Co-biodigestion With Grass: A Review

Ishmael M Ramatsa, Esther T Akinlabi, Daniel M Madyira, Robert Huberts, Vincent Gray

***Abstract*- This review summarizes the benefits accrued with co-digestion technology. Different substrates differ in-terms of their chemical composition and these differences lead to complications during digestion. One way in which these complications can be abated is by way of co-digestion. Co-digestion process plays a vital role also in balancing the nutrients required by microorganism for stability and performance. The potentials of generating biogas from different substrates and the role of nutrients and trace elements entrained in the substrate during the anaerobic digestion are also highlighted.**

Keywords: benefits, buffer, co-digestion, grass silage, nutrients and pH

I. INTRODUCTION

Biogas technology offers a very attractive route to make use of waste biomass to partially meet energy demand in the society. South Africa for example now experiences power cuts due to huge energy demands and concerted efforts are now geared towards renewable energy for a sustainable solution. In fact, biogas can provide multiple benefits to the users at large as a fuel for environmentally friendly electricity generation. Biogas as a renewable energy can be produced from wastes such as organic waste from market, swine farming, cattle farming, chicken farming, and the food industry. Over several years, ideas for the utilization of waste have been put forward. However, anaerobic digestion of biomass to produce energy in the form of biogas is arguably the most beneficial, and likely to be of commercial interest.

The use of anaerobic technology as a way of treating wastes to produce biogas comes with benefits such as fertilizer and fuel as summarized in Figure1.

Manuscript received March 23, 2015; revised April 03, 2015

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Co-digestion can be defined as the treatment of a combined mixture of two different biomass or substrate under anaerobic conditions. Combination of different substrates can sometimes produce more or less biogas depending on the characteristics of each of the substrates in the digestion. Anaerobic digestion is characterized by a series of biochemical transformations caused by the anaerobic bacterial degradation of organic matter. The whole process involves several distinct stages. i.e., hydrolysis, acidogenesis, acetogenesis, volatile fatty acid oxidation by secondary syntrophic proton reducing bacteria and the final stage of methanogenesis.

The term "biogas" is commonly used to refer to a gas which has been produced by the biological breakdown of organic matter in the absence of oxygen. Biogas is one of the products formed during the anaerobic digestion process, and consists of CO_2, CH_4, H_2S, H_2, H_2O and some traces of other substances depending on the composition of the substrate.

The purpose of this paper is to review the anaerobic co-digestion of grass with other available biodegradable solids wastes and the benefits that comes with co-digestion. Grass is one of the most abundant feeding materials available in South Africa, and mostly ends up in landfills as it is a part of municipal waste, and is generally considered as one of the major agricultural products that covers over 80% of South Africa agricultural land [1].

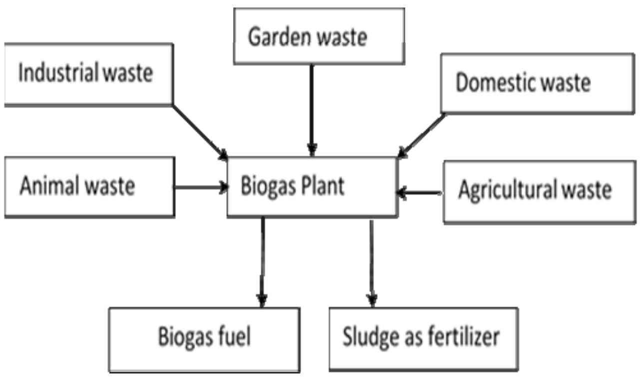

Fig 1: Schematic representation of benefits that accrue with anaerobic digestion

A. Benefits of co-digestion

Anaerobic degradation of organic material depends of several factors [2] such as the pH value, temperature, nutrients contents, Carbon to nitrogen (C/N) ratio, inhibitors

ISBN: 978-988-14047-2-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

and Carbon to Phosphorus (C/P) ratio. One of the options for improving the yield of anaerobic digestion of organic matter is co-digestion, and in the recent years, much effort has been dedicated to improving the performances of digesters through co-digestion of biomasses with different chemical compositions. Therefore, monitoring the conditions mentioned above provide a measure to prevent an unpredicted system failures that could results from unbalanced sub-optimum digester operational conditions. During the anaerobic digestion, it is expected that the C/N ratio should be in the range 20/1 – 30/1 [3]. A co-digestion process helps by providing the buffering capacity and supplementation of wide range of missing nutrients, while wastes with enough carbon content can keep the C/N ratio in balance for all wastes that are low in C/N [4]. Co-digestion can make use of nutrients and bacterial diversities in various wastes to optimize digestion conditions for the digestion process thereby leading to the maximum production of the biogas at the long run. Fig 3 shows different substrate iterms of their C/N ratio. pH and nitrogen can be manipulated by co-digestion of different substrates. This is very much important if one want to drive the reator towards stability. This technique also overcome the disadvantage of inhibition in single digestion [22]. Co-digestion with other substrate had been widely carried out as shown in Table I and II.

