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RESEARCH ARTICLE

ENHANCEMENT OF BIOGAS PRODUCTION FROM ANAEROBIC CO-DIGESTION OF WASTEWATER SLUDGE, KITCHEN WASTE AND MANURE

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ABSTRACT

Bioenergy is the most outstanding renewable source among other fuels that are non-renewable and running out. Globally, the main cause of the energy crisis is a scarcity of natural resources. In this respect, harnessing the abundant renewable sources for energy production can help to alleviate the crisis of energy. Developing countries needs an incessant supply of cheap and clean energy sources. Bioenergy production from biomass such as manure, agricultural residue, and municipal solid waste. it is economically feasible because organic substrates have high nutritive values for micro-organism (especially kitchen waste), high biodegradability rate, and high calorific values. This study has investigated the anaerobic co-digestion of wastewater sludge, Manure and kitchen waste for bio-energy production and analyzed the parameters which have significant effect on digestion process. This process has also decreased the excess of BOD, COD, N and P about 64.07%, 60.16%, 56.06% and 71.02% respectively which indicated the organic fraction utilized by microbes. Anaerobic co-digestion enhances biogas production when treating such wastes wastewater sludge, Manure and kitchen waste combined.

KEYWORDS

wastewater sludge, Manure, Kitchen Waste, Mesophilic Anaerobic Co-Digestion, Waste to Energy.

1. INTRODUCTION

Globally, the main cause of the energy crisis is a scarcity of natural resources. Energy is the backbone of every country's economy. Developing countries needs an incessant supply of cheap and clean energy sources. About 80% of the oil resources have depleted. It is obvious that non-renewable energy resources depleting with every tick of a clock, and prices of fuel increases day by day (Luoma, 2009). At the same time, renewable energy sources and modern technologies available have to solve the problems tackled by developing countries. Pakistan has also been getting energy from the respective sources, thermal (oil/gas / furnace steam), hydel, and nuclear (Bhatti et al., 2012).

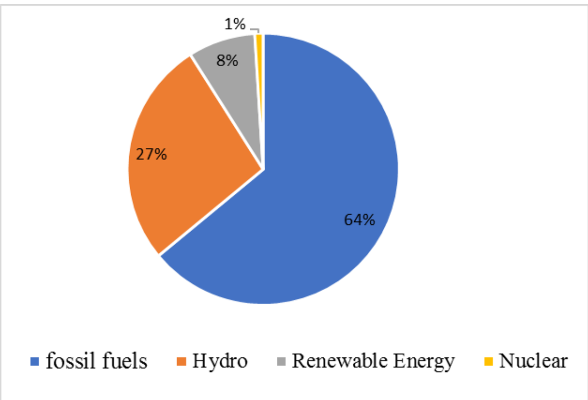

Figure 1: Total energy production in Pakistan from renewable and nonrenewable resources (Abbasi et al., 2020).

People all across the world are working hard to find alternative/renewable resources in order to prevent the planet from getting black. It is the time to convert our focus towards green energy resources. Non-renewable resources should provide a fraction of the energy while rest of the energy must be fulfilled by the renewable resources (Wang and Han, 2011). Energy is a necessary part in development and growth of every country economy. Fossil fuel particularly oil and gas are finite, in some extent, and considered depleting resource and efforts are put to looking for new energy sources. These resources are delineated as solar, wind, geothermal and biomass (Gelegenis et al., 2007). Biomass energy includes animal manure, agricultural residue, wood-fuel, wastewater sludge and other biological based fuels. These organics resource has their own potential to produce energy.

Table 1: Biogas Production Potential from Different Biomass (Ogur and Mbatia, 2013; Malik and Bharti, 2009; Berktay and Nas, 2007).

Biomass	Biogas potential Kg/m³
Manure	0.2
Poultry	0.11
Kitchen waste	0.3
Sewage sludge	0.6

Above table show the different yield of biogas from different biomass. Different biological and chemical process used to convert biomass into bioenergy and most common process are anaerobic digestion and combustion respectively (Masood et al., 2014). Biomass is an outstanding energy source because it produces similar fuels like natural gas, and crude oil. it also has high nutritive value for micro-organism, high

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biodegradability rate and high calorific values. Biomass energy only depends on the accessibility of raw material (Qdais, 2007). Animal waste is abundant and renewable source for the biogas production. Pakistan is an agricultural country, and livestock is raised in large numbers by the people to suit their requirements. Cattle produce the most manure (12–18 kg/day), whereas poultry produced about (0.07–0.2 kg/day) (Rahut et al., 2019). Animal farming is one of Pakistan's most important agricultural industry, greatly contributing to the country's agricultural economy, which means that a considerable amount of animal manure is produced, which can be used as a sustainable energy source.

