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Generation Of Biogas From Organic Waste In Salem Tamil Nadu

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ABSTRACT

Biogas typically refers to an odorless gas produced by anaerobic digestion (AD) of biomass using microorganisms. It has an approximate composition of 70-50% Methane (a combustible gas), 30-50% Carbon dioxide and other trace gases depending on the nature of the biomass. The idea of using the organic municipal solid waste (OMSW) or simply municipal bio waste as feedstock for biogas production represents an environmentally sustainable energy source since it improves solid waste management while simultaneously providing an alternative clean energy source. Among other applications, the gas can be used for heating, cooking and electricity generation. However, notwithstanding, OMSW as a feedstock for AD comes with its own unique challenges compared to other forms of biomass. Our project therefore reviews the specific opportunities, challenges and techno-economics of using OMSW as sole feedstock supply for biogas production.

Keywords: Generation, Biogas, Organic Waste, Salem, Tamil Nadu

1. INTRODUCTION

Anaerobic digestion of biomass for energy production dates back as far as the 10th Century B.C with the earliest available record being around the 19th century. The first anaerobic digester was built in Bombay India in 1859 and the first notable use of biogas in England also dates back to the same year. Over the years, farm based manure has been the most extensively used feedstock for biogas digesters. However other sources have gradually been adopted as alternatives including bio waste, food crops, faecal sludge and municipal sewerage among others. The synthesis of biomass to produce energy is a growing trend worldwide as the quest for clean energy alternatives instead of the traditional fossil fuels intensifies. In this regard, there have been several technologies developed such as the synthesis of bioethanol from Sugar rich energy crops such as corn, the making of biodiesel from vegetable oils and animal fat as well as the production of biogas by anaerobic digestion of biomass among others. However, most of the proposed energy crops also double as food crops, a report by the Food and Agricultural Organization (FAO) of the Indian Nations (2008) indicated that increased use of food crops for bioenergy production in a bid to increase its supply will lead to increased food prices. This in the short run will help agricultural economies to grow significantly but in the long run will lead to food insecurity in developing nations. Therefore, to prevent the risk of increased global food insecurity, alternative types of biomass for bioenergy production should be introduced other than food crops. In this context, other energy crops have been proposed such as Jatropha for bioenergy production. But just like food crops, all planted biomass requires resources such as land and water to be able provide a sustainable biomass supply and yet both land and water are also very vital resources for the global energy balance. This therefore disqualifies planted biomass as the best source for bioenergy production. Other than energy crops, bioenergy in the form of biogas can still be produced from biodegradable wastes through AD. It is in this view that the concept of using the organic fraction of municipal solid waste as a feedstock for biogas production becomes a promising potential solution towards the production of alternative environmentally friendly and sustainable energy.

World over, urbanization is on the increase leading to increased waste generation and reduction in available space within urban centres. The waste generated is commonly sorted for recycling and the non-recyclables which are usually the large percentage are taken to landfills. The issue now is the continuously reducing space for land filling as well as the continuous emissions of landfill gas containing mostly methane which is a potential greenhouse gas . A report by FAO in 2011 showed that at least 33% of the global food supply goes to waste annually totalling to 1.3 billion tonnes of food waste worldwide. If this waste is used for biogas production, it can yield up to $367m^3$ of biogas per dry tonne at approximate 65% methane with energy content $6.25kWh/m^3$ yielding 894TWh annually which is about 5% of the world’s electricity needs. In 2011, South Africa generated 59 million tons of municipal waste of which 13% was classified as organic waste and another 35% classified as non-recyclable waste. Biogas produced by anaerobic digestion can be economically manufactured at both small and large scale plants and therefore can be tailored to supply rural and urban gas needs as well as meet regional and nationwide energy demands. The quality of raw biogas can be further upgraded by enriching its methane content up to the natural gas level (75-98%). Biogas has lower emission rates than natural gas or any other fossil fuel for that matter hence possesses much less potential for polluting the environment compared to fossil fuels as shown in table 1 below.

Table 1 Comparison Of Gaseous Emissions From Heavy Vehicles

g/kg	CO	HC	NO_x	CO_2	Particulates
Diesel	0.20	0.40	9.73	1053	0.100
Natural Gas	0.40	0.60	1.10	524	0.022
Biogas	0.08	0.35	5.44	223	0.015

Biogas is now widely used in developing countries as an alternative and renewable source of energy for wide spread range of applications including among others cooking, lighting and heating in households. The digestate from anaerobic digestion is a very useful fertilizer in agriculture. In contemporary times, biogas has been used most extensively on small and large scales in India and China. Currently in Germany and Sweden, biogas technology is in advanced stages and being used as a vehicular fuel and to produce clean electricity in the Mega Watt range.

