INVESTIGATION INTO AGRO-FOOD WASTE BENEFICIATION IN KANSANGA – CENTRAL REGION IN KAMPALA, UGANDA

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ABSTRACT

Agricultural waste generation poses a significant challenge to food security and threatens the social and environmental stability of the world ecosystem. There is little or no support from the government with regards to policies, resources mobilization and strategies to motivates waste reclamation, or to support its use as raw materials for industrial resources/clean energy generation. Pre-existing designs for wastes handling proved too expensive, inaccessible, and with a low-performance throughput. The focus of this research is toward the development of a waste management strategy and scheme which emphasize the conversion of reusable wastes to energy, in Uganda. In the present paper, the author's analyses the availability organic waste resources, around the city of Kampala in Uganda. Animal Dung & Biomedical-degradable Wastes (ADBD), and Vegetables, seeds & Fruit-peel Wastes (VSFP) were sourced from different hot-spots. Fruit peels, seeds, corn cob, sugarcane bagasse, rice husk, groundnut shells, as well as animal droppings, and wastes from abattoirs, market centers, restaurants, homes, and industries fall into the categories of ADBD and VSFP waste selected for the study. Bio methanol gas which was derived from the ADBD and VSFP substrate gave 52.4% and 48.6% respectively. Effective waste collection, and management is needed to transform the huge agricultural propensity and waste generation for socio-economic and environmental gain.

Keywords: Agro-waste Management; Bioenergy; Sustsainable Production; Uganda

1. INTRODUCTION

The concept of bioenergy has gained popularity since the last century and continues to grow due to regional and resource-dependent factors, including the interest to domestic sourcing of secure and diverse energy systems to promote rural economic development. The potential of biomass as a renewable energy source to mitigate anthropogenic greenhouse gas (GHG) emissions hold a great promise to by reducing demand for fossil fuels. With the high rise in the amount of Agro-based industrial waste from the commercial processing of agricultural Produce, most likely used as animal feed or in other cases, burned as an alternative for elimination, such wastes have an enormous propensity for utilization in farms, pharmaceutical industries, bio-plants for energy creation and in manufacturing processes. Trash should never be considered “wastes” but most likely to be regarded as raw materials for industrial processes and activities, to explore the possibilities for use as sustainable resources while maximizing value with little or no loss. Research has been carried out about evaluating the land area, and the energy available during the exploitation process of bioenergy production. More so, while the tendencies for achieving success are considered, researchers have explored cost-effective designs of efficient and effective techniques and bioengineering technologies to sort and utilize agricultural and food wastes which may pose no security challenge for food production and standard of living, or impact negatively on the environment (Raji & Onu, 2017).

2. LITERATURE

The shells of tropical plants studied by (Zoveidavianpoor & Gharibi, 2016)(Saha et al., 2018), where treated as deformable substrates used as proppant to improve fracture conductivity and for the development of high strength composite materials. Concrete reinforcement; groundnut and oyster shells, cork, rice husk, and bagasse ash and tobacco wastes, present a significant potential for their usage due to combined properties as replacement alternatives for cement (Prusty, Patro, & Basarkar, 2016) and as sustainable construction material (Madurwar, Ralegaonkar, & Mandavgane, 2013)(Liuzzi, Sanarica, & Stefanizzi, 2017). Agro-waste derived carbons was also experimented upon by (Saha et al., 2018)(Peter, Abolarin, & Anafi, 2017)(Kazmi, Munir, Patnaikuni, Wu, & Fawad, 2018) for reinforcement purpose. (Saha et al., 2018) Obtained a highly microporous carbon extract through one-step carbonization of lignin, orange peels, apricot seeds, and walnut shells. Mustard cake and pine needle, hybridized with a sisal fiber based polymer (Kumar, Kumar, Gangil, & Kumar Patel, 2017) offering satisfactory physical and mechanical advantages. (Sultana, Naseer, & Nigam, 2015) utilized leaves from neem and kikar plant as agro waste for cereal preservation, through an artificial means of growing Aspergillus parasiticus to prevent aflatoxins production. Also (Neethu, Mujeeb Rahiman, Rosmine, Saramma, & Mohamed Hatha, 2015) investigated on neem, groundnut, and coconut cakes for production of enzymes, which show substantial potential for use as a cost-effective substrate for lipase production. In a co-hydrothermal (CHT) treatment and extraction process, bio-oil, 5-hydroxymethylfurfural (5-HMF) is recoverable from agro-wastes according to (Shamsul, Kamarudin, & Rahman, 2018), this waste comprises, animal manure, treated sludge and other agri-residues including seeds and leaves.

