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Influence of Microwave Pretreatment on Biogas Production from Co-Digestion of Corn Cobs and Cow Manure

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ABSTRACT

This study aimed to produce biogas after microwave pretreatment of corn cobs and cow manure in a co-digestion system. The batch digester was manufactured from 10 PVC cans having a volume of 1050ml per each. Microwave pretreatment at the power of 294, 511 and 700 W and exposure time of 5, 10 and 15 minutes were applied to samples of corn cobs and cow manure "each sample has a mass of about 736.1 g. Its effects on biogas production were identified. The microwave added energy (SE) from microwave pretreatment was determined at range from 1198,207 to 8,558.62 kJ. kg^{-1} TS obtained about 10.82-46.8% increase in biogas production. The optimal microwave pretreatment obtained power of 511 W per 10 min exposure time. That adds a specific energy of 4165.195 kJ. kg^{-1} TS produced daily biogas of 307.95 ml/day. Microwave pretreatment with the co-digestion of corn cobs and cow manure is a suitable technology for energy production.

***Keywords**:* Microwave pretreatment, Co-digestion, Corn cobs, Biogas

INTRODUCTION

Agricultural wastes have lignocellulosic nature as corn cob could be utilized as substrates for biogas production although its nature difficult was needed a pretreatment. They used the effects of extrusion as mono pretreatment and integration with alkali and/or with the enzymatic hydrolysis for estimated to progress of the production of methane by corn cob anaerobic digestion and also impacted of after and before pretreatment on that production. Successive alkali extrusion and enzymatic hydrolysis pretreatment are achieved as the key enhancement with increasing of 22.3% in methane volume produced by corn cob anaerobic digestion (Rodríguez *et al.* 2017). Some experiments were done by Deublin and Steinhauser, (2008) cleared that hydrolysis rate has increased by mechanical, chemical, biological, or thermal pretreatments to breakdown cell walls and dissolve cell components forming them simply used by anaerobic microorganisms. Also They found the advantage of pretreatment were, biogas yield increasing by shortening the hydrolysis phase and reducing Hydraulic Retention Time (HRT);.Gregor and Grilc (2012) reported that the physical pretreatment is the best current recognized disintegration methods are grinding and mincing. The particle size is inversely proportional to the energy required for grinding and mincing. In the organic waste, state the experimental value for particle size is between 1.0 and 4.0 mm. Furthermore the biogas yield increased by this pretreatment is more than the energy required for this.

Frantseska and Gidarakos (2017) indicated that using microwave pretreatment for heating lignocellulosic agro industrial wastes (cotton gin waste, juice industry waste, olive pomace and winery waste) previous to anaerobic digestion for producing methane. Different effects on disintegration and methane possible have been by microwave heating. The difference were imputed to the specific properties of each substrate combined with the pretreatment conditions microwave pretreatment led to soluble in high level for both juice industry waste and winery waste. Aylin et al. (2018) studied the effect microwave pre-treatment on biogas production from the microwave. Maximum methane yield was 0.32 L CH_4/g VS added and biogas yield was 0.46 L/g VS added. These were gained from the co-digestion of 30 min microwave pretreated wastewater sludge and olive pomace. Akgul *et al.* (2017) reported that integrating thermal pretreatment (microwave and microwave with TPAD) produced the maximum quantity of additional heat 4.2-5.8 kJ/g VS that could be applied when they were studied on single-stage mesophilic anaerobic digestion (AD) and temperature-phased AD (TPAD) treating wastewater sludge with pretreating by low energy-input (2.5 kJ/g total solids) ultra-sonication and microwave irradiation were evaluated. The objectives were to attain a higher net energy along with enhanced digestate for agricultural applications.

WBA (2019) reported that the growth of the anaerobic digestion (AD) industry which produces biogas had been came from the development of alternative waste treatment methods and the need for non-fossil fuel-based energy sourcesSamer *et al.* (2014) identified that aerobic treated to manure and slurry (water +manure) was reducing harmful gaseous emissions before treated anaerobically to produce biogas.

