Biogas Production from Date Palm Trees Residues

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Abstract

A laboratory scale of biogas production using anaerobic digestion of date palm wastes (DPWs) was conducted. The effects of pretreatment of substrate, pH, temperature and type of substrate (dry waste and fresh waste) on the biogas production were investigated in batch mode digesters, also the addition of nitrogen source to reduce the carbon to nitrogen ratio (c/n) was investigated. The results revealed that mesophilic conditions of 35 ^oC give the highest biogas production, pH below 6 will inhibit the biogas production, and the production of biogas from fresh waste is higher than the dry waste.
The percentage of methane gas in the produced biogas reaches 48 % for fresh waste with addition of nitrogen source, the results were encouraging to carry further studies on methane production from DPWs.
Keywords: Anaerobic digestion (AD), biogas production, Date palm tree residues.
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1. Introduction

Rapid population growth and increased consumption of energy push towards search for new environmentally friendly energy sources, biomass include all organic waste are considered as a source for extracting renewable energy and converting it into useful heat or power in an efficient way. Palm tree is one of the principal agricultural products in Libya, apart from dates, secondary products of palm trees including palm midribs, leaves, stems, fronds and fruit bunch accounts for thousands of tons of organic material. Date palm residues are considered a renewable natural resource because it can be replaced in a relatively short period of time. Usually date palm wastes are burned in farms or disposed in landfills which cause environmental pollution in dates producing arias.
Direct burning of palm trees waste must be stop and exploitation of producing methane gas from palm trees residues should be considered.
This study explores the anaerobic digestion technology (AD) as one of the main options for processing the biodegradable organic materials from date palm trees on a laboratory scale experiments.
The composition of a substrate is very important for the microorganisms in the biogas process and thus also for process stability and gas production. The substrate must meet the nutritional requirements of the microorganisms, in terms of energy sources and various components needed to build new cells, the substrate also needs to include various components needed for the activity of microbial enzyme systems, such as trace elements and vitamins.[1]
A Carbon to Nitrogen (C/N) ratio ranging from 20 to 30 is considered optimum for anaerobic digestion process, If the C/N ratio is very high, methanogens will rapidly consume the nitrogen for meeting their protein requirements and will no longer react with the left over carbon content of the material. As a result, gas production will be low. On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonium ion (NH4). The presence of excess NH4 will increase the pH of the biodigestate in the digester and thus a pH higher than 8.5 will start showing toxic effect on methanogens population.[2]
Bioenergy crops with high contents of cellulose, hemicellulose and lignin hemicellulose must be broken down into their corresponding monomers sugars, so that micro-organisms can utilize them in the energy conversion process through biological route. In order to maximize the digestion rate of cellulose-rich materials, it is beneficial to apply pre-treatment to break up the complex structure of cellulose and make it more accessible for digestion.
pretreatment processes are broadly classified under three categories; (i) mechanical or physical, (ii) chemical and physico-chemical, and (iii) biological.[3]
Luk´aˇs Kr´atk´y et al investigated the effect of hydrothermal treatment (liquid hot water pretreatment technology (LHW)) to obtain more digestible biomass. The results reveled that effectiveness of LHW pretreatment grows with increasing processing temperature and time. LHW pretreatment increases the amount of biogas and decreases the residence time in the fermenter.[4]

Mukhtar M. Ashur and Iman M. Bengharbia studied the effect of temperature and pH on biogas production from organic fraction of MSW, experiments were conducted at 35℃, 45℃, 55℃, 65℃ and the pH was controlled to be close to 7.0, results reveled that mesophilic condition (35℃) yield the highest biogas production, while the lowest production was at 65℃ pH below 6.0 inhibited gas production and the methane gas percentage of the produced gas was 45%, [5].Lili yang et al investigated the effect of pH on biogas generation, the results reveled that significant increase of methane yield could be achieved by pH adjustment from food waste and a pH of 8.0 gives the maximum methane yield of 171.0 ml/g of total solids which was 7.57 times higher than the pH uncontrolled group.[6]