2 ORGANIC SOLID WASTES

Waste management is all those activities and action required to manage waste from its inception to its final disposal. This includes amongst other things, collection, transport, treatment and disposal of waste together with monitoring and regulation. It also encompasses the legal and regulatory framework that relates to waste management encompassing guidance on recycling etc. The term usually relates to all kinds of waste, whether generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, or other human activities, including municipal (residential, institutional, commercial), agricultural, and special (health care, household hazardous wastes, sewage sludge). Waste management is intended to reduce adverse effects of waste on health, the environment or aesthetics. Waste management practices are not uniform among countries (developed and developing nations); regions (urban and rural area), and sectors (residential and industrial)

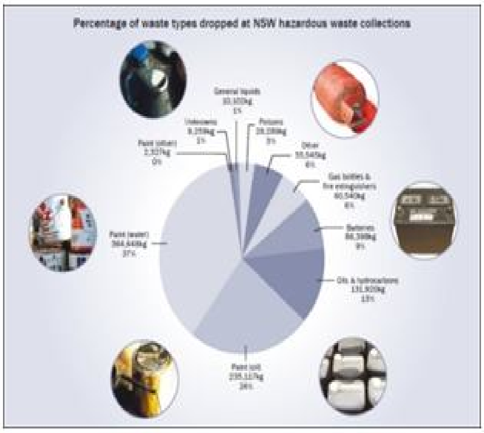

Figure. 1 Percentage Of Waste Types Dropped At Nsw

Figure. 2 Organic Waste

3.1 Organic Waste In Salem

To convert biodegradable waste, including vegetables and food materials, into power, the Corporation has proposed to establish three bio-methanation plants at a cost of Rs. 4.10 crore in the city.The bio-methanation cum power generation plants are to come up at Kakayan burial ground on Court Road Colony (Ward 12) with a 10 tonnes per day capacity at a cost of Rs. 1.60 crore; near Kuppai Medu on Erumapalayam Main Road (Ward 44) with a 10 tonnes per day capacity at a cost of Rs. 1.60 crore; and five-tonne capacity plant at Shevapet burial ground (Ward 28) at a cost of Rs. 90 lakh. Officials said that solids in the organic waste decompose rapidly and can be treated to produce electricity. "In the absence of oxygen, micro-organisms break down the organic matter into a stable residue and generate methane-rich biogas," they added. Of the more than 300 tonnes of municipal solid waste generated everyday in all the 60 wards, about 40 tonnes of biodegradable solid waste was collected from vegetable markets, hotels and other eateries in the city.

Currently, the wastes are disposed off without processing. Hence, the project would help in utilising the waste and generating electricity.

3.2 Objective

Setting up a self-sustaining and profit making farm within 50 kms radius of Salem city that will use organic farming techniques (totally devoid of chemical fertilizer usage), use modern agricultural farming techniques and equipment, cultivate traditional varieties of crops and sell the produce directly

Goals:

1.Use solar power and agro waste to generate electric power and attain self-sufficiency.
2.Use drip irrigation and minimize water usage.
3.Use solar powered air-conditioned storage to temporarily store and transport
4.Develop a dairy farm based on high yielding Tharparker cows.
5.Use high yielding, disease resistant traditional varieties of seeds for farming.
6.Set-up chain stores throughout Salem city and sell the produce directly to the consumer.
7.Set-up a small orphanage within the farm and train the inmates in the organic farming techniques.
8.Develop, test, document and publish the practical guides for the use of other farmers.
9.Create a seed bank of traditional varieties of crops
10.Bring more acreage either by leasing / acquiring the adjacent lands

3.3 Trend In Use Of Fertilizer (Organic And Inorganic)

3.3.1 Potential Availability Of Organic Manure

The total cropped area of the district is 0.20 Million ha. If the manure requirement is calculated at 12.5 t / ha, the total requirement / annum will be 2.5 Million tonnes. The estimated availability of organic manure is given in Table-17. The total quantity available in 2006 was 2.20 Million lakh tonnes. About 20 % of the manure is used for purposes other than agriculture like biogas, fuel, fish feed etc., Remaining quantity is essentially used in agriculture. Even though there is a decrease in the availability of organic manure like FYM, goat and sheep manure over the years, there is an increase in the total quantity due to enormous increase in the availability of poultry manure. But about 60 % of the poultry manure is not used in the district. It is learnt that the manure is sold outside and is transported to Kerala for use in plantation crops. Over the past two and a half decades, farmers have become increasingly dependent on chemical sources of nutrients for obtaining higher grain yields to meet the demands of enlarging population. The use of green manure crops, animal manures and composts which traditionally were important sources of nutrients, declined substantially as chemical fertilizers became increasingly available. The price of chemical fertilizers was subsidized, thereby enabling farmers to apply maximizing doses.

