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Biomethane: An Efficient Source for the Production of CNG and Formaldehyde

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Abstract
Worldwide demand of oil has created great inflation in 2016. So, to reduce the gap between demand and supply of energy, the production and use of bio fuels have entered a new era of global growth. Use of bio resources to fulfill this demand has potential to reduce the global warming via reduction in emission of sulphur, particulates, CO_2, CO and CH_4. In this study biogas was generated from cattle dung by using fabricated anaerobic biogas digester. This biomethane was easily separated from biogas by scrubbing with water. This biomethane can be utilized either as a transportation fuel by compressing it in to compressed natural gas (CNG) or it can be converted in to liquid fuel, like formaldehyde (HCHO). Expansion of bio fuel production by efficient conversion technologies will increase global demand for agricultural products and results in the creation of new jobs at every stage of the production process to promote rural development in terms of environmental and social benefits.

Keywords: *Global warming, Biomethane, CNG, Formaldehyde.*

1. Introduction

The demand of fossil fuel is increasing day by day but the resources are limited. So to get rid of this problem, we are bound to develop an efficient technology which may provide us the alternative fuel as a substitute of fossil fuel. Transport sector is the largest consumer of the fossil fuel. Cow dung is used as biomass, which can disintegrate itself in CH_4, CO_2 and H_2O. Digestion of biomass is an anaerobic process in the presence of bacteria, at ambient pressure and temperature of 35^{o}C. Cow dung is supplied to the anaerobic digester as a water slurry resulting biogas generation, containing CH_4, CO_2 and H_2O. Biogas is a potential renewable energy source for rural India.

These bacteria decompose organic matter and produced methane and other gases in the process of completing their life-cycle in an anaerobic condition. As living organisms, they tend to prefer certain conditions and are sensitive to micro-climate within the digester. There are many species of methanogens and their characteristics [1]. The different methane forming bacteria have many physiological properties in common, but they are heterogeneous in cellular morphology. Some are rods, some cocci, while other occur in clusters of cocci known as sarcine. The family of methanogens is divided in to *Rod-shaped bacteria* (Non-sporulating, methanobacterium, Sporulating, methanobacillus) and *Spherical bacteria* (Sarcine, methanosarcina, methanococcus).

When dealing with solid and particulate material it is often the hydrolysis step that is rate limiting. However, when easily degradable material is present or when soluble monomers are available, enrichment of acids might take place because methanogenesis becomes the rate- limiting step [3]. Conversion of biomass to biogas is catalysed by a complex mixture of microorganisms, each having a different role in the process, It may be like *(i) Hydrolysis*: degradation of complex organic macromolecules in to monomers during digestion (ii) *Acidogenesis*: conversion of soluble monomers into volatile fatty acids (iii) *Acetogenesis*: production of acetic acid and (iv) *Methanogenesis*: conversion of acetic acid, H_2 and carbon dioxide in to methane.

On the other hand, oxidation of biomethane to formaldehyde is an economically attractive process. A considerable effort has been made to study catalysts which are active and selective for the partial oxidation of biomethane because of the need to convert surplus natural gas mainly methane to value added products [7, 11]. Presently formaldehyde is manufactured from methane via synthetic gas and methanol. Direct formaldehyde production from biomethane would potentially reduce both capital and operating costs, and therefore be of considerable industrial importance [4, 9, 10]. It has been found that the formaldehyde selectivity increases with increasing temperature at a fixed methane conversion [2, 8, 12]. The aim of present study is to use this biogas methane as an efficient vehicle fuel after purifying the biogas and also to identify suitable catalysts which could convert biomethane directly in to formaldehyde at atmospheric pressure and relatively at low temperature conditions [14,15,16].

2. Methodology

2.1 Biogas generation

An anaerobic digester having volume of 60 litres, made of stainless steel, was used for biogas generation. Only two third volume of digester was filled with cow dung slurry. The temperature of the anaerobic digester was kept constant and anaerobic condition was maintained [13]. For maintaining phosphorus, sucrose and nitrogen, di-potassium hydrogen orthophosphate, molasses and urea were used respectively. Time taken to start the gas production was 25 days after first feeding with cow dung (Table 1) [14].