In most of the areas it is used for the production of biogas by anaerobic digestion process (Ashraf et al., 2019). Utilization of animal manure for biogas production is a useful way for supplying energy to rural areas, which will benefit the country's economic development while reducing environmental problems. Biogas production increased by the co-digestion of manure with the other kinds of waste (Khan et al., 2021). Bioenergy can also be produced from municipal solid waste. Its disposal has now become a major concern around the world in recent years (Park et al., 2008). It is due to rapid increase in population growth and modernization. solid waste generation has been steadily growing over time. Every day, about 0.30–1.2 kg per person of solid garbage generated (Upadhyay et al., 2005). It is estimated that Pakistan's urban areas generate about 60.000 tons of municipal solid garbage (Zaigham and Nayyer, 2005). Every day, conventional disposal techniques for the municipal solid waste are, land filling,

Composting and incineration. these treatments are most common for solid waste disposal (Schaub and Leonard, 1996). However, these strategies have serious environmental consequences, such as Air pollution and water contamination from leachate discharge from dumped garbage (Zhang et al., 2007). So, the best approach to manage solid waste is anaerobic digestion process. Anaerobic digestion (AD) process not only produce biogas (a promising renewable energy source), but its residue can also be used as a fertilizer in agriculture (Falk, 2012). It primarily consisted of 60 to 65 % CH_4 contents and 35 to 40% CO_2 contents with the traces of (H_2S), moisture, and other pollutants. Hydrolysis, fermentation and methanogenesis are the main stages of AD (Kumar et al., 2019). Just like municipal solid waste and manure, bioenergy can also be produced from sewage sludge. About 80% of the world wastewater released from industries, homes, business sectors are discharged into water bodies without any proper treatment. Untreated wastewater and sludge have serious effects on public health, also pollute water bodies, both surface water and ground water as well (Un-Water, 2015).

It also leading eutrophication conditions in seas and oceans due to nutrient's discharged into water bodies. Sewage sludge contained nutrient like Nitrogen and phosphorous which creates deoxygenated dead zone in water. According to United Nations World Water Assessment Program, 2017 untreated wastewater also impacted world marine ecosystem, biodiversity, livelihood and food chain of aquatic fauna (United Nations World Water Assessment Programme, 2017). Only 50% to 60% generated wastewater treated, the reason is that wastewater treatment plants in especially developing and low-income countries were operated below their designated capacity (Andreoli et al., 2007). The remaining of wastewater is sewage sludge which typically contains 1 to 2% dry particles by weight of wastewater (Murtaza and Zia, 2012). wastewater produced from municipal sectors is about 5.45 x 109 m3 /year and from industrial sectors is 1.309 x 109 m 3 /year (Maragkaki et al., 2018). It is anticipated that only 8% of wastewater is treated in sewage treatment facilities. Prior to the final discharge of sewage sludge, its, must be treated.

Biosolids are basically nutrient- and energy-dense substances that can be used as a soil conditioner or as a fertilizer's replacement in agricultural field and also a source of renewable energy production. Sewage sludge produced from wastewater treatment can be used for the production biogas by anaerobic digestion process. Production of biogas from anaerobic digestion has a number of benefits, including efficient management of sludge and reduced sludge creation, as well as generating a valuable bio-fuel as a by-product, it also lowering the Green House Gas emissions, and ending carbon nutrient chain (Chua et al., 2013).

1.1 The Energetic Potential from anaerobic co-digestion of organic waste

Global potential of biogas production from the conversion of organic carbon to biogas is 0.15 m3 of biogas per m3 of waste at a temperature of 23 to 44°C with the CV 35.9 MJ/m3 CH4. The potential of Bio-energy production from kitchen waste and wastewater sludge is between 215 to 465ml/ kgs. The concentration of Biogas production increases by the anaerobic digestion manure, kitchen waste and sewage sludge (Demirel and Scerer, 2008).