Use of organic materials to build up soil fertility is an age-old practice in India. The continuous addition of organic materials with or without mineral fertilizers will help to maintain the soil organic matter at a reasonable level. Such materials rarely supply sufficient nutrients to produce moderate to high yields. Organic manures not only supply nutrients but they also improve soil physical and chemical properties.(Table.2)

Table 2. Estimated Availability Of Organic Manure (Lakh Tones)

Sl No	Animal type	Quantity produced @	2002		2004		2006	
			Populn lakhs	Manure avail	Populn lakhs	Manure avail	Populn lakhs	Manure avail
1	Cattle	10kg/day/ animal	4.14	15.10	4. 05	14.77	3. 96	14.46
2	sheep	0.5kg/day/ animal	1.48	0.54	1. 46	0.53	1. 40	0.51
3	Goat	0.5kg/day/ animal	3.99	1.46	3. 89	1.42	3. 79	1.38
4	Poultry	25kg/year / bird	129.6	3.24	192.8	4.82	256.5	6.41
			Total	**20.34**		**21.543**		**22.77**

Table-3 Estimated Availability Of Crop Residues In Lakh Tones

No	Crop	1997		1998		1999		2000		2006	
		Prod	CR	Prod	CR	Prod	CR	Prod	CR	Prod	CR
1	Rice	0.95	1.43	0.99	1.49	1.20	1.80	1.09	1.64	.69	1.03
2	Total Millets	0.34	.52	0.32	0.48	0.29	0.44	0.22	0.33	.33	0.49
3	Total Pulses	0.20	0.30	0.16	0.24	0.23	0.35	0.26	0.39	.05	0.07
4	Total Oil Seeds	1.33	2.00	1.314	1.97	1.39	2.09	1.38	2.06	.88	1.33
5	Sugar Cane	0.80	0.16	1.36	0.27	1.32	0.26	1.66	0.33	1.84	0.37
	Total		4.40		4.45		4.92		4.75		3.29
	50 %		2.20		2.22		2.46		2.38		1.65

3.4 Potential Availability Of Crop Residues

Crop residues are the plant parts remaining in a field after the harvest of a crop, which include stalks, stems, leaves, roots, and weeds. Agricultural crop residues include corn stover (stalks and leaves), sorghum straw, rice straw and processing residues such as nut hulls.The estimated availability of crop residues in the district is given in the Table 18. The trend shows a decline in the availability of crop residues over the years mainly due to reduction in area and production of rice, millets, pulses and oilseeds. Even though there is an increase in area and production of sugarcane, it does not contribute as the residue from sugarcane is less. Out of the total quantity, 50 % is normally used as dry fodder for livestock especially paddy straw, sorghum straw, ground nut haulms etc., and the remaining residues are available for utilization in agriculture.(Table.3). The total quantity of organic manure available is 1.82 + 0.16 = 1.98 Million tonnes. But the requirement is estimated to be 2.57 Million tonnes. There is a deficit of 22.7 % in organic manure. Moreover 60 % of poultry manure is reported to be transported to Kerala and hence, still the deficit increases. So, the potential for the use of organic manure is high. In many places unavailability of organic manure is often quoted as the reason for non application of organic manure in the district.

3.5 Fertilizer Consumption

The inorganic fertilizer consumption pattern over years is given in Table -19. It is evident that 26824 MT of chemical fertilizers were used in 2005-06 out of which about 50 % fertilizer is Nitrogenous fertilizers. P fertilizer is the least consumed fertilizer. There is a steady increase in fertilizer consumption over years from 14509 MT in 2001-02 to 26284 MT in 2005-06 at a growth rate of 24 % per annum. This is mainly because of the adoption of high yielding varieties and improved agricultural practices. This clearly shows that the farmers have been dependant on chemical source of nutrients for observing higher yields.

3.6 Pesticide Consumption

Regarding the pesticide consumption also, there is a tremendous increase in the consumption over years especially the dust form. There is six fold increases in the consumption of dust form and 12 % increase in the consumption of liquids. This trend is attributed to the cultivation of high yielding varieties of crops in place of traditional varieties.

3.7 Initiatives In Organic Farming

In order to switch over from the usage of chemical inputs that are hazardous to human health, awareness is being created among the farming community to use organic inputs viz., neem based products, vermi-compost and bio-fertilizers like azospirillum, phosphobacteria etc. by various organizations.

3.7.1 Government Initiatives:

Organic farming in the district is in an infant stage. The government department of Agriculture has just initiated the activities related to organic farming. The state Department of Agriculture,along with the centre, under the National Programme for Organic Farming has covered 12 districts including Namakkal wherein some participants underwent a five day training from March. Subsequently another training, including certification agencies, NGOs, service producers, leading organic farmers participated in a ten day programme from march-21. In the district level, training is being given to the farmers on vermin composting technology, preparation of enriched FYM etc. More emphasis is given for the use of biofertlizer, biological control using Trichogramma viridi.

Similarly training is given to farmers under the project IAMWAM on organic farming. It is planned to take up organic cultivation of specific crops under the concept organic farming by the Tamil Nadu Agricultural University under the same project. The Department of Agriculture is also rendering the following services indirectly towards the promotion of organic farming through the following institutes.

Sugarcane Parasite Breeding Station – Mohanur:

Sugarcane Parasite Breeding Station is located at Mohanur where Salem Co-operative Sugar Mill is located. In this Station, Sugarcane egg parasites of Trichogramma chilonis are produced for the control of Sugarcane internode borer. The egg parasites are supplied to the farmers through Agricultural Extension Centre or directly to the farmers.

Coconut Parasite Breeding Station – Velur:

Coconut Parasite Breeding Centre is located in Paramathi Taluk. The main objective is to control coconut black headed caterpillar – Opising arenogella as biological method of control by releasing of egg parasite namely Braconids - Bracon breulcornis. Every year about 5,00,000 Broconids are produced and released in 500 ha of coconut fields in Namakkal District.

Bio Control Lab – Namakkal

Bio control lab is functioning at Namakkal Panchayat Union near Namakkal Agricultural Extension Centre. It is programmed to produce 1000 Kgs. of Trichoderma Viridi, 2000 Kg. Pseudomonas fluorescense and 200 Ltrs. of NPVs. More over, agricultural inputs like seeds, bio-fertilisers and bio-pesticides are being marketed and distributed through Agricultural Extension Centres.Some new schemes are to be implemented by the Government of Tamil Nadu for promoting organic farming at an outlay of Rs. 28.2 Million.

3.7.2 Scheme On Bio-Fertilizer Distribution Under 50% Subsidy
It is proposed to distribute the bio fertilizers through Agricultural Extension Centres for better crop yield. At present, biofertilizers are produced in the State owned bio-fertilizer laboratories and distributed to the farmers. 10 % are sold under 50 % subsidized rate under schemes available through department such as NPDP, OPP and ICDP. Remaining 90% of the stock is sold at full rate.

3.7.3 Scheme On Composting Of Farm Waste Through Pleurotus (Rs. 1.2 Million)
The scheme attempts to quicken the process of composting and also to compost with better composition of farm waste with the help of Pleurotus species. To popularise this technology, it is proposed to supply the farmers with one kg of pluerotus with 5 kgs of urea along with a booklet as kit. Each kit worth Rs. 120/- will be supplied to 10,000 farmers at a cost of Rs. 12 lakhs.

3.7.4 Vermi Composting Of Agricultural Wastes (Rs. 1.60 Million)
To popularize the technology of Vermi composting, it is proposed to conduct demonstration in 500 centres in the State. Besides, at the rate of 50 farmers per centre (50 500) i.e. 25000 farmers will be trained in Vermi composting technology. To popularize this technology among other farmers, necessary awareness has to be created. This scheme will be implemented in all districts except Nilgiris district in the State during the Tenth Five Year Plan period at total cost of Rs. 16 lakhs.

3.7.5 Green Manure Scheme (Rs. 19.40 Million)
Application of Green Manure is one of the practices recommended for increasing soil health, soil structure and water holding capacity of the soil and facilitate better drainage and releases locked up nutrients besides improving soils status in the long run at a cheaper cost. Green Manure seed farms will be raised in selected holdings of farmers, state seed farms and state oilseed farms and distribute to the farmers at 25% subsidy through Agricultural Extension Centres of the Department of Agriculture at a cost of Rs. 1.94 Crores.

3.8 INITIATIVES BY NGO'S
There are around 19 registered NGOs in Namakkal district**.** Out of them only a few NGOs have taken iniatives in organic farming. M/S kandasamy Kandar Environmental Organization is giving training on solid waste management for efficient recycling of organic wastes. Akhil Dr. B. R. Ambedkar Trust of Erumappatty block has initiated training in vermicomposting. The Tamil Nadu Organic farmers Technology Association led by S.R. Sunderaraman organized series of small training workshops to introduce chemical farmers to organic methods. The training at Namakkal was initiated and conducted from 7-8 May 2005. Tribal welfare Association, Kolli Hills and Lamp (Tribal Welfare Co-operative Society) of Kolli hills are taking efforts for such initiatives.

3.9 Promotion Of Organic Farming By Ms Swaminathan Research Foundation
M/S MS Swaminathan Research Foundation at Namakkal is taking up the venture of promotion of organic cultivation of pine apple, minor millets and also spices. The primary occupation in Kolli Hills is agriculture. Cultivation is mostly through natural farming with farmyard manure (FYM) inputs and family labor using local landraces of Samai, Thinai, Varagu, Panivaragu and Upland paddy. Fruit yielding crops like Banana, Guava, Pomegranate and Jack are grown in the backyards of houses and farms. Crops like Tapioca, Pepper, Cardamom and Coffee are also cultivated as cash crops.

