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Original Paper

Comparison of Biogas Concentrations in Various Environmental Conditions and Determination of the Optimal Period of Its Production at Environment Temperature

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Abstract

Albania, as a part of Western Balkan, has a variety of climate systems. This type of climate has a closed connection with waste treatment process. The biogas volume produced by the experimental environmental was 0.6 m^3. The maximum methane concentration in biogas was reached at 55.8%/volume. The enclosed area (in oval circle) is another indicator of this system. This area extends over the period from 14.08.2018 until 26.08.2018 (12 days). The biomethane maximum biogas concentration reached 53.5 %/vol. up to 55.8% vol. The concentration drop was 4.2 %/vol. The main factor was the temperature. In the period of maximum durability the temperatures were minimum 30 ℃ and maximum 42 ℃. Another contributing factor was the inoculum. Since inoculum was made from the treatment of four types of waste of different nature, then the concentration of microorganisms was higher. The purpose of the comparison between the two experiments is the sustainability of biogas production as well as the biomethane concentration biogas concentration on waste treatment. Environmental temperature was studied in three different regions of Albania: Shkodra, Tirana and Vlora. The observations showed that the region of Vlora has the longest period of average daily temperature (June 14th to October 1st).

Keywords

thermal equilibrium, performance of biogas, analytical relation

1. Introduction

Albania is a country that lies in Balkan Peninsula, in South-Eastern Europe. Albania has two different climate zones. The coast of Albania has a Mediterranean climate. This area has long hot summers and wet but mild winters. Inland is a continental climate (https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-in-Albania). However, winters here are severe with a high chance of snow. Albania's climate is strongly influenced by the country's location. Temperatures are affected from both the Adriatic and the Albanian Alps. Heat waves can disappear quickly by sometimes very heavy rain and thunderstorms, with the daily temperature falling by more than ten degrees within a day (https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-in-Albania).

Biodegradation rates in the bio-toilet system are affected, among several factors, by environmental conditions such as temperature, moisture content, oxygen availability and pH. Temperature is one of the most important factors affecting microbial growth and biological reactions. Temperature can exert an effect on biological reactions in two ways: by influencing the rates of enzymatically catalyzed reactions and by affecting the rate of diffusion of substrate to the cells (Grady, Daigger & Lim, 1999). Of all the factors affecting the yield of biogas temperature of the digester environment is the most important. The temperature of the region decides the group of methanogenic bacteria that shall be stimulated for production of methane (Ahuja et al., 2016). Temperature control therefore becomes an important design criterion while designing anaerobic biogas digesters. Use of digester insulation, maintaining temperature in the digester via heat exchangers, heating elements, placing digesters inside a water bath, and injecting steam in the digester are some of the means of maintaining temperature of the digester in its operating range (Energypedia, "DigesterHeating" [Online]; Waste Digester Design Instructor Materials). In practice, sudden environmental changes, e.g., dramatic increases or drops in temperature, may cause severe disturbances in all parameters of the process, and the system requires a long period of time to adapt to a stable state. Furthermore, the temperature has a significant impact on the growth and metabolism of microorganisms and the interactions between the microbial groups (Alvarez & Lidén, 2008; El-Mashad, Zeeman, van Loon, Bot & Lettinga, 2004; Xiong, Chen, Wang & Shi, 2012; Rademacher, Nolte, Schonberg & Klocke, 2012).

2. Material and Methods

For the construction of the plant at environmental temperature for the production of biogas in Albania, the average daily temperatures for the areas under study were carefully observed. This was one of the main steps in order to continue further. The average daily temperatures for the annual period 2013-2017 were taken by the Meteorological Center of the Albanian Air Force. Part of the metodology is and comparison of biogas production between two experimental proves: mixing with inoculum containing and mixing without inoculum containing, under the same temperature-pressure conditions. The period in which the environmental experiment was applied, was July-September 2018. The regions included in the study, showed in Figure 1, were: Shkodra, Tirana and Vlora as part of the Western Lowlands of the Republic of Albania. The Western Lowlands represent the largest plain province and is one of the largest plains of the Balkan Peninsula. The main constituent units of the Western Lowlands are: Shkodra lowland, Field between Lezha city and River of Shkumbin, hilly ridge of Rodon-Krrabë, field of Elbasan, Dumre-Darsia Plateau, field of Myzeqe and Hills of Mallakastra.

