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EFFECT OF MICROWAVE PRETREATMENT OF COW MANURE ON BIOGAS PRODUCTION IN UP-FLOW DIGESTER

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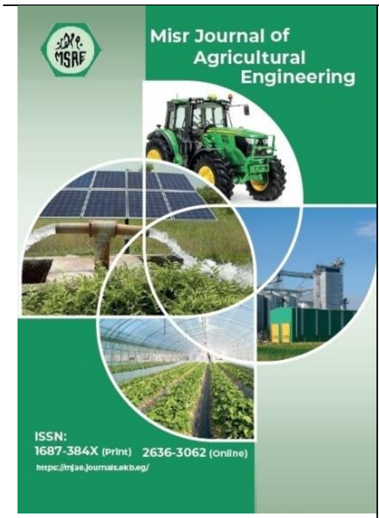

Keywords:
Pretreatment;
Microwave;
Biogas production.

ABSTRACT

This study examines the impact of microwave technique (MW) pretreatment, microwave treatment accelerates the breakdown of organic matter, leading to higher biogas production. (10% TS) of cow manure prior to digestion process in an up-flow anaerobic blanket (UASB) reactor on the biogas production. A microwave pretreatment unit was established alongside two UASB prototypes: one connected to MV unit and the other serving as control. The study analyzed different microwave exposure durations (10, 20, and 30 minutes) and intensities (270, 450, and 630W). Results showed that microwave pretreatments significantly enhanced biogas production compared to the control, with a remarkable 569.30% increase at 20 minutes,450 watt. Cumulative biogas yield varies with exposure durations and power levels. At low power, increasing exposure time from 10 to 30 minutes improved biogas output; similarly, at medium power, extending exposure time from 10 to 20 minutes raised biogas production, while extending to 30 minutes resulted in decreasing biogas production. At high power, extending exposure time from 10 to 20 minutes reduced biogas production, however a slight non-significant increase was observed when extending from 20 to 30 minutes. Increasing power levels significantly affect output, at 10 minutes, higher power level led to more daily biogas production, and similar trends were observed at 30 minutes. Specifically, raising power from 270 to 450 watts results in a 42.48% rise in cumulative output, while increasing from 450 to 630 watts led 9.1% decrease. Therefore, while raising power levels initially boosts biogas production, excessive increases lead to a decrease in the biogas production.

INTRODUCTION

Anaerobic digestion (AD) is a promising technology for sustainable energy production, transforming various organic resources into biogas, a renewable source of energy (**Rasapoor et al., 2020**). AD has proven effective in utilizing sustainable biomass, including locally sourced resources, municipal and industrial bio-waste, and agricultural residues **(Le Pera et al., 2022).** Over the past 40 years, biogas technology has been one of the most significant advancements in pollutant degradation and electricity generation, efficiently reducing pollution while producing energy (**Hassan et al., 2017)**. Despite these advantages, AD for biogas production faces challenges, particularly with the accumulation of intermediate products such as volatile fatty acids (VFAs), which can inhibit methane and biogas production (**Rodriguez et al., 2017; and Sathyan et al. 2023)**. This has underscored the importance of pretreatment methods that can enhance AD efficiency, reduce reliance on fossil fuels, and support alternative waste treatment techniques (**Karthikeyan et al., (2018)** and **WBA (2019).** One critical benefit of environmental AD is its role in minimizing direct carbon emissions from food waste disposal (**Shekwaga et al., 2021**). Pretreatment technologies usually necessitate physical mechanisms based on biomass dissolution methods, such as chemical, mechanical, and thermochemical pretreatment as **Shah (et al., 2015)** demonstrate. Depending on the substrate's properties and physicochemical structure, a variety of pretreatments can be applied before AD to maximize biodegradability and improve the production of biogas **(Zhen et al., 2017, Kainthola et al., 2019** and **Karthikeyan et al., 2024)** Among the various pretreatment techniques, microwave (MW) pretreatment has garnered interest in its effectiveness in boosting biogas production. As electromagnetic waves with frequencies from 300 MHz to 300 GHz, microwaves can cut processing time by half and lower operational costs **(Smith & Carpentier, 2012; Zhang, 2017; Guzik et al., 2021).** Studies have examined factors such as MW power and duration, showing that specific energy inputs can greatly optimize biogas production **(Feng et al., 2018, Simonetti et al., 2018** and **Suruagy et al., 2023)**. For example, **(Alagoz et al., 2018)** found that the highest yields of biogas were 0.46 L g^{-1} VS added by microwave pretreated for 30 minutes. On corn cobs, the specific energy added by MV ranged from 1198.2 to 8558.6 KJ kg^{-1} TS caused about 10.82- 46.80 % increases in biogas yield. The optimum yield obtained was 4165.2 KJ kg^{-1} TS at 511 W and 10 min exposure time **(Salem et al., 2022)**. Temperature and heating rates also significantly impacted the production of biogas. Recent findings by (**Suruagy et al., 2023)** several temperatures (85, 115, 145, and 175 ◦C) and heating rates (7.8, 3.9, and 1.9 ◦C/min) were used. With a final temperature of 175 ◦C and a heating rate of 3.9 ◦C, the biogas production increased by 73.19%. The AD of MV food waste demonstrated optimal process performance at 85 ◦C and 7.8 ramp compared to the control. However, samples treated at 175 ◦C displayed poor process performance and lower methane output. According to the previously stated facts, the primary objectives of the current research are:

Discovering the effect of pre-treatment of cow manure using microwave technology with energy levels and exposure times under study on biogas production and determining the best energy level and optimal exposure time.

MATERIALS AND METHODS

This study evaluated the effect of microwave pretreatment on biogas production from cow manure (10% total solids) using two up flow digesters developed at the Tractor and Farm Machinery Research and Test Station.

The mesophilic temperature of 40 ± 2 ˚C was maintained in two prototype digesters. One digester received microwave pretreatment, while the other served as the control. Three power levels (designated as MP270, MP450, and MP630) and three exposure intervals (10, 20, and 30 minutes; marked as T10, T20, and T30) were used to evaluate the impact of different microwave settings on the production of biogas from up flow digesters. by examining the three replicates' average values for every treatment.

1. Microwave pretreatment unit.

The microwave pretreatment unit and its accessories are illustrated in Figures (1 and 2). The unit function is based on an interaction structure supporting electromagnetic waves; the microwave unit consists of:

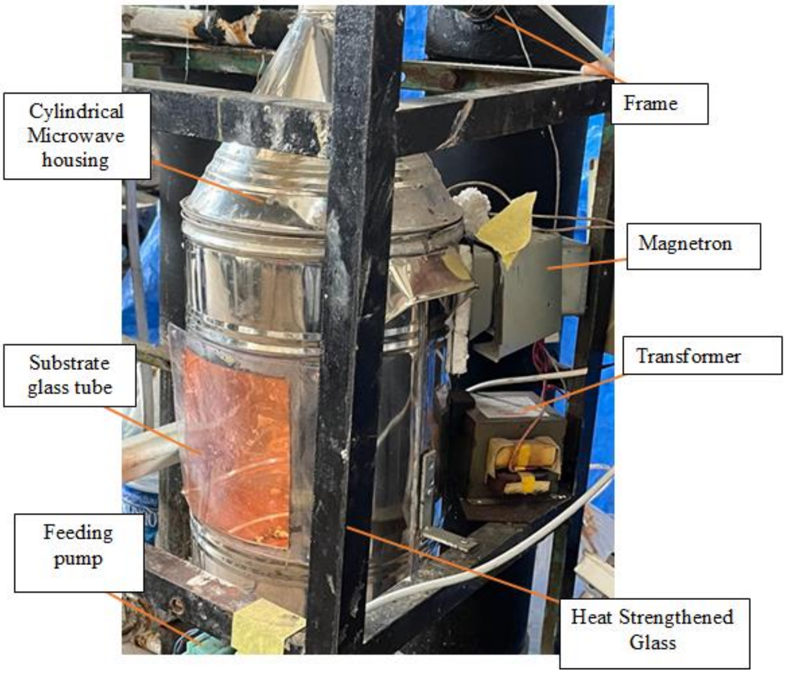

Fig. (1): Cylindrical Microwave unit

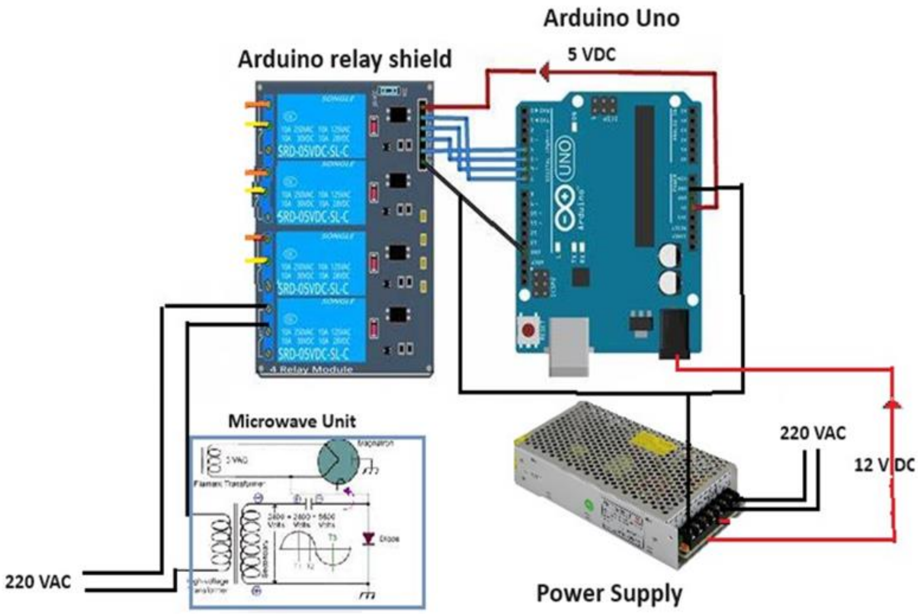

Fig. (2): A schematic of the wiring diagram for the microwave transformer and its attachment with the control unit.

1.1. Cavity magnetron.

The cavity magnetron is a high-power vacuum tube, is crucial in microwave heating systems, converting electrical and magnetic energy into microwaves for rapid heating. As the system's core, the magnetron generates microwave energy at a frequency of around 2.45 GHz, resonating within a designed cavity. This setup enables efficient energy transfer, allowing materials to heat quickly and uniformly.

1.2. Microwave transformer.

Responsible for stepping up the voltage to a level that can efficiently generate microwave energy. In this case, the LGL-900E-4, 220 V, 50 Hz model is used.

1.3. Substrate glass tube.

A glass tube with an outer diameter of 25.2 mm and an inner diameter of 25 mm was used. The glass tube is chosen for its chemical resistance and high-temperature resistance.

1.4. Cylindrical Microwave housing.

The cylindrical metal housing provides thermal processing for cow manure through microwave heating, a fast and efficient method. The metal structure effectively reflects microwave energy, preventing leakage and ensuring optimal absorption by the manure. This design, with a diameter of 26 cm, is engineered to be compatible with microwave wavelengths, enhancing energy efficiency in the heating process.

1.5. Arduino Uno.

The Arduino Uno is a versatile and widely used microcontroller board, that controls the operation after being programmed to manage the system.

1.6. Arduino Relay Shield.

The Arduino Relay Shield is an add-on board for the Arduino microcontroller that simplifies controlling high-voltage or high-current devices. It typically includes multiple relays (usually 1 to 8), allowing for flexible and efficient control of various devices in a single system.

2. The digestion unit (up flow).

The digestion unit composed of digester tank, mixing system, heating system, water jacket, gas collection system, inlet and outlet ports and control Systems.

3. The Heating System.

The heating system for biogas production is a vital component that supports the anaerobic digestion process by maintaining optimal temperatures for microbial activity.

3.1. Heating medium.

Hot water circulated through the water jacket, maintaining consistent digestion temperatures. A traditional Fresh Brand electrical water heater (30 liters) has technical data of 1500- watts, 220 V, with dimensions (L x W x H) of 55 x 40 x 40 cm and a weight of 8 kg was utilized.

3.2. Circulation pumps.

Pumps circulate the heating medium to ensure even temperature distribution within the digester. Which pumped water from the water heater to the water jacket and back to the water heater in a closed circuit to obtain the appropriate temperature for the digestion process.

3.3. Temperature controller.

Automated sensors and controllers monitor and adjust the temperature within the digester. STC-1000 model.

4. Sludge feeding system.

It consists of a sludge preparation tank, feeding pump, a dimmer device and feeding solenoid valve.

4.1. Sludge Preparation tank.

An 18-liter tank was used, in which cow manure is placed after setting the appropriate dilution of soluble solid for the experiment.

4.2. The feeding pump.

The O-MAX centrifugal pump model B-5 is used to feed the sludge to the digester was utilized.

4.3. A dimmer device.

The device is coupled with the feeding pump to regulate the pump speed (rpm).

4.4. The feeding solenoid valve.

delivers the cow manure to both the microwave pretreatment unit, and the control digester.4. Feeding solenoid valve.

5. Fresh cow manure.

Fresh cow manure was brought from the Farm of Dairy Cattle of the Research Station, Faculty of Agriculture, Alexandria University. The manure was collected directly after secretion from cows. The analysis was done to determine the characteristics of it. The result of the analysis is summarized in Table (1).

Table (1). Characteristics of cow manure.

Parameters	Measured value
Total solids (T.S), %	17.05
Total volatile solids (T.V.S), %	62.53
Total organic carbon (T.O.C), %	36.27
Total nitrogen (T.N), %	1.549
Carbon / Nitrogen ratio (C/N ratio)	23.42: 1
pH	8.07

6. Instruments and Measurements.

Several instruments were utilized to acquire the essential measurements during this experimental work.

6.1 Digital electronic balance.

The samples were weighted using electrical balance Model (Chyo MP 3000) made in Japan with a capacity of 3100 g and an accuracy of 0.01 g.

6.2. Electrical Oven.

The samples were dried in an electrical oven Model of WS 200, type 117-0200.

6.3. Digital Muffle Furnace.

Model (F-14) from Korea with technical data for a temperature range of 100 to 12000 °C. Also, the pH Meter and Gases sensors have been used.

7. Experimental measurements.

Total solids (TS) were determined following (**Hamilton and Zhang, 2011),** while Volatile solids (VS) were estimated according to (**Wittmaier, 2003).** Organic matter and organic carbon (O.M & O.C) were measured as described by **(Black et. al., 1965).** Biogas production rate was measured using water displacement technique as outlined by (**Gosch et al., 1983).** Adjusting the moisture content was done as reported by (**LO et. al., 1981).** The Adjustment of the volume of biogas production is corrected according to the standard conditions using the formula stated by (**Gosch et al., 1983).** The digester loading rate is calculated using the formula of **(LO et al., 1981).**

RESULTS AND DISCUSSION

1. Effect of microwave pretreatment on cumulative biogas production.

The cumulative biogas production at standard temperature and pressure STP (L) for the treatments exposed to microwave radiation is shown in Figure (3). The effects of different microwave power levels (MP270, MP450, and MP630) on biogas production, (L) under varying durations (T10, T20, and T30), resulted in increased production compared to the control unit. Trend analysis indicated that both the power level and duration of microwave exposure positively influenced biogas production. These results are agreed with (**Dai et al., 2017),** who stated that microwave radiation offers benefits over traditional heating techniques, such as efficient and effective volumetric heating, and rapid heat transfer. Similarly, **(Lan et al., 2020)** stated that microwave pre-treatment of anaerobic co-digestion of sludge and food waste enhances biogas production.

