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Enhancing Biogas Production by Mixing Slaughterhouse Wastewater and Domestic Sludge to Cover Energy Demand for Wastewater Treatment Plant

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ABSTRACT

Enhancement in biogas production from co-digestion of slaughterhouse wastewater (SHW) mixed with primary sludge (PS) was evaluated, and compared with biogas production from digestion of SHW, and PS separately. Lab experiments were conducted under mesophilic conditions using bench scale batch digesters. Biodegradability of organic matter in Co-digestion system was found 51% greater than SHW digestion individually.

Keywords: *Biogas Production, Slaughterhouse Wastewater, Domestic Sludge, Anaerobic Digestion, Energy Demand, Wastewater Treatment, Palestine*

INTRODUCTION

World energy consumption is exponentially increasing due to the development in technologies and the increasing in the world's population [1]. Energy is the main nerve of our life growth and world development [2]. The global energy demand is covered from utilizing fossil fuel, but the use of fossil fuel is problematic, it emits greenhouse gases (GHG) into the atmosphere causing the global warming [3][4].

Palestine faces the same energy, environmental and economic problems. Moreover, Palestine has no natural energy sources and has limited access to it because it lies under Israeli military occupation for more than 60 years.

Renewable energy, such as biogas and solar, is one of the preferable solutions to the growing energy challenges [5]. Biogas is considered a renewable fuel as it originates from organic materials decomposition [6]. Anaerobic Digestion AD is an anaerobic process of decomposition of organic materials into simple components and in four stages: hydrolysis, acidogenesis, aceto genesis and methanogenesis (See Fig.1 [7-9]).

Many studies found for anaerobic digestion of slaughterhouse wastes from different origins as cow, sheep, bovine, swine and poultry [10-20]. Anaerobic digestion of domestic sludge for biogas production was also reported [21-24]. This study evaluates and assesses the feasibility of biogas and methane production using co-digestion of SHW and PS as a step toward creating an alternative energy source and saving the energy cost in wastewater treatment plant (WWTP).

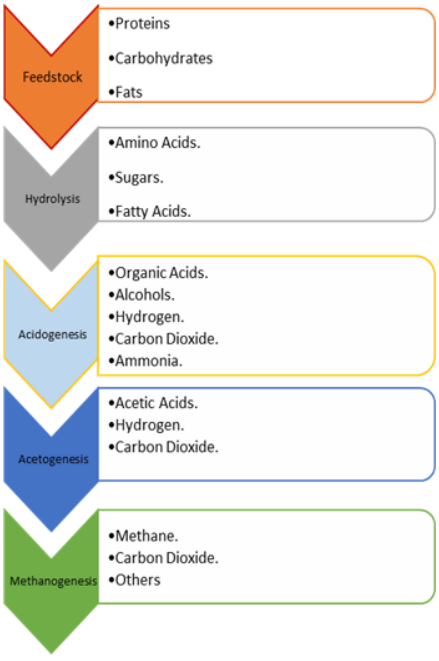

Fig1. ***Anaerobic digestion stages.***

METHOD AND MATERIAL

Lab experiments were conducted between January and March 2017 under mesophilic condition (35±2°C) using bench scale batch anaerobic digesters at Water and Environmental Studies Institute laboratories, An-Najah National University in Nablus, Palestine [25]. Nablus city is located in northern Palestine (see Fig2. [26]).

Fig2. *General location map*

Slaughterhouse waste was brought from Nablus city slaughterhouse while domestic sludge was obtained from Nablus west wastewater treatment plant. Two main experiments were conducted, in first experiment (EXP1), 2000 mL graduated cylinders filled with barrier solution have been used (see Figure 3). In the second experiment (EXP 2), 600 mL serum bottles filled with barrier solution were used. Blank (control) reactor with inoculum only has been used for comparison (see Fig. 4).

Fig3. *Experimental setup for EXP 1.*

Fig4. *Experimental setup for EXP 2.*

In total, 12 batch reactors have been used to carry out the experiments, the first 5 reactors have volume of 2000 mL, and the rest have volume of 600 ml. Initially, at the first day 400 mL of inoculum was added into each digester then it was directly flushed with pure N_2 gas. Later, the inoculum amount was determined based on 2/1 ratio between inoculum and substrate. Biogas produced was collected by water displacement method and measured using multi gas detector to determine its methane content. Water displacement method is illustrated in Fig. 5.

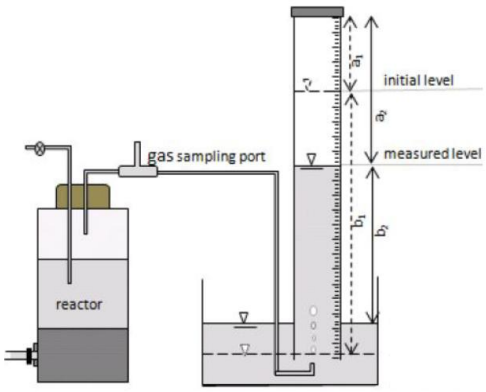

Fig5. *Schematic for gas measuring unit modified after [27, 28].*

Characteristics of the tested substrates for EXP 1 and EXP 2 are presented in Tables 1 and 2.

Table1. *Characteristics of raw tested substrates (EXP 1)*

Parameters	Sewage Sludge (SS)	Slaughterhouse wastewater (SHW)	Inoculum
PH	7.28	7.68	7.15
TS(mg/L)	25.11	5.76	21
VS(mg/L)	19.09	4.76	16.36
COD(mg/L)	37400	10860	22500

Table2. *Characteristics of raw tested substrate (EXP 2)*

Parameters	Primary Sludge (PS)	Slaughterhouse wastewater (SHW)	Inoculum
PH	5.77	6.7	7.18
TS (g/L)	18 ± 0.11	7.2 ± 0.16	21.6 ± 0.18
VS (g/L)	14.51 ± 0.13	6.46 ± 0.17	11.45 ± 0.11
COD(mg/L)	16400	8500	16200
ALK (mg $CaCO_3$/L)	3450	1150	3700
VFA (mg CH_3COOH/L)	2332	340	340

All collected wastewater samples were analyzed for their content of pH, solid's content, COD, Volatile Organic Acids (VFA), and Buffer capacity (ALK). All parameters were analyzed according to standard methods for examination of water and wastewater [29].

Results And Discussions

EXP1. Results

There was no biogas production took place for EXP1 for a period of 5 weeks which lead to inhibition in methanogenesis function.

This was due to that I/S ratio was lower than 1 for all reactors, therefore overloading took a place in the digestion process. This result confirmed with published research [30-32].

EXP2. Results

pH Values: The pH value for the PS fed reactor before anaerobic digestion was 6.28, whereas the pH value for the SHW fed reactor was 6.89, while the pH for the Co-digestion fed reactor was 6.45. At the end of experiments, SHW reactor had the largest pH value, 7.52. This higher pH might be due to the higher protein concentration in SHW content [33,34].

Total Solids TS Analysis: Percent reduction in TS for the reactor fed with PS was 23.2%, while that was 17% reduction for reactor fed with SHW and 20% reduction for reactor fed with Co-digestion mixture.

Volatile Solid Analysis:

It was found that PS sample has the higher biodegradable volatile solids than SHW.

Volatile Fatty Acid Analysis:

The VFA value was declined to 33% and 72% for D-CO and D-PS samples respectively. While it increased by 42% in the SHW reactor. Similar data was found in the literature [35, 36].

Buffer Capacity:

It was found that all of samples had an alkalinity concentration between 1500 and 5000 mg/L as $CaCO_3$ which are within the optimum alkalinity range.

Biogas and Methane Yield:

From the daily gas and methane production data presented in Fig. 6,7 & 8, it can be shown that the biogas and methane production started at a higher production rate. The Co-digestion increased (a) the productivity of gas yield when it was compared with gas yield from digest of the PS, and SHW in solo digestion system and (b) the activity of the biomass, that were involved in the anaerobic digestion process [37-39].

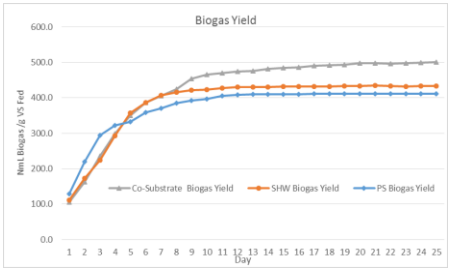

Fig6. *Accumulated biogas production.*

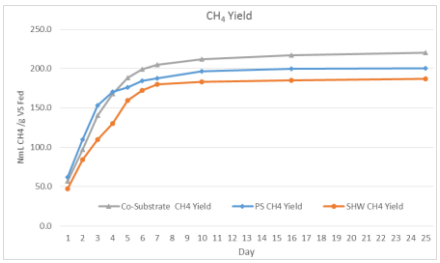

Fig7. *Accumulated net methane production.*

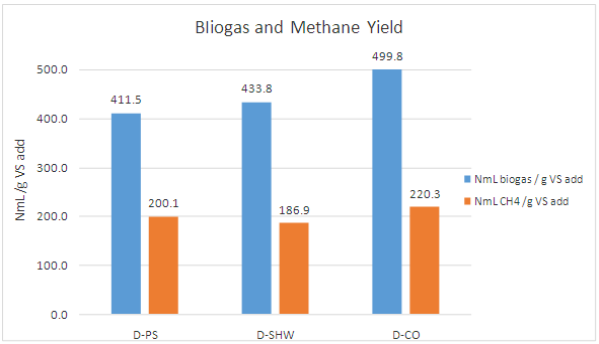

Fig8. *Biogas and methane production of different tested substrates.*

The main factors that are responsible on lowering methane production from SHW comparing with PS include ammonia, Sulfate Reducing Bacteria (SRB), and accumulation of VFA in digester. Published research are in agreement of this study results [40,41].

Modeling for Biogas Production

Multiple regression analysis performed using MATLAB to formulate a mathematical equation for biogas production [42].

The biogas yield of biogas is significantly affected by the pH of feed substrate, alkalinity, and VFA content in feed sample and accordingly the MATLAB regression model was set.

MATLAB regression model based on biogas production data from co-digestion of SHW and PS, at temperature 35 ± 2 °C, in batch system, with I/S = 2, was found to predicts biogas yield:

Y= 54.3938 x pH + 85.1345 x ALK – 84.0979 x VFA

Where:

Y: biogas yield from 1 g VS feed (ml).

pH: pH value of tested substrate.

ALK: alkalinity content in feed substrate (g/l).

VFA: volatile fatty acid content in feed substrate (g/l).

$R^2 = 0.9995$

CONCLUDING REMARKS

Based on the results of this study, the following concluding points were observed:

- Biogas and methane yield increased when the Co-digestion of SHW with PS took place compared to separate application,
- The role of inoculum in digestion process is crucial, since if it was in amount less than the imposed quantity, the system will inevitably fail or will take a long time to build new bacterial cells. This costs a lot of time, and therefore would not be in favor of the researcher.

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