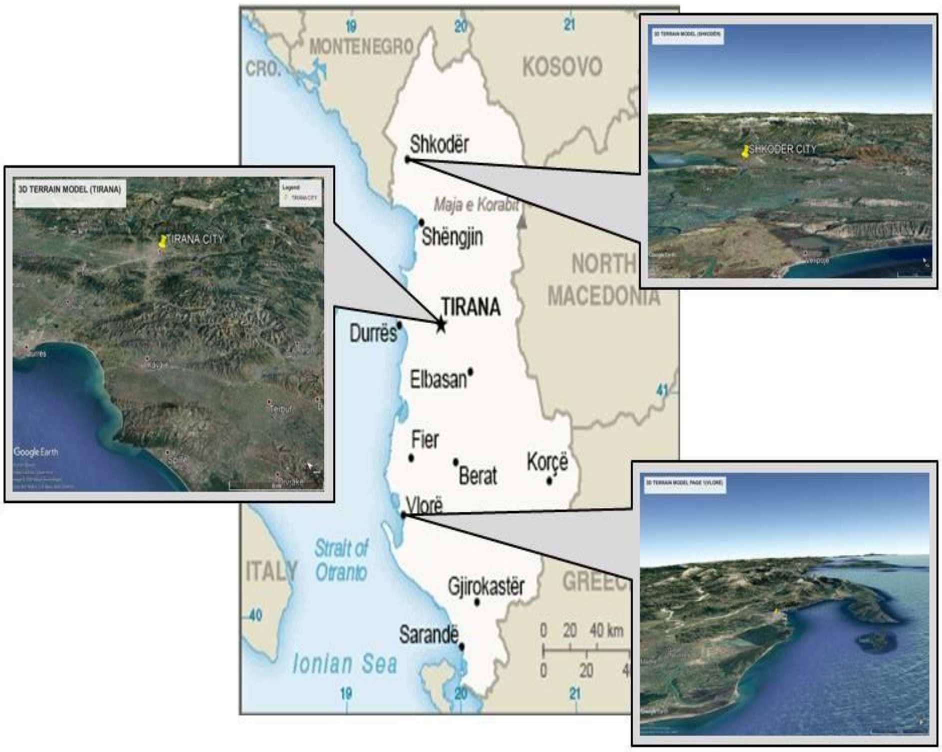


Figure 1. Included Areas in the Study in Republic of Albania

3. Results and Discussion

The predicted experimental time period should be applied up to 35 days but the experiment lasted for up to 50 days. The reason was for observing the production capacity of the biogas mix. According to Attar, Mhetre, and Shaale (1998) for a population of 28.6 million birds, produces 1575.5 million kg/year of waste, biogas produced is ≈116.6 million m^3/year (Attar, Mhetre & Shawale, 1998). So, based on the above data, 1 kg of poultry treated in anaerobic digester produces 2.02×10^{-4} m^3/day of biogas. Based on the Regional Statistical Yearbook (2016), the Ministry of Agriculture, Rural Development and Water Administration of Albania, 1 head (cattle) produces 37.19 kg of waste per day and 1 bird produces 0.06 kg of waste per day (Regional Statistical Yearbook of Albania, 2016).

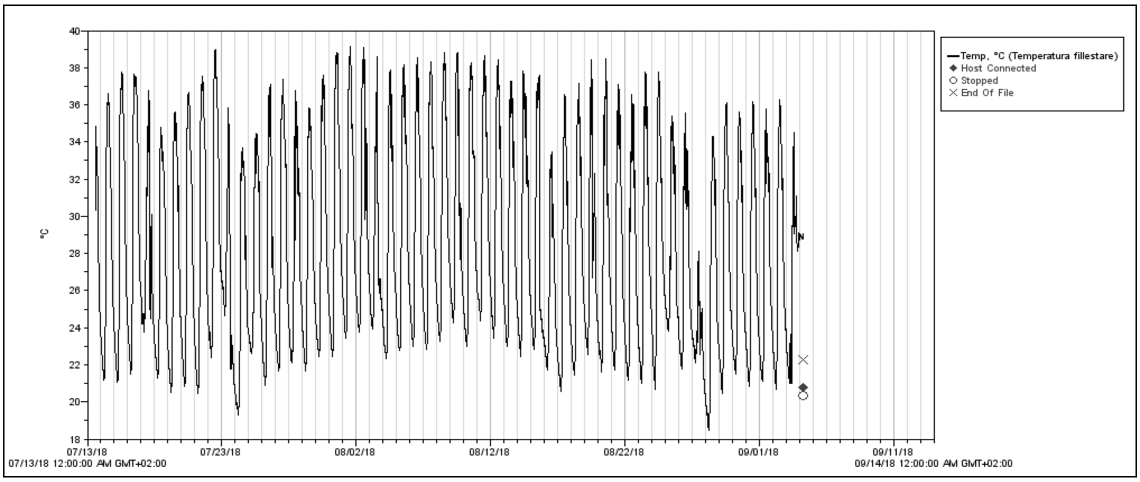


Figure 2. Temperature Measurement Frequency in Greenhouse Environment with Datalogger Sensor