Z. Ismail and A. Talib, investigate the potential of anaerobic co-digestion for biogas production using abundantly available waste from date palm trees, The experimental work demonstrated that the volume of produced biogas significantly affected by inoculum addition, pretreatment of waste materials, temperature conditions. The thermophilic conditions improved the biogas yield by approximately 23%.[7]

Jaafar study the possibility of using an Iraqi date fruit named Zahdi pulp waste from syrup production as a substrate for biogas production at thermophilic digestion with activated sludge as inoculum. Methane was produced with a yield of 570 mL/ g VS of substrate. Addition of 1% yeast extract solution as nutrient increased methane yield by 5.9%l. [8]

Aljuhaini et al studied the effect of pretreatment and operating conditions on the yield of biogas through AD of palm trees waste peter results were optioned by using NaOH for pretreatment. [9]

2. Materials and methods

The palm tree waste was brought from the southern oases of Libya from the area of Wadi Al Hayat valley which located in midland of Fizan Region. The valley is famous of its vegetation cover; in particular the growth of palm trees forests. Gharaya town is the most famous for its palm trees forests as it contains more than 150 palm trees farms, with 500-1500 palm trees in each. During the harvest season, each palm tree yields an average of 25 – 35 Kg of rotten dates in addition to number of (12-15) leaves, with an average weight of 20 Kg, and to number of (7- 10) fruit bunches, with an average weight of 15 kg. By the end of harvest season, there will be tons of wastes coming from the palm trees as shown in Figure 1. The huge amount of waste are not managed properly as they are either burnt or disposed by burying them in the desert sand

Figure 1: Dry leaves, and rotten date at harvest season

2.1 Substrate preparation

The midribs , fruit bunches and rotten date were first cut and grinded. Then the midribs and fruit bunches was thermally pretreated to break the resistant layer of lignin, Water under high pressure and temperature were used for periods of 15 and 30 minutes, after that it was introduced to electrical mixer for further size reduction. The mixture was weighted and divided into samples according to the experiment requirements.

2.2 Inoculum preparation

The inoculum used in the experiment was prepared on lab-scale from a mixture of 270 g of caw's manure and 135 g of food wastes, with ratio 2:1. The mixture then mixed with water to produce a solution of 1600 mL, the mixture introduced to a batch reactor under mesophelic condition (35- 38°C) until gas production starts.

2.3 Reactor

Two liters glass batch digester was used in this research. It has three openings on the top, the middle used for introducing raw materials after that it used for fixing temperature sensor, the other for collecting generated gas and third one for fixing (pH) sensor as shown in Figure 2a. The reactor was installed in water path equipped with electrical heather with a thermostat to control temperature. The generated gas is collected in a graduated cylinder. For the purpose of gas analysis gas is collected in special plastic bags as shown in figure2b.

Figure 2a: batch reactor system

Figure 2b gas collection process for analysis

3. Methodology

In the first run three batch reactors were used and named as R1, R2 and R3. To investigate the impact of thermal pretreatment and the pH, the three reactors have a total solid content of 10 %. Reactor (R1&R2) contains dry waste thermally Pretreatment for 30 minute. With pH controlled not to be less than 6.5 and not to exceed 8.0 for R1 and not to be less than 5.5 for R2, while the mixture in R3 was thermally treated for 15 minutes and the pH controlled not to be less than 6.5. For the second experiment fresh palm trees wastes were tested in order to make comparison between the potentiality of yielding biogas from fresh wastes and dry wastes. Three reactors R1, R2, & R3 were used. R1 was filled with 10% of dry palm trees wastes that were thermally treated for 30 Min, with adding one gram of NH4CI in order to maintain source of Nitrogen. R2 was filled with 10% of fresh palm trees residues, with adding one gram of NH4CI and R3 was filled with 10% total solid waste of fresh palm trees residues without adding any source of nitrogen. The three reactors were operated under mesospheric conditions.