Sorathia *et al.* (2012) reported that temperature for anaerobic digested has significantly affect biogas production. Through varied range of temperature can created methane. Optimal range of temperature, for bacteria, that generated methane was (29 - 41°C). Gioelli *et al.* (2011) and Sambusiti *et al.* (2015) reported that the physical chemical properties of produced biogas was affected by Change in temperature as well as other components in the reactor. A principal feature was the

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solubility of biogas components, especially methane, in the reactor liquid mixture. Biogas plants that work at low temperature release effluents with a higher content of dissolved methane compared to biogas plants that run at high temperature. The dissolved methane in the effluent is then released into the atmosphere as a greenhouse gas. Gregor and Grilc (2012) reported that ideal substrate C: N ratio is then 20 – 30: 1. The C: N ratio higher than 30 the germination of microorganisms has been slowly because low genesis for protein and hence low energy and structural material metabolism of microorganisms. Thus the observation substrate degradation efficiency is minimized. Otherwise low C : N ratio as 3 : 1 can be led to successfully digest at high nitrogen content substrates were used ("that is often the case using animal farm waste") ammonium inhibition able to be done that must been thought about carefully. Kainthola *et al*. (2019) stated that The degradation with high carbon content in substrates more than 35 : 1 comes slow because short bacterial development and multiplication due to the nitrogen reduction, but the biogas production is interval longer. Furthermore activity of bacteria is impeded with a C: N ratio less than 8:1 due to immoderate ammonium content is formed in great amount then the process becomes toxic and inhibit. Amigun *et al*. (2012) observed that anaerobic digestion process is economical, quietly simple, and can be operated for small and large scales in rural and urban sites. The hydrolysis rate has increased by mechanical, chemical, biological, or thermal pretreatments to breakdown cell walls and dissolve cell components forming them simply used by anaerobic microorganisms (Deublin and Steinhauser, 2008).

This study aimed to enhance biogas productivity from the co-digestion of corn cobs and dairy cow manure using microwave pretreatment on the pilot scale as a batch digester.

MATERIALS AND METHODS

The main experiments of this research were done at the Tractor and Farm Machinery Test and Research Station, Agriculture Research Center (ARC), Alexandria Governorate. To achieve the research aim the digester, microwave and raw materials were prepared.

Batch anaerobic digester

It consists of 10 pilot scale 1050 ml batch PVC cans (digesters) to the running condition on biogas producing and locate the optimum configuration and conditions of the operation for enhancing biogas production as shown in Fig (1).

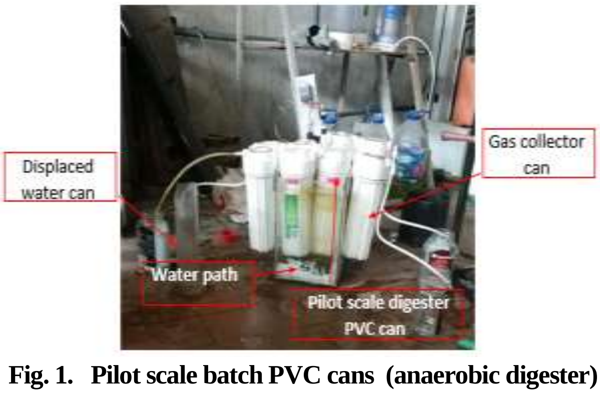

Fig. 1. Pilot scale batch PVC cans (anaerobic digester)

Microwave device

A household- type microwave oven (First 1 F-2020), with maximum power output of and frequency of 700 W and 2.45 GHz was used to pretreatment in the experiments at different studied variables.

Raw materials specifications

Corn cobs

Corncobs were obtained from the farm of the faculty of agriculture at Alexandria University, Alexandria Governorate. After harvesting corn crops. The main properties of corncobs were determined before being used in the study as shown in Table. (1)

Cow Manure

Cow manure was gotten from the farm of the dairy cattle of the research station, faculty of agriculture, Alexandria University, Alexandria Governorate. The manure was occupied directly after secretion from cows and analyzed for chemical features such as total solids, volatile solids, organic carbon, and total nitrogen as recorded in Table (1)

Table 1. Chemical analysis of corncobs and manure:

Parameters	Corn cobs	Cow manure
Total solids (T.S) , %	94.45	17.05
Total volatile solids (T.V.S), %	73.76	62.53
Total organic carbon (T.O.C), %	42.78	36.27
Total nitrogen (T.N), %	0.67	1.549
Carbon / Nitrogen ratio (C/N ratio)	63.85: 1	23.42: 1

Experimental procedures

A laboratory hammer grinding mill machine (FML-100) was used for milling corncobs and sieved to get particles less than 2.5 mm. Then the microwave pretreatment for each treatment of the co-substrates samples masses of about 739.45 g and TS of 10%. The samples treated in the microwave with, power of 294, 511 and 700 W at an exposure time of 5, 10 and 15 min. This power led to adding a specific energy ranging from 1198.207 to 8558.62 kJ kg-1 TS of co-substrates. After that the co-substrate was cooled to room temperature. Then it is introduced in the batch container of the anaerobic digestion (fig.1). The effect of microwave pretreatment has been evaluated by average daily biogas production ml/day, cumulative biogas production, average biogas production rate ml/ml/day, and microscopic evaluation for the microwave pretreatment of co- substrates (mixture corn cobs and cow manure 1:1 TS)

At anaerobic digestion of both control (untreated) and the microwave pretreated liquid cow dairy manure and corn cobs was established at mesophilic temperature (40± 2°C) in a batch operation mode as stated by El-Ashmawy, (2004). Within a water path to attain a constant mesophilic temperature of the anaerobic digesters had been set and maintained. The biogas production rate using the water displacement method under laboratory conditions was volumetrically measured by cumulating biogas as shown in Fig (2). The volume of biogas production was corrected according to the standard conditions (zero˚C and one bar pressure).

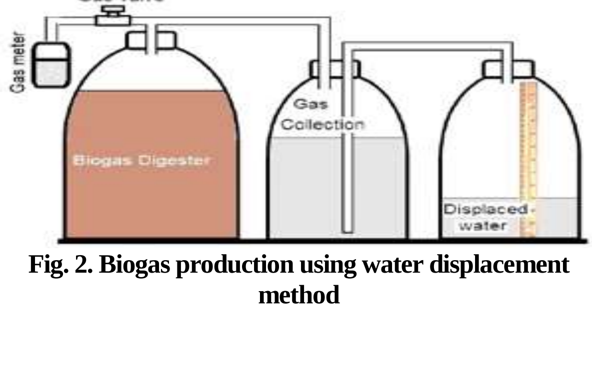

Fig. 2. Biogas production using water displacement method

Ten experiment sets were conducted; there were control co substrate (no microwave pretreatment), 9 MW pretreated as plotted in Table (2).

Table 2. Symbols of microwave pretreatment level

Symbol Treatment	C	M1	M2	M3	M4	M5	M6	M7	M8	M9
Power, (W)	-	294	294	294	511	511	511	700	700	700
Exposure time, min	-	5	10	15	5	10	15	5	10	15

An inoculum of 100 ml was added into 736.1 ml of sample in a 1050 ml cans for each set. The inoculum had the following characteristics: total solids (TS) of 6.86%, volatile solids (VS) of 5.71%. Based on total solid (TS) content of corn cobs and cow manure, both were mixed in 1: 1 (Corn cobs: Cow manure) on dry mass.

To determine the moisture content and total solids content (TS), an electric oven model of WS 200, type 117-0200 with temperature ranging from 30 to 300 °C was used to dry influent and effluent samples. The digital muffle furnace model F-14 Korea with technical data temperature ranging from100 to 1200^{0}C and Power volt 220v, it was used to ignite the dried influent and effluent samples to get the volatile solids contents (VS), respectively. Scanning electron microscopy (SEM) in Faculty of Science Alexandria University model of JSM-IT200 for pretreatment microscopic evaluation.

Total solids (TS)

Samples of the cow manure, corn cobs and mixture from both with the ratio of 1: 1 before digested were oven-dried at 105°C to constant mass, (APHA, 2005).

Volatile solids (VS)

The dried samples from the total solids locating in a digital muffle furnace were ignited at 600°C for two hours. The loss in mass was possessed as the volatile solids percentage (APHA, 2005). The volatile solids (VS) mass in kg was specified as stated by (Wittmaier, 2003):

$$VS\,(kg) = M_{fresh} \times VS\% \quad \text{........................ (3-1)}$$

Organic matter and organic carbon (O M & O C)

Percentage of organic matter has been determined from the percentage of ash was utilized the following equations (Black *et al* 1965):

$$O\,M\,(\%) = 100\,(\%) - ash\,(\%) \quad \text{.................. (3-2)}$$

Where:

ash (%) is the solid remains after burning

$$O\,C\,(\%) = O\,M\,(\%) / 1.7421 \quad \text{..................... (3-3)}$$

Total nitrogen

Organic nitrogen ON the raw sample was measured at the laboratory, Faculty of Agriculture Alexandria University, was determined as ammonium sulphate by Kjeldahl method.

The specific energy (SE)

The energy utilized to unit of Solid mass from raw material (TS) on pretreatment unit to estimate the disintegration and solubilization concert of the sample according to Peces *et al* (2015).

$$SE = \frac{P \times T}{W \times TS} \quad \text{............(3-4)}$$

Where

P: pretreatment power, W
T: pretreatment duration, (sec)
W: mass of pretreated material, (kg)

RESULTS AND DISCUSSION

The specific energy add microwave pretreatment

Specific energy adds to the substrate during pretreatment in the householder microwave for every power per time shown in Fig (3)

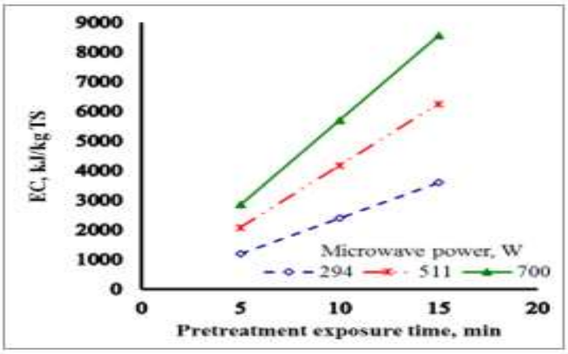

Fig. 3. the specific energy adds at different levels

The figure above illustrates some of the main characteristics of the specific energy add to the co- digestion substrate by microwave pretreatment at different levels of power and time respectively through pilot scale batch digester.

The influence on average daily biogas production and a cumulative

The result of microwave pretreatment on average daily biogas production (ml/day) at mesophilic temperature (40± 2°C) and 20 day retention time comparing with the control (without pretreatment) 209.77 ml/day The figure (6a) illustrates that was increased with the specific energy add from 210.6 ml/day at M1, 213.7 ml/day at M4, 216.14 ml/day at M2, 232.5 ml/day at M7 and 253.98 ml/day at M3 until the maximum value 307.95 ml/day at M5. The most surprising aspect of the data is the decrease in M6.M8 and M9 with an average of 202.01, 203.83and 82.4 ml/day respectively. Also, the effect of microwave pretreatment on bacterial activity a biodegradability is shown through cumulative biogas (ml) set out in Figure (6b). This can be compared with the control 1954.84 ml the increase was 1960.68, 2088.314, 2132.62, 2166.42, 2237.69, 2444.3, 2643.5 and 3260.68 ml for M1, M8, M6, M4, M2, M7 and M5 respectively. While there is a clear trend of decreasing at M9 with 857.76 ml.