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2.1 Biowaste conversion, technologies and practice in Uganda

Ref. (Okot-Okumu & Nyenje, 2011) Investigated the failing international strategy for solid waste management and suggested that low budget policy and lack of fiscal decentralization which gives power to the urban council to handle wastes, and with stakeholders ill-interest to participate, mar sustainable waste management in Uganda. Proposed, convenient and cost-effective designs of a digester for smallholder farmers presented in (Kabyanga et al., 2018). While vermicomposting as a possible alternative system for bio waste handling is suggested by (Komakech, Zurbrügg, Miito, Wanyama, & Vinnerås, 2016). Supercritical water gasification of agro wastes and fruit residues is viable for waste conversion and promotes bioenergy production. Biodegradable wastes treated in a hydrothermal conversion process for the production of biofuels (Nanda, Isen, Dalai, & Kozinski, 2016)(Koutra, Grammatikopoulos, & Kornaros, 2017) is treated. Reports about a Ugandan study to explore the viability of electricity generation from waste gas in Kampala (Scarlat, Motola, Dallemand, Monforti-Ferrario, & Mofor, 2015) assessed the electrical potential of the landfill at 31,000 MWh in 2009 and predicted to reach 26,600 MWh by 2011.

Organic wastes is seen to have great potential as a source of energy, as more than 500,000 households in Uganda keep/own cattle or sheep. The country is considered to reach agricultural nation with plentiful food and cash crop cultivation year-in, year-out. Although, the country has since begun exploitation and of the raw mineral for commercialization and is in the finalization stages of transporting it overseas (Onu & Mbohwa, 2018), little concern is shown in the ecoconservation discussion. The implication of the dependence on conventional energy sources will lead to future exploitation of lands for growing of energy crops, and the potential of agricultural waste conservative practice to facilitate energy savings, and reduce the harmful effects due to emissions caused by anthropogenic activities. In the present article, the researcher explores the incessantly dumped and readily discarded agro-wastes within the Uganda metropolis to access their energy potential.

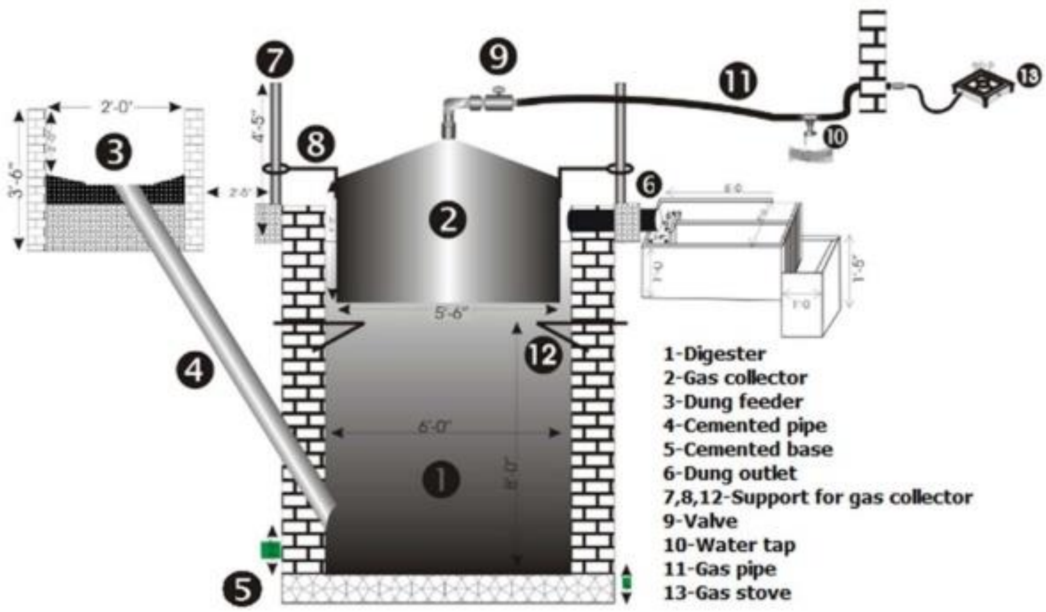

Figure. 1. An illustration of $5m^3$ biogas plant (Kamran, 2018)