Figures 2 and 3 give temperature differences in their values (Chart 1: min 20 ℃ and max 38 ℃; Chart 2: min 30 ℃ and max 42 ℃). These temperature changes are due to the achievement of thermal equilibrium (outside the anaerobic environment) and the endothermic processes (heat-absorbing processes) of the microorganisms inside the mixture. The experiment gives us the "right" to think that we can predict the performance of biogas production from agricultural waste in function of environmental temperatures, taking linear equations composed of three variables:

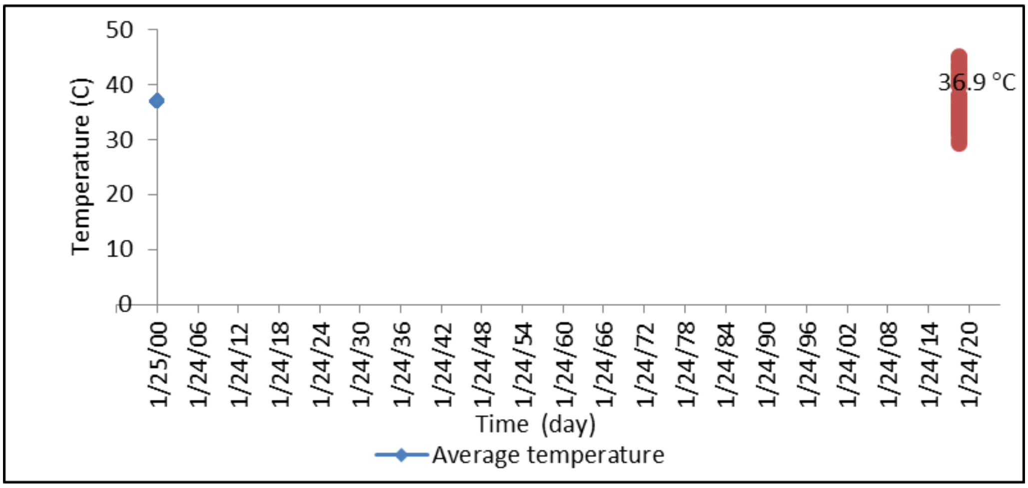


Figure 3. Temperature in Anaerob Environmental and Its Average Temperature

M (Methane)

T_1 (greenhouse temperature)

T_2 (temperature in anaerobic environment)

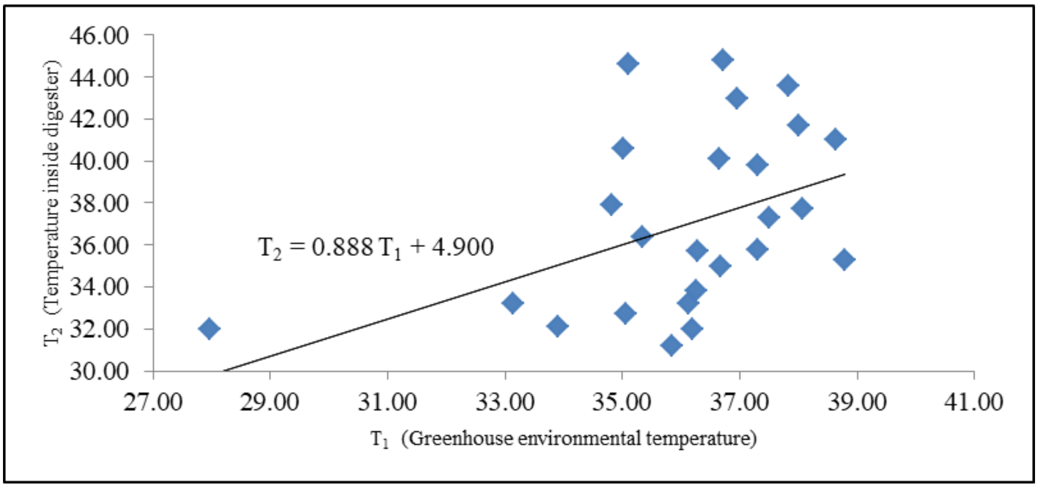


Figure 4. Relation between Two Applied Temperatures

The relationship between the temperatures: in the greenhouse environment and in the induced temperature environment is given by equation 1, showed in Figure 4.

