ECO-FRIENDLY COOKING GAS FROM SUGAR MILL WASTE

By

P. THANGAMUTHU
Karnataka Sugar Institute, NH4A, Belgaum-Khanapur Road, Zadshahpur, Belgaum–590 014, Karnataka, India
thangamuthu_p@yahoo.co.in

KEYWORDS: Filter Cake, Digester, Organic Matter, Methanisation, Biogas.

Abstract

IT WAS FOUND that biogas or cooking gas can be produced successfully from sugarcane filter cake. It contains a considerable amount of organic matter in the range of 73% to 77% including 1.8% to 3.0% sugar. After analysing the constituents of the filter cake and after finding its suitability, a laboratory scale study was conducted. As a result it was established that maximum biogas can be produced using filter cake as a feed stock when the concentration of its solids is 6% to 8%; beyond which the production rate decreases. It was also established that average biogas of 0.39 L/d was higher at 8% concentration than with other feed concentrations. After optimising the results, a pilot scale study was conducted during which it was established that the filter cake gives a biogas production of 65% to 75% instead of 50%–52% in the case of cow dung which requires 1:1 dilution to make a slurry for feeding. The filter cake requires 1:1.25 dilution as it contains 26% to 32% dry matter. Recommendations for biogas plant selection and installation are given. The increase in fertiliser value of digested filter cake, power generation, indirect way of helping afforestation, and environmental protection are discussed.

Introduction

About half of the world’s population depends on fire wood for cooking purposes. Water-containing materials from plants and animals contribute to bio-fuels. Such materials should be utilised to keep pace with the growth of biomass, since excessive cutting of woods leads to deforestation and also direct combustion leads to excessive smoke causing air pollution. The gasification is done in two ways. The first is by bio-degradation in which a large amount of biogas is obtained.

The second is thermo-chemical conversion or pyrolysis which yields producer gas comprising carbon monoxide and hydrogen (CO, H_2). The development and utilisation of renewable sources of energy along with conventional sources is essential to meet the growing demand for energy in the world. In particular, among the non-conventional energy sources is ‘biogas’.

In India there are about 500 working sugar mills, crushing about 300 million tonnes of sugarcane, producing about 12 million tonnes of filter cake which is one of the by-products of the sugar industry. This filter cake is being used as fertiliser in and around the sugar mill areas. In some factories, the cane growers do not want to use it as a manure. In such areas it is a great problem for the sugar mills to dispose of the filter cake.

The factory has to spend a large amount for the disposal by engaging lorries or tractors. If it is dumped on public lands, it will affect the environment and the surrounding village people may object to it. If it is not removed from the filter cake yard, the accumulation may sometimes affect the rate of crushing or will lead to stoppage of crushing if the area required for storage is insufficient. If the filter cake produced is not taken by cane growers, the factory has to spend extra money for the disposal and thereby increases the cost of production. In each sugar mill, a canteen is provided for the employees. The canteen will run around the clock during the crushing season. In the off-season also the canteen has to operate for the preparation of meals, '*tiffin*', tea, coffee etc.

Fire wood is used as a fuel. A 2500 t cane/d plant utilises about 150–200 t of fire wood per annum. In money value, it will be about $8500. So, to avoid the deforestation for fire-wood, a study on filter cake utilisation for the production of biogas and to increase the fertilising value of filter cake was carried out.

Generally in India, in rural areas, the people cannot rely on LPG (liquefied petroleum gas) for cooking purposes as the availability is very unreliable, Hobson *et al.* (1981). Only the urban area people are enjoying this benefit. The rural area people in addition cannot afford to use it, because its cost is higher compared to fire wood.

Additionally, firewood is easily available due to deforestation. To some extent, the biogas acts as an eco-friendly bio fuel in rural areas. Biogas can be generated using cow dung in general in rural areas. However, the maintenance cost for cattle has caused the people to abandon it. That is why a number of '*gobar'* (cow dung) gas plants in the rural areas are not functioning and have been left abandoned.

The outcome of the research resulted in the identification of sugarcane filter cake as a potential alternative source for biogas generation to utilise it in sugar factory canteens as well as in rural areas. Additionally, the fertilising value of digested filter cake improves.