Biogas production rate

The obtained data revealed that the outcomes from microwave pretreatment have been presented in figure (7-a) provides that the biogas production rate was increased when compared with the control that registries 0.1998 ml/ml/day, while M1, M4,M2,M7,M3 and M5 within value 0.2001,0.2035,0.0.2058,0.2214,0.242and 0.293, respectively.

Moreover the ratio of increasing was 0.411%, 1.87%, 3.04%, 10.82%, 21.1% and 46.8% for M1, M4, M2, M7, M3 and M5 respectively as shown in figure (7b). While, the average biogas production decreased by 2.83%, 3.7% and 59.59% for M6, M8 and M9 respectively as shown in figure (7b). Also figure revealed that values to M6, M8 and M9 were 0.194, 0.192 and 0.078 ml/ml/day respectively.

Broadly speaking, we found Biogas production rate values for each SE gradually increase till M5 then it came to decrease too unexpectedly, for the high value of M9 that pretreatment, in particular, was blown down in the house holder microwave during the exposure time. Initially, The most striking remarkable result to emerge from the data is that a decline in biogas productivity after SE level M5,the closest explanation for that is microwave pretreatment increase power level thus, the temperature was led to generate inhibitors has an inverse effected on biogas productivity. These results were corresponded with Appels *et al*. (2013) and Den *et al.* (2018).

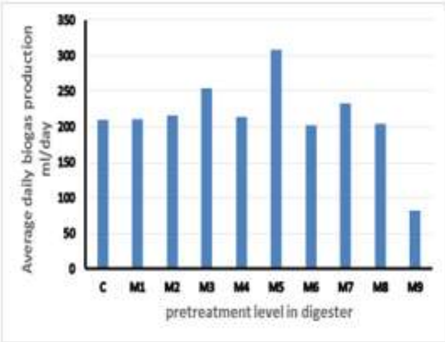

Fig. 6a. Average daily biogas production (ml/ml/day)

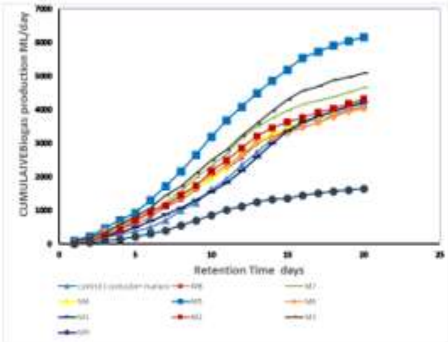

Fig. 6b. A cumulative biogas (ml)

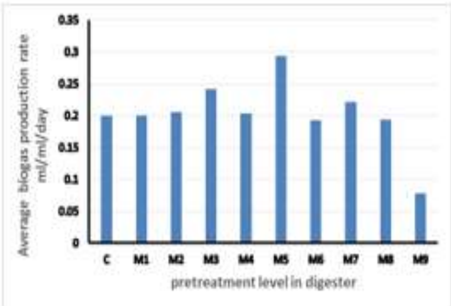

Fig. 7a. Biogas production rate

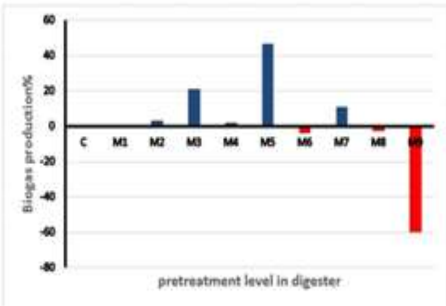

Fig. 7b. ± Biogas productivity

Scan electronic microscope

Microwave radiation regularly affects the announcement of bound water into the free liquid phase, as a consequence of the disruption occurrences in the structure of a particular material relative Marin *et al.* (2010). Figure (8b) shows the optimum microwave pretreatment M5 disarrange the structure of a particular substrate releasing bound organic matter into solution and disintegrating cell walls that are within the Extracellular Polymeric Substances shown in figure (8a) to release intracellular organic matter two main methods of microwave pretreatment a thermal specific impacts of electromagnetic radiation (non-thermal microwave effect) by polar and polarizable molecules rapidly oscillating and trying to adjust themselves to the incoming electromagnetic waves. The microwave energy is converted to heat by internal resistance to rotation triggering bond putrefaction and re-orienting. The thermal impacts cover the disintegration of organic matter such as denaturation of membrane proteins and the release of intracellular organelles. Previously mentioned is in agreement with Yu *et al.* (2010); Houtmeyers *et al.* (2014) and Zhen *et al*. (2017)