3. MATERIALS AND METHODS

3.1 STUDY AREA

The study was carried out in Kansanga – central region in Kampala, Uganda. The district was selected because of the concentration of small and medium-sized markets and butchery.

3.2 MATERIALS

Simple, available and affordable materials were used for this research investigation: a 90 liter fixed dome digester, Mercury-in-glass thermometer, suspended spring balance, digital pH meter, wheelbarrow, spade, stick, substrates consisting of Animal Dung & Biomedical-degradable Wastes (ADBD), and Vegetables, seeds & Fruit-peel Wastes (VSFP), and finally a GA5000 Plus Gas Analyzer. The categories of biomass that was considered in the present study included, wheat straw, sugar cane bagasse, poultry/animal dung, meat residue, and plant stalks, etc, mixed and graded into two substrates. A conceptualization of an anaerobic digestion process, as in figure 1, to estimate biogas yield as per the different substrates is conducted.

3.3 METHODS

3.3.1 PREPARATION OF SUBSTRATES FOR BIOGAS PRODUCTION

Stones and non-biodegradable materials where separated from the substrates after random collections from designated hot spots within Kansanga before feeding the digester, the VSFP and ADBD were mixed separately in water (ratio of 1:1) by volume. The mixture was then placed in the 90 liters fixed dome. Weighing of the substrates was done using a suspended spring balance. Each set up had a thermometer inserted in the gas vent to measure temperature, while a digital pH meter was used to determine the pH of the separate mixtures.

3.3.2 PRODUCTION OF BIOGAS FROM ADBD AND VSFP

A 90 liters fixed dome digester was constructed with an inlet tank, outlet, and gas tap. ADBD were collected and fed, 30 kg mixed with 30 liters of water according to the method of Ituen et al. [15], until 100 kg of ADBD to 100 liters of water was achieved. Initial temperature readings were read off from the thermometer and fermentation was allowed for only 23 days while the top of the fixed dome digester was kept tight to avoid exchange oxygen. A similar routine was followed, as in the production of biogas from ADBD above. The VSFP was checked for stones and other unnecessary materials before mixing with water by the researcher, and the same procedure was followed as in the former. Regular observation of the set-up was ensured to take the measurements and observe consistency of the digestion process throughout the medium.

Table 1. Emission characteristics of ADBD mixture for 23 days

ADBD and water							
Days	**CH_4 (%)**	**CO_2 (%)**	**O_2 (%)**	**CO (ppm)**	**H_2S (ppm)**	**pH**	**Temp (°C)**
1	0.0	0.0	0.0	0.0	0.0	0.00	25.0
2	0.0	0.0	0.0	0.0	0.0	0.00	25.0
3	0.0	0.0	0.0	0.0	0.0	0.00	25.0
4	3.0	10.8	2.1	1.0	154.0	7.68	25.0
5	12.0	10.2	1.4	7.0	185.0	7.64	25.0
6	17.4	20.4	1.8	4.7	135.0	7.40	26.0
7	22.6	21.9	0.9	4.3	171.0	7.00	27.8
8	23.6	17.4	1.0	3.0	159.7	6.73	28.3
9	24.1	20.0	1.9	3.3	85.0	6.63	29.0
10	26.7	20.7	1.4	3.3	154.0	6.47	26.0
11	35.0	23.5	1.0	3.0	85.3	6.57	27.0
12	30.3	24.0	1.5	1.3	84.7	6.40	26.0
13	36.4	23.4	0.8	1.0	115.3	6.37	25.0
14	36.3	24.5	1.4	2.3	141.0	6.30	26.7
15	30.3	20.1	2.9	1.6	158.3	6.49	26.0
16	38.7	21.6	0.9	3.3	172.0	6.00	28.0
17	40.9	24.9	1.7	1.7	290.7	5.90	26.0
18	43.6	24.0	0.9	1.3	290.3	5.80	25.0
19	45.6	25.7	0.5	2.7	272.0	5.60	28.0
20	44.5	27.0	0.7	2.5	157.0	5.40	30.0
21	40.2	25.0	0.4	1.7	242.3	5.57	29.0
22	48.6	24.4	0.1	2.0	290.7	5.90	30.0
23	47.1	20.5	0.3	3.3	260.3	6.00	31.0