2. Materials and Methods

2.1 Collection of waste

This research was conducted to analyzed the contribution towards sustainable development from resource and energy recovery. Also examined the status of energy recovery and technology from the co-digestion of organic waste. In 1st trail Manure was used as a control and in 2nd trail manure, kitchen waste and sewage sludge were used for anaerobic co-digestion. In order to test the research trials, suitable samples were collected from different sources and analyzed. The biogas production was determined by a gas analyzer.

2.2 Pretreatment of kitchen waste

The main issue associated with kitchen waste is that it contains mixture of biodegradable and non-biodegradable contents as well as toxic materials with chemical and physical heterogeneity. As a first phase, non-biodegradable matters segregated manually divided into organic biodegradable parts, nonbiodegradable, and toxic components that could interfere with the anaerobic digestion process. After physically separating biodegradable trash, the waste was shredded manually to provide a uniform feed mixture. This shredded sample was manually mixed with sewage sludge and manure.

2.3 Experimental setup

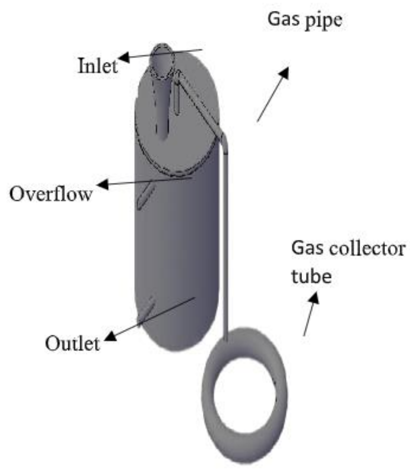

Figure 2: Batch type bioreactor for anaerobic digestion

A batch lab scale bioreactor was used to check the biodegradability rate of organic feedstock shown in figure 2. Digester was made of plastic with the capacity of 20L volume. Working volume of digester was 10L. tyre Tube was used to store the gas. Volume of gas produced measured with the weight balance. Digester was connected to tube by plastic gas pipes with the help of metallic valves. For methane production Archaebacteria are the most common type of methanogenetic group that are suitable for the mesophilic anaerobic co-digestion. these bacteria naturally present in gastrointestinal tract of the animals (Hansen et al., 2007). Temperatures condition between 25 to 45°C and pH ranges of 7.2 to 8.6 are considered ideal for mesophilic digestion. Methanogenic bacteria grow best under such conditions (Hussain et al., 2015). To achieve particulate size reduction of less than 2 mm and uniform slurry production, a sample of waste was shredded manually (Rajakovic and Knezevic, 2006). Reactor was placed in a sunlight so that bacteria's get maximum temperature for biodegradation process.

Table 2: Feedstock Proportion Used for Anaerobic Digestion Process.

	Kitchen waste Kgs	Manure Kgs	Sewage Sludge Kgs
Trail I		100%	
Trail II	30%	30%	40%

2.4 Analysis of waste sample

All the waste sample were analyzed according to Standard approaches described by NEQS for the analysis of water and wastewater treatment at national institute of biotechnology and genetic engineering Faisalabad. Different parameters of waste were Analyzed in laboratory such as Ph, Temperature, BOD, COD, TOD, N, P etc.

Table 3: Characteristics of feedstock before Anaerobic Co-Digestion.

Parameters (Un-digested waste)	Sewage sludge, kitchen waste, manure
BOD5 (Biological Oxygen Demand) mg/l	32210
COD (chemical oxygen demand) mg/l	91990
N (Total Nitrogen) mg/l	132
P (phosphorus) mg/l	14.6
C/N (Carbon to Nitrogen Ratio)	29.21
VS (Volatile solids) mg/l	362
TS (Total solid) mg/Kg	5300

Above table showed the results of parameters analyzed after anaerobic co-digestion. Initially, low temperature and pH were measured with the highest values of BOD, COD and TOC and high concentration of Nitrogen and phosphorus. Carbon to nitrogen ratio was obtain 29.21. carbon, nitrogen and phosphorus are the major nutrients required for the bacterial cell growth (Sheng et al., 2013). Carbon to nitrogen ratio indicated the capability of substrate to degrade. Optimal concentration of C/N required for microbes between 20 to 30:1 (Choi et al., 2020). Organic substrate with low C/N ratio starts to produced more NH3. If C/N ratio is too high it has effects on protein structure of bacteria and ceased the fermentation process and no methane yield will obtain (Schober et al., 1999).

3. Results and Discussion

Below table showed the Results of analyzed parameter that monitor the performance of the anaerobic co- digestion of multiple waste such as Sewage sludge, Kitchen waste and Manure. pH value increased from acidic to slightly alkaline after co-digestion. At initially volatile acid produced during digestion process which lower the pH values, because polymer was converted into monomers (propanoic and Ethanoic Acid to oxides of carbon). Low pH is not suitable for the formation of methane. If pH remains below 6 it will unfavorable for the Microbes, and they will start to die (Olguin, 2012).

Table 4: Characteristics of Feedstock After Anaerobic Co-Digestion.

Parameters (Un-digested waste)	Sewage sludge, kitchen waste, manure
BOD5 (Biological Oxygen Demand) mg/l	11570
COD (chemical oxygen demand) mg/l	36642
N (Total Nitrogen) mg/l	58
P (phosphorus) mg/l	14.77
C/N (Carbon to Nitrogen Ratio)	4.23
VS (Volatile solids) mg/l	142
TS (Total solid) mg/Kg	1838

Above table showed the results of significant reduction in parameters such as BOD, COD that cause sever pollution if discharged into the environment without any proper treatment.

3.1 Temperature and pH

Most important parameters which have significant effect on AD process are Temperature and ph. Best suitable temperature was obtained inside the digester. Initially temperature was 25oC but later, due to microbial activities temperature and pH were increased, due to which production of biogas also increased.

3.2 Total solid and volatile solid

Reduction in Total solid was obtained 65.32% and volatile solid was 60.77%. Volatile solid reduction could be reached 72% in mesophilic condition (Schober et al., 1999). The amount of CH_4 produced is proportional to the sludge's organic content. The volatile solids are widely considered to be a suitable estimate of the organic matter in the sludge. Hence, a considerable fall in the volatile solid content indicated a sufficient amount of CH_4 gas produced.

3.3 (BOD)5, COD, TOC

BOD, COD, TOC, were very high which indicated the high food availability for the microbes. These results indicated the strong potential of contamination, necessitating treatment prior to its final disposal or reuse. The BOD analysis is basically an assessment of the available food for microbes in the sample. If extra food present in the waste the more Dissolve Oxygen will be required. Bod examine the amount of oxygen used by the bacteria as they stabilized the organic matter under controlled condition i.e. temperature and time. Other organic matters also used oxygen for their oxidation. Nitrification was also interfered in BOD processes. For this reason, inhibitor was used. The result showed that BOD 60.07%, COD 60.1%, TOC %, Decreased.

3.4 Nitrogen and phosphorus in waste sample

Nitrogen and phosphorus contents decreased by 56.06% and 71.02% respectively. Nitrogen and phosphorus used as a nutrient supplement for the adequate resources for the microbes in order to complete the digestion process (Eryildiz and Taherzadeh, 2020). The digestion of nitrogenous substances such as urea and protein results in the creation of ammonia. It was also observed that all the nitrogen and nitrates converted or reduced into ammonia by anaerobic digestion (Roshto, 2012). So, AD is the good approach for the removal of nitrogen and to avert the eutrophication condition in water bodies.

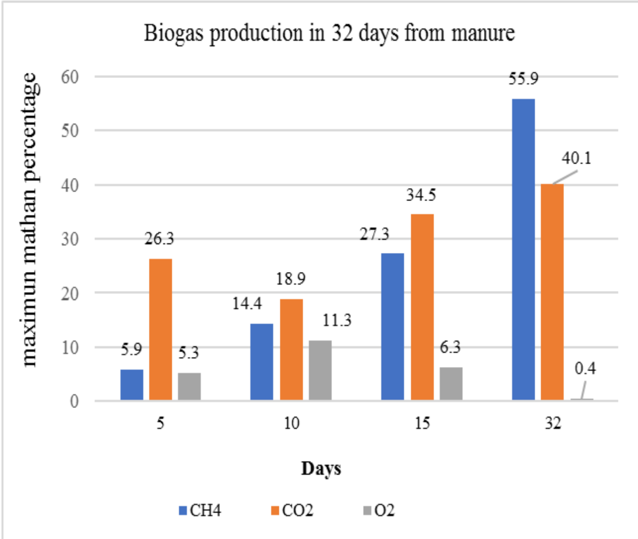

Figure 3: Composition of Gases in biogas from anaerobic digestion of manure.

Above graphs represented the percentage of diffenet gases produced within 32 days of retention time by anaerobic digestion process of manure. At the start of the fermentation co₂ concentration was high 26.3% with the lowest values of metahne which was observed only 5.3%. with the passge of time micrbes start to digest nutrient available in feedstock production of methane increased with the reduction of co₂ and other trace gasses.