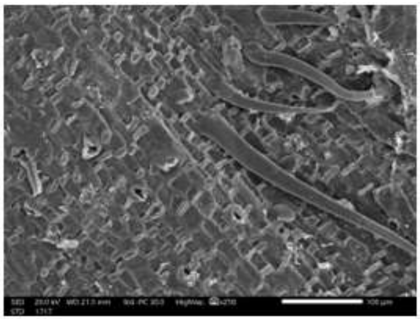

Fig. 8a. Control(un pretreatment)

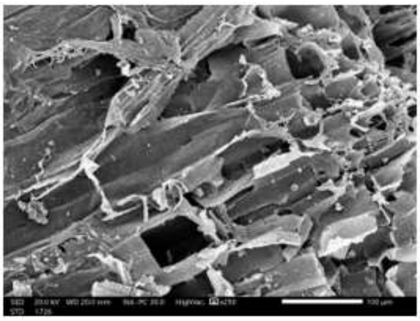

Fig. 8b. Microwave pretreatment M5

CONCLUSION

This study inspects of the productivity biogas after microwave pretreatments of corn cobs and dairy cow manure at the co-digestion system. The microwave pretreatment applied to co-digestion of corn cobs and cow manure samples affected a promoted increase in biogas yield based on specific energies added. The specific energy added SE by microwave pretreatment from 1198.207 to 8558.62 Kj kg^{-1} TS caused about 10.82-46.80 % increases in biogas yield. The optimum level of microwave pretreatment obtained at 4165.195 Kj kg-

[1]TS was 511 W and 10 min exposure time. The microwave pretreatment for Co-digestion of corn cobs and cow manure performs appropriate techniques for energy production.

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تأثير المعالجة المسبقة بالميكروويف على إنتاج الغاز الحيوي في الهضم المشترك لقوالح الذرة وروث البقر

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الملخص

تهدف هذه الدراسة إلى إنتاج الغاز الحيوي بعد المعالجة بالميكروويف لقوالح الذرة وروث البقر في نظام الهضم المشترك. حيث تم تصنيع هضم الدُفعة بإستخدام 10 عبوات تجريبية بسعة 1050 مل لكل علبة. تم تطبيق المعالجة بالميكروويف عند قدرة 294 و 511 و 700 واط وفترة تعرض 5 و 10 و 15 دقيقة لعينات من قوالح الذرة وسماد الأبقار "كل عينة تبلغ كتلها حوالى 736.1 جم" وذلك لبيان تأثيرة على إنتاج الغاز الحيوي. تم تحديد الطاقة المضافة بالميكروويف (SE) وكانت قيم المعالجة المسبقة بالميكروويف وجد أنها تتراوح بين 1198.207 إلى 8558.62 كيلوجول. كيلوجرام مادة صلبة مما تسبب فى زياده قدرها 10.82-46.8٪ في إنتاج الغاز الحيوي. لوحظ أن القيم المثلى للمعالجة المسبقة بالميكروويف كانت عند قدرة 511 واط و 10 دقائق من زمن التعرض والتى تضيف طاقة تبلغ 4165.195 كيلوجول. كيلوجرام مادة صلبة وأنتجت حوالي 307.95 مل / يوم من الغاز الحيوي اليومي. ومن هذا فإن المعالجة بالميكروويف للهضم المشترك لقوالح الذرة وروث البقر تكون تقنية مناسبة لإنتاج الطاقة.