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EFFECT OF ULTRASONIC PRETREATMENT OF COW MANURE ON BIOGAS PRODUCTION USING AN UP-FLOW ANAEROBIC SLUDGE BLANKET REACTOR

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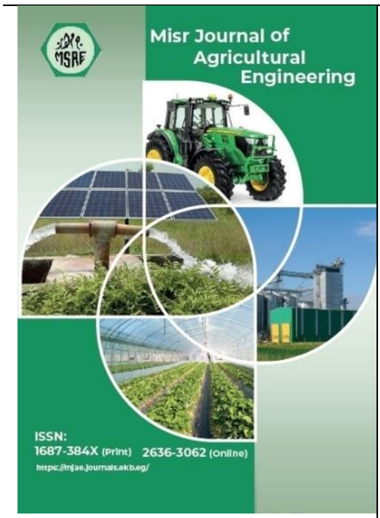

Keywords:
Pretreatment;
Ultrasonic;
Biogas production

ABSTRACT

This study investigates the effect of ultrasonic technique (US -20 kHz) pre-treatment, of cow manure (10% T.S.) on biogas production with up-flow anaerobic sludge blanket (UASB). Ultrasonic accelerates the breakdown of organic matter. Tow UASB prototypes were established: one is attached with a US unit, and the other serving as a control, with varying exposure durations (10, 20, and 30 minutes) and power levels (50, 100, and 150W). The results indicate that ultrasonic pretreatment significantly enhanced biogas production, reaching up to 478.55% over control at ultrasonic 150 watt, time 10 minute. For exposure power levels of UP50T30, UP100T30, and UP150T30, the cumulative biogas production increased by 172.22, 433.18, and 394.91%, respectively compared to control. Data indicated that increasing exposure power from UP50 to UP100 increase in cumulative biogas production, meanwhile, cumulative biogas production decreased by increasing exposure power from UP100 to UP150. However, increasing power to 150 W resulted in a decline in biogas output, indicating a potential negative effect on higher power levels. At low power, extending exposure times (from 10 to 30 minutes) resulted in increases in total biogas generation by 30.82%, 85.40%, and 172.22%, respectively, over control. At medium power, biogas production improved with longer exposure times. Conversely, at high power, increasing exposure from 10 to 20 minutes decreased cumulative biogas output from 37.49 to 31.80, a slight increase to 32.07 liters at 30 minutes. These findings demonstrate while ultrasonic pretreatment can enhance biogas production, increasing the energy level over time leads to decreased production.

INTRODUCTION

Energy security and climate change have become among the most important factors that have led to the trend towards converting traditional energy into renewable energy. Biomass plays an influential role in this transformation. In recent years, there has been growing interest in enhancing anaerobic digestion (AD) efficiency through various pretreatment methods to increase biogas yield. Biogas is an option with great potential, as it provides many capabilities that make it an alternative to fossil fuels, especially in remote areas. So, the most hopeful technology is anaerobic digestion (AD), which transforms organic resources into biogas **(Rasapoor et al., 2020).** AD is the most widely used method for converting organic-rich substances into clean, sustainable products. This interest is driven by the need for sustainable energy solutions and the reduction of environmental impacts associated with organic waste. Biogas can be generated from sustainable biomass, particularly locally sourced materials, municipal and industrial bio-waste, and agricultural residues **(Le Pera et al., 2022).** Biogas technology has been cited as one of the most important developments in pollutant degradation or transformation and electricity generation over the past four decades **(Hassan et al., 2017)**. It impedes the generation of biogas and biomethane by lowering the production of intermediate products (Volatile Fatty Acids, or VFAs) **(Rodriguez et al., 2017)**. It was prompted by the need to have alternatives to fossil fuels and the development of alternative waste treatment techniques, as stated by (**Karthikeyan et al., 2018)** and (**WBA 2019).** AD for food waste minimizes direct carbon emissions to the environment **(Shekwaga et al., 2021).**

Pretreatment technologies are crucial for enhancing the biodegradability of substrates in anaerobic digestion (AD), as they help to break down complex organic structures, making them more accessible for microbial activity. These technologies include chemical, mechanical, and thermochemical methods, each with distinct mechanisms for biomass dissolution (**Shah et al., 2015)**. For instance, chemical pretreatments like acid or alkaline hydrolysis modify the pH, facilitating the breakdown of lignocellulosic materials, while thermochemical methods use heat and chemicals to disrupt tough cellular structures **(Zhen et al., 2017, Kainthola et al., 2019** and **Karthikeyan et al., 2024)**. However, these approaches often come with limitations such as high energy requirements or the generation of inhibitory by-products **(Kainthola et al., 2019).**

In this context, **ultrasonic (US) pretreatment** has gained attention as a promising alternative due to its efficiency in improving substrate solubilization without the need for chemical additives (**Zhou et al., 2023; Chen et al., 2023**). Unlike other methods, ultrasonic pretreatment utilizes high-frequency sound waves to induce **cavitation**—the formation of microbubbles that collapse and generate intense shear forces. This mechanical action disrupts cell walls and enhances the release of intracellular components, increasing the hydrolysis rate during AD (**Li & Yang, 2023)**. Studies have shown that ultrasonic pretreatment can increase biogas yield by up to 60%, depending on the substrate and operational parameters, making it a competitive and sustainable option compared to traditional methods **(Silva et al., 2023)**.

