

Comparision Of Formulas To Calculate Biogas Production

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Abstract

Environmental pollution is one of the major problems plaguing the modern world today. The environment and the various elements in the environment need energy to meet their need. So there is a need to extract energy from solid waste. The studies on conversion of solid waste to energy have resulted several alternatives including the biogas generation. There are several alternatives in estimation of biogas yield from the bio degradable fraction of solid waste. The study uses the formulae proposed by researchers to compute the yield of biogas from the variants of organic wastes. These will facilitate the outcomes and bring out the proximate or parities. In the present study the comparison of the formulae suggested by different researchers was made. Different types of solid wastes such as kitchen waste, fruit waste and sludge are considered for the study. The solid waste characteristics of each waste were taken from the literature. The COD of the waste is estimated. The results obtained were used to arrive the selection of equation for the estimation of biogas yield for a given waste. The equations suggested by Youssef A *et.al* (2010), Bouille and Dubois (2004) are giving similar biogas yield values with $\pm 20\%$ variations for the solid wastes considered except fruit waste. Based on the study it can be concluded that either Youssef A *et.al* (2010) (or) Bouille and Dubois (2004) equation may be used for approximate estimations of biogas yield in the absence of any experimental data from anaerobic digestion experimentation. The results obtained from co-digestion of wastes yields more when compared to the yield of individual wastes.

Key words: Organic waste, Formulas, Biogas production, Waste to energy, Anaerobic digestion.

Introduction:

Environment means surroundings, which includes the abiotic and biotic components and their interdependence. It consists of atmosphere, hydrosphere and stratosphere. Biosphere is a thin shell that encapsulates the earth, together with the hydrosphere. It is within the biosphere that the life forms of earth, including humans, live. Life-sustaining materials in gaseous, liquid, and soil forms are cycled through the biosphere, providing sustenance to all living organisms. In the cyclic process material and energy transfer takes place. In fact the environment and the various elements in the environment need energy to meet their need. Plants use the solar energy for their food production. Solar energy is a renewable natural source of energy that is essential for all life forms. It also keeps the environment warm and health. Apart from this natural energy, human beings started deriving energy from sources other

than solar. These may be conventional or non-renewable and non-convention or renewable. These sources of energy and the demand for the materials lead to industrial revolution, production of various products, consumerism and so on. Of late the so called development trends lead to change in the land use pattern, demographical changes, urbanization etc. These changes induced new challenges particularly in the environmental protection and conservation of resources.

To protect our environment, everyone should have awareness about surroundings. Due to the pressures of population and technology, the biophysical environment is being degraded, sometimes permanently. This has been well recognized, and several countries have begun placing restraints on activities that cause environmental degradation. Since the 1960's activity of environmental

movements has created awareness of the various environment issues.

The environmental issue may be classified as global issues and local issues. The global issues include global warming and climatic change, ozone depletion, loss of biodiversity and so on. Some of the local issues of importance are waste water disposal, polluted air emissions, solid waste disposal. The solid waste is a waste which seems to be local issue, but it is an issue plaguing all the towns and cities across the globe. Hence its effective measures are not only important at local but also global level. The waste is now treated as a wealth or resource, if the planning of ISWM is properly made. Most of the developed countries are implementer industrial ecology that shows a way for the utilization of waste as a resource rather a material that is fit for disposal. The integrated solid waste management (ISWM) basically aims at Reduce, Reuse, Recycle or Recover principle. One of the objectives of recovery is to extract energy from the waste. The waste to energy is catching up because of

1. Availability of biomass.
2. Stress on renewable resources.
3. Need to overcome the solid waste hazards and disposal problem.
4. Successful research and development and with financially viable technology.

The study also looks in to the aspects of waste to energy and conversion waste in to a resource.