Table 2. Emission characteristics of VSFP mixture for 23 days

VSFP and water							
Days	**CH_4 (%)**	**CO_2 (%)**	**O_2 (%)**	**CO (ppm)**	**H_2S (ppm)**	**pH**	**Temp (^oC)**
1	0.0	0.0	0.0	0.0	0.0	0.00	24.0
2	0.0	0.0	0.0	0.0	0.0	0.00	24.0
3	0.0	0.0	0.0	0.0	0.0	0.00	24.0
4	17.4	15.0	0.2	68.3	101.3	7.03	24.7
5	25.7	19.5	1.9	27.0	270.6	6.90	25.3
6	29.9	22.3	0.9	6.7	398.3	6.77	27.0
7	36.1	25.6	1.1	5.7	123.7	6.70	29.0
8	35.6	25.1	1.7	5.0	186.7	6.54	25.0
9	38.6	27.2	0.8	4.3	827.7	6.44	29.0
10	42.2	29.5	0.5	2.3	825.3	6.03	26.0
11	44.2	30.0	0.4	2.3	760.0	6.00	26.7
12	43.0	28.9	2.0	1.7	820.3	6.85	26.0
13	45.5	30.2	0.2	1.3	198.0	5.61	24.7
14	48.0	30.0	0.7	2.0	176.0	5.52	27.0
15	44.1	26.9	2.9	1.0	355.3	5.60	26.3
16	46.2	29.6	0.7	2.0	423.3	5.69	28.0
17	41.5	27.0	1.4	2.3	326.0	6.06	25.3
18	40.1	26.0	0.3	2.7	291.0	6.29	24.0
19	40.3	27.0	0.6	2.7	225.0	6.23	27.3
20	40.4	27.3	0.4	2.7	250.6	6.70	29.0
21	29.4	14.6	8.4	1.7	279.0	5.86	26.7
22	48.9	19.8	0.9	2.7	271.3	5.72	30.6
23	52.4	25.1	0.1	1.0	258.9	5.57	32.0

3.3.3 DATA COLLECTION AND ANALYSES

Production of methane and carbon dioxide gas were the primary interest of the researcher as per the investigation. Both the ADBD and VSFP mixture tested by measuring using the GA5000 Plus Gas analyzer starting from day 4 and results organized in a spreadsheet application for analyses, shown in table 1 and 2. More so, records of trace gases (hydrogen sulfide, and carbon monoxide) were collected simultaneously, however, was not considered to be significantly relevant for this research report. The pH and temperature taken within the 23 days of digestion were observed to be non-different from each other since the experiment was conducted in August 2018 and the temperature in Uganda within the period was stable as expected.

4. RESULTS AND DISCUSSIONS

Observation of temperatures within the digester (s) ranged between 24^oC - 32^oC. The nights were considerably cold and expectedly affected the yield gas production in both cases. However, since the temperature of the digester was always within the mesophilic range (25^oC - 35^oC), gas production was observed [16].

The experiment shows an increase in methane production with time as observed in Fig. 1. The maximum methane production for ADBD mixture was obtained on day-22, at 48.6%. The highest value of methane produced from VSFP mixture was obtained on day-23, at 52.4%. Thus implies VSFP wastes to have produced the highest biogas for the experimental design. The production of carbon dioxide gas was noticed to be significantly high on the first day and peak on the day-20 at 27.0% for the ADBD mixture. Regardless, The VSFP mixture was observed to produce its highest carbon dioxide of 30.2% on the day-13 of digestion (figure 2). This could have occurred due to the high concentration of nitrogen to carbohydrates-based wastes content ration of the fruit peel, seeds, and corn stalks, etc., in the VSFP, compared to the ABDB. The concern with carbon dioxide production from the substrate is found below 40% maximum operable value (25 – 40); thus, had no reactive effect on the methane production.