Filter cake as a feedstock

Filter cake is a solid residue which is a by-product of sugar industry, Balasubrammaniam and Kasturei Bai (1988). The filter cake has essential nutrients besides containing a considerable amount of organic matter Nunez *et al.* (1985) and sugar Paturau (1982).

Table 1—Analysis of sugarcane filter cake (dry basis).

Sl. No.	Constituents	Content in press mud %
1	Organic matter	73–77
2	Organic carbon	40–57
3	Total solids (T.S.)	26–32
4	Volatile solids (V.S.)	18–24
5	Ash	7–11
6	Moisture	68–72
7	Sugar	1.8–3.0
8	pH	4.4–4.8
9	Nitrogen	2.0–3.5
10	Phosphorus	0.5–0.78
11	Potassium	0.28–0.38
12	Sulfur	1.2–1.4
13	Calcium	3.0–3.8
14	Protein	14.5–18.0

Table 1 shows the analysis of sugarcane filter cake, while Table 2 gives the analysis of constituents in the total solids present in the filter cake Nunez (1985).

Table 2—Constituents of total solids.

Constituents	Quantity %
Volatile solids	66.80–70.90
Ash	30.70–32.80
Protein	51.88–54.54

Tables 3 and 3A provide data on biogas production from filter cake during different weeks at varying total solids concentration, and Table 4 the methane content of biogas generated from filter cake.

Table 3—Biogas production from filter cake in different weeks at varying total solids concentration.

Solid concentration %	Period of digestion (days)									Total biogas production L
	0–7	8–14	15–21	22–28	29–35	36–42	43–49	50–56	57–60	
4	3.80	3.40	2.10	1.98	1.18	0.70	0.40	0.38	0.18	14.00
6	3.20	3.83	3.29	2.48	2.39	2.28	1.59	1.98	0.35	20.68
8	2.40	4.20	4.40	3.98	2.78	2.40	1.20	0.78	0.48	22.40
10	0.86	1.10	1.40	2.44	1.59	1.38	1.18	0.91	0.59	11.80
12	0.49	0.89	1.44	1.88	2.11	1.45	1.33	1.18	0.68	11.79
14	0.23	0.34	0.40	0.70	1.58	0.98	0.44	0.15	0.08	4.51

Table 3A—Details of biogas production from filter cake.

Ex. Pt. No.	Initial volatile solids	pH	Average biogas production L/day	Period of highest biogas production	Highest production L/day	Temp. ^0C
1	2.81	6.9–7.1	0.26	4^{th}–13^{th}	1.8	28–31
2	4.18	6.9–7.1	0.35	7^{th}–24^{th}	1.8	28–34
3	5.58	6.9–7.1	0.39	12^{th}–30^{th}	1.1	28–34
4	6.95	6.9–7.2	0.19	16^{th}–32^{nd}	1.9	28–34
5	8.31	6.9–7.1	0.18	20^{th}–35^{th}	1.9	28–34
6	9.70	6.9–7.2	0.08	26^{th}–37^{th}	1.7	28–34

Table 4—Methane content of biogas generated from filter cake.

Solid concentration %	Methane (CH_4) content %
4	67.5
6	70.8
8	71.8
10	70.3
12	64.8
14	64.1

Experimental aspects Lakshmanam *et al.* (1990)

Volume of biogas

The generated biogas was measured at a fixed time by an electronic gas meter.

Moisture and total solids

By evaporating the moisture of a known weight of sample in an air-oven at 105°C, the loss of weight of sample was calculated as moisture and the remaining as solid concentration.

Ash and volatile solids

By ignition of a known quantity of sample in a muffle furnace at 550°C for one hour, the ash and volatile solids were determined.

Protein

Protein was estimated by Kjeldahl's nitrogen analysis multiplying total nitrogen by a factor of 6.25.

pH

By using a digital type pH meter.

Determination of methane

By gas chromatography (porapak-Q column) with hydrogen as a carrier.

Biogas production from filter cake

Procedure

Cattle dung and water in the ratio of 1:1 are first mixed in a tank and then the mixture (slurry) is allowed to pass through the inlet into the digester. A strainer (sand catcher) has been provided to prevent the sand particles from entering the digester. The slurry ferments and produced biogas collects in the gas holder or in the gas storage dome, depending on the design of the plant. Biogas is drawn from the plant through a pipeline directly to the points of use. To drain out the condensed water in the pipeline, a drain valve has been provided. Daily, after the gas has been used, the digester is freshly filled with slurry, taking care that an equal amount of digested slurry comes out from the digester.

Results and discussions

Tables 1 and 2 summarise the chemical composition of the used filter cake.

It should be pointed out that the dry substance of filter cake is 26%–32% higher than that of cow dung (18%) requiring dilution for efficient biogas production.

Table 3 indicates that the biogas production increases from 4% to 8% dry substance, culminating at 6% with 22.40 L biogas. Beyond 8% solids, the biogas production decreases. However, during the first week of operations, the highest biogas production was achieved with feed of 4% solids, which gradually changed during the following weeks (2 to 6) in favour of 6% and 8% feed solids.

The average biogas production of 0.39 L/d was reached at 8% feed concentration. Highest methane production was observed at 8% solids. The above results indicate the potential of filter cake as feed stock for biogas generation.

Pilot scale studies

In the pilot scale studies, a 4 cubic metre capacity digester was used. Initially, the seed development was done by charging cow dung slurry (by mixing one part of cow dung with one part of water) to build the essential population of methanogenic bacteria. After the stabilisation of the methanogenic operation, the bacterial population was adequate as indicated by the sufficient methane production. Filter cake slurry prepared by mixing one part of filter cake with 2.5 parts of water was added. Biogas production was found to be 0.7–0.8 m^3/d with about 50%–52% methane during the first week of initial feeding with cow dung slurry. The gas production increased to a steady level of 2 m^3/d after a week of feeding with filter cake. After three months of continuous feeding with filter cake, biogas production increased to 2.4–2.6 m^3/d. It was observed that, after charging with filter cake, the methane content of biogas gradually increased from 50%–52% with cow dung to 65%–75% with filter cake slurry.

Initially, the Karnataka Sugar Institute, Belgaum has commenced a trial with a 4 m^3 *gobar* gas plant in a near-by sugar mill. After successful completion of the trial, it recommended to all the cooperative and public sector sugar mills to put up a biogas plant with capacities varying from 60–75 m^3/d for canteen cooking purposes.

Similarly, the Institute has helped the cane growers in and around the mills in the cooperative as well as public sector sugar mills. In addition, it has helped to set-up 3–4 m^3/d capacity small plants in the rural areas. Now, there are about 100 industrial type biogas plants with a capacity of 60 m^3/d in 100 sugar mills including cooperative, public and private sector sugar mills in India. About 200 of 4 m^3/d capacity domestic type biogas plants are now operating near sugar mills in India utilising filter cake as a feedstock for the production of biogas Thus the sugar mills in India are helping the rural people to enjoy the benefit of biogas for safe cooking by avoiding the use of firewood.

Tips for biogas plant installation

1. Select an elevated dry and open area exposed to sunshine for a greater part of the day.
2. It should be near the kitchen.
3. The ground water level should be minimum 2 metres.
4. There should not be any drinking water well or hand pump within the range of 15 metres from the gas plant.

Capacity

1. Each kg of filter cake produces 0.05–0.06 m^3 of bio gas.
2. The gas required for cooking per day per person is estimated to be 0.3 m^3.
3. For a sugar factory canteen, the gas requirement for some 250 persons is 75 m^3.

Selection of bio-gas plants Malik *et al.* (1995).

1. Floating gas holder, commonly called KVIC type (Khadi & Village Industries Commission).
2. Fixed dome called Janatha type.
3. Pragati model.
4. Modified fixed dome called Deenabandhu model.
5. KVIC type plant having digester made of angle iron and polyethylene sheet called Ganesh model.
6. KVIC type plant having digester made of pre-fabricated ferro-cement segments.
7. KVIC type plant made with fibre glass, reinforced plastic.
8. The floating type drum was found to be more efficient compared to other types. The floating drum should be rotated once or twice a day so that a stirring effect will be created. If the plant is in regular use, 1:1 ratio of urea and di-ammonium phosphate added once in a fortnight will enhance the growth of the methanogenic bacteria. Diluted molasses or effluent can also be used to enhance gas production. Generally, the retention time varies from 30–50 days. Instead of mild steel, fibre glass can also be used for the drums to avoid corrosion. If a stirring arrangement is provided, the retention time is reduced. The retention time may vary from digester to digester. If a higher production rate is required, the rate of feeding may be increased. Generally, feeding should be in the morning.
9. The fixed dome plant should strictly be made by well-trained master masons who have the experience of constructing such plants; material quality is of importance (bricks, cement) for avoiding cracking and gas leaks Malik *et al.* (1997).