3.10 Case Study Of Successful Organic Pine Apple Cultivation In Kolli Hills
A study on the scenario of pineapple export and the impact on the farmers was carried out by MSSRF. Data collection, mapping and compilation of data on fruits like pineapple and guava and crops like millets and pepper, have been carried out by MSSRF for organic certification. Ecocert has certified the organic nursery, and the organic pineapple cultivating farmers received NOP (National Organic Programme, USA) certificates. In addition, about 35 ha of fallow land has been put under organic pineapple farming, with a financial subsidy of Rs 5 lakhs from DRDA, Namakkal. In the Kolli hills, five villages with a large area under pineapple production were identified. The pineapple farmers were mobilized into self-help groups (three women, one man and one mixed groups). Their capacity to negotiate was developed through group discussions and training programmes with external agencies. MSSRF brought together the pineapple farmers and the Ion Exchange Enviro-Farms Pvt Ltd (IEEFL), a Pune-based organic export company. ECOCERT International, a Germany-based organic certifying agency, was approached for certification. A group of multidisciplinary experts inspected the site and certified the entire area as an organic production zone for pineapple cultivation (232 acres). Men and women members of the self-help groups pooled the produce coming from the various localities to ensure quality while marketing it at the collection centers. The process instilled a feeling of collective ownership and enhanced the business skills of the self-help members.

The collection was done under the supervision of IEEFL. Nearly 40 tonnes have been marketed, out of an estimated potential of 400 tonnes. The increase in profit through organic marketing is estimated at about 40 percent. Self help groups are periodically trained by the Scientists of CFTRI and Kuringi Organic Farms from Kodaikanal on organic cultivation methods and export packing. These groups have been involved in this venture for the last three years. The export quantity has increased from 20 to 100 tonnes in the last two years. This organic produce export venture has created confidence among SHGs. This effort not only promotes stable household income, but also reduces drudgery. Farmers are also safe from losses on account of fluctuating market demands and from exploitation by middlemen. The case study highlighted the effectiveness of the SHGs in procuring pineapple for export, and pointed out to some of the emerging requirements, like the effective adoption of organic agricultural techniques, documentation, demonstration and internal control mechanisms (MSSRF, 2003).SHG members of Kolli Hills and Namakkal were taken on an exposure trip to Krisna Vermibio unit at Namakkal. Organic farming training with DRDA and IEEF was organised for the organic pineapple growers. 133 tons of organic pineapples worth Rs 6.65 lakhs were exported to the USA through IEEF. SHGs supplying organic pineapple received an incentive of Rs 66,000 to get the organic product-marketing certificate from ECOCERT. Two SHGs in Thirupulinadu were facilitated to receive Rs 2.5 lakhs for organic pineapple cultivation through Indian Bank.

4. MICROBIOLOGY OF BIOGAS FORMATION

Biogas forming bacteria is a large group of complex and independent microbe species, most notable of which is the methane-producing bacteria. The process of biogas formation is split into three (3) steps: hydrolysis, acidification, and methane formation as elucidated below;

4.1 Hydrolysis

At this stage the microorganisms externally enzymolyse organic matter using their extracellular enzymes such as cellulase, amylase, protease and lipase. The bacteria at this stage decompose the long and complex molecular chains of the carbohydrates, proteins and lipids into shorter simpler parts such as monosaccharides, peptides and amino acids .

4.2 Acidification

In the second step, acid-producing bacteria are involved. These are responsible for the conversion of the simple intermediates from step 1 of fermenting bacteria into molecules of acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria can survive under both anaerobic and aerobic conditions as well as acid conditions. These bacteria utilise the dissolved oxygen or boundedoxygen in the solution and carbon to produce acetic acid. By doing this, they create an anaerobic condition which is vital for the methane producing microorganisms in the final step of methanogenesis. In addition, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphides and traces of methane. This process is only possible with energy input, since bacteria alone are not capable of sustaining that type of reaction, hence referred to as endergonic.

4.3 Methane Formation

Methane-producing bacteria also known as Methanogens are involved in the third step. These decompose compounds with a low molecular weight such as hydrogen, carbon dioxide and acetic acid created in step two to form methane and carbon dioxide. Methane-producing bacteria are exclusively anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogenic bacteria belong to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial genera. They belong to the genus archaebacter .

4.4 Conditions For Anaerobic Digestion

1. Digester Temperature

Temperature inside the digester has a major effect on the biogas production process. There are various temperature ranges during which anaerobic fermentation can take place

Psychrophilic ($< 30^oC$)
Mesophilic ($30 – 40^o$ C)
Thermophilic ($50 – 60^o$ C)

However, anaerobes are most active in the mesophilic and thermophilic temperature ranges . The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35° C. When the ambient temperature goes down to below 10^o C, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25º to 30° C. Proper insulation of digester helps to increase gas production in cold climates or highaltitudes .

2. Concentration of feedstock

The solids concentration in the influent to the biodigester affects the rate of fermentation. The amount of fermentable material of the feed in a unit volume of slurry is defined as solids concentration. The mobility of the methanogens within the substrate is gradually impaired by increasing solids content, and the biogas yield may suffer as a result. Ordinarily 6-9% solids concentration is best suited. In an experiment reportedly conducted in China, the optimum concentration of solids was considered to be 6% in summer but between 10 and 20% in winter and spring. When temperatures are low and materials take longer to decompose; it is better to have a higher total solids concentration, although this might result into impeded flows through the digesters.