However, the effectiveness of ultrasonic pretreatment is influenced by several factors, such as frequency, power input, and duration. While optimal sonication can significantly enhance biogas production, prolonged or excessive treatment may lead to the formation of inhibitory compounds, reducing overall efficiency **(Lan et al., 2020).** Ultrasonication is a relatively new and very effective mechanical pretreatment technique that can improve the sludge's biodegradability **(Pilli et al., 2010).** The average biogas increase was 27% by US pretreatment **(Houtmeyers et al., 2014)**. About 20% more biogas and methane were produced from ultrasound-pretreated diluted olive mill wastewater than from the untreated (**Oz and Uzun,**

2015). US pre-treatment has been shown to be a green method of improving organic matter's biodegradability **(Zeynali et al., 2017** and **Filibeli et al., 2018).**

US pre-treatments applied to sludge samples prior to co-digestion increased methane generation by 52% than untreated **(Alagöz et al., 2018)**. The frequency, power, and duration of US have the largest effects on the degree of hydrolysis on rice straw, the application of 37 and 102 kHz reduced the amount of hemicellulose by roughly 25.78% and 20.82%, respectively. (**Pansripong et al., 2022)** mentioned that the hemicellulose concentration dropped by approximately 21.95% and 18.75% than the un-pretreated straw. *Scenedesmus* sp. and *Pinnularia* sp. are broken down using ultrasonic technology. *Scenedesmus* sp. that was sonicated for 150 and 200 seconds yielded the highest CH_4 yields, 309 ± 13 cm^3 g^{-1} VS and 313 ± 15 cm^3 g^{-1} VS, respectively **(Debowski et al., 2022)**.

(Lan et al. 2020) found that optimal sonication parameters could reduce the particle size of organic matter, thereby enhancing microbial access. They observed that increasing the sonication duration up to a point improved biogas yield, but prolonged exposure could lead to diminishing returns due to the formation of inhibitory compounds. Frequency of 20 kHz were employed. 18 minutes of sonication produced the maximum methane yield (2380 kJ kg^{-1} TS), but longer sonication exposure produced lower methane yields **(Zeynali et al., 2017)**. The low frequency of 20 kHz and various sonication periods (20, 40, and 60 min) have been used to evaluate the effectiveness of ultrasound pretreatment **(Zerroukia et al., 2021)**. The biogas yield rose by 47, 57, and 60% over the control for sonication times of 20, 40, and 60 minutes, respectively. Despite the promising results of ultrasonic pretreatment, there is a lack of comprehensive studies exploring its long-term impact on biogas yield stability and the economic feasibility of scaling up this method for industrial applications. Furthermore, the effects of varying substrate compositions on the efficiency of ultrasonic pretreatment remain underexplored, particularly for mixed waste streams. The current study aims to bridge these gaps by developing a novel ultrasonic unit tailored for diverse substrates and evaluating its performance in continuous flow digesters

According to the previously stated facts, the primary objectives of the current research are:

Concluding the effect of pre-treatment of cow manure using ultrasound technology and finding the best variables for the energy levels and exposure times under study on the production of biogas when digested in up flow digester.

3. MATERIALS AND METHODS

3.1 Experimental Setup

Two prototypes of up-flow digester prototypes were developed at the Tractor and Farm Machinery Research and Test Station to evaluate the impact of ultrasonic pretreatment on biogas yield. The digesters were maintained at a mesophilic temperature of 40 ± 2 ˚C with an inoculum concentration of 10%. Various operational parameters, including ultrasonic exposure duration and power intensity, were systematically investigated. The ultrasonic unit was integrated into the experimental setup, testing three ultrasonic exposure durations (10, 20, and 30 minutes) and three power levels (50, 100, and 150 W). The primary aim was to identify the optimal ultrasonic parameters for maximizing biogas production compared to a control digester without ultrasonic treatment.

3.2. Ultrasonic pretreatment unit.

The ultrasonic pretreatment unit was designed to enhance the biodegradability of cow manure. The unit consisted of the following components:

3.2.1. Power supply.

A DC power supply (12–30 V, 3A max) was utilized to operate the entire ultrasonic system, ensuring stable voltage output for optimal functionality.

3.2.2. Signal Generator.

The signal generator (Top Ward Brand TFG-8101) provides the necessary high-frequency electrical signals to the ultrasonic to the transducer, a critical component for generating ultrasonic waves.

3.2.3. Power amplifier unit.

The power amplifier increased the signal strength from the generator to a suitable level for driving the ultrasonic transducers, ensuring effective cavitation.

3.2.4. Control System (Arduino Uno)

An Arduino Uno microcontroller was programmed to manage the system's operation, integrating various components for seamless control.

3.2.5. Arduino Relay Shield.

The Arduino Relay Shield facilitated the control of high-voltage devices, enabling the simultaneous management of multiple components within the ultrasonic unit.

3.2.6. Ultrasonic Ceramic Disc transducer.

Six piezoelectric ceramic disc transducers were affixed along a PVC substrate tube (32 mm outer diameter, 26 mm inner diameter). These transducers converted electrical signals into ultrasonic vibrations. The assembly was placed inside a 4-inch PVC tube and connected to a solenoid valve at one end, as illustrated in Figures (3.1 and 3.2).

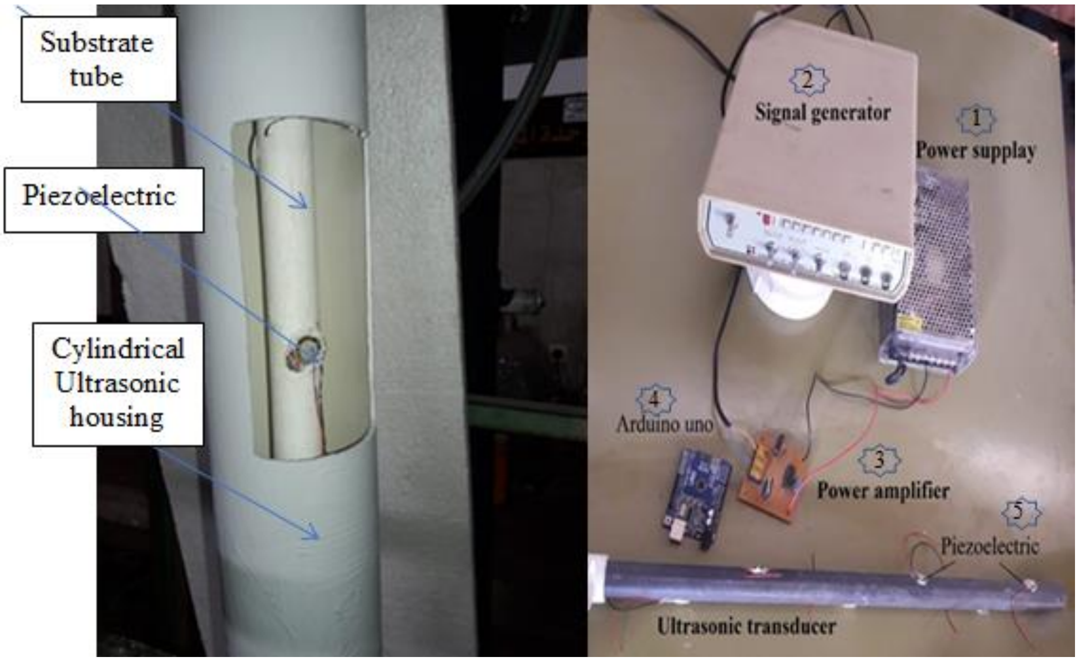

Fig. (3.1): the ultrasonic pretreatment unit and its parts.

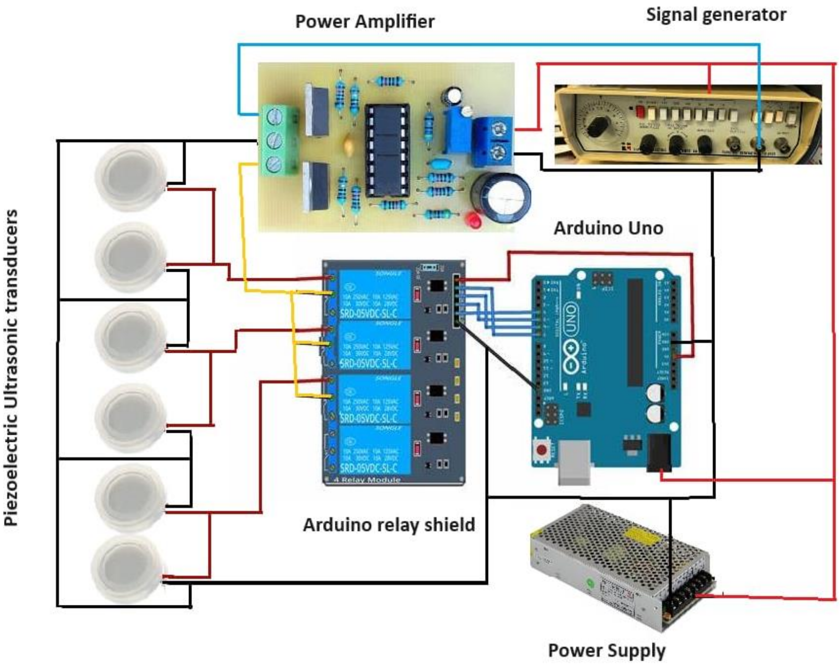

Fig. (3.2): Schematic circuit diagram of the Ultrasonic unit.

3.3. The Digestion unit.

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

3.3.1. The digester (up flow).

The up-flow digester, constructed from stainless steel for enhanced durability and heat conduction, measured 100 cm in length with an inner diameter of 12.36 cm and a thickness of 1.0 mm. The effective volume of the digester was 10 liters.

3.3.2. The Heating System.

To maintain optimal mesophilic conditions, a heating system was employed. It consisted of an electrical water heater (30 liters, Fresh Brand), a circulation pump, and an automated temperature controller (STC-1000 model). Hot water was circulated through a water jacket surrounding the digester to ensure uniform temperature distribution.

3.4. The sludge feeding system.

The feeding system included a preparation tank, a centrifugal feeding pump (O-MAX B-5), a dimmer for speed control, and a feeding solenoid valve.

3.4.1. Sludge Preparation tank.

An 18-liter tank was used for preparing cow manure, adjusting the solid content to the desired dilution.

3.4.2 Feeding Mechanism

The prepared sludge was pumped into the digester using a centrifugal pump, with the flow rate controlled by a dimmer device. A solenoid valve regulated the feed delivery to the digester.

3.5. Substrate: Fresh Cow Manure

Fresh cow manure was collected from the Dairy Cattle Farm at the Research Station, Faculty of Agriculture Alexandria University. The manure was analyzed for its physicochemical properties before use. The characteristics are summarized in Table (3.1).

Table (3.1): Characteristics of fresh 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

3.6. Instruments and Measurements.

Accurate measurements were essential for evaluating the performance of the digesters and the impact of ultrasonic pretreatment. The following instruments were utilized:

3.6.1 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.