$$T_2 = 0.888\, T_1 + 4.9 \quad (1)$$

Equation 1 represents the analytical relation between T_1 and T_2. The equation 2 generated by the graphio-analytical relation, showed in Figure 5, represents the relation between the temperature inside the digester in the function of the methane produced.

$$M = 0.202\ T_2 + 31.33 \quad (2)$$

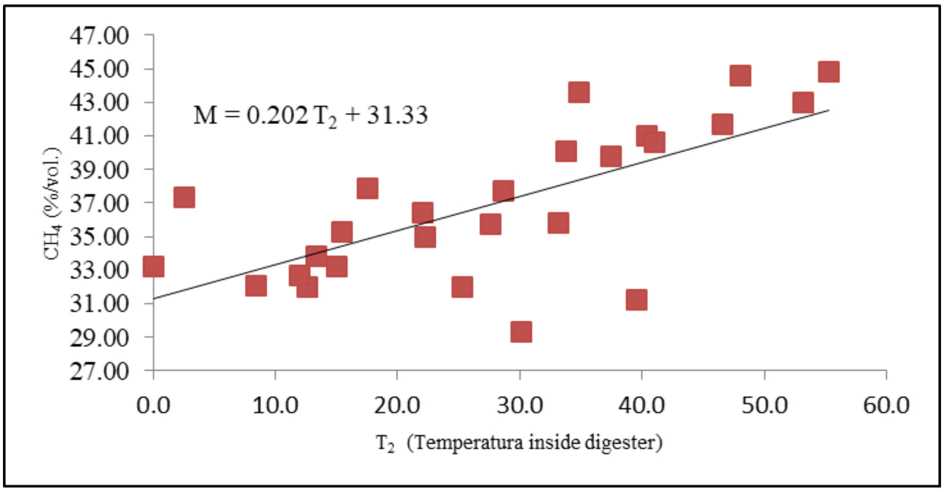


Figure 5. Performance of Methane Production as a Function of Temperatures in the Anaerobic Environment

The combination of equations (1) and (2) enables us to establish the analytical link between produced biogas and greenhouse temperature, ie between M and T_1 variables.

Generating equation 3 from two equations 1 and 2 at the same time allows us to predict how the biogas production performance can be in the future (always in "greenhouse" environmental conditions).

$$M = 0.179\ T_1 + 32.319 \quad (3)$$

The biogas volume produced by the experimental environmental was 0.6 m^3. The maximum methane concentration in biogas was reached at 55.8%/volume. Chart 5 shows a steady performance in biogas production from the BES system (**B**atch **E**nvironmental **S**ystem) (inoculum + substrate), and more to biomethane biogas concentration. The enclosed area (in oval circle) is another indicator of this system. This area extends over the period from 14.08.2018 until 26.08.2018 (12 days). The biomethane maximum biogas concentration reached 53.5 %/vol. up to 55.8% vol. This showed the maximum sustainability achieved in biogas production in "greenhouse" environmental conditions but this period did not last long. The decrease in concentration was observed between 26.08.2018 and ongoing. The concentration drop was 4.2%/vol. The main factor was the temperature. In the period of maximum durability the temperatures were minimum 30 ℃ and maximum 42 ℃. Another contributing factor was the inoculum. Since inoculum was made from the treatment of four types of waste of different nature, then the concentration of microorganisms was higher. The purpose of the comparison between the two experiments is the sustainability of biogas production as well as the biomethane concentration biogas concentration on waste treatment.