Components of a plant

A biogas Plant consists of the following parts:

1. Mixing tank and inlet.
2. Digester.
3. Gas holder or gas storage dome.
4. Outlet and compost pit.
5. Gas main outlet and valve, pipelines, water fittings, gas stove lamp and similar appliances suitable for biogas.

Selection of depth of digester

The depth or volume of the digester is determined by the retention period which depends upon the average ambient temperature of the area. Commonly these are:

1. Plants based on 30 days retention period.
2. Plants based on 55 days retention period.

Cost of the plant

Cost of installation varies according to the type and size of the plant. On average, a FRP model is 5% more and a ferro-cement digester model is 10% less than the KVIC model.

The cost of the plant will vary depending on location. In India, the cost of the floating drum type model with 60 m^3 capacity about $6000–7000.

Facilities provided by the State and Central Government of India

The State Energy Development Corporation under the control of State Governments and the Ministry of Non-Conventional Energy Sources, Government of India are providing facilities for promotion, construction, after sales services and repairs. It also provides subsidy facilities.

The State Government and KVIC (Kadhi and Village Industries Commission) have created biogas cells at the state and district level for providing technical guidance, supervision in the construction, maintenance of plant and arrangement, inputs like cement, steel and institutional finances providing post installation servicing facilities etc.

Power from biogas

One cubic metre of biogas produces 250 watts of electricity (with the aid of oil engine and generator). It has increased thermal efficiency and calorific value as compared to biogas from cow dung. The biogas can effectively be used for cooking, running farm machinery and also for lighting farm houses.

Fertilising values

The digested filter cake which leaves the digester is rich in nitrogen, phosphorus and potassium. Field trials with sugarcane comparing raw filter cake vs. digested filter cake showed increased yields from digested filter cake.

There is also no wax and sulfur in digested filter cake. It was also discovered that digested filter cake acts as a weedicide. When using digested filter cake for wetting agricultural wastes in bio-manuring, the methanogenic bacteria act as catalysts in decomposing the organic residue. The digestion period is also reduced by about 40%.

Conclusion

Biogas from filter cake is a clean and cheap gaseous fuel. It contains 65%–75% methane which is combustible and it is produced by digestion. The fertilising value of the filter cake does not diminish but rather enhances during the digestion process.

Thus, the filter cake converts by digestion to two useful products, fuel and fertiliser. It should be handled with care (fire hazard) and it saves on cooking time.

It is a non-conventional energy source. The Central and State Governments are encouraging this program.

Biogas is an eco-friendly, non-fossil fuel replacing firewood for cooking, thus helping to prevent deforestation for the benefit of the environment.

Acknowledgement

The author expresses his heartfelt thanks to both the chairman and the director of the Karnataka Sugar Institute, Belgaum for their encouragement in conducting the research and permission for publication of this paper. He also wants to thank all his colleagues and staffs of KSI who assisted and contributed.

REFERENCES

Balasubramaniam, P.R. and Kasturi Bai, R. (1988). Biogas plant effluent in aquaculture. School of Energy Science, Madurai Kamaraj University, Madurai 625 021 (India).

Hobson, P.N., Housefield, S. and Summers, R. (1981). Methane production from agricultural and domestic wastes. Andrew Porteous (ed.). Applied Science Publishers, Barking, England: 269.

Lakshmanan A.R. ***et al.*** (1990). Biogas production from sugarcane filtercake - Lab scale and pilot plant studies', Urja (India) /27/2/25.

Malik, R.K. and Dalel Singh (1995). Biogas generation from anaerobic digestion of cattle waste and molasses. Proc STAI, 57: 551–558.