3.6.2. Electrical Oven.

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

3.6.3. Digital Muffle Furnace.

A digital muffle furnace (Model F-14, Korea) with a temperature range of 100 to 1200°C was used for determining volatile solids.

3.6.4 pH Meter and Gas Sensors

A pH meter and various gas sensors were used to monitor pH and biogas composition throughout the experiments.

3.7 Analytical Methods

The total solids (TS), volatile solids (VS), and organic matter (OM) were determined using standard procedures **(Hamilton and Zhang, 2011; Wittmaier, 2003; Black et al., 1965)**. Biogas production was measured using the water displacement method as described by **Gosch et al. (1983)**. Moisture content adjustments were made according to **LO et al. (1981)**, and biogas volumes were corrected to standard conditions using the formula from (**Gosch et al. 1983)**.

RESULTS AND DISCUSSION

The study investigates the effect of ultrasonic pretreatments on biogas production using up-flow digesters with nine treatment combinations. Each treatment was conducted in triplicate, and the average of these replicates was used as the result for each treatment. The experiment spanned ten days for each setup. The treatments were three power levels of 50, 100, and 150 watts represented by UP50, UP100, and UP150, respectively, and three exposure times of 10, 20, and 30 minutes represented by T10, T20, and T30, respectively.

4.1. Impact of Ultrasonic Pretreatment on Biogas Production

Figure (4.1) illustrates the cumulative biogas produced (in liters) at standard temperature and pressure STP (L**)** for each ultrasonic treatment. The results in the figure indicate that all ultrasonic pretreatment parameters exceed the control unit. An increasing trend in biogas production was observed with rising power levels and prolonged exposure times, particularly between UP50 and UP100 across T10 to T30. However, at the highest power level of (UP150), extending the exposure time T10 to T20 resulted in a 15.2% decrease in biogas production. A slight recovery of 0.94% was observed when extending exposure from T20 to T30. The maximum increase of 478.55% was recorded with the UP150-T10 treatment, suggesting that higher power combined with shorter exposure yields the most significant results.

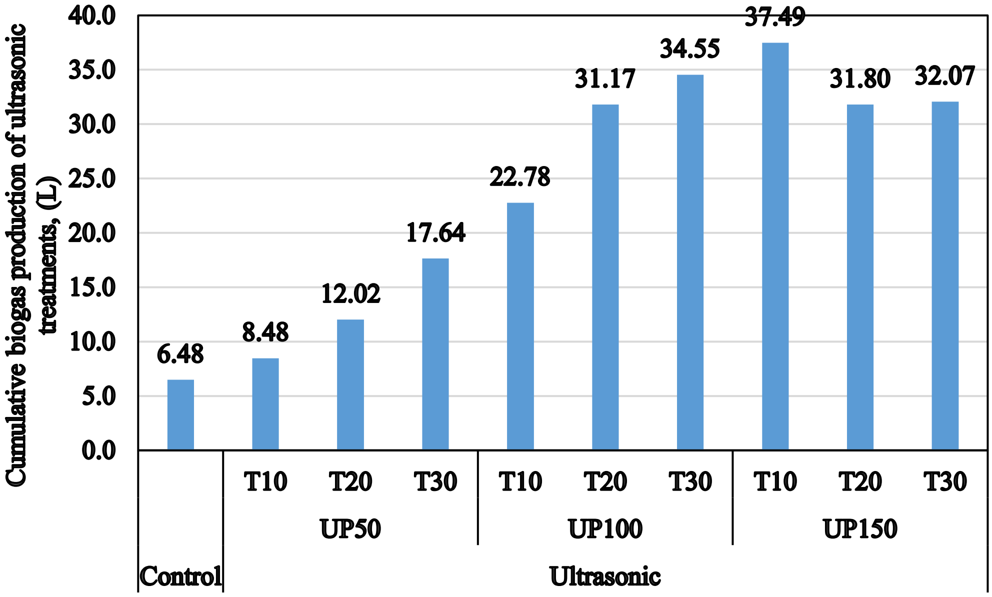

Fig (4.1): Impact of applying different ultrasonic exposure power and time levels on cumulative biogas produced as compared to the control (L).

4.2. Influence of ultrasonic exposure Times and Power on biogas yield.

Analysis of different exposure times revealed consistent improvements in biogas production over the control across all power levels. Biogas production increases significantly at UP50 with longer exposure times, by 41.75% (T20) and 108.02% (T30). At the medium power level (UP100), the increases were more moderate at 36.83% (T20) and 51.67% (T30). At the highest power (UP150), biogas production decreases slightly with longer exposure times, dropping by 15.21% (T20) and 14.46% (T30). This suggests that (T10) is the optimal exposure time, at the highest power level. While at lower power levels (UP50 and UP100), longer exposure times yield better results. **Meegoda *et al.*, (2018)** highlight that moderate ultrasonic power improves biogas yields by enhancing microbial digestion, but excessive power can damage cells. Similarly, **Uddin and Wright (2022)** found that while longer exposure at lower power (50W) leads to higher gas production (up to 107.06%), while, at higher power levels (150W) reduced the yield due to overexposure by 15.20%.

4.2.1 Effect of ultrasonic exposure duration at UP50.

As shown in Figure (4.1), the total biogas output (L) increased consistently with longer exposure at UP50. All pretreatments produced more biogas at higher rates when the exposure duration was extended compared to the control. Cumulative biogas yields were 30.86%, 85.49%, and 172.22% higher than the control for T10, T20, and T30, respectively. These findings align with those of (**Arman et al. 2023)**, who reported improved biogas yields with prolonged ultrasonic pretreatment.

4.2.2. Impact of ultrasonic exposure duration at UP100.

The results in Figure (4.1) indicate that cumulative biogas production initially increased with exposure duration but showed a decline beyond a certain point. When the ultrasonic exposure time was extended from 10 minutes (T10) to 20 minutes (T20), the cumulative biogas output decreased from 37.49 L to 31.80 L, reflecting a reduction of 15.18%. Extending the exposure duration further to 30 minutes (T30) resulted in a slight and statistically insignificant increase in biogas output to 32.07 L.

Despite this drop at higher exposure durations, the overall biogas yields at the high-power level (UP150) were still significantly higher compared to the control, with increases of 478.55%, 390.74%, and 394.91% for T10, T20, and T30, respectively. These findings demonstrate a notable enhancement in biogas generation at shorter exposure times, but the diminishing returns at longer durations suggest potential overexposure effects.

The observed trend is consistent with the results reported by (**Zeynali et al. 2017**), who investigated the impact of ultrasonic pretreatment on biogas production from fruit and vegetable waste. In their study, ultrasonic pretreatment was applied at three sonication times (9, 18, and 27 minutes) using a frequency of 20 kHz and an amplitude of 80 mm. The highest methane yield was recorded at 18 minutes of sonication, with a value of 2380 kJ/kg of total solids. However, extending the sonication time to 27 minutes led to a reduction in methane yield. Their findings also indicated that the energy content of the biogas produced was double the input energy required for sonication, highlighting the efficiency of ultrasonic pretreatment at optimal exposure times.

This comparison underscores the importance of optimizing ultrasonic exposure duration to maximize biogas yield, as excessive sonication can negatively impact the microbial activity necessary for effective biogas production.

4.3. Effect of ultrasonic power on cumulative biogas production at different times.

The cumulative biogas production (L) for samples subjected to ultrasonic radiation at varying duration times, (T10, T20, and T30 minutes) is displayed in Figure (4.2).

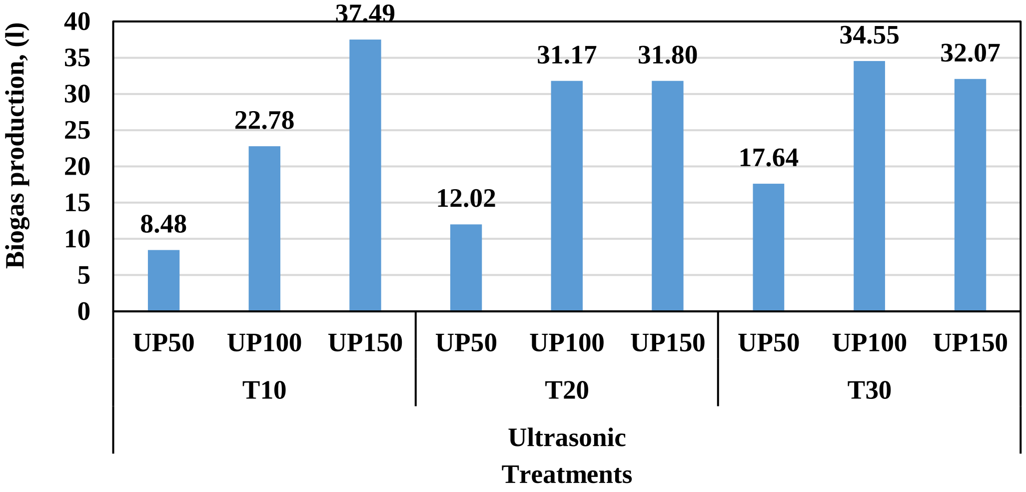

Fig. (4.2): Effect of the ultrasonic exposure power at different exposure duration (T10, T20, and T30 minutes) on the total yield of biogas, (L)

4.3.1. Effect of Ultrasonic Power on Cumulative Biogas Production at T10.

The figure (4.2) displays cumulative biogas production (L) for samples subjected to ultrasonic radiation at varying power levels over the T10 exposure period. The findings demonstrated a considerable increase in cumulative biogas generation over control.

Increasing ultrasonic power from UP50 to UP150 resulted in a substantial rise in biogas production, with gains of 30.86%, 251.54%, and 478.55%, respectively. **Joshi and Gogate (2019)** reported the effect of different operating parameters for pretreatment of food waste during anaerobic digestion, such as exposure time (over the range 2–14 min), power (0.2–1W mL^{-1}), duty cycle (20–80%) and substrate loading (3–11%w v^{-1}) has been found. Highest increase in soluble chemical oxygen demand with final value as 18500 mg L^{-1} (±20) (increase of 61.5%) was found at best treatment conditions of 10 min as exposure time, 0.4 W mL^{-1} as power density, 60% as duty cycle and 7% w/v as the substrate loading.

4.3.2. Effect of Ultrasonic Power on Cumulative Biogas Production at T20.

Biogas’ production increased by 85.49%, 381.01%, and 390.74% for UP50, UP100, and UP150, respectively. It was clear that the cumulative biogas yields of the three treatments and the control varied significantly. Therefore, it is important to note that adding UP150 (high power) of ultrasonic power resulted in a minor rise in cumulative biogas produced, from 31.17 to 31.80 liters, respectively. This means that additional power was added without significantly increasing the amount of biogas acquired. The impact of ultrasonic power on cumulative biogas production at T20 is consistent with study by **Arman *et al.*, (2023).**

4.3.3. Effect of Ultrasonic Power on Cumulative Biogas Production at T30.

The results showed that increasing the exposed power levels significantly increased the cumulative biogas production over the control. Biogas’ production increased by 85.49%, 381.01%, and 390.74% for UP50, UP100, and UP150, respectively. The data also indicated that increasing the exposure power from UP50: UP100 consequences in an increase in the cumulative biogas production, meanwhile, the cumulative biogas production decreased by increasing the exposure power from UP100 to UP150. This means that more power was added negatively affecting the cumulative biogas production. The findings of (**Lan et al., 2020)** show that frequency, power, and duration have the largest effects on the degree of hydrolysis, may be used to explain these results. The ideal hydrolysis time is 5 hours when the following ultrasonic pretreatment parameters are met: a power of 600 W, a time of 25 minutes, a degree of hydrolysis of 22.94%, and a frequency combination of 20, 40, and 60. When compared to the treatment that did not get ultrasonic pretreatment, the degree of hydrolysis increased by 4% and the hydrolysis period was reduced by 3 hours.

4.4 Predicting the biogas production of cow manure pretreated with an ultrasonic unit.

Statistical regression was used to develop prediction equations for the total amount of biogas produced for each treatment as illustrated in Figure (4.3).

4.4.1. At UP50 Watts.

For each of the three exposure intervals, the following prediction equations were produced together with their coefficient of determination.

$$Y\ (UP50T30) = 1.7474\ X - 0.005 \qquad R^2 = 0.9998$$

By increasing the exposure time to T30 at UP50, the highest increase in production it was found, the slope was 1.75 L/day. The R^2 value 0.9998 indicates a linear relationship is close to being ideal.

$$Y\ (UP50T20) = 1.2077\ X + 0.0026 \qquad R^2 = 0.9998$$

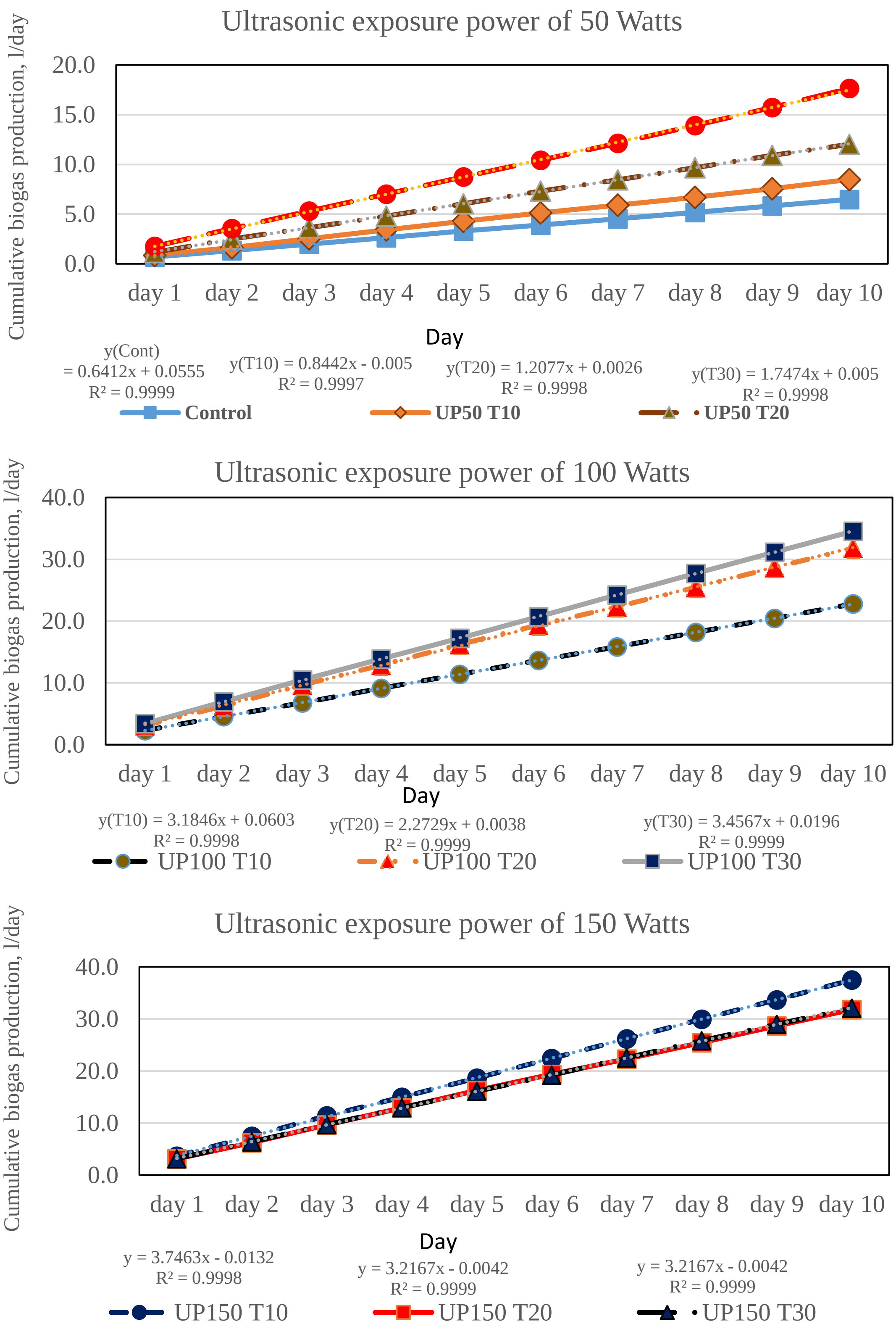

Fig. (4.3). Impact of the duration of ultrasonic exposure on the total amount of biogas produced (L).

After T20 of exposure to pretreatment atUP50, the slope was 1.2 L/day and the R^2 value was 0.9998, this increasing value indicated also to excellent linear relationship.

$$Y\ (UP50T10) = 0.8442\ X + 0.005 \qquad R^2 = 0.9997$$

At T10 and UP50, the slope was 0.84 L/day, the R^2 value was 0.9997 this indicates to perfect linear relationship.

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

Without any pretreatment, the slop was found to be 0.64 L/day and the value of R^2 was 0.9999 whish indicates a perfect linear relationship.

At lower energy level: depending on the slopes, the increase in biogas production appears with increasing exposure times, it was observed that the lowest biogas production was found with the control unit

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.

4.4.2. At UP100 Watts.

The following prediction equations were discovered, together with their coefficient of determination, for each of the three exposure times.

$$Y\ (UP100T30) = 3.4567\ X - 0.0196 \qquad R^2 = 0.9999$$

At medium power and exposure time of T30 minutes, the highest increase in gas production value per day was found, the slop was near 3.5 L Day^{-1}, the R^2 Value was 0.9999 whish indicates a perfect linear relationship.

$$Y\ (UP100T20) = 3.1846\ X + 0.0603 \qquad R^2 = 0.9998$$

The average gas production was found at UP100 after T20 of pretreatment, the slop was 3.1 L/day, R^2 value was 0.9998,

$$Y\ (UP100T10) = 2.2729\ X + 0.0038 \qquad R^2 = 0.9999$$

After T10 of pretreatment, the lowest gas production was measured at UP100, the slop was 2.3 L Day^{-1}, and value of R^2 was 0.9999 whish indicates an excellent linear relationship.

At medium power level: as the exposure time increases, we notice an increase in biogas production according to the slopes in the previous equations

4.4.3 At UP150 Watts.

For every one of the three exposure times, the following prediction equations were identified along with their coefficient of determination:

$$Y\ (UP150T30) = 3.2167\ X - 0.0042 \qquad R^2 = 0.9999$$

At the UP150 and time of T30 pretreatment, the average gas production was found whish the slop was 3.21 L/day and the value of R^2 was close to 1.0 this indicates to the perfect linear relationship.

$$Y\ (UP150T20) = 3.1846\ X + 0.0603 \qquad R^2 = 0.9999$$

After T20 of treatment and at the highest power, there was a slight decrease in gas production, the slop was 3.18 L/day and R^2 value was 0.9999, this led to the perfect linear relationship.

$$Y\ (UP150T10) = 3.7463\ X + 0.0132 \qquad R^2 = 0.9998$$

The highest gas production was found at the highest power and the lowest exposure timeT10 of pretreatment, the slop was 3.74 L/day, the R^2 was 0.9998 whish led to perfect linear relationship.

At the high energy level: we find the highest increase in production depending on the slope being found at the lowest exposure time. With increasing exposure time, production decreased, then a non-significant increase in production occurred at the highest exposure time

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 ultrasonic exposure times are applied to the sludge prior to feeding the digester.

7.4. General prediction formula for predicting the cumulative biogas production

The simple regression equation between exposure strength and exposure time, with its coefficient of determination, the equation was:

$$\text{Bogas production} = 0.21075391\ UP + 0.23736142567UT - 0.70225909 \qquad R^2 = 0.8017$$

The error root mean square of observed and predicted cumulative biogas production for ultrasonic is 4.41 L

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

$$\text{Biogas Production} = - 0.002\ UP^2 + 0.711\ UP + 0.005\ UT^2 + 0.056\ UT - 20.059 \quad R^2 = 0.8910$$

The error root mean square of observed and predicted cumulative biogas production for ultrasonic is 3.267L.

When added term of interaction UP *UT, 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:

Ultrasonic Multiple Regression equation:

$$\text{Biogas prod.} = - 0.002\ UP^2 + 0.005\ UT^2 + 0.856\ UP + 0.784\ UT - 0.007\ UP*UT - 34.63 \qquad R^2 = 0.951$$

Which UP represents Ultrasonic power, UT represents exposure time of ultrasonic and UP*UT represents interaction between UP and UT

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 2.185 L.

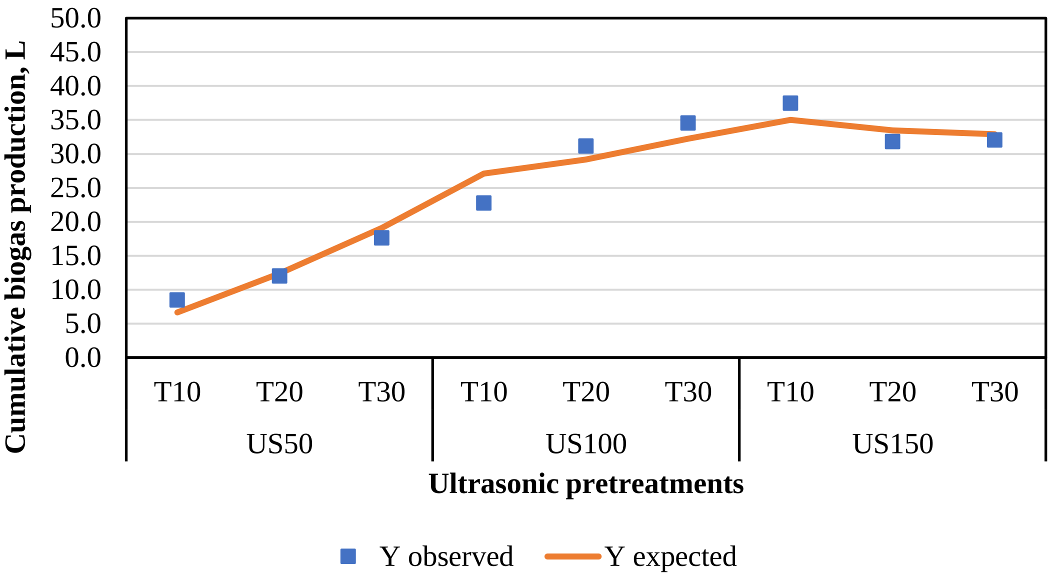

Fig. (6): The observed and expected cumulative biogas production (L) at varying Ultrasonic power and time levels.

CONCLUSION

The results showed that increasing the exposed power levels significantly increased the cumulative biogas production over the control. The percentage increase of the cumulative produced biogas over the control was172.22, 433.18, and 394.91% for exposure power levels of UP50, UP100, and UP150, respectively. The data also indicated that increasing the exposure power from UP50 to UP100 consequences in an increase in the cumulative biogas production, meanwhile, the cumulative biogas production decreased by increasing the exposure power from UP100 to UP150. This means that more power was added negatively affecting the cumulative biogas production.

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تأثير المعالجة المسبقة لروث البقر باستخدام تقنية الموجات فوق الصوتية على إنتاج الغاز الحيوي مستخدما الهاضم ذو السريان المستمر

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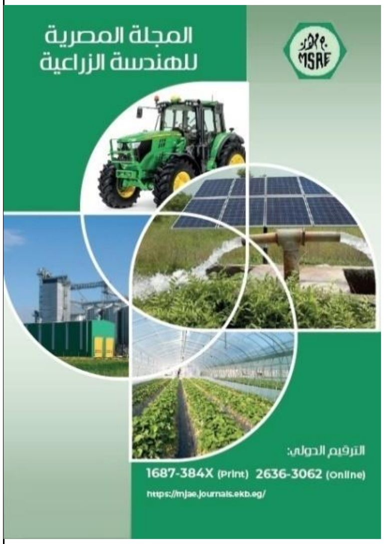

الكلمات المفتاحية:
المعالجة المسبقة؛
الموجات الفوق صوتية؛
انتاج الغاز الحيوي

الملخص العربي

تبحث الدراسة تأثير المعالجة المسبقة لروث البقر على إنتاج الغاز الحيوي باستخدام تقنية الموجات فوق الصوتية مع إستخدام الهاضم ذو السريان المستمر- حيث تعمل الموجات على سرعة انهيار المادة العضوية - تم انشاء نموذجين من الهاضم ، تم إلحاق أحدهما بوحدة المعالجة والآخر استخدم كوحدة تحكم. تمت دراسة ثلاث فترات تعرض وثلاث مستويات للطاقة أشارت النتائج أن المعالجة المسبقة بالموجات الفوق الصوتية عززت إنتاج الغاز الحيوي مقارنة بوحدة التحكم , وجدت أعلى نسبة للغاز عند مستوى الطاقة الأعلى مع أقل فترة للتعرض ,أشارت النتائج أن زيادة مستوى الطاقة من المنخفضة إلى المتوسطة أدت إلى زيادة إنتاج الغاز مع زيادة وقت التعرض للموجات الفوق صوتية بينما انخفض الإنتاج عند مستوى الطاقة الأعلى مع زيادة وقت التعرض ,عند مستوى الطاقة المنخفض مع زيادة وقت التعرض من عشرة دقائق إلى ثلاثين دقيقة ارتفع الغاز مقارنة بالتحكم, عند مستوى الطاقة المتوسطة ارتفع إنتاج الغاز الحيوي التراكمي مع زيادة وقت التعرض عند الطاقة الأعلى أدت زيادة فترة التعرض من عشرة الى عشرين إلى انخفاض الغاز , بينما أدت زيادة فترة التعرض إلى ثلاثين دقيقة إلى زيادة غير معنوية في الإنتاج , النتائج أشارت أن المعالجة بالموجات تعزز انتاج الغاز وذلك يعتمد على مستوى الطاقة وفترة التعرض.

البنفسجية البالغة ١٩٦٠ ميكروووات/سم^{٢}، ادى إلى تعقيم الروث بطاقة نوعية قدرها ٢٥,٥١ كيلووات ساعة/كجم وتكلفة تعقيم قدرها ٣٥,٧١ جنيهًا مصريًا/كجم. أدى تعريض الروث إلى ١٤٧٠ ميكرو واط/سم^{٢} من الأشعة فوق البنفسجية لمدة ٦ ساعات إلى تحقيق كفاءة تعقيم بنسبة ١٠٠٪، وطاقة نوعية تبلغ ٨,٨٠ كيلووات ساعة/كجم، وتكلفة تعقيم تبلغ ١٢,٣١ جنيهًا مصريًا/كجم.

ختامًا، يعد استخدام الأشعة فوق البنفسجية في تعقيم روث الدجاج تقنية معالجة موفرة للطاقة واقتصادية.