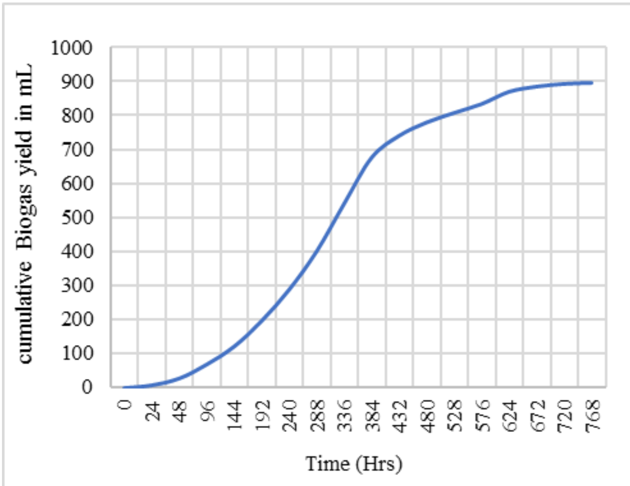

Figure 4: Biogas Yield from Manure.

The graph between cumulative biogas yield and time showed that maximum 895mL of biogas produced which is 179ml/kg of manure sample. at the beginning there was no production of biogas. However, with passage of time and increment in temperature inside the digestor increased the yield of biogas after 10 days of digestion gas production abruptly increased.

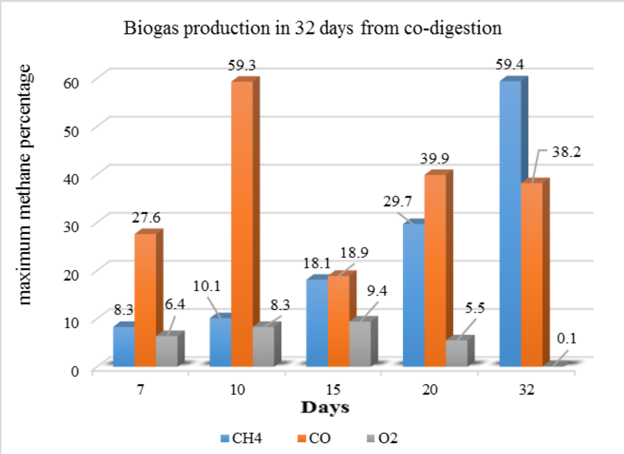

Figure 5: Composition of Gases in biogas from anaerobic Co-digestion of wastewater sludge, manure and kitchen waste.

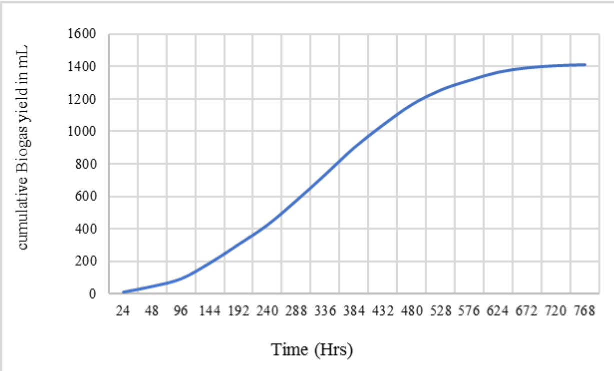

Figure 6: Biogas Yield from wastewater sludge, Manure, and kitchen waste

Above graph indicated that there was small amount of biogas produced initially, but after 96 hours there was abrupt increase in biogas production (Isci and Demirer, 2007). Within 15 to 20 days biogas production was maximum after that stationary phase starts. From anaerobic co-digestion 282mL/kg of biogas produced.

4. Conclusion

AD is a widespread application for the treatment of biomass. Anaerobic Co-digestion had distinct effect on the volumetric methane yield with the significant improvement of 10%. Significant Reduction in BOD 64.07% COD 60.16%, TOC 77.7%, N 56.06%, P 71.02%, TS 65.32% and volatile solid 60.77% were obtained. 179mL/kg of biogas produced from manure which acted as a control and 282 mL /kg of biogas production from anaerobic co-digestion of S.S, M, and K.W. The remaining (digestate) of anaerobic digestion process is beneficial for the crops could be used as a fertilizer (soil conditioner) in agricultural field. AD process has small operational cost.

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