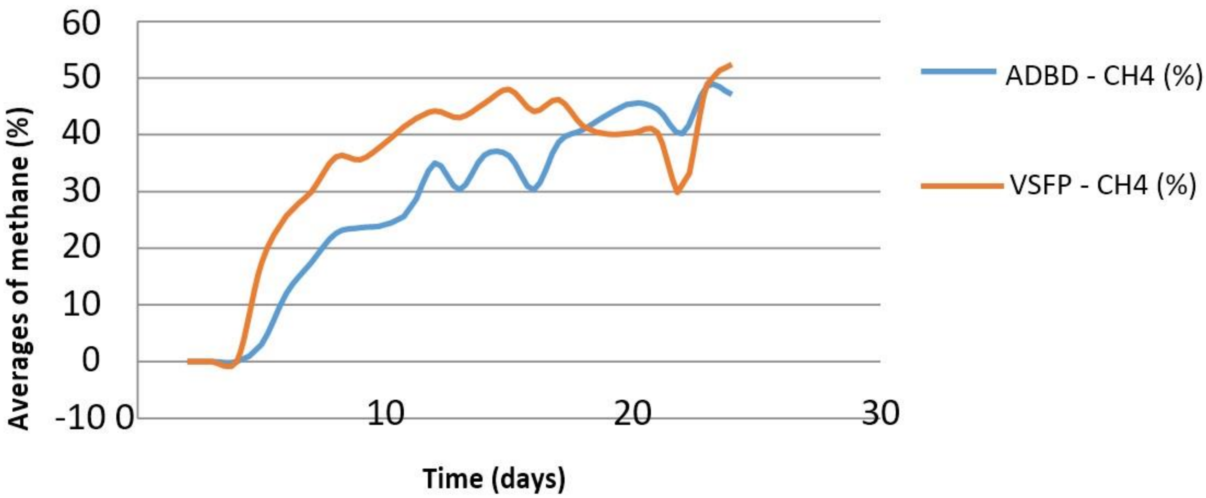

Figure. 2. Average methane production against time

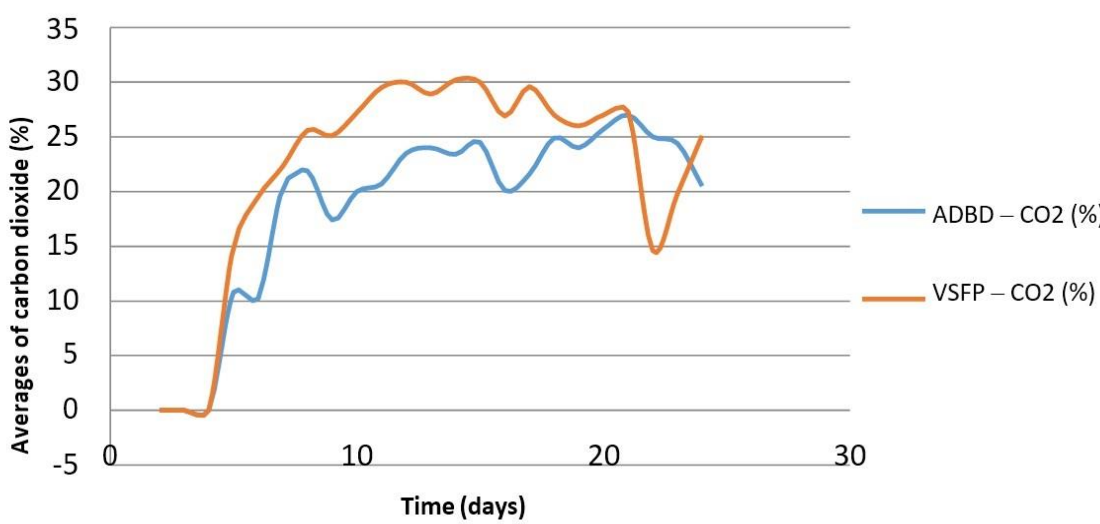

Figure. 3. Average carbon dioxide production against time

The results obtained in pH shows that the experiment was conducted within the pH range for optimum methane production for both substrate mixtures except for only a few days when the pH was less than 6.0. For the ADBD, it occurred from day 17 up to day 22, and for the VSFP it was noticed on days 13 to day 16 and also from day 21 to day 23 when the pH did not go below theoretical range. These were due to gaseous exchange and continuous feeding of the digester which led to substrates becoming acidic.