4. Results and discussion

4.1. The effects of thermal pretreatment and pH As shown in Figures 3 and 4 the substrate which treated for 30 minutes gives higher biogas production. pH also effects biogas production when pH was maintained within 6.5-8.0 to avoid high acidic condition give higher biogas production for the same pretreatment time. Retention time was 30 day as shown Figure 3.

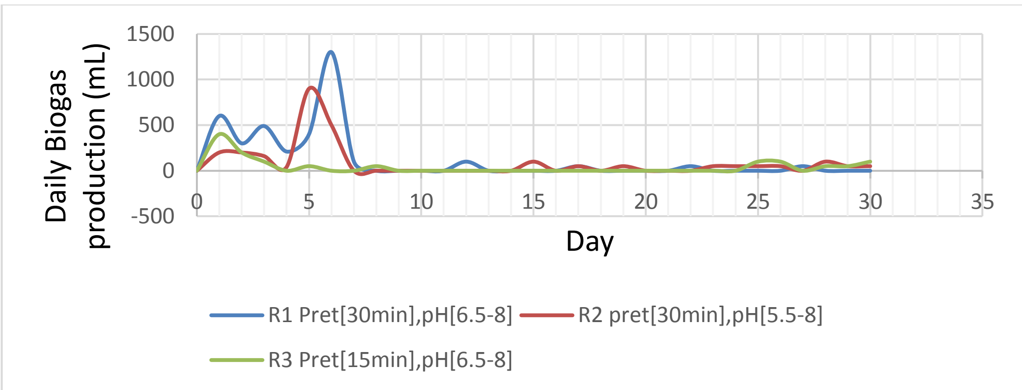

Figure 3: Daily Biogas Production from Different reactors

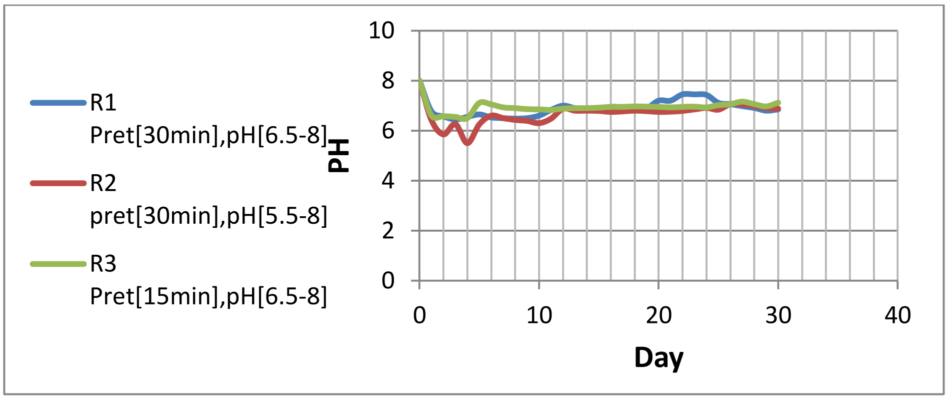

Figure 4.: pH Variation in Different reactors in Experiment (2)

Figure 5 show that the thermal pretreatment for 30 minutes was better than the thermal pretreatment for 15 minutes as well as maintaining the pH within 6.5 – 8.0 was better than maintaining the pH at 5.5-8.0 .

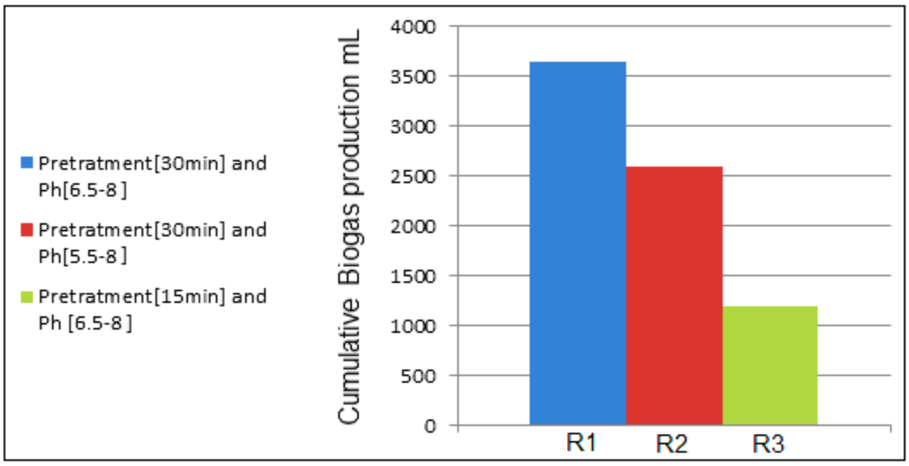

Figure 5: The Effects Thermal pretreatment and pH

4.2. The effects of using dry or fresh waste and adding nitrogen source.

Daily Biogas Production and pH Variation from Different reactors in Experiment 2 shown in Figures 6 and 7

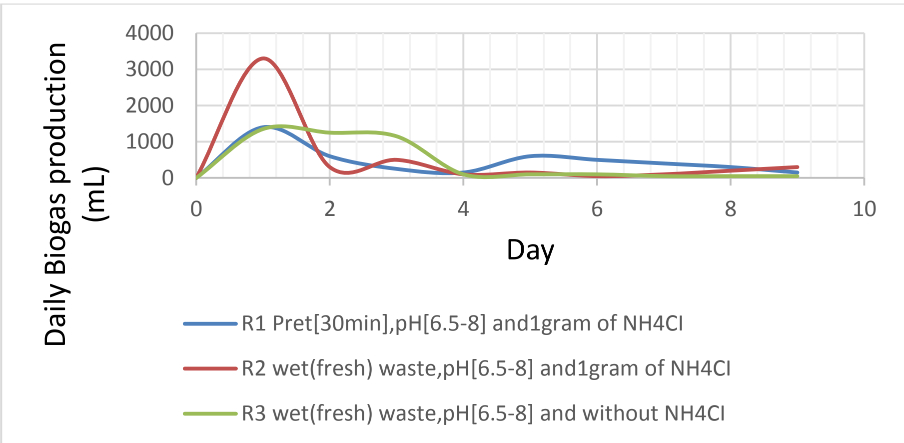

Figure 6: Daily Biogas Production from Different reactors in Experiment (3)

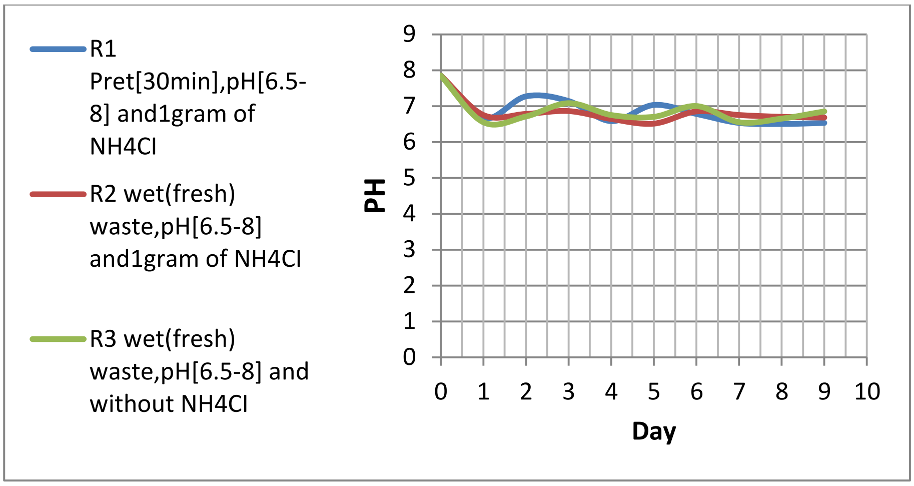

Figure 7: pH Variation from Different reactors in Experiment (3)

Through the experiment it has been observed that the production of biogas from fresh waste with nitrogen source (NH_4Cl) gives best biogas production compared to dry waste with nitrogen source (NH_4Cl) and fresh waste without nitrogen source (NH_4Cl). As well as bio-gas production of dry waste with nitrogen source (NH_4Cl) is better than biogas production from fresh waste without nitrogen source (NH_4Cl) as shown Figure 8

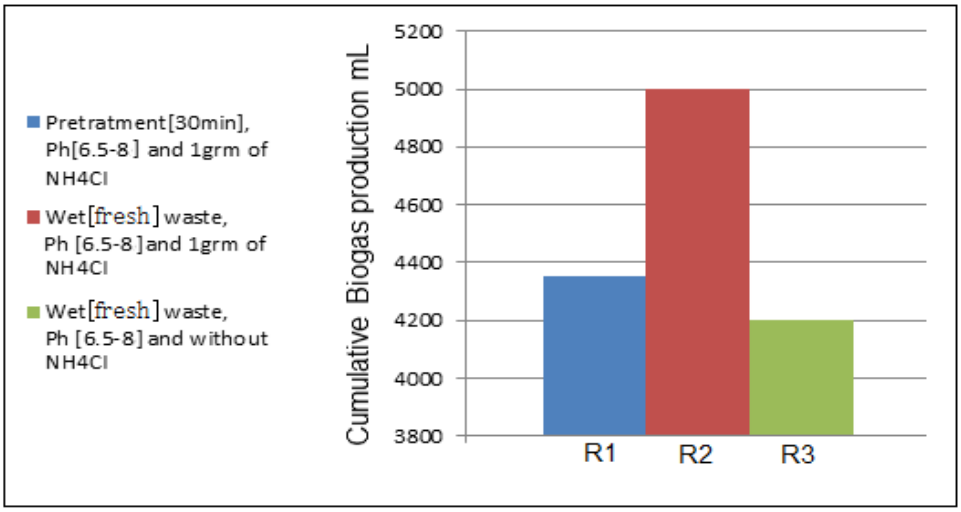

Figure 8: The effects of using of dry and wet (fresh) waste and adding nitrogen source

4.3. Biogas Analysis

Biogas analysis form each experiment is shown in Tables 1 and 2

Table 1: Biogas analysis from first experiment

N.O	Thermal pretreatment	Waste type	PH	CH_4 (mole %)	N_2 (mole %)	Co_2 (mole %)
R1	30 minute	dry	6.5-8	10%	6%	84%
R2	30 minute	dry	5.5-8	6%	12%	82%
R3	15 minute	dry	6.5-8	-	-	

Table 2: Biogas analysis from second experiment

N.O	Thermal pretreatment	PH	Waste type	NH4Cl	CH_4(mole%)	N_2(mole%)	Co_2 (mol %)
R1	30 minute	6.5-8	dry	1grm	30%	16%	52%
R2	-	6.5-8	fresh	1grm	48%	10%	42%
R3	-	6.5-8	fresh	without	20%	6%	72%

Biogas produced from dry samples showed low concentration of methane, which is attributed to the high percentage of carbon to nitrogen ratio in the substrate that is mainly cellulose, cellulose is very difficult to be digested, Because of that it has been thermally treated and after the addition of chemical nitrogen source an improvement in the concentration of methane was noticed.

Biogas produced from fresh samples showed high concentration of methane, which is attributed to the balance percentage of carbon to nitrogen ratio in the substrate compared to dry waste and after the addition of chemical nitrogen source an improvement in the concentration of methane was noticed.

4. Conclusion

Based on the results obtained in this research the following conclusions were reached.

- Heat treatment of date palm residues are very useful to improve the production of biogas.
- The percentage of methane gas in the produced biogas reaches 48 % for fresh waste with addition of nitrogen source
- Maintain the pH in the digester at range 6.5-8 more efficient to produce biogas.
- Retention time for fresh waste inside the digester is less than the retention time for dry waste.
- Palm tree wastes contain a high ratio of carbon comparing to nitrogen specially the dry one and addition of nitrogen source is required.

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