomasses (Rice husk & Rice straw) is also calculated to check their potentiality towards biogas generation. The result of combustion & Chemical analysis is presented in table 2.1 &2.2

Table 2.1 Results comparison of Combustion Analysis

(Present Work & Literature)

Feed Materials	Present work			Literature data			Author
	FC	ASH	VM	FC	ASH	VM	
Cattle Dung	22.3	9.6	67	19.3	19.3	46.4	Roy et al., 2010
Kitchen Waste	17.6	5	69	---	---	---	----
Rice straw	12	20	66	15.6	20.1	64.3	Miles et al;1995
				13.91	20.38	65.7	Channiwala and parikh;2002
Rice husk	9	15	69	19.2	18	62.8	Miles et al;1995
				16.95	21.24	61.81	Channiwala and parikh;2002

Table 2.2 Results comparison of Chemical Analysis (Present Work & Literature)

Feed materials	Present work			Literature			Author
	C (%)	N (%)	O (%)	C (%)	N (%)	O (%)	
Cow dung	35.20	1.6	55.42	33.33	--	1.68	Raheman and Mondal, 2012
				31.6	6.12	37.8	Roy et al., 2010
Kitchen waste	31.10	0.675	49.20	-----	------	-------	
Rice husk	29.30	0.355	39.75	38.9	0.6	32.0	Kirubakaran et al., 2009
				49.3	0.8	43.7	Miles et al., 1995
Rice straw	32.11	0.984	41	36.9	0.4	37.9	Kirubakaran et al., 2009
				50.1	1.0	43	Mile et al., 1995

3.0 PARAMETRIC STUDY OF BIOGAS GENERATION

All the biomass resources are collected from central part of India. In this present study generated biogas is measured from three different phases of feed materials. First phase includes biogas generation from cow dung slurry for three different feed ratios. Second phase is done for mixture of cow dung and kitchen waste towards generation of biogas and third phase consists of digestion of wastes from kitchen along with lignocellulosic biomass (rice straw) for generation of biogas. Study of biogas generation is done in anaerobic digester designed and made by economically available materials. Similarly biogas generation is done under mesophilic conditions and optimum slurry temperature is achieved by using thermal insulation of anaerobic digester. Thermal insulation is achieved by tarpal canopy structure over digester and surface glazing of digester. Rice straw is utilized as a support media for attachment and growth of microorganisms. Volumetric method is used to measure the quantity of biogas. Effect of slurry temperature, pH value, Hydraulic retention time, feed ratio is also studied during generation of biogas.

3.1 COLLECTION OF FEED MATERIALS

In this study, feed materials like as cow dung, kitchen waste are gathered from central part of India. Similarly, lignocellulosic biomasses (rice straw and rice husk) are also gathered from central part of India. In this present work, collected kitchen waste includes food waste, uncooked vegetables, raw eggs and meat, peel of fruits etc. so, kitchen waste is grinded everyday in mixer and grinded kitchen waste is used as feed materials. The samples of lignocellulosic biomasses (rice straw & husk) are gathered, washed and sun dried for 6 to 7 hour to detach extra moisture. Subsequently these samples are allowed to dry in an oven for 1 day and grinded by milling machine. Rick husk is sieved by Indian standard sieve and the rice husk powder retained on 0.85 mm sieve is further used as a feed material. Similarly, rice straw is dried for 15 days and chopped to make 2mm to 3 mm in length and this 2 to 3mm chopped sample is used for feed material for biogas generation.

3.2 CONSTRUCTION & SET-UP OF ANAEROBIC DIGESTER

In the present study, anaerobic digesters of 20 litres capacity for all phases of feed materials are prepared using various materials like as water jars, cock for outlet, funnel, PVC pipe, gas pipe, tyre tube for storing gas, two valves for closing and starting. Anaerobic digester is prepared based with proper arrangement of Inlet, outlet and gas pipe as shown in fig3.1

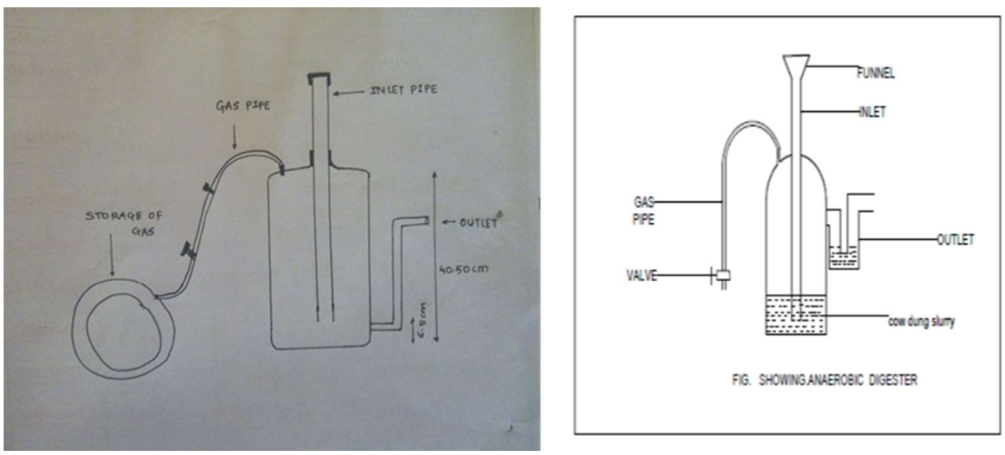

Fig 3.1 Design of Anaerobic Digester [Rode & Swarup, 2017]

3.3 MEASUREMENT OF BIOGAS

This study is done on every phase of feed materials for retention time of 30 days. 03 digesters are prepared for phase –I, 03 digesters of 25 litters each are prepared for phase-II and 02 digesters are prepared for phase –III. In phase-I cow dung is analysed for generation of biogas using three different ratio 1:1, 1:1.5 and 1:2. In phase II comparative analysis of biogas generation from co-substrate of cow dung-kitchen waste is done and in phase III effect of kitchen waste and rice husk is analysed for different feed ratio towards biogas generation. During daily activities substrate slurry is added daily into the digester through inlet. pH value and temperature is also recorded by digital pH meter and thermometer. Similarly, generated biogas is measured by volumetric method. In this method, the relation DENSITY=WEIGHT / VOLUME is used for the measurement of biogas. Initial weight and final weight of tube is measured daily by electronic weighing balance. Then weight is calculated by difference between initial weight and final weight of tube. Then volume of biogas generated is calculated by considering density of biogas as 1.18 kg/ m3. Results of biogas generation from Phase I, II and III are presented in chart 3.1, 3.2 & 3.3 respectively and result comparison of produced biogas with literature are presented in table 3.1

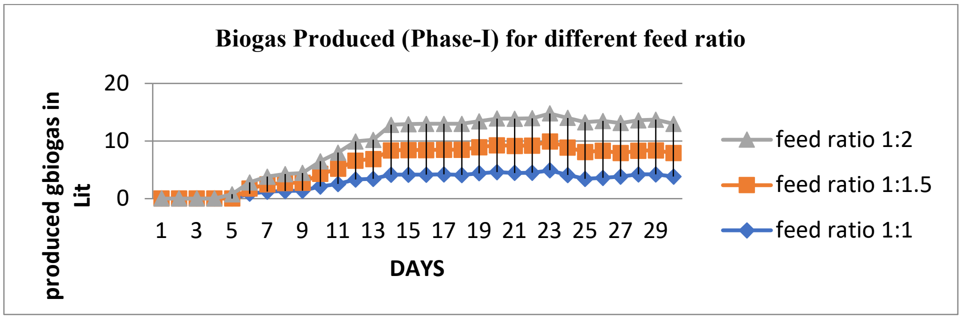

Chart 3.1 Biogas produced (Phase-I) for different feed ratio

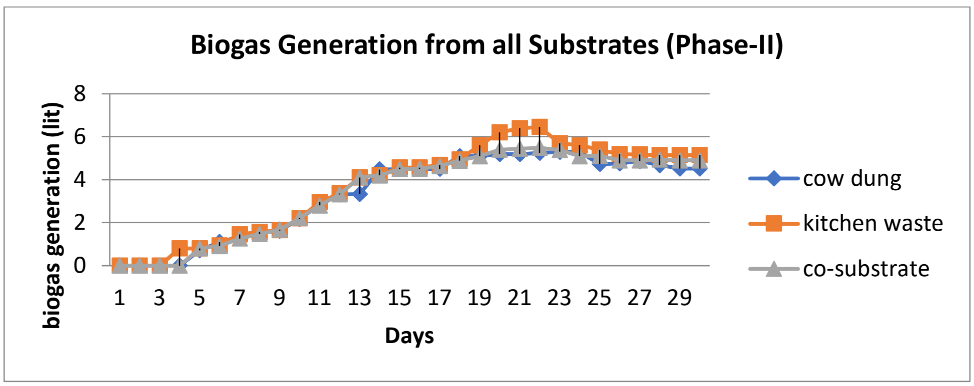

Chart 3.2 Biogas Generation from all Substrates (Phase-II)

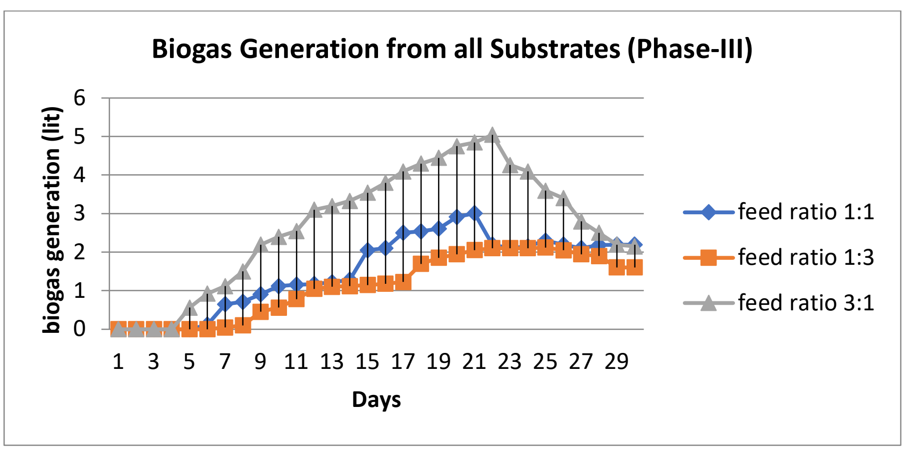

Chart 3.3 Biogas Generation from all Substrates (Phase-III)

Table 3.1 Results comparison of produced biogas (Present Study & Literature data)

Literature	Results
Thakur et al;	Wastes from kitchen generates 55% more

2019	biogas than that of cow dung slurry
Tiwari et al., 2008	Slurry temperature of conventional biogas plant using surface glazing and Tarpal insulation was found to be 29^0C
putri et al., 2012	Increase of water addition ratio will increase the generation of biogas
Present study	Kitchen waste produces 10% more biogas than that of cow dung for same feed ratio
Present study	Slurry temperature of conventional biogas plant using surface glazing and Tarpal insulation is found to be 33^0c
Present study	Water addition increases the yield of biogas.

4.0 PARAMETRIC STUDY ON BOD AND COD REDUCTION

This chapter introduces the examination of BOD and COD value, percentage of reduction in BOD and COD value after digestion, Role of HRT towards reduction in the value of BOD and COD. In this present study BOD5 value and COD value of fresh slurry and digested slurry is determined by using standard test procedure according to IS: 3025 (Part 44) reaffirmed 2003. In this chapter reduction in the value of BOD5 and COD for cow dung, kitchen waste substrate is analyzed and factors affecting the reduction in BOD5 and COD is examined. The results of reduction in the value of COD & BOD are presented in table 4.1 & 4.2 respectively. Similarly, significance of HRT on COD & BOD removal is presented at chart 4.1 & 4.2 respectively. Results comparison of COD and BOD removal with literature is presented in table 4.3

Table 4.1 COD value of feed materials/Substrates

Feed materials/substrates	0 dayCOD (mg/lit)	5 dayCOD (mg/lit)	15day COD (mg/lit)	30day COD (mg/lit)	Reduction in (%) COD
Cow dung	32600	29800	20200	18800	42.33%
Kitchen waste	51600	46500	36300	28200	45.34%

Table 4.2 BOD value of feed materials/Substrates

Feed materials/substrates	Initial BOD (mg/lit)	BOD after 5days (mg/lit)	BOD after 15 days (mg/lit)	Final BOD (mg/lit)	Reduction in BOD (%)
Cow dung	20200	18300	10600	8300	58.91%
Kitchen waste	31400	28400	12200	10300	67.19%

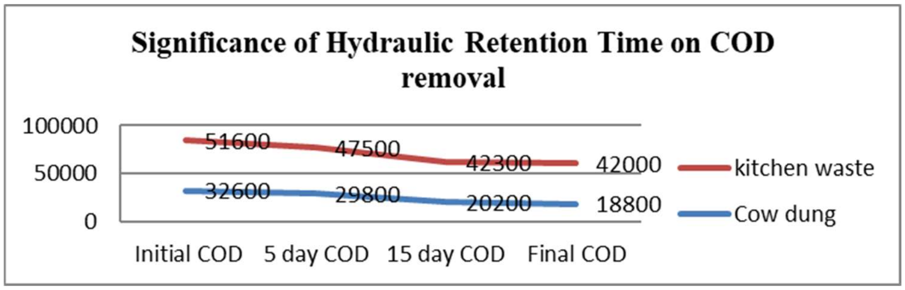

Chart 4.1 Significance of Hydraulic Retention Time on COD removal

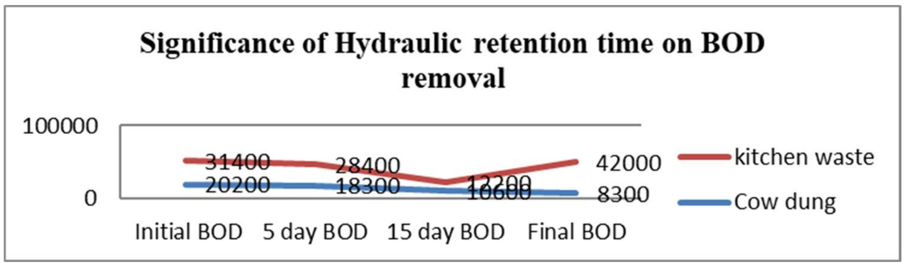

Chart 4.2 Significance of Hydraulic Retention Time on BOD removal

Table 4.3 Results comparison of BOD & COD removal (Present work & previous literatures)

Literature	Results
Isni Utami et al; 2015	67% COD reduction and 75% BOD reduction achieved for HRT of 72 hours
R. Omar et al; 2008	51 % COD reduction achieved for cattle manure
Kumar sonu and bhasker das; 2016	COD removal for kitchen waste was 60000 to 45000 mg/lit. COD removal for cow dung was 32000 to 16000 mg/lit.
Present study	Percentage COD reduction for cow dung achieved as 42.33% and 45.34% for kitchen waste Percentage BOD reduction for cow dung achieved as 58.91% and 67.19 % for kitchen waste

5.0 CONCLUSIONS

5.1 ANALYSIS OF ORGANIC WASTE & LIGNOCELLULOSIC BIOMASSES

It is observed from the combustion analysis that % moisture content of biomass resources affects the heating value of biomass and % moisture content of rice husk and straw ranges from 10 to 15% and % moisture content of cow dung & kitchen waste ranged ranges from 75 to 85%. The % ash content is found to vary from 0.5-20% for organic wastes as well as lignocellulosic biomasses. Similarly, % Volatile matter content for organic wastes as well as lignocellulosic biomasses used in the present study is found to be 60 to 75% and this high volatile matter present specifies that good potential for biogas generation. Fixed carbon content is found to be more than 9% for all the biomasses. Similarly, fixed carbon content of rice straw is found to be 9% comparatively rice husk is of 15% and concluded that rice straw has good potential of biogas than rice husk. From the result of chemical analysis, it is observed that the % nitrogen content of lignocellulosic biomasses (rice husk & rice straw) is found in between 0.35 to 1%. Whereas % carbon content of lignocellulosic biomasses (rice husk & rice straw) ranges from 29 to 33% which makes the C: N ratio high. It is observed that all biomasses have high cellulose content and good for biogas generation but lignin content of both the lignocellulosic biomasses is found to be almost 25% which is quite high. Similarly, calorific value of Rice straw is found to be higher than Rice husk and hence rice straw is selected for co-digestion with kitchen waste.

5.2 PARAMETRIC STUDY OF BIOGAS GENERATION

Ratio of cow dung to natural water (1:2) is found to be optimum feed ratio towards biogas generation. Similarly it is observed that thermal insulation of digester using surface glazing & tarpal canopy over digester maintain 330c temperature of substrate and which generates optimum volume of biogas. Similarly it is observed that volume of biogas increase with increase in temperature. In phase-II, investigation on generation of biogas is done on individual substrate of cow dung & kitchen waste and similarly done for co-substrate of cow dung & kitchen waste. it is observed that biogas generated from kitchen waste is 10% more than that of cow dung and it's only due to more nutrients present in the kitchen waste substrates. Similarly it is observed that more gas is generated through alkaline substrates of biomass. It is observed that, pH value of kitchen waste substrate is changed very fast from acidic to alkaline and hence generated more volume of biogas. Similarly, 5% more biogas is generated by kitchen waste alone than co-substrate. In phase III, rice straw is mixed with kitchen waste as a substrate for digester and effect of feed ratio, particle size, temperature, pH value towards biogas generation is studied. It is observed that 2 to 3mm length of rice straw provides good volume of biogas generation. It is also observed that 25% utilization of rice straw along with kitchen waste slurry given optimum feed percentage of straw for co-digestion.

5.3 PARAMETRIC STUDY ON COD & BOD REDUCTION

To accomplish the aim and objective of the study towards waste minimization, BOD and COD value of substrates analyzed at initial day, 5th day, 15th day, final day of retention time and it is observed that reduction in the value of BOD and COD concentration is continuously happened with increment in time. From the present investigation, it is observed that, percentage reduction of BOD is more than that of COD. It is also observed that percentage reduction in COD for kitchen waste slurry is 3 to 4 % more than that COD of cow dung slurry. Similarly, it is also observed that the percentage reduction in BOD for kitchen waste slurry is 8 to 10 % more than that BOD of cow dung slurry.

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