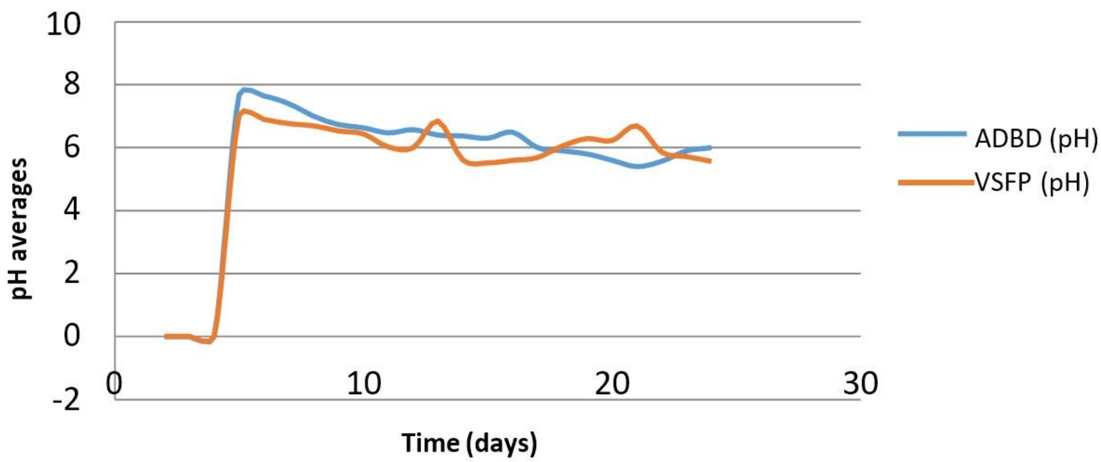

Figure.4. pH averages against time

Consequently, methane and carbon dioxide percentage content could not reach the optimum value. Hence, it is ascribed to the formation of free volatile fatty acid which is toxic and affects methane-forming bacteria and also the same when the pH is above eight (8) which did not occur in this case research. The ABDB substrate had initial pH as 7.68 on day-4 and was observed to reduce to the lowest value of 5.4 on day-20, and after that, it increased up to 6.0 on the day-23 of digestion as shown in Fig. 3. While the VSFP showed pH values to be lower than those of the biogas produced from ABDB in most days. The rise and fall of the pH were due to continuous loading of the digester which had led to the pH values to fluctuate, and this also contributed to the methane percentage content as observed below the expected values for both substrates.

5. CONCLUSION

This study reveals the tendency to produce usable gas from the abundant agricultural waste which poses a threat to the settlers in the central region of the city of Kampala. Biogas was generated and analysed for methane, carbon dioxide, pH, and temperature from substrates classified into ABDB wastes and VSFP wastes. The maximum productivity of methane for a mixture of 30 kg VSFP and 30 liters of water was found to be 52.2%, and also the mix of 30 kg of ABDB and 30 liters of water gave 48.6%. It was observed that the values of methane and carbon dioxide obtained from day 19 to day 23 were within the theoretical range, i.e. 45 - 70 for methane and 25 - 40 for carbon dioxide. The research reserves that much still need to be done to enlighten business commuters and farmers of the strategies and technologies that can change wastes for the benefit of the community. Government is obliged to encourage the waste collection, sorting, processing and conversion for the gainful course to a commercial scale. The citing of a biogas plant within any of the Universities (Kampala International University, Kampala University-

Original or International University of East Africa) closest to the market is a potential spot to exploit and manage the agro-waste generated in Kampala.

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