Scope of the Project:

The studies on conversion of solid waste to energy have resulted in several alternatives including biogas generation. There are several alternatives in estimation of biogas yield from the biodegradable fraction of solid waste (Giovanni E et.al, 2012). The energy can be obtained from biomass through Refuse Derived Fuel (RDF). The stoichiometric chemical reaction formula is one of the popular for the estimation of biogas that can be produced from the organic waste. However, the usage of this formula request the chemical elemental constituent analysis to estimate kitchen waste, restaurant waste, fruit waste and sludge and obtained from different literature that has been studied. It is a not an easy task. As an alternative, several researchers proposed

empirical formulae to estimate the biogas production using organic characteristics of the solid waste such as BOD, COD, and VS etc. (Shamugam P and Horan N.J, 2008) .Use of these equations is results in different quantitative estimates with significant differences. Hence, there is a need to suggest appropriate equation to estimate the biogas yield from biodegradable solid waste. Hence, the work has been taken up to suggest an appropriate formula i.e. suitable for the conditions prevailing in this region of India. The work requires further literature review and detail study and comparison of estimates and actual gas production.

Objectives of the Study:

The study uses the formula proposed by researchers to compute the yield of biogas from the variety of organic wastes. These will facilitate the comparison of the outcomes and bring out the proximate or parities. The objectives of the work include:

1. Estimation of the biogas yield from different types of solid waste using the available formulae in the literature.
2. Comparison of the biogas yield composed using the formulae and with the actual yield from the process plants.
3. To identify the approximate formula that should be used for the conditions prevailing in the vicinity.

Materials And Methods

Types of organic waste:

There are different types of solid wastes generated in the surroundings of an environment. Among all the fraction and type of waste organic and biomass are important that can be sued for recovery of energy. The types of organic waste mostly used for biogas generation are restaurant or food waste, kitchen waste, waste from sludge and fruit waste.

Restaurant or food waste:

Food waste is a growing issue, and the disposal of it is controversial, given increased food prices and the resources required. Food waste makes up an estimated approximately 8.4% by weight of municipal solid waste in developing countries (Wei Wu, 2007).

The food waste includes uneaten food and food preparation leftovers from residences, commercial establishments such as restaurants, institutional sources like school cafeteria, and industrial sources like factory lunchrooms. Food waste is a significant component of the organic waste stream.

Kitchen waste:

Biogas, depending on the feed materials, contains methane, carbon dioxide, nitrogen and typically hydrogen sulphide and other sulphur compounds, such as siloxanes and aromatic and halogenated compounds. Kitchen waste contains high amounts of organic contents i.e. sugars, lipids, proteins, cellulose and other compounds which are degraded easily. The use of biogas using kitchen waste as feedstock can help solve the problem of energy deficit and at the same time, allow the safe disposal of kitchen waste which is often unscientifically dumped or discarded.

Sludge:

The pollution of water, air and soil by municipal, industrial and agricultural wastes is a major concern of public authorities who imperatively have to encourage the development of effective and non-expensive treatment technologies. Although it is not recent, the process based on the anaerobic digestion for the treatment of the waste organic fraction, is getting very attractive from the environmental and the economical points of view. It consists of a biological degradation of the organic matter, under anaerobic conditions, where a biogas, mainly methane (CH₄) is evolved, and hence providing a renewable source of energy which may be used in the production of electricity and heat. Generally various types of residual sludge from the waste water treatment plants are rich in organic matter. The high strength of organic matter in the sludge makes it suitable for anaerobic digestion and biogas production. In order to treat these solid wastes, it is first required to characterize them and second to choose a treatment mode depending on their types and their possible final destinations. Generally, distinction is made between primary sludge which are recovered by simple waste waters decantation, and are of high concentrations in mineral and organic matter, and the biological or secondary sludge

resulting from a biological treatment of waters. These latter have different compositions, depending on the nature of the degraded substrate, the operation load of the biological reactor and the eventual stabilizing treatment.