Table 1: Specification of biogas digester

SNo	Parameter	Units	Parameter Value
1	Volume of digester	Litre	60
2	Volume of slurry	Litre	40
3	Digester temperature	^{0}C	35
4	Slurry feed rate	kg /day	5
5	Gas production rate	Litre/day	18
6	N/P ratio		15
7	Material of Construction		Stainless Steel
8	(Cow dung/ Slurry)		1:1 by weight

2.2 Scrubbing of Biogas

For biogas scrubbing physical/chemical absorption method is generally applied as they are effective even at low flow rates that the biogas plants are normally operating. This method is less complicated, requires fewer infrastructures and it is cost effective also. One of the easiest and cheapest method is to use of pressurized water as an absorbent. The raw biogas is compressed and fed into a packed bed column from bottom; pressurized water is sprayed from the top. The absorption process is, thus a counter-current one. This dissolves CO_2 as well as H_2S in water, which are collected at the bottom of the tower. The water could be recycled to the first scrubbing tower. This perhaps is the simplest method for scrubbing biogas [5, 17].

2.3 Catalyst Preparation

Catalysts were prepared by wet impregnation method by using their respective metal nitrates in desired quantity. Silica was taken as a support in desired quantity and mixed with nitrate solution of the active metals. The mixture was heated at 60 °C under constant stirring for 4 h and left for 15 h. The mixture was dried in an oven at 110 °C for 12 hr. Finally, it was calcined at 450 °C for 3 hr. The powdered catalyst has been pelletized at 7.5 tonne/cm^2 pressure and broken to small particles and sieved in size ranges of 425 to 500 micron. Sieved catalysts were used for the test of catalytic activity in the tubular micro reactor [14].

2.4 Production of Formaldehyde

For the production of different products, a schematic diagram of the experimental procedure for the performance evaluation of catalytic activity is shown in Fig.1. Mixture of air and biomethane was passed through the bed of catalyst, supported by glass wool on both sides. The experiments were carried out for different sets of catalysts.

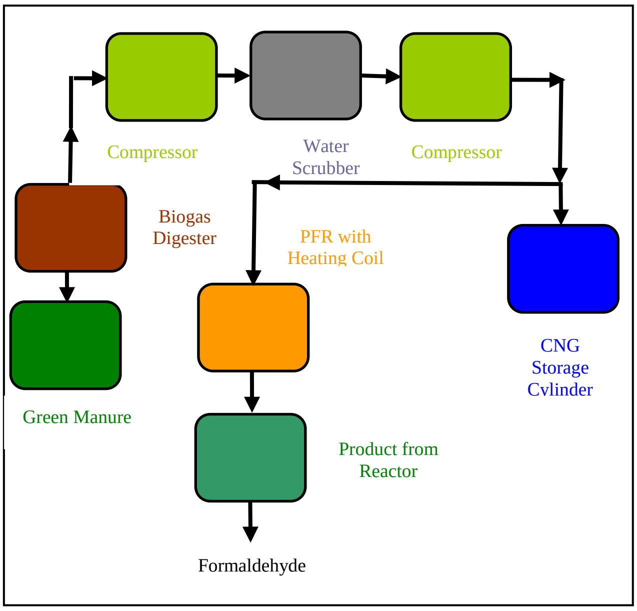

Fig.1. Procedure for catalytic conversion of biomethane

2.5 Compression and Bottling of Biomethane in Cylinders

Biogas, containing mainly methane, could not be stored easily, as it does not liquefy under pressure at ambient temperature. Its critical temperature and pressure are -82.5 °C and 47.5 bar respectively. Compressing the biogas reduces the storage requirements, concentrates energy content and increases pressure to the level required overcoming resistance to gas flow. The net gas available per day for bottling will be 18 litres having energy value of 0.612 MJ while it was stored at 20 MPa. The bottling will fulfil the fuel requirement in rural transport; and it will make villages pollution free and supply enriched manure [5, 6, 17].

3. Results and Discussion

The aim of this study is to explore the potential of biogas production from organic waste and its prospects in wider perspective. It is important to prioritize processes, production system and products that are efficient with regard to the land area used and the use of organic byproducts and wastes, and also according to their environmental impact, particularly in terms of reduction of greenhouse gas emission i.e. to reduce global warming.

In Indian context, biogas scrubbing, compression and storage can results an efficient resource of vehicle fuel. We can purify this biomethane by different physical and chemical methods like, water scrubbing, chemical absorption in NaOH /KOH and biological methods. Among these methods, water scrubbing is most cost effective method.

On the other hand, it was observed that no definite trend in the variation of percent HCHO selectivity with reaction temperature has been observed with different sets of catalysts. The reason in the decline in the HCHO selectivity at high temperatures by these catalysts is due to the decomposition of HCHO in to CO and H_2. Now it is necessary to invent new sustainable technology which can reduce the gap between the global demand and supply of energy to promote urban as well as rural development in terms of economy and environmental protection.