B. Potential of methane production from different substrates

Nitrogen forms part of the essential nutrients required for the survival of micro-organisms responsible for anaerobic digestion. The supply of the required nitrogen is very much dependent on the type of organic substrates used. Some substrates can produce high amounts of biogas even when they are digested as pure a substrate, while some are unable to produce the required biogas when digested as pure substrate. In such a case, a co-digestion of a mixture of different substrate becomes an alternative option. Fig 2 shows methane content of different pure digestion substrates. Grass appears to be second highest in terms of methane content [5].

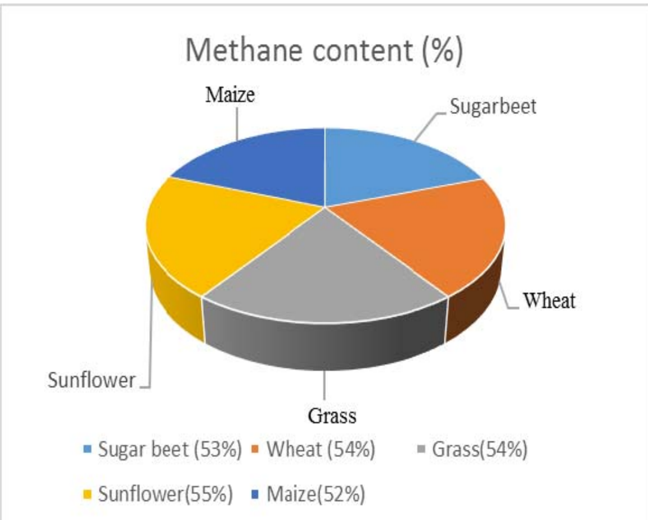

Fig 2: Methane content from different substrates

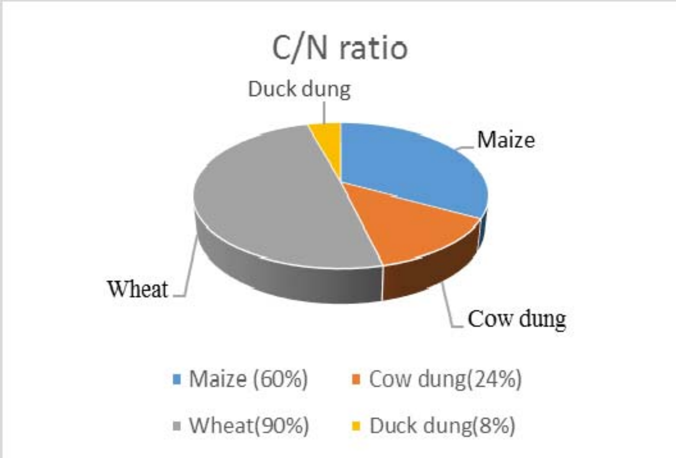

Fig 3: Characteristics of different substrate in terms of C/N ratio.

Table I: Characteristics of raw substrates

Characteristics	Grass silage	Pig manure	Inoculum
pH	**4.5**	**7.4**	**7.9**
NH_4-N(mg/l)	**0**	**1550**	**1930**
VFA(%DM)	4.9	3.1	0

VFA: (Volatile Fatty acids).

Table II: Characteristics of grass and pig manure

	Ratio1	Ratio2	Ratio3	Ratio4
PM/GS ratio	1:00	3:01	1:1	1:03
pH	**7.5-8.0**	**7.1-8.0**	**6.9-7.9**	**6.5-7.8**
Total Methane(ml)	7833	8517	8417	7484
NH_4-N(mg/l)	**1562**	**1430**	**1288**	**1160**

PM (Pig Manure); GS (Grass Silage)

C. Feedstocks.

Biogas production from different feedstocks present some difficulty especially when the system is designed to produce biogas quantitatively from individual substrate, and consequently, this render a challenge as different feedstocks respond differently under applied defined parameters of anaerobic digestion (e.g. volatile solids, organic loading rates, pH, mixing and temperature).