Malik, R.K. and Dalel Singh (1997). Biogas production from cattle waste and distillery effluent mixed slurry. Proc. STAI, 59: 37–42.

Nunez A.G. and Leal, M.S. (1985). Biogas from the treatment of sugar waste in a horizontal reactor. Cuba Azucar: 13–16.

Paturau, J.M. (1982) (Ed.). By-products of the cane sugar industry. An introduction to their industrial utilisation, 2nd revised edition. Elsevier, Amsterdam, Oxford, New York.

PRODUCTION DE BIOGAZ A PARTIR DES ÉCUMES D'UNE USINE SUCRIERE

Par

P. THANGAMUTHU
Karnataka Sugar Institute
NH4A, Belgaum-Khanapur Road, Zadshahpur, Belgaum – 590 014, Karnataka, Inde
thangamuthu_p@yahoo.co.in

MOTS-CLÉS: Ecumes, Digesteur,
Matiere Organique, Methanisation, Biogaz.

Resumé

IL A ÉTÉ constaté que du biogaz ou gaz de cuisson peut être produit avec succès à partir des écumes produites dans les usines sucrières. Elles contiennent une quantité considérable de matière organique de 73 à 77% y compris le sucre de 1.8 à 3.0%. Après l'analyse des constituants des écumes et l'identification de leur utilité possible, une étude à échelle de laboratoire a été effectuée. Il a été ainsi établi qu'un taux maximal de biogaz peut être produit à partir des écumes quand la concentration des solides est de 6 à 8%. Après ce seuil le le taux de production diminue. Il a également été établi qu'une production de biogaz de 0.39 L/jour était supérieur à 8% de concentration qu'aux autres taux utilisés. Après optimisation des résultats, une étude pilote a été menée au cours de laquelle il a été établi que les écumes donne une production de biogaz de 65 à 75% au lieu de 50–52% dans le cas de fumier de vache qui nécessite une dilution de 1:1 pour faire une boue pour l'alimentation. Les écumes nécessitent une dilution de 1:1.25 car elles contiennent 26 à 32% de matière sèche. Des recommandations pour la sélection d'usine de production de biogaz et les installations connexes sont énoncées. L'augmentation de la valeur en termes d'engrais des écumes fermentées, la production d'énergie, le moyen indirect d'aider le boisement et la protection de l'environnement sont abordés.

GAS PARA COCINAR ECOAMIGABLE A PARTIR DE RESIDUOS DE INGENIOS AZUCAREROS

Por

P. THANGAMUTHU
Karnataka Sugar Institute
NH4A, Belgaum-Khanapur Road, Zadshahpur, Belgaum- 590 014, Karnataka, India
thangamuthup@yahoo.co.in

PALABRAS CLAVE: Torta de Filtros, Digestor, Materia Orgánica, Metanización, Biogás.

Resumen

SE ENCONTRÓ que el biogás ó gas para cocinar puede ser producido exitosamente a partir de tortas de los filtros de la cana de azúcar. Contienen una cantidad considerable de materia orgánica, en el rango de 73 a 77%, incluyendo de 1.8 a 3.0% de azúcar. Después de analizar los constituyentes de las tortas de los filtros y después de encontrar su conveniencia, se realizó un estudio a escala de laboratorio. Como resultado se estableció que un máximo de biogás puede producirse empleando torta de los filtros como materia prima, cuando la concentración de los sólidos es de 6–8%, más allá de estos valores decrece la producción. Se estableció, así mismo, que el promedio de biogás de 0.39 L/d era mayor a8% de concentración que a cualquier otro valor. Después de optimizados los resultados, se realizó un estudio a escala piloto, en el cual se comprobó que la torta de filtros rinde una producción de biogás de 65% a 75% en lugar de 50–52% que se obtiene con excretas de vacas, que requieren una dilución 1:1 para lograr la consistencia del fango de alimentación. La torta de los filtros requiere una dilución de 1:1.25 ya que contiene 26 a 32% de materia seca. Se brindan recomendaciones para la selección e instalación de las plantas de biogás. Se discute en el valor fertilizador de la torta de los filtros digerida, la generación de energía, vías indirectas de forestación y la protección ambiental.