4.5 Loading Rate

Loading rate is the amount of raw materials fed per unit volume of digester capacity per Day. Gas production is also highly dependent on the loading rate. Studies have shown that methane yield increased with a reduction in the loading rate. If the loading rate is too high, there will be more substrate than the bacteria can decompose. If the digester is being overloaded, the gas production will rise up initially and then fall after a while when inhibition occurs. Inhibition is caused because methanogens multiply more slowly than the acid forming bacteria and the gas inhibits the methanogens from producing methane and thus the gas production will be inhibited.

1. feed materials composition and nutrients

Anaerobic digestion processes are able to utilize a large number of organic materials as feedstock, including animal manure, human waste, crop residues and other wastes. Although, in order to grow, bacteria need more than a supply of organic substances as a source of carbon and nutrients, they also require certain mineral nutrients. In addition to carbon, oxygen and hydrogen, the generation of biomass requires an adequate supply of nitrogen, sulphur, phosphorus, potassium, calcium, magnesium etc. Agricultural residues and wastes usually contain adequate amounts of these elements.

2. Hydraulic retention time (HRT)

Retention time (also known as hydraulic detention time) is the average time spent by the input slurry inside the digester before it comes out. In countries with colder climates; the HRT may go up to 100 days as compared to warmer climates where the values lie between 30-50 days. Shorter retention time is likely to face the risk of washout of bacterial population while longer retention time requires large volume of the digester and hence more capital. There is a linear relationship between retention time and the digester temperature up to 35° C, the higher the temperature, the lower the retention time and the reverse is true .

3. P_H value

The methane-producing bacteria live best under neutral to slightly alkaline conditions. The pH in a biogas digester is directly dependent on the retention time. In the initial stages of fermentation, large amounts of organic acids are produced by acid forming bacteria; this in turn leads to the pH inside the digester falling to values below 5. This inhibits or even stops the digestion process. Methanogenic bacteria are very sensitive to pH and do not thrive below pH 6.5. Later on, as the digestion process continues, concentration of ammonium increases due to digestion of nitrogen which can increase the pH value to above 8.Once the process of fermentation has stabilized under anaerobic conditions, the pH will normally take on a value of between 7 and 8.5

4. Carbon-Nitrogen ratio

The ideal Carbon/Nitrogen (C/N) ratio for anaerobic biodigestion is between 20:1 and 30:1. Methanogenic bacteria use Nitrogen to meet their protein requirements. Therefore in cases of high C/N ratios higher than the optimum ranges, the Nitrogen will be depleted rapidly by the bacteria and will no longer react on the left over carbon remaining in the material thereby reducing the gas production. For cases of lower rations than the desired range, the excess Nitrogen will result into Ammonia (a strong base) formation hence raising the working PH over the desired 8.5 inhibiting the microbes and ultimately dropping gas production rates .

5. Toxicity

Mineral ions, heavy metals and the detergents are some of the toxic substances that inhibit the normal metabolism of methanogens in the digester. Small quantities of mineral ions (e.g. sodium, potassium, magnesium, ammonium and sulphur) also stimulate the growth of bacteria, while a heavy concentration of these ions will have a toxic effect. Detergents including soap, antibiotics and organic solvents among others inhibit the activities of the methane producing bacteria and addition of these substances into the digester should be avoided. Therefore the source of water for mixing the feedstock should be taken into consideration.

6. Agitation
Stirring of the digester contents needs to be done to ensure intimate contact between the microorganisms and substrate which ultimately results in improved digestion process. Agitation of the digester contents can be carried out in a number of ways, for instance daily feeding of the digester instead of periodical gives the desired mixing effect.

7. Air-tightness
Biological activities of anaerobic microorganisms including their development, breeding as well as metabolism do not require oxygen to take place. They are indeed very sensitive to the presence of oxygen. The breakdown of organic materials if any in the presence of oxygen will yield carbon dioxide instead of the desired output methane whereas in airless conditions methane is produced.
In addition, if the digester is not sealed to ensure the absence of air. The action of the microorganisms and the production of biogas will be inhibited and some will escape. It is therefore crucial that the biogas digester be air and watertight.

8. Moisture content
The microorganisms' excretive and other essential metabolic processes require water to take place hence the feedstock should have optimum moisture content for performance of the bacteria. The optimum value of moisture content should be about 90% of the total volume of feedstock.
Excess water in the feedstock leads to a fall in the rate of production per unit volume of feedstock and on the other hand, inadequate water leads to an accumulation of acetic acids which inhibit the digestion process and hence production. Furthermore, a thick scum will form on the surface of the substrate. This scum may prevent effective mixing of the charge in the digester.