Under normal conditions, grass grows better in high temperature regions, it is the most predominant form of food providing most of the feed requirements for ruminants [13] either through grazing or after conservation as hay or, more recently, silage [14]. Notwithstanding, the usage of grassland as a renewable source of energy through biogas

ISBN: 978-988-14047-2-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

generation also contributes sufficiently to the protection of the environment through the reduction of greenhouse gases, and due to grasslands ability to sequester carbon dioxide into soil matrix and the utilization of carbon dioxide during the process of photosynthesis, and many other socio-economic benefits. Bio-methanation of grass is an area still under active research [15]. High potential of Methane generation has been shown in the studies conducted by Amon *et al, (*2007). The interest in utilizing grass as feed stock for methane production is due to its abundance and its high yield potential in terms of biogas quantity. In countries like Germany, grass come second after maize silage for biogas plants raw materials [16].

D. Role of nutrients and trace elements entrained in the substrate during anaerobic digestion

Availability of nutrients during anaerobic digestion plays a very key role in the performance and stability of the digester. Elements such as N (nitrogen) , phosphorus (P) , potassium (K) , calcium (Ca) , and magnesium (Mg) primarily are linked to the digestate, and are needed potentially as fertilizer supplements or other valued added products, and they are also important for physiological survival of the micro-organisms inside the digester (David et al, 2014). The deficiency of these crucial elements may have a detrimental effect on the yield of biogas production. Schattauer et al (2011), showed their work that nutrients such as cobalt, nickel, molybdenum and selenium are of critical importance in the production of biogas and the deficiency of such elements can inhibit the methanogenesis process (Schattauer et al, 2011). Damirel and Scherer, 2011, observed that the unavailability of these trace elements can upset the stability and the performance even though some of the process conditions may remain undisturbed.

II. Selection of Substrates for Co-Digestion

Organic wastes available for co-digestion may include animal manure, energy crops, food wastes, sludge, chicken wastes and garden wastes as summarized in Fig 1. The most cited advantages of anaerobic co-digestion include increased biogas production which is attributed to supplements from other co-digested substrates. A few selected results are presented in Table I and II to show the advantages of substrate co-digestion. The co-digestion of two or more substrates results in better digester performance than mono-digestion in terms of higher methane content [23]. Studies have shown that substrates that are rich in carbohydrates and lipids with high volatile solids content are good candidates for co-digestion with other substrates [24]. Other studies have found that the selection of a particular substrate for anaerobic co-digestion is largely dependent on economic considerations, availability and the potential methane yield [25, 26].

III. Conclusion

Co-digestion benefits the anaerobic digestion process. These benefits include the increase in the stability of the reactor, reduction of toxic compounds, and an improved nutrient balance, and these lead to an increase in biogas yield. The availability of trace elements are of paramount importance during anaerobic digestion as this leads to the stability and performance of the digester. Grass as an abundant biomass affords an opportunity to co-digest with other available organic biomass for balancing of the required nutrients during the production of biogas.

Acknowledgement

The authors wish to express their gratitude to the National Research Foundation (NRF) and University of Johannesburg (UJ) for providing financial support.