Fruit waste:

Fruit waste is a part of municipal solid waste which is typically disposed of directly to a landfill site. In order to utilize this valuable renewable resource, anaerobic biological processes can be employed to convert fruit waste to biogas. This usable gas is then used to generate electricity. This paper describes a comprehensive study to set up technology for converting fruit waste to electricity via biogas production. First, the fruit waste characteristics (type and composition) were systematically evaluated, and then laboratory experiments for biogas conversion to explore gas production from the waste were carried out. The biogas plant was then designed, based on the information obtained. Finally, a comparison of biogas plant with landfill was performed using life cycle assessment (LCA) to determine environmental impacts, and economic evaluation to assess daily processing costs. The results from waste characterization in one of the biggest fruit markets in Indonesia showed that the three main component fruit types were orange (64%), mango (25%), and apple (5%). Rotten fruit contributes up to 80% of the total waste in the fruit market. Based on the experimental work, the potential gas production in the biogas plant was calculated to be approximately 1075 Nm³/day, comprising 54% methane, based on 10 tons per day of fruit waste. The comparison demonstrates that it is a better option to utilize fruit waste in a biogas plant, in terms of LCA and daily operational costs, than to dispose of it in landfill.

Agricultural waste:

These wastes constitute manure and other agro based waste from the crop cultivation practices. The management of these wastes generates solid wastes rich in organic matter and hence is potentially biodegradable, requiring adopted methods.

Bio-gas production:

The potential for the recovery of energy from solid waste is high. The energy contained in the organic

matter must be converted to a form that can be used more easily. The recovery of heat by burning the organic material and biogas production from the solid Biogas from organic fraction of solid waste comes under the process of energy recovery. It can be done by anaerobic digestion, direct gasification etc.

waste are the options that are spoken of more frequently. The production of

Table 1: Yield of biogas obtained from different types of wastes taken from different literature

Type of Waste	Biogas Yield	Author
Kitchen waste	1300 ml	Ripon kumarsaha et al, Md.Fashiarahamn, Hasan Ali, 2012
	0.4 m ³ /kg of vs	T.Dlabaja and J.Malatak, 2013
Waste from sludge	0.125 m ³ /kg vs _{fed}	David Bolzonella, Paolo Pavan, Bahistoni, Franco cecchi, 2005
	150 m ³ /ton	Dinesh swaroop and RomeelaMohee, 2006
Food waste	51500 m ³ /day	Hogskoan Halmstad, 2008
	0.55 m ³ /kg vs	
	0.03 m ³ /kg	
Fruit waste	0.375 m ³ /kg of vs	Hogskoan Halmstad, 2008
	360 ml	

Several researchers proposed different formula to estimate the biogas yield. The proposed formulae use different variables viz COD, BOD, volatile solids (VS), B₀ (Highest methane yield) for the estimation of biogas yield. It is necessary use the appropriate equation with early measurable characteristics of organic solid waste. In this direction, the present study evaluated the suitability of the equations for the estimation of biogas yield. It may be useful for the future analysis to find out the theoretical yield of biogas.

Table 2: The Constituents of Biogas Produced from Organic Matter (Thomas H. et.al, 1970)

Gas	Chemical Formula	Volume
Methane	CH ₄	40-70%
Carbon dioxide	CO ₂	30-60%
Other gases	-	1-5%
Hydrogen	H ₂	0-1%
Hydrogen Sulphide	H ₂ S	0-3%

COMPUTATION OF BIOGAS YIELD:

In general, the biogas production or yield is generally estimated from the experimentation. However, it will be better to have some formula which will be useful to estimate the biogas yield from the direction of organic waste either as a simple substance or from co-digestion. This is essential particularly at planning stage and it gives judicious inputs for the decision makes with reasonable estimates.

The equation used in the DayetIfrah project (Giz 2009, youssef M et.al 2010) to calculate the produced biogas Q (m³/d) was:

(A) The formula used in DayetIfrah (2009) presented by youssef A et.al (2010)

Q biogas = 0.3*COD total..... (1)

(B) Boursier (2003) used the formulae for calculating the volume of produced biogas which seemed to be applicable in the case of continuous fermentations of completely mixed animal and human substrates. The formulae are

Vg = Ps * COD reduced..... (2)

Where

Vg: Quantity of biogas produced, m³/day

Ps: Specific gas production (from the figure)

COD reduced/d: Chemical Oxygen Demand removed per day (kg COD/d)