5.PROCESS

5.1 Waste Collection
It includes the procedure and method of waste collection.it is done by two methods

5.1.1 Direct Collection
The sanitation waste is directly collected through pipelines of suitable dimension. It is better to have a poly vinyl chloride (PVC) for waste collection, which is of corrosion resistant in nature and having a comparatively better life .the liquid kitchen waste is also being collected directly by the aid of PVC pipes.

5.1.2 Indirect Collection
The solid kitchen waste is being collected and is introduced into the digester. The waste is being collected by the help of waste collection drum which are being placed at different places where the bio mass is being generated.

5.2 Segregation
The wastes which are being collected by indirect method are being segregated into biodegradable and non-biodegradable wastes. The biodegradable waste will be introduced into the digester.

5.3 Digestion
Anaerobic digestion is used for decomposing the biodegradable material and thereby producing biogas which can be used as source of fuel in kitchen.in anaerobic digester the bio degradable material will be broken down by the help of microorganism in the absence of oxygen.

6.SUBSTRATE QUALITY FOR ANAEROBIC DIGESTION

The quality and quantity of organic matter available for use in a biogas plant constitutes the basic factor of biogas generation. The volumetric yield of biogas per kilogram (kg) varies from one substrate to another depending on the composition as well as nature of the substrate. In addition, the percentage of methane obtained from the resultant biogas also varies independently according to type of biomass material .The yield of biogas in litres per kg of various materials is summarized in Table 4 alongside the percentage of methane production per raw material.

Table 4 Biogas Production Potential From Different Wastes

Raw Material	Biogas Production Litres/kg	Methane Content In Biogas (%)
Cattle Dung	40	60
Green leaves	100	65
Food Waste	160	62
Bamboo Dust	53	71.5
Fruit Waste	91	49.2
Bagasse	330	56.9
Dry Leaves	118	59.2

6.1 Key Substrate Parameters For Anaerobic Digestion

For efficient biogas production, a clear understanding of the nature of the input substrate has to be made because the properties of the substrate have a direct bearing on the resultant volume of the biodigester, the quantity/quality of output biogas and hence the project cost. Among the substrate parameters that should be ascertained are: Total Solids (TS), Total Volatile Solids (TVS), Substrate Dryness, Chemical Oxygen Demand and organic loading rate. These have been summarized as below;

1. Total Solids (TS)
This is the total amount of solid matter present in a given substrate. The Total solids' content of a substrate is obtained by weighing the residue or dry material left after drying it for 48 hours at 105^{o}C. The mass obtained is the raw estimation of both the organic and inorganic content of the substrate .

2. Total Volatile Solids (Tvs)
Volatile solids (VS) also referred to as the organic fraction of the total solids represent the digestible portion of the total solids normally expressed as a percentage. It is determined by heating the TS to 550^{o}C for 24 hours. The balance of the process is the inorganic fraction of the TS

3. Chemical Oxygen Demand (COD)
This parameter is the indicator on the oxygen equivalent of organic material in a substrate. It gives a precise estimation of the organic (degradable) material content of a given substrate sample . COD is determined by adding a strong chemical oxidizing agent to the substrate in an acidic medium .

4. Organic Loading Rate (OLR)
Organic loading rate (OLR) represents the amount of organic material that is added to the biodigester within a given amount of time usually expressed volume per day. The OLR gives an indication on the amount of volatile solids to be fed into the digester each day thereby becoming a key parameter in the sizing of the plant. Usually the OLR of a given system is pre-determined basing on several factors among with are the pumpability of the substrate and its composition among others. Therefore, OLR governs the design and dictates the value for the HRT

6.2 Substrate Pre-Treatment

This refers to all the processes that the feedstock undergoes prior to use in anaerobic digestion. These processes range from physical ones like sorting and particle size reduction to chemical processes like alkali treatment and metal addition among others. The pre-treatment of feedstock can yield higher biogas production rates and volatile solids reduction. The main effects that pre-treatments have on various substrates are particle-size reduction, biodegradability enhancement, formation of refractory compounds and loss of organic material. The various performance enhancers are as elaborated below;

1. Seeding
Seeding is a way of kick-starting a newly commissioned biogas plant by feeding it with previously digested material from another established plant. Alternatively, materials such as ruminant manure are often used to seed a new reactor, so as to reduce the plant start-up time. The method aims to introduce inoculum into the system.

2. Particle size

The particle sizes of the substrate directly affect digestion as it has direct indications on the available surface area for hydrolysing enzymes especially with plant fibre. Methane yield and fibre degradation have been found to improve with decreasing particle sizes within the feedstock from 100mm to 2mm .

3. Alkali Treatment

Treatment of biodigester feedstock with alkali solution has been found to improve biogas production and reduce cellulose production especially when using plant material. The degradation rate of paper waste was also found to increase by adding Sodium hydroxide (NaOH) . However, alkali solutions often lead to saponification reactions in continuous plants. These reactions tend to yield generate compounds leading to tremendous drops in acetate and glucose degradation rates.