References

[1] Department of Agriculture Available: http:www.nda.agric.za. Accessed 10/02/2015.
[2] J Mata-Alvarez., S Mace., P Llabres. Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives. Biresour Technol 2000, 74:3-16.
[3] D. L Hawkes. Factors affecting net energy production from mesophilic anaerobic digestion. In Strartford DA, Wheatley BI, Hughes DE (eds) Anaerobic digestion 1981 pp 131-150.
[4] D. J Hills, D. W Roberts. Anaerobic digestion of dairy manure and field crops residues. Agric Wastes 3: 179- 189, 1981
[5] P Weiland. Biogas production: current state and perspectives, Mini-Review: Appl Microbiol Biotechnol, 2010, 85:849–860.
[6] R Chamy. P Poirrier. M.C Schiappacasse., D Alkalay. L Guerrero. Effect of ammonia content in the biodegradability of the salmon industry wastes. Bioprocess Eng. 19: 1–5, 1998
[7] S Sung, T Liu. Ammonia inhibition on thermophilic digestion. Chemosphere 53: 43–52, 2003
[8] K.H Hansen., I. Angelidaki, B.K Ahring. Anaerobic digestion of swine manure: inhibition by ammonia. Water Res. 32: 5–12, 1998
[9] S. Xie., P.G Lawlor., J.P Frost., Z Hud. X. Zhan (2011). Effect of pig manure to grass silage ratio on methane production in batch anaerobic co-digestion of concentrated pig manure and grass. Bioresource Technology 102: 5728–5733.
[10] H.B Nielsen., I Angelidaki. Strategies for optimizingrecovery of the biogas process following ammonia inhibition. Bioresour 2008, Technol. 99: 7995-8001.
[11] J.I Eze., N.D \Onwuka and, C.E Okeke. Generation of biogas from brewery Effluent. Journal of Solar Energy2003, 14 Pp 115-120
[12] National Department of Agriculture (2005). Strategic Plan for the National Department of Agriculture. Directorate Agricultural Information Services, Pretoria Available:8http://www.nda.agric.za/docs/strat_plan_05.htm. Accessed: 11/03/2015
[13] FM Espinoza-Escalante, C Pelayo-Ortız, J Navaro-Corona, Y Gonzalez-Garcıa, A Bories, H Gutierez-Pulido. Anaerobic digestion of the vinases from the fermentation of Agave tequilana Weber to tequila: The effect of pH, temperature and hydraulic retention time on the production of hydrogen and methane. Journal Biomass and Bioenergy 2009, 3:14–20
[14] A Hopkins, R.J Wilkins. Temperate grassland: key developments in the last century and future perspectives. Journal of Agricultural Sciences 2006; 144:503–23.
[15] J. S Brockman, R. J Wilkins. Grassland. In: Soffe RJ, editor. Primrose McConnell's the agricultural notebook. 20th ed., Blackwell Publishing; .2003.
[16] M.D.A Rounsevell, F Ewert , I Reginster, R Leemans , T. R Carter. Future scenarios of European agricultural land use. II. Projecting

ISBN: 978-988-14047-2-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

changes in cropland and grassland. Agriculture Ecosystems and Environment 2005; 107(2–3):101–16.

[17] P Weiland. Biomass digestion in agriculture: a successful pathway for the energy production and waste treatment in Germany. Engineering Life Sciences 2006; 6. No. 3.

[18] A Shattauer., E Abdoun., P Weiland., M Plochl., M Heiermann. Abundance of trace elements in demonstration biogas plant. Boisyst. Eng 2011. 108, 57-65.

[19] M David. Wall Eoin Allen., Barbara Straccialini, Padraig O'Kelly. D Jerry. Murphy, 2014. The effect of trace elements addition to mono-digestion of grass silage at high organic loading rates.

[20] B Dimeral, P Scherer. Trace elements requirements of agricultural biogas digesters during biological conversion of renewable biomass to methane. Biomass Bioenergy 2011, 35, 992-998.

[21] T Amon. B., Kryovoruchko, V., Zollitsch, W., Mayer, K., Gruber. Biogas production from maize and dairy cattle manure- influence of biomass composition on the methane.

[22] C Zhang, et al. Batch and semi-continuous anaerobic digestion of food waste in a dual solid-liquid system. Bioresour Tech 2013; 145: 10-6.

[23] M. Macias-Corral, Z. Samani, A. Hanson, G. Smith, P. Funk, H. Yu, and J. Longworth, Anaerobic digestion of municipal solid waste and agricultural waste and the effect of co-digestion with dairy cow manure, Bioresource Technol. 99 (2008), pp. 8288–8293.

[24] M.J. Cuetos, X. Gómez, M. Otero, and A. Morán, Anaerobic digestion of solid slaughterhouse waste (SHW) at laboratory scale: influence of co-digestion with the organic fraction of municipal solid waste (OFMSW), Biochem. Eng. J. 40 (2008), pp. 99–106.

[25] A. Lehtomäki, S. Huttunen, and J.A. Rintala, Laboratory investigations on co-digestion of energy crops and crop residues with cow manure for methane production: effect of crop to manure ratio, Resour. Conserv. Recy. 51 (2007) pp. 591–609

[26] W. Parawira, M. Murto, R. Zvauya, and B. Mattiasson, Anaerobic batch digestion of solid potato waste alone and in combination with sugar beet leaves, Renew. Energ. 29 (2004), pp. 1811–1823.

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ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)