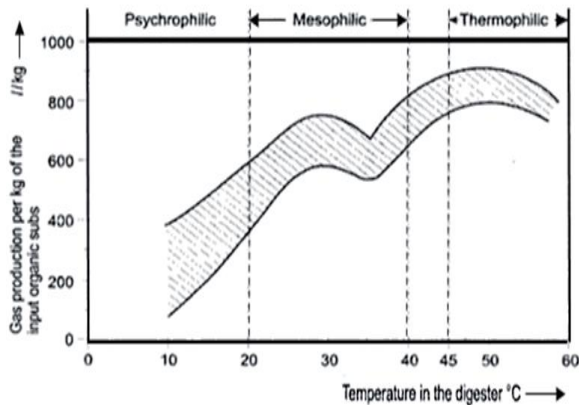


Fig1: Temperature effect on gas production (Nijaguna, 2002)

(A) Bouille and Dubois (2014) used the following formulae to estimate the biogas yield

$$Q = B_0 \cdot M_0 \dots (3)$$

Where

Q: The amount of biogas produced, m³/day

B₀: The potential of biogas production (figure)

M₀: Oxidisable matter

M₀ could be expressed in relation of BOD₅ and COD by using the empirical relationship

$$M_0 = (BOD_5 + 2 \text{ COD})/3 \dots (4)$$

Where

COD: Chemical oxygen Demand, kg/d

BOD₅: Biochemical Oxygen Demand for 5 days, kg/d

Additionally, we know that COD/BOD₅ = 2.5 and therefore

$$M_0 = 0.6 \text{ COD} \dots (5)$$

Good correlation was also observed between the CODs determined from the empirical equations and that calculated experimentally. Direct measurement of the COD of a solid waste is often thought to produce erroneous results and thus the volatile solids are generally used to quantify the organic strength of solid wastes (Han et al. 2005; Lin et al., 1999). However, COD data is required for reactor design to estimate the bio kinetic yield. Consequently, COD estimation based on empirical formula provides an attractive alternative to the experimental COD for

design purposes. According to this the formula is given to calculate COD value as

$$\text{COD} = 1.4 * \text{VS kg/day} \dots (6)$$

(Shamugam P and Horan N.J, 2008)

COD = Chemical oxygen demand, kg/day

VS = Volatile solids, kg/day

The solid wastes and the characteristics considered for this study are presented below.

Table3: Characteristics of different wastes

Waste	Characteristics	Source
Kitchen waste	Volatile Solids(VS)=260g, Temperature(T)=35°C	Ripon kumar et.al, 2012
Food waste	Volatile Solids(VS)=275g, Temperature(T)=37°C	Wei Wu, 2007
Fruit waste	Volatile Solids(VS)=6175g, Temperature(T)=40°C	Wei Wu, 2007
Sludge	Volatile Solids(VS)=434g, Temperature(T)=36°C	Mendez J.M.C et.al, 2009

Biogas Yield Model Calculations:

1.

sing Eq.1 adopted by Youssef A et.al (2010)

$$Q \text{ biogas} = 0.3 * \text{COD}_{\text{tot}}$$

$$\text{COD}_{\text{tot}} = 29.76(\text{COD of human waste}) + 0.85(\text{COD of manure})$$

$$= 30.61 \text{ kg/d}$$

$$\text{Therefore, } Q \text{ biogas} = 0.3 * 30.61$$

$$= 9.183 \text{ m}^3/\text{d}$$

2.

sing Eq.2 adopted by Boursier (2003)

$$V_g = P_s * \text{COD}_{\text{reduced}}$$

Where

V_g: the quantity of biogas produced (m³/d)

P_s: the specific gas production

$$= 310 \text{ l/kg (obtained from Fig.1)}$$

$$\text{COD}_{\text{reduced}}/\text{d} = 30.61 \text{ kg/d}$$

$$\text{Therefore, } V_g = 310 \text{ l/kg} * 30.61 \text{ kg/d}$$

$$= 9489.1 \text{ l/d}$$

$$= 9.4891 \text{ m}^3/\text{d}$$

3.

sing Eq.3 adopted by Boullie and Dubois (2004)

$$Q = B_0 * M_0$$

Where

Q: the amount of biogas produced (m³/d)

B₀: the potential biogas production
 =310 l/kg (obtained from the figure)