4. Thermal/Thermo chemical Pre-Treatment

Pre-heating of substrate before anaerobic digestion has proved to improve methane production as well as volatile solids reduction. Studies have also showed that pre-heating of substrate that has been treated with chemical additives (thermo-chemical) even gives better results .Thermo chemical pre-treatment of chicken manure with Sodium hydroxide or Sulphuric acid at 100 ^{o}C has been found to increase both the biodegradability of the substrate and the methane yield .

5. Ultrasonic Pre-Treatment

Commonly used in sewage sludge treatment, the feedstock is treated using ultra sonic sound waves. Generally the method has been found to improve biogas production from anaerobic digestion. The mechanical shear forces caused by ultrasonic cavitation are the key factor for sludge dis- integration, and collapse of cavitation bubbles which significantly alter the feedstock characteristics .

6. Metals

Addition of certain metals to the feed material has been found to increase biogas production. Anaerobic co-digestion of cattle manure with potato waste was improved in terms of biogas production by the addition of heavy metals at 2.5 mg /l rather than 5mg/l, with the greatest increase from Cd2+ followed by Ni2+ then Zn2+.

7. MUNICIPAL AS FEEDSTOCK FOR BIOGAS PRODUCTION BIOWASTE

7.1composition Of Municipal Solid Waste (Msw) Municipal Solid Waste

General Waste as defined by the National Environmental Management (NEM) Waste Act, 2008 (Act No. 59 of 2008) of South Africa is that waste that does not pose an immediate hazard or threat to health or to the environment, and includes; domestic waste, building and demolition waste, business waste; and inert waste. It includes predominantly household waste (domestic waste) with the occasional addition of commercial wastes collected by a municipality within a given area. They are in either solid or semi-solid form. There are five broad categories of MSW

- Biodegradable waste: food and kitchen waste, green waste,
- Recyclable material: paper, glass, bottles, cans, metals, certain plastics, etc.
- Inert waste: construction and demolition waste, dirt, rocks, debris.
- Composite wastes: waste clothing, Tetra Packs (polystyrene), waste plastics such as toys.
- Domestic hazardous waste & toxic waste: medication, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish.

Therefore the organic fraction of municipal solid waste is made up of food and kitchen waste as well as green waste. 48% of the 59 million tonnes of MSW collected in South Africa in 2011 was OMSW.

7.2 Qualities Of Omsw As A Substrate For Anaerobic Digestion

1. TS

OFSMW is a predominantly solid substrate with a TS content of 30% as well as relatively large particle sizes [30]. It is of heterogeneous nature with a complex composition which usually makes estimates or measurements for its composition quite difficult

2. VS

OMSW has a high range of volatile solids ranging between 90-95% of TS and 28-29% of wet weight

3. Optimum Organic Loading Rates (OLR)

OMSW gives optimum anaerobic biodigester performance at organic loading rates between 5-10kgVS/m^3.

4. P_H

Due to a high volatile fatty acids contents from food waste (the predominant composition), OMSW tends to be acidic yielding overall PH levels lower than the desired 7 .

5.Biogas yield

Values from literature indicate that depending on the source of the OMSW, the substrate can yield approximately anywhere between 300 to 500 m^3 of biogas per tonne of volatile solids of 65% methane. The average biogas production from OMSW is 367m^3/ tVS [30]. Table 5 below shows the various biogas yields as quoted from different sources.

Table 5 Experimental Biogas Yields For Omsw

Source	Biogas yield m^3/tVS
Discarded Food	355
Food waste	367
OMSW	310-490
OMSW	300-400
OMSW	390
Food Waste	472

8 CONCLUSION

From various researches, it is clear that technically the production of biogas from the anaerobic digestion of the organic municipal solid waste is a potential solution to environmental conservation, sustainability and provision of alternative clean energy. OMSW as a substrate for production of biogas from AD is very efficient especially due to its ability to give higher biogas yields of good quality per unit weight than most available substrates and its abundance as well as availability at low costs. However, there are some draw-backs on the use of OMSW as a substrate for production of biogas such as its heterogeneous nature that calls for extra sorting of the substrate, big particle sizes that are harder to work with in AD and its high acidity due to high concentration of fatty acids that inhibit methanogens. All these can be solved via several developed pre-treatment techniques such as sorting, alkali additions, grinding among many at an additional cost to the project. These factors in mind, the use OMSW in anaerobic digestion becomes a costly venture compared to most of the other available substrates like farm manures that will not require pre-treatments such as sorting.

Therefore, more research is recommended on techno economic pre-treatment innovations that can improve the properties of OMSW for anaerobic digestion such as low-cost systematic sorting at source to ensure good quality feedstock, treatments that can improve pH and reduce particle sizes simultaneously. In addition, central governments should aim to subsidies AD technology to improve its economic viability as an investment. City planners can also start integrating bio digesters in the urban setting as a waste management strategy and a useful clean energy source.

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