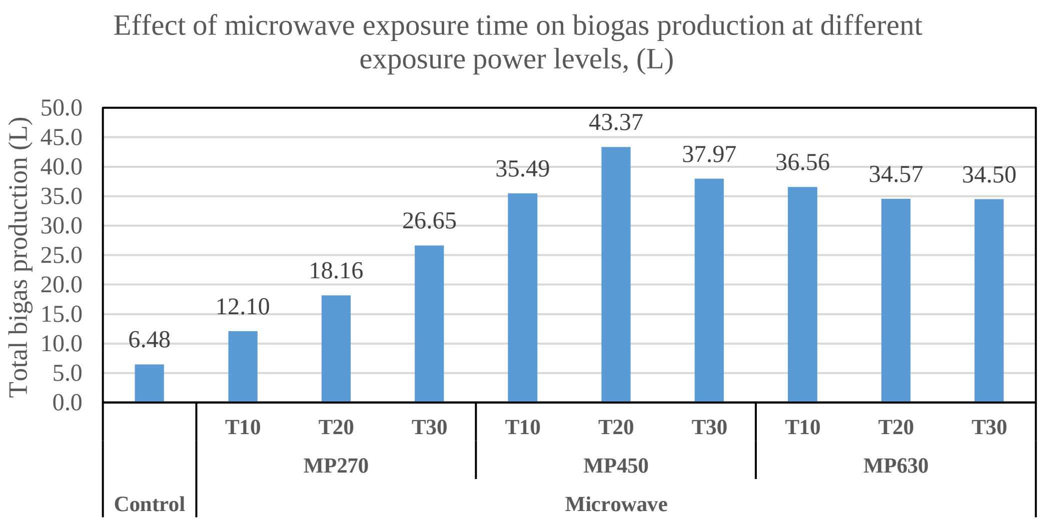

Figure (3). Effect of microwave exposure power and time levels on cumulative biogas production, (L).

2. Effects of Varying Microwave Power on Biogas Production.

The trend analysis showed that measurements tend to increase with both the power level and duration of microwave exposure. This is expected since higher power and longer exposure times typically provide more energy, which can lead to more pronounced effects on the sample being measured. However, the data reveals a few interesting points, i.e.,

Consistency across time, for the lower power MP270, the increase in measurements is relatively steady and consistent across the different durations. This suggests a linear, consistent response of the sample to the microwave exposure, making it relatively straightforward to anticipate changes based on duration alone at this power level.

Variability at higher power levels, at higher power settings, such as MP450 and especially at MP 630, the data reveals variability in measurement values. The data shows some fluctuations and even a slight decrease in average measurements at longer durations (e.g., MP 630 at T30) has a lower average than at T10. This could suggest that at higher power levels, the sample might be reaching a saturation point or undergoing changes that aren't strictly linear with power input. It might also indicate possible degradation or other complex reactions at higher energy inputs. This aligns with the idea that more power and longer exposure lead to more significant effects.

Diminishing Returns at Extended Durations, the results at MP630 show that after a certain duration (e.g., T20 and T30), the measurements do not continue to increase but rather show a decline. This could be due to the sample reaching a maximum capacity for change, or other factors like overheating or degradation that counteract the initial effects of the microwave. The results suggest that microwave treatment is effective in altering the sample's characteristics, with significant changes observed across different power levels and durations. However, effectiveness seems to vary with power level, with diminishing returns or increased variability at higher power levels. For practical applications, the data suggests that there might be an optimal range of power and time that maximizes the desired effects without introducing too much variability or risking negative effects like degradation. For instance, MP450 in T20 might offer a good balance between effectiveness and consistency. All previous information in the figure demonstrated that the overall biogas production for all microwave treatments exceeded control. The daily biogas production was somewhat fluctuating in the prior statistics as well, but since the Up-flow digester's flow is continuing, stable biogas production may be attained.

In practical terms, these findings suggest that careful calibration of microwave power and duration is essential for optimizing outcomes, and that understanding the initial state of the sample can help tailor the treatment for the best results. This result was also proven by (**Lan et al. 2020)** the anaerobic co-digestion of sludge and food waste, microwave pre-treatment could increase the biogas production, the highest methane production (19.93±0.99% higher than the control). Also, the findings of (**Jang and Ahn 2015)** may help to explain these results, they investigated the impact of microwave irradiation pretreatment on solubilization and biodegradation in anaerobic digestion of waste-activated sludge (WAS). Significantly more solubilization occurred at microwave final temperatures (100-170°C). The greatest degree of WAS solubilization (72%) within the design parameters happened at 170°C. At 170°C, the greatest volatile solids removal efficiency of 62.4% was attained. Both the cumulative biogas production and yield, which ranged from 2.3 to 5.7 l/l and 154 to 393 ml/g peaked at 135°C, respectively.

3. Effect of Microwave Exposure Time on Biogas Production.

Microwave exposure can potentially enhance biogas production by improving the breakdown of organic matter, but the optimal exposure times and power levels need to be carefully balanced to maximize benefits while minimizing any adverse effects. Figure (4) demonstrates the effect of varying exposure time on biogas productivity. This figure shows the effect of different pretreatment times on cumulative biogas production. It was a significant effect of increasing from MP270 to MP450 at T10, and by increasing power to MP630 was found a non-significant effect. At the exposure period of T20, the highest gas production was found at level MP450, then it decreased at MP630. Over the T30 gas production increased with increasing power to MP450 and then decreased at MP630. These findings align with previous research that indicated that microwave treatment enhanced the solubilization of organic materials, facilitating microbial digestion and ultimately leading to increased biogas yields (**Zhang et al., 2014 and Ethaib et al., 2015**).

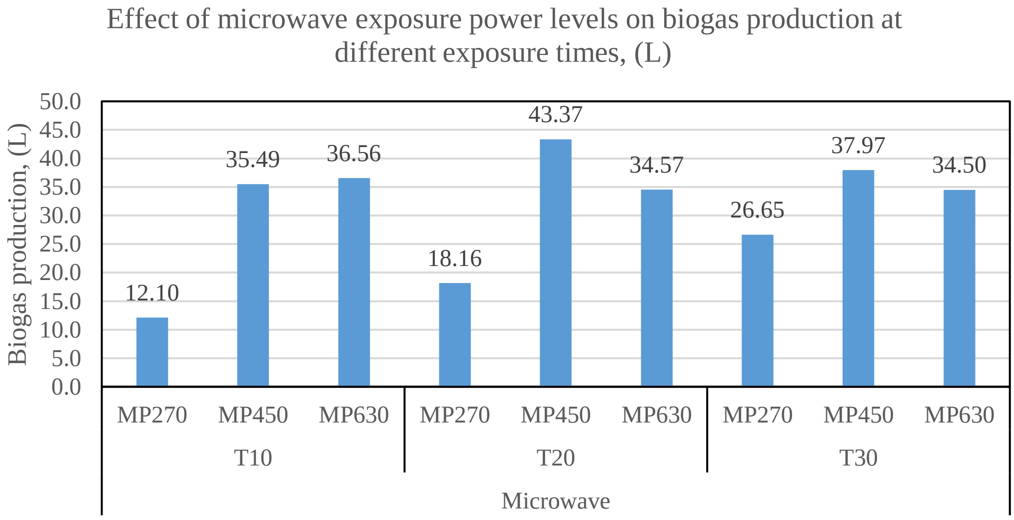

Figure (4). Effect of microwave exposure power levels on cumulative biogas production, (L) at different exposure times.

The results suggest that while medium power levels (MP450) are optimal for maximizing biogas production, excessively high-power levels may negatively impact biogas yields due to potential over-processing or degradation of organic matter (Zhou et al., 2016). The overall performance of microwave pretreatment appears to be influenced by both exposure time and power level, underscoring the importance of optimization in biogas production processes, **(Wang et al., 2022).**

4. Effect microwave exposure times on biogas production at MP270 W.

Cumulative biogas yields (L) as a result of exposing manure to different exposure times of microwave radiation were studied and displayed in Figure (3). The results demonstrated that extending the exposure period from T10 to T30 minutes led to an increase in the cumulative biogas yield over the control. The cumulative biogas yields of the three treatments over the control were significantly different as demonstrated in the figure. **(Agrawal et al., 2023),** reported that application of microwave (MW) treatment enhanced the solubilization of the feedstock and rendered 10% higher methane yield as compared to untreated anaerobic sludge and Fruit and vegetable waste 25:75 ratio at operating power of 300 Watts. Performance analysis indicated the highest VS reduction of 77% for microwave pretreatment.

5. Effect microwave exposure times on biogas production at MP450 W.

The results showed that extending the exposure period from T10 to T20 minutes led to increased cumulative biogas production. The increase was 22.2 %. On the other hand, increasing the exposure time from T20 to T30 minutes decreased the cumulative biogas production, the decrease was 12.45 %. The graph showed that the three treatments' trends were very similar, with only a small difference between them. Therefore, the data indicates that different microwave exposure treatments lead to varying levels of biogas production, with the T20 treatment yielding the highest results. However, increasing the exposure time by T30 led to more increase in the manure temperature resulting in over cooking or evaporating more moisture from the manure and changing the total solid content, and thus driving it to dry, resulting in reducing sludge digestion and biogas generation.

According to **(Vieira et al., 2023),** the anaerobic digestion of microwave food waste performed best at 85 ˚C with a ramp temperature of 7.8 ˚C. This resulted in no accumulation of intermediate products, up to 77% more methane being produced in the first week of digestion than under other conditions, and a 96.36% reduction in the duration of the lag phase when compared to the control. However, regardless of the heating rate, samples treated at 175 ◦C continuously displayed poor process performance and low methane output, which may have been caused by the creation of difficult-to-digest molecules. This study emphasizes how crucial it is to modify the microwave's power and temperature while pre-treating fresh vegetables in order to maximize the generation of methane.

6. Effect microwave exposure times on biogas production at MP630 W.

The results demonstrated that extending the exposure period from T10 to T20 led to a decrease in the cumulative biogas yield with 5.44 %. On the other hand, increasing the exposure period for T20 to T30 minutes slightly decreases with 0.20 %. The graph showed that there are no significant differences in the overall amount of biogas produced by the three treatments.

According to (**Sumardiono et al., 2015),** the best gas production from fresh and dried water hyacinth was obtained at 560 Watt at 7 minutes, 400 Watt at 7 minutes of microwave pre-treatment, pretreated fresh and dried water hyacinth has been produced 75.12- and 53.06-mL g^{-1} TS, respectively. The un- pretreated fresh and dried water hyacinth produced biogas of 37.56- and 33.56-mL g^{-1} TS, respectively.

7. Predicting the biogas production of the Up-flow digester integrated with a microwave unit.

7.1. At MP270 Watts

A statistical regression was performed to generate prediction equations of the cumulative biogas produced for all treatments as presented in Figure (5).

The prediction equations achieved for the three exposure times and their coefficient of determination compared to the control are:

$$Y\ (MP270T30) = 2.9765\ X - 0.114 \qquad R^2 = 0.9999$$

The highest biogas production rate is seen here, with exposure to MP270 Watts for T30 minutes. The slope is 2.9765, meaning the biogas production increases by nearly 3 liters/day. The R^2 value of 0.9999 signifies an almost perfect linear relationship.

$$Y\ (MP270T20) = 1.7959\ X + 0.1526 \qquad R^2 = 0.9996$$

Represents exposure at MP270 for T20. The production rate further increases with a slope of 1.7959 liters/day. The R^2 value is 0.9996, indicating a strong linear fit with lees rate.

$$Y\ (MP270T10) = 1.2122\ X + 0.0407 \qquad R^2 = 0.9998$$

Represents biomass exposed to microwaves at MP270 for T10. The biogas production increases more rapidly than the control group, with a slope of 1.2122 (about 1.2 liters day^{-1} increase). The R^2 value of 0.9998 again indicates a strong fit to the linear model.

$$Y\ (Control) = 0.6412\ X + 0.0555 \qquad R^2 = 0.9999$$

Represents the biomass without any microwave treatment. The biogas production grows slowly, and the linear equation shows a slope of 0.6412, meaning the production increases by approximately 0.6412 liters per day. The R^2 value of 0.9999 suggests an excellent fit to the linear trend.

Where:

Y = the cumulative biogas production, L

X = number of days after starting feeding the sludge to the digester

T10, T20, and T30 = the exposure time treatments of 10, 20 and 30 minutes, respectively .

The high values of the coefficients of determination demonstrate the high accuracy of these equations in estimating the total amount of biogas produced when the same microwave exposure times are applied to the sludge prior to feeding the digester.

Impact of Microwave Exposure: The longer the biomass is exposed to microwaves (from T10 to T30), the higher the cumulative biogas production. This demonstrates that microwave treatment accelerates the breakdown of organic matter, leading to higher biogas production. It was evident that at the 270 W power level, the slopes increased with increasing exposure time

Linear Growth: The linear equations suggest that biogas production follows a steady, linear growth over time in each case. The high R^2 values (close to 1.0) indicate that the data fits the linear trend well.

Comparison to Control: The untreated biomass (Control) produces much less biogas compared to the microwave-treated groups, showing that microwave exposure significantly enhances the efficiency of biogas production.

7.2. At MP450 Watts

The following prediction equations, along with their coefficient of determination, were obtained for the three exposure times:

$$Y\ (MP450T30) = 3.8011\ X - 0.2309 \qquad R^2 = 0.9999$$

This equation indicates that the biogas produces with a rate of 3.٨ L Day^{-1}.

$$Y\ (MP450T20) = 4.4015\ X - 0.57463 \qquad R^2 = 0.9998$$

This equation indicates that the biogas produces with a rate of 4.4 L Day^{-1}.

$$Y\ (MP450T10) = 3.604\ X - 0.5494 \qquad R^2 = 0.9999$$

This equation indicates that the biogas produces with a rate of 3.6 L Day^{-1}.

The data indicates that different microwave exposure treatments lead to varying levels of biogas production. It was clearly at the energy level of 450, by increasing the time from 10 to 20 minutes, the highest percentage of biogas production was found, while when the time was increased to 30 minutes, the production of biogas decreased ,it resulted in overcooking, a change in moisture content, and a change in the structure of the organic matter. The high R^2 values across all treatments suggest that the linear models fit the data very well, confirming the effectiveness of the treatments.

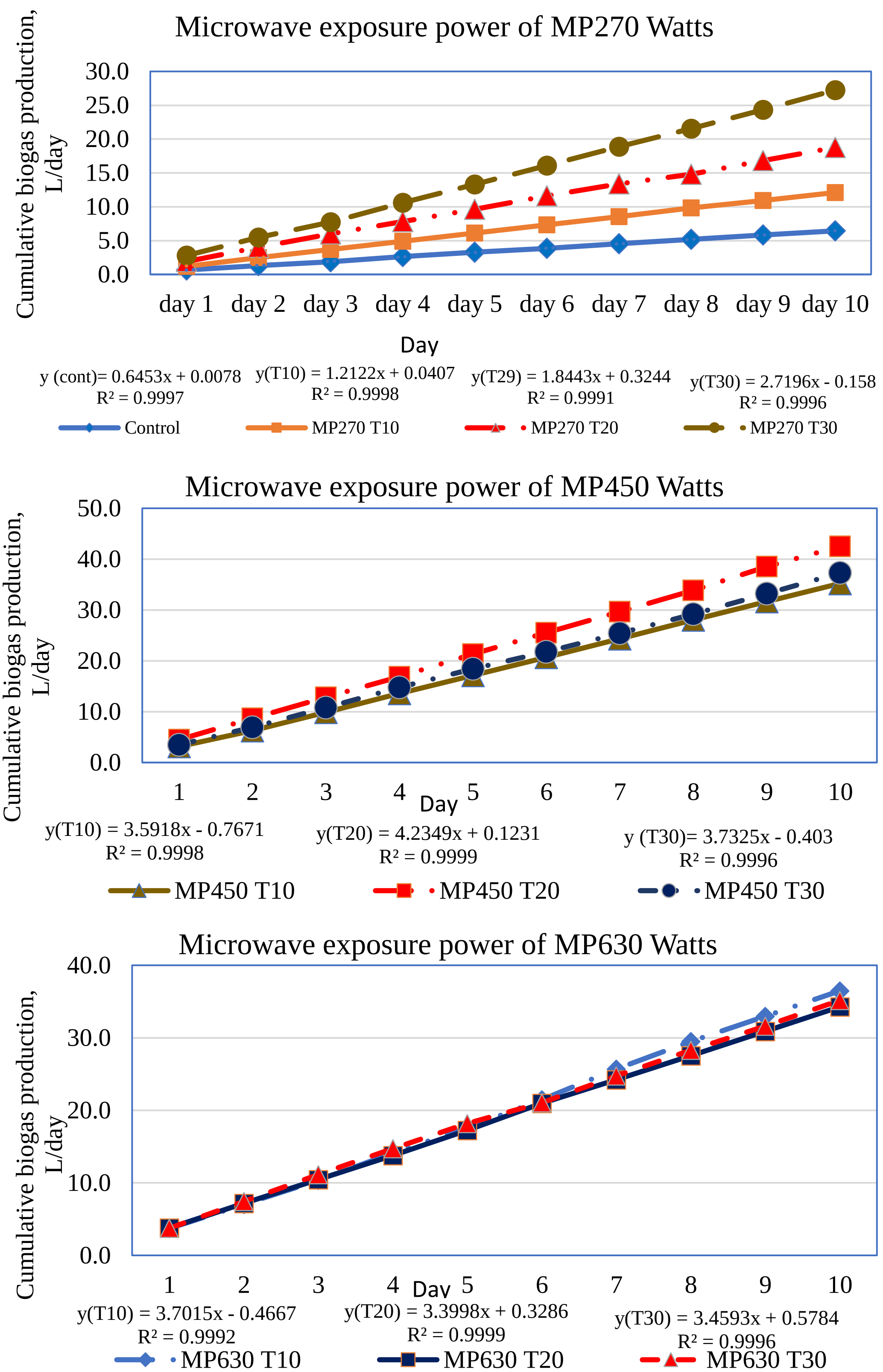

Fig. (5): The cumulative biogas production (L) at varying microwave power and time levels.

7.3. At MP630 Watts

The three exposure periods' prediction equations, along with their coefficient of determination, are

$$Y\ (MP630T30) = 3.6792\ X + 0.5784 \qquad R^2 = 0.9996$$

At the maximum power and maximum exposure time, the greatest gas production was found, the slopes were 3.7 L Day^{-1}. With the value of R^2 0.9996, which led to a perfect linear relationship.

$$Y\ (MP630T20) = 3.4407\ X - 0.1438 \qquad R^2 = 0.9999$$

After T20 of exposure time for the pretreatment, at maximum power, the gas production was represented by the slope 3.44 L Day^{-1} and the R^2 Getting closer to 1.0, this indicated an excellent linear relationship.

$$Y\ (MP630T10) = 3.4363\ X + 0.\ 2545 \qquad R^2 = 0.9999$$

At the minimum pretreatment exposure time and maximum power, found the gas production represented by the slope 3.44 L Day^{-1} and the value of R^2 0.9999 which led to perfect linear relationship.

At the high energy level, the slopes at the exposure time from 10 to 20 showed a decrease in biogas production, while the slope at the exposure time of 30 minutes showed a non-significant increase in biogas production.

When the same microwave exposure times are applied to the manure before feeding the digester, the high values of the coefficients of determination show how accurate these equations are in estimating the total amount of biogas produced.

7.4. General prediction formula for predicting the cumulative biogas production

A general prediction equation of the cumulative biogas production was created using statistical simple regression. The following prediction equation, together with its coefficient of determination,

$$\text{Bogas production} = 0.04403635036\ MP + 0.26358345499\ MT + 5.90 \qquad R^2 = 0.548$$

The error root mean square of the observed and predicted cumulative biogas production was = 6.21 L

And when using multiple regression as a polynomial consideration the following prediction equation, together with its coefficient of determination:

$$\text{Bogas Producción} = -3.398E\text{-}4\ MP^2 + 0.350\ MP - 0.0127\ MT^2 + 0.771\ MT - 59.904 \quad R^2 = 0.8694$$

The error root mean square of the observed and predicted cumulative biogas production was 3.340 L

When added term of interaction MP *MT, general prediction equation of the cumulative biogas production was created using statistical multiple regression as a polynomial consideration with interaction between exposure power and exposure time.

The following prediction equation, together with its coefficient of determination

$$\text{Biogas prod.} = 0.396MP + 1.997\ MT - 3.398E\text{-}4\ MP^2 - 0.013\ MT^2 - 0.002\ MP \times MT - 80.470 \quad R^2 = 0.957$$

Which MP represents Microwave power, MV represents Microwave exposure time. and MP x MT represents the term of interaction between exposure power and time.

The high coefficient of determination demonstrated that this equation has a high degree of accuracy in predicting the total amount of biogas produced over time. The expected and observed biogas generation as a result of the calculated equation is shown in Fig. (6). The error root mean square of the observed and predicted cumulative biogas production is 1.907L.

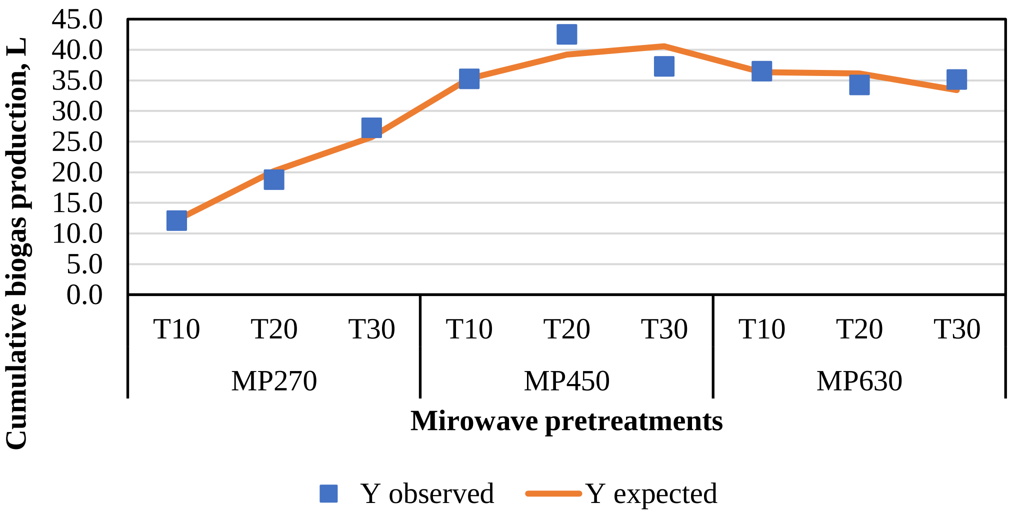

Fig. (6): The observed and expected cumulative biogas production (L) at varying microwave power and time levels.

CONCLUSION

The results indicated that extending the exposure duration at low power enhanced biogas production for microwave pretreatment. However, when the device operated at high power, biogas production decreased with increasing exposure time. The results for the top three treatments were, in general, 43.37, 37.61, and 36.49 liters for MP450T20, MP450T30, MP630T10, respectively.

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أثر المعالجة الميكروويفية لروث البقر على إنتاج الغاز الحيوي في الهاضم ذو السريان المستمر

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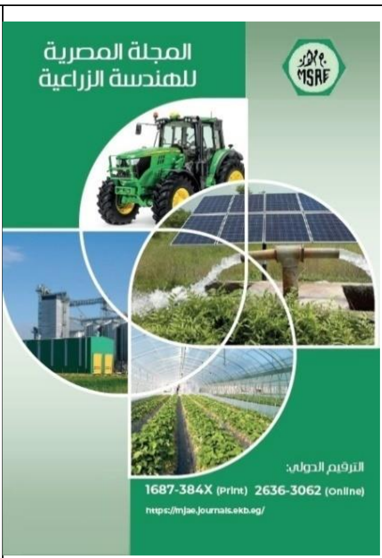

الكلمات المفتاحية:
المعالجة الأولية؛
الموجات الدقيقة؛
إنتاج الغاز الحيوي

الملخص العربي

تتناول الدراسة تأثير المعالجة المسبقة لروث البقر بتقنية الموجات الدقيقة قبل عملية الهضم في الهاضم اللاهوائي ذو السريان المستمر على إنتاج الغاز الحيوي. تم إنشاء وحدة معالجة مسبقة بالموجات الدقيقة جنبًا إلى جنب مع نموذجين من الهاضم أحدهما متصل بوحدة المعالجة المسبقة بتقنية الميكروويف والآخر يعمل كوحدة تحكم. قامت الدراسة بتحليل ثلاث فترات من التعرض بالموجات الدقيقة، وثلاث مستويات طاقة، أظهرت النتائج أن المعالجة الأولية عززت بشكل كبير إنتاج الغاز مقارنة بوحدة التحكم، يختلف إنتاج الغاز الحيوي التراكمي باختلاف فترات التعرض ومستويات الطاقة. عند استخدام مستوى الطاقة المنخفض أدت زيادة أوقات التعرض إلى تحسين نسبة الغاز وبالمثل عند الطاقة المتوسطة أدى تمديد وقت التعرض من عشرة إلى عشرين دقيقة إلى زيادة نسبة إنتاج الغاز, بينما أدى التمديد إلى ثلاثين دقيقة إلى انخفاض إنتاج الغاز , عند الطاقة المرتفعة أدى زيادة وقت التعرض من عشرة إلى عشرين دقيقة إلى انخفاض إنتاج الغاز ولكن لوحظ زيادة طفيفة غير ملحوظة عند زيادة الوقت إلى ثلاثين دقيقة, اثرت مستويات الطاقة بشكل كبير على الإنتاج عند الوقت عشرة دقائق أدى ارتفاع مستوى الطاقة إلى زيادة نسبة الغاز ولوحظ اتجاه مماثل عند ثلاثون دقيقة, يؤدي رفع الطاقة المنخفضة إلى المتوسطة إلى زيادة في الإنتاج التراكمي , بينما ادت زيادة الطاقة من المتوسطة إلى المرتفعة إلى انخفاض في الإنتاج , نجد أن زيادة الطاقة يؤدي في البداية إلى تعزيز إنتاج الغاز لكن الزيادة المفرطة أدت إلى انخفاض الإنتاج.