M₀ = 0.6 COD

= 0.6 * 30.61

=18.366 kg/d

Therefore,

Q = 310 l/kg*18.366 kg/d

=5693.46 l/d

=5.693 m³/d

Type of Waste	Formula	Organic Loading Rate (OLR)	%Of Volatile Solids	COD Value Kg/d	Temp °C	Biogas Yield m ³ /d
Restaurant/ Food waste	Q biogas=0.3*COD _{tot}	2.75 kg vs m ⁻³ d ⁻¹	22	37	0.385	0.1155
	V _g = P _s * COD _{reduced}					0.25975
	Q = B ₀ * M ₀					0.15477
Kitchen waste	Q biogas=0.3*COD _{tot}	1.3 kg vs m ⁻³ d ⁻¹	20	35	0.364	0.1092
	V _g = P _s * COD _{reduced}					0.23296
	Q = B ₀ * M ₀					0.139776
Waste from sludge	Q biogas=0.3*COD _{tot}	4.344 kg vs m ⁻³ d ⁻¹	38	36	0.60816	0.182448
	V _g = P _s * COD _{reduced}					0.395304
	Q = B ₀ * M ₀					0.2371824
Fruit waste	Q biogas=0.3*COD _{tot}	9.5 kg vs m ⁻³ d ⁻¹	65	40	8.645	2.5935
	V _g = P _s * COD _{reduced}					1.81545
	Q = B ₀ * M ₀					1.08927

Table 4: Biogas yield from various types of wastes obtained from different literature

Summary:

The organic component of solid debris produced through multiple operations can be utilized for a variety of uses such as reuse and recycling, and recuperating energy. The recuperation of energy is a vital component of managing waste, among which of those involves the generation of biogas from organic waste. The highest yield of biogas from different wastes is obtained from Equation 2 than equations 1 and 3 except in the fruit waste, while the highest yield of biogas from fruit waste is obtained from equation 3 than equations 1 and 2. It has been observed that the Biogas yield of co-digestion is more than that obtained from the digestion of the individual waste. The equation 1 presented by Youssef A et.al (2010) may be used for the computation of biogas yield from co-digestion of organic waste. Bio sludge produced from wastewater treatment plant should be used for extraction of gas.

It may be used as replacement to the cow dung in co-digestion plant. The estimation of biogas yield from the organic matter is essential to the planners and decision makers for taking meaningful decision. The estimation of biogas yield from different organic wastes can be made either through experimentation or formulae. In the absence of experimentation, approximate biogas yield can be estimated appropriate formulae are used. In the present study the comparison of the formulae suggested by different researchers was made. Different types of solid wastes such as kitchen waste, food waste, fruit waste and sludge were considered for the study the solid waste characteristics of each waste were taken from the literature using Table 2. The COD of the waste is estimated. The results obtained were used to arrive at selection of the equation for the estimation of biogas yield for a given waste. Based on the formulae the analysis is done to find out the yield of

biogas from different wastes like restaurant waste, kitchen waste, sludge and fruit waste. It also has been found the results of literatures obtained from co-digestion of cow dung and pig waste produced in the Netherland (De Mes T.Z.D et.al, 2010) and the co-digestion of human and animal waste produced in the Morroccon context (Youssef A et.al,2010) were used for the present study.

Conclusions:

Based on literature the biogas yield which is derived from different wastes by using different formulae, the following conclusions have been drawn.

1. The equations suggested by Yuossef A et.al (2010), Bouille and Dubois (2004) are giving similar biogas yield values with $\pm 20\%$ variations for the solid wastes considered except fruit waste.
2. Based on the study it can be computed that either Youssef A et.al (2010) or Bouille and Dubois (2004) equation may be used for approximate estimations of biogas yield in the absence of any experimental data from anaerobic digestion experimentation.
3. The results obtained from co-digestion of wastes the biogas yields more is when compared to the yield of individual waste.

SCOPE FOR FURTHER STUDY:

At present days the biogas is used for many purposes and basing on situations and conditions the yield is changed day by day and year by year. So there is a scope for further study by doing experiments and also finding it theoretically.

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