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Assessment the use of Water Hyacinth in the Production of Biogas and Fertilizer, Egypt

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I. Abstract

In Egypt, water hyacinth (WH) invades the Nile River and most of irrigation and drainage networks, causing tremendous problem related to quality and quantity of water. This research investigated the anaerobic digestion (AD) of four fermentable mixtures composed of WH, cattle manure, and water at ratios of 1:10:60 (mix.1), 1:4:25 (mix.2), 1:2:18 (mix.3), and 1:0.3:1.3 (mix.4) respectively. The results revealed that the maximum amount of gas production was attributed to mix.3 (975 L) within retention time of 75days. The rate of biogas production is higher upon dry WH (195 L/kg VS) as compared to fresh WH (39 L/kg). The chemical analysis of the produced sludge indicated that all elements contain the basic nutrients of the plants and all the elements within the permissible limits of the law of soil improvement.

II. Keywords: Aquatic weeds, Biogas, water hyacinth

III. Introduction

Water hyacinth (WH) is a free-floating plant that growing where it is not wanted. The growth rate of this plant is faster, where it has doubling time of 7-12 days. It is considered a problematic plant causing problems of interfering with the navigation, increasing water losses, reducing fish production, and providing suitable environment for insects that cause human diseases such as malaria and bilharzias. It was reported that WH can achieve a growth rate of 17.5 metric tons per hectare per day [1]. All means to control the WH require high cost and man power and actually leading to nothing except temporary removal of the WH. Moreover, several tons of agriculture residual and animal manure annually are burned leads to sever diseases and creating suitable environment for insects. In fact, the removed aquatic weeds from waterways and animals' wastes are considered non recycled materials due to lack of scientific and economic studies. On the other hand, the energy consumption has increased steadily over the last few years as the population has grown. As a result, the countries became more dependence on fossil fuels such as coal, and gas.

Fortunately, in the last few years, many developed countries have made great efforts to get benefits from these materials, especially in the field of biogas and agriculture fertilizers productions. Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. The organic waste, such as dead plant and animal wastes, kitchen waste, and food waste, can be converted into a gaseous full called biogas. It is composed of 5070% methane, 28-38% CO2 gas, H2S gas, and several other gases of 2%. This gas is nontoxic, odorless, colorless, and lighter than air, and produces no exhaust after combustion. It is agreed that there is a biogas production optimum at around 35 °C, pH 7–8 and in aqueous solution with a DS (dry substance) content of around 10% [2].

Indeed, all the previous studies in the last few years revealed that the biogas production can be affected by temperature and pressure, solid content and loading rate, retention period, water content, and stirring or agitation of the content of digester. In fact, this technology achieves clean, cheap, and renewable energy

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and is proven in many parts of the world. The released Biogas can be used as a fuel for any heating purposes and producing electricity that is useful for rural communities.

China and India have embarked on large scale programs in domestic biogas [3]. In Zimbabwe, reported that the rate of biogas production is higher upon dry WH as compared to fresh WH and 1Kg of dry WH yield 12 liters of biogas, while fresh WH can only produce 1.3 liters per Kg. [4]. In Thailand, indicated that the most suitable mixture of raw material ratio of water, cow dung, rice straw, and WH for biogas production is 2:1:1:1 [5]. The produced Biogas can be used instead of coal and electricity [6].

In Bangladesh, reported that the production of biogas from Cow dung, Poultry waste, and WH is 0.034 m3/kg, 0.058 m3/kg, and 0.014 m3/kg respectively [7]. The Poultry waste produced maximum gas (0.026 m3) at the 8 th day retention time, whereas cow dung and WH produced maximum gas 0.0263 m3 and 0.012 m3 respectively at the 26 th day. In German, produced methane yield of 348 m3 per ton for Maize and 380 m3 per ton for Barley [8]. A study reported that mono-digestion of Salvinia moles (SM) produced less total biogas (155 L/kg VS) than WH (267 L/kg VS) and cabomba (221 L/kg VS) [9].

A research investigated the yield of biogas through batch scale anaerobic digester (AD) using WH and SM as the feedstock and cow dung as inoculum. The inoculum to substrate ratio was at 2:1 on VS basis. They reported that the WH seems to be a promising feedstock for biogas production (552 L/ kg VS) in comparison to SM (221 L/ kg VS) [10].

IV. Study Objectives

Regarding the overcome both the spread of WH in water courses and scarcity of energy in rural region of Egypt, the general goal of this paper was to get benefits from the removed aquatic weeds and in the meantime keep the environment safe. While the specific objective was to find out the maximum amount of WH to be mixed with cattle manure and water to produce an acceptable and economical amount of biogas.

V. Methodology

Biogas disaster is a device in which the digestion process occurs. Four small biogas model units were designed and installed in the laboratory of the channel maintenance research Institute (CMRI). The model is in shape of cylindrical with volume of capacity 959 liters (1.3 m Height and 1.1 m diameter). It included plastic tank of two parts, upper part is movable for gas storage known as gas tank, and the lower part is joined with upper part by nut-bolt arrangement for gas processing and for easy discharging the sludge (leftover). As shown in Table 1, four fermentable mixtures comprised of WH, cattle manure, and water at rations (1:10:50), (1:4:25), (1:2:18), and (1:0.3:1.3), were prepared respectively. Each mixture was placed inside each digester and left for 3 weeks unused for fermentation process.

Table 1: The studied Mixtures

Mixture	WH (kg)	Cattle manure (Kg)	Water (Kg)	Ratio
mix. 1	10	100	500	1:10:50
mix. 2	20	80	500	1:4:25
mix. 3	25	50	450	1:2:18
mix. 4	160	80	200	1:0.3:1.3

VI. Results and Analysis

Table 2 and Fig.1, present the produced biogas throughout the retention time for the studied mixtures. The results indicated that the total amount of gas production were 975 L(mix 3), 801 L(mix 1), 785 L (mix.4), and 710 L (mix.2). Hence, the fermentable mix.3 composed of WH, cattle manure, and water at ratio 1:2:18 yielded the maximum gas production. So, it can be reported that the optimum Biogas of dry and fresh WH were 195 L/kg VS and 39 L/kg fresh respectively.

Table 2: Biogas Production for the studied Mixtures

Day	Biogas Production (Liter)				Day	Biogas Production (liter)			
	mix1 .	mix. 2	mix. 3	mix. 4		mix1 .	mix. 2	mix. 3	mix. 4
0	0	0	0	0	51	610	427	623	723
5	29	40	110	154	55	724	498	658	729
11	67	54	200	201	59	786	510	789	733
14	120	102	286	289	65	792	588	820	745
20	198	123	320	385	69	800	623	868	767
26	277	198	387	447	70	801	635	932	784
30	310	243	410	598	75		708	956	785
34	365	278	468	634	80		710	972	
37	422	299	521	687	85			975	
41	476	322	558	672					
46	568	367	599	710					

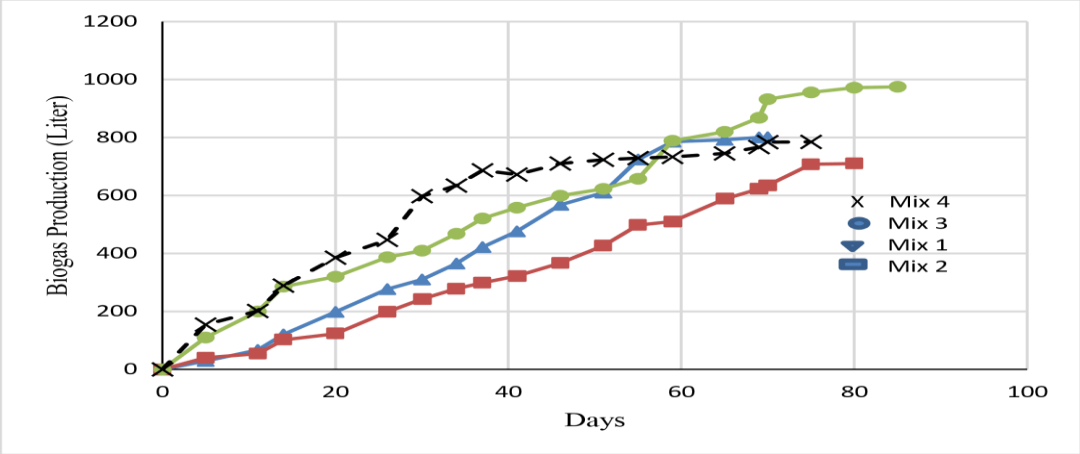


Figure 1: Biogas Production for the Studied Mixtures

The retention times were 70 days for mix.1, 80 days for mix.2, 85 days for mix.3, and 75 days for mix.4. The gas production in volume percent can be divided into slots of hydraulic retention time. For mix.1 as shown in Fig.2, about 23% gas was produced during the first slot (0-20 day), about 35% gas was produced during the second slot (20-41day), about 40 % gas was produced during the third slot (41-59 day), and about 2% gas was produced during the fourth slot (59-70 day). For mix.2, as shown in Fig.3, about 23%, 28%, 27%, 26%, and 2% gas were produced during the first slot (0-20 day), second slot (20-41day), third slot (41-59 day), fourth slot (59-70 day), and the fifth slot (70-80 day) respectively.

For mix.3 as shown in Fig.4, about 32%, 24%, 23%, 17%, and 4% gas were produced during the first slot (0-20 day), second slot (20-41day), third slot (41-59 day), fourth slot (59-70 day), and the fifth slot (70-85 day) respectively. For mix.4 (Fig.5), about 50%, 34%, 9%, and 7% gas were produced during the first slot (0-20 day), second slot (20-41day), third slot (41-59 day), and fourth slot (59-75 day) respectively. Hence, it could be concluded that the retention time for producing approximately 75% of biogas was 45 days for mix.1, 55 days for mix.2, 45 days for mix.3, and 35 day for mix.4.

The test trails proved that the economic and sufficient capacity of the digester for using in one house is 7.5 m^3 (diameter of 1.9 meters and height of 2.65 meters) in order to produce 2.5 m^3 gas per day.

Practical applications have shown that 1 m^3 of Biogas can run stove for 2.5 to 3 hours.

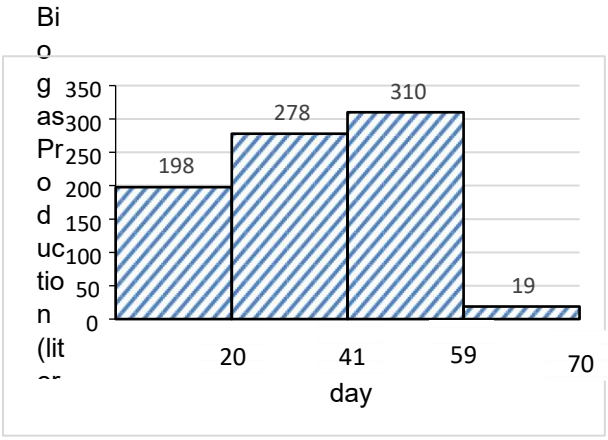


Figure 2: Biogas Production for Mix. 1

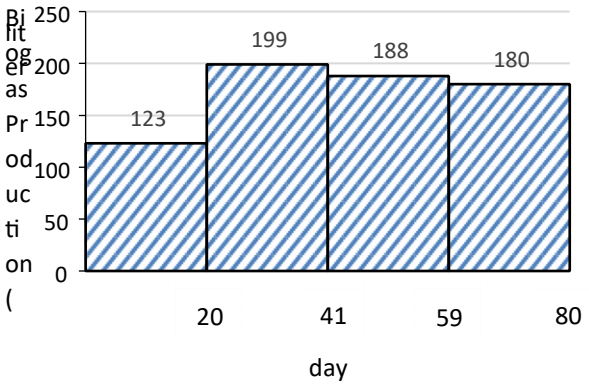


Figure 3: Biogas Production for Mix. 2

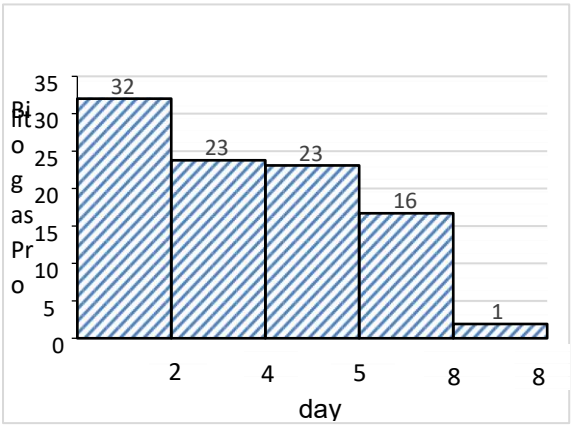


Figure 4: Biogas Production for Mix. 3

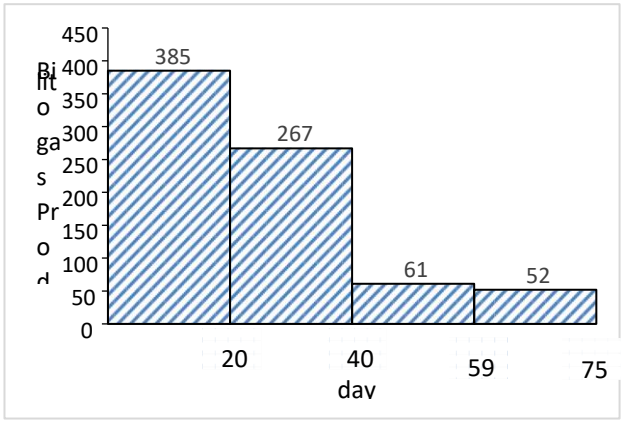


Figure 5: Biogas Production for Mix. 4

The physic-chemical properties of WH and animal manure included the total solid (TS), volatile solid (VS), Carbon/Nitrogen, and carbohydrate content, were studied and presented in Table 3. In this study, the VS content of water hyacinth was found to be closer to many studies investigated the biogas potential. A research obtained the biogas potential in the range of 150–300 L biogas / kg VS and the carbohydrate content of WH was found to be higher [11]. Another research concluded that a higher carbohydrate content of water hyacinth may be correlated to higher cellulose content, the Carbon/Nitrogen (C/N) is an important parameter that determines the biogas production, and the C/N ratio ranging from 20 to 30 was found to be optimal for biogas production [12]. The C/N ratio of WH (29) of the present study was found to be in the optimal range for biogas production. as suggested by many researchers.

Table 3: Physic-Chemical Properties of Wastes

Parameters	WH	Cattle manure
TS%	12	18
VS%	86	70
C/N ratio	29	17
Carbohydrate content	40	28

The slurry resulted from the digester (leftover) is called bio-fertilizer (organic) and is harm for insects such as flies and mosquitoes. The slurry composed of organic matter 60%, iodine 1.9%, phosphorus 1.5%, potassium 0.6%, and appropriate quantities of micro components. The leftover could be used directly with irrigation water or dried and packed in sacks for marketing, where it is an excellent fertilizer for the crops production and can be used instead of chemical fertilizer.

In order to specify the quality of the produced Bio-fertilizer (organic), samples were collected and the chemical and heavy metal analysis were conducted. Table 4, presents the chemical analysis included the basic nutrients (carbon, nitrogen, organic matter, phosphorus, potassium). Table 5, presents the heavy metals such as iron, manganese, zinc, copper, nickel, and lead. The results of the analysis showed that the nutrients of the plants and all elements within the permissible limits according to the law of fertilizers and soil improvement.

Table 4: Chemical Analysis of the Produced Bio Fertilizer

Day	**Mixture**	**Organic Carbon (%)**	**Organic Matter (%)**	**C/N Ratio (%)**	**TN**	**TP**	**K**
					mg/kg		
80	mix.4	0.94	1.89	0.426	219.79	153.50	330.56
	mix.3	1.18	2.36	2.12	55.53	108.20	1117.67
	mix.2	1.43	2.87	0.344	416.44	479.50	1942.50
	mix.1	0.90	1.79	1.744	51.41	67.20	56.17

Table 5, Heavy Metal Analysis for the Produced Bio Fertilizer

Day	Mixture	Fe	Mn	Zn	Cu	Cd	Pb
		mg/kg					
80	mix.4	89	14.97	8.67	0.18	ND	0.14
	mix.3	50.65	1.65	5.97	0.18	ND	0.07
	mix.2	418.50	26.15	19	0.60	ND	0.38
	mix.1	33.47	0.86	0.72	0.19	ND	0.44

VII. Conclusions

The results indicated that the water hyacinth (WH) have a great potential in producing biogas. The optimum gas production was attributed to the mixture ratio 1:2:18 for WH, Cattle manure, and water respectively. The maximum amount of gas was 975 L within retention time of 75days. The rate of biogas production is higher upon dry WH (195 L/kg VS) as compared to fresh WH (39 L/kg). The quality of the produced Bio-fertilizer (organic) matched the permissible limits of law of fertilizers and soil improvement.

VIII. Acknowledges

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