4. Conclusions

Fabricated digester produces biogas, having 60% bio methane and 35% carbon dioxide and this biomethane becomes equivalent to natural gas. Hence biomethane stands out as promising alternative, together with the 'second generation' vehicle fuels that are based on lignocelluloses. In other side, we can convert this bio methane to formaldehyde by partial oxidation with different oxidizing catalysts. On the other hand, it can be used as cooking gas, electric generators and vehicle fuel. Due to its potential, we have to develop other efficient technologies for storage in cylinders for various purposes.

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References

[1] Alexander M., Introduction to soil microbiology. *John Wiley & Sons*, Inc. 227-231(1961).

[2] Arena F., Frusteri F.and Parmaliana A., Kinetics of the Partial Oxidation of Methane to Formaldehyde on Silica Catalyst. *AIChE Journal*, 46(11), 2285-2294 (2000).

[3] Borjesson P. and Mattiasson B., Biogas as a resource-efficient vehicle fuel. *Trends in Biotechnology*, 26(1), 7-13 (2007).

[4] Enger B.C., L. Rune and Holmen A., A review of catalytic partial oxidation of methane to synthesis gas with emphasis on reaction mechanisms over transition metal catalysts. *Applied Catalysis A: General*, 346, 1–27(2008).

[5] Kapdi S.S.,Vijay V.K., Rajesh S.K. and Prasad R., Biogas scrubbing, compression and storage: perspective and prospectus in Indian context. *Renewable Energy*, 30, 1195-1202 (2005).

[6] Kapdi S.S.,Vijay V.K., Rajesh S.K. and Prasad R., Upgrading biogas for utilization as a vehicle fuel. *Asian Journal on Energy and Environment*, 7(4), 387-393 (2006).

[7] Kennedy M., Sexton A, Kartheuser B, Coda E.M.G., McMonagle J. B. and Hodnett B.K., Selective oxidation of methane to formaldehyde: comparison of the role of promoters in hydrocarbon rich and lean conditions. *Catalysis Today*, 13, 447-454 (1992).

[8] Khan M.M. and Somorjai G.A., A Kinetic Study of Partial Oxidation of Methane with Nitrous Oxide on a Molybdena-Silica Catalyst. *Journal of Catalysis*, 91, 263-271 (1985).

[9] Koranne M.M., Goodwin J.G. and Marcelin J.G., Oxygen involvement in the partial oxidation of methane on supported and un supported V_2O_5. *Journal of Catalysis*, 148, 378-387 (1994).

[10] Koranne M.M., Goodwin J.G. and Marcelin J.G., Partial oxidation of methane over silica and alumina supported vanadia catalysts. *Journal of Catalysis*, 148, 388-391(1994).

[11] Parmaliana A., Sokolovskii V., Miceli D., Arena F. and Giordano N., On the nature of the catalytic activity of silica- based oxide catalyst in the partial oxidation of methane to formaldehyde with O_2. *Journal of catalysis*, 148, 514-523(1994).

[12] Rytz D.W. and Baiker A., Partial Oxidation of Methane to Methanol in a Flow Reactor at Elevated Pressure. *Ind. Eng. Chem. Res.*, 30, 2287-2292(1991).

[13] Satyanarayan S., Murkute P. and Ramakant, Biogas production

enhancement by Brassica compestries amendment in cattle dung digesters. *Biomass and Bioenergy*, 32, 210-215(2008).

[14] Singh D., Pratap D.,Vashishtha M. and Mathur A.K., Direct catalytic conversion of biogas methane to formaldehyde. *International Journal of ChemTech Research*, 2(1), 476-482 (2010).

[15] Smith, M.R. and Ozkan U.S., The partial oxidation of methane to formaldehyde: Role of different crystal planes of MoO_3. *Journal of Catalysis*, 141, 124-139(1993).

[16] Zhen K.J., Khan M.M., Mak C.H., Lewis K.B. and Somoriai G.A., Partial Oxidation of Methane with Nitrous Oxide over V_2O_5-SiO_2 Catalyst. *Journal of Catalysis*, 94, 501-507 (1985).

[17] Boateng C.O. and Kwofie E.M., Water Scrubbing: A Better Option for Biogas Purification for Effective Storage, *World Applied Sciences Journal 5 (Special Issue for Environment)*, 122-125 (2009).

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