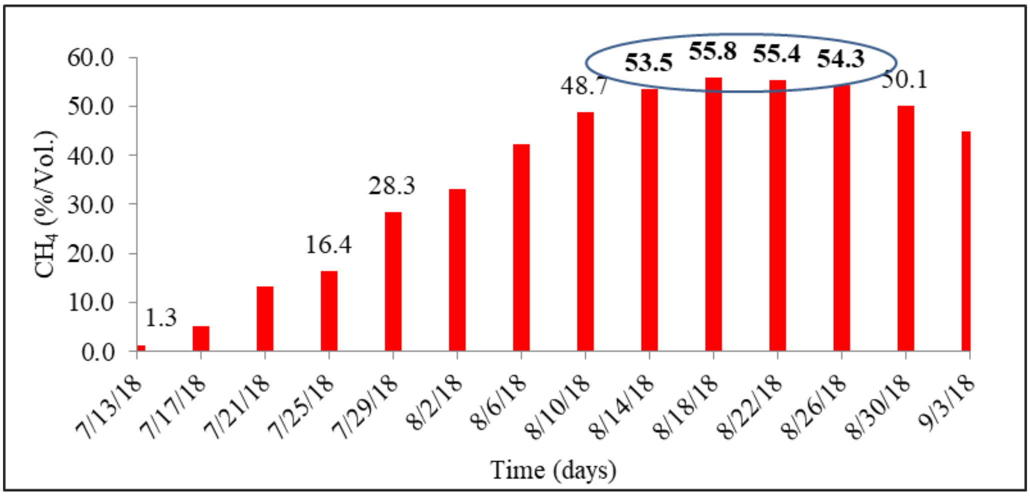


Figure 6. Concentration of Biomethane in Biogas Produced by Inoculum-substrate Mixture Under "Greenhouse" Environmental Conditions (BES System)

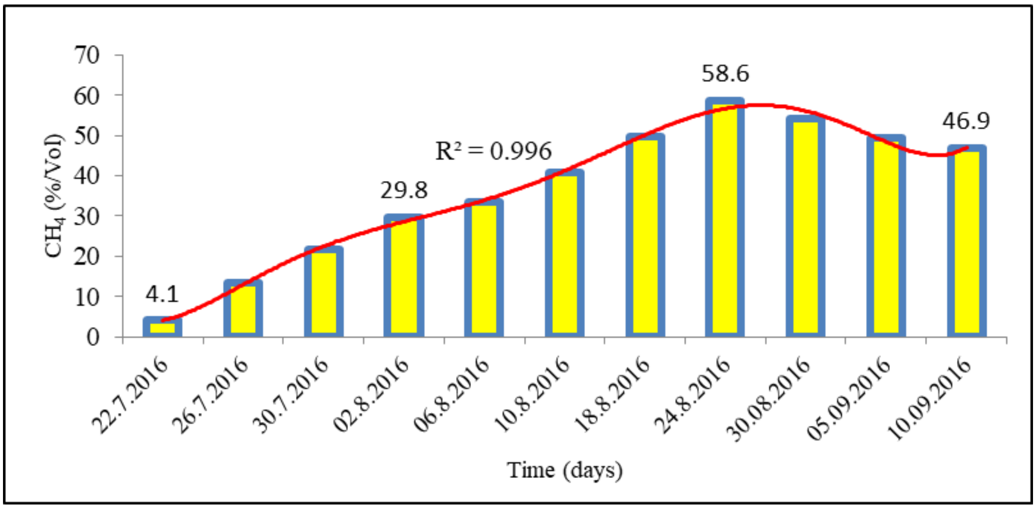


Figure 7. Concentration of Biomethane in Biogas Produced Under "Greenhouse" Environmental Conditions, without Inoculums "Participation" (BES System, Dissertation "Evaluation and Optimization of Indicatorial Parameters in Biogas Production from Agricultural Waste, in Albanian Conditions", 2019, Experiment 2, page 80)

Figure 7 shows the higher biomethane concentration on biogas, the higher its calorific point. Despite the maximum concentration in the BES system, the second experiment is 58.6%/vol., i.e., 2.8%/vol. CH_4 more, this does not mean that the system is the best. His persistence in concentration is small. The concentration dropped by almost 8%/vol. after six days. The BES system (inoculum-based) showed high concentration stability (about 12 days). From this reasoning it appears that the obtained biogas based on inoculum has a more consistent consistency in focusing on "greenhouse" environmental conditions than biogas that does not include inoculum. We see that the maximum mean temperature reached 27.5 ℃ while the minimum average temperature reached 22 ℃. This showed that this period was the optimal biogas production period from the development of our environmental experiment (without induced temperature). This was reflected in green zone (Figure 8). In the green zone we distinguish three zones (**Area 1** above 27.5 ℃, **Area 2** or intermediate area between 22 ℃ and 27.5 ℃, **Area 3** below 22 ℃). The area in which the experiment with environment temperature can operate is Area 2. This is the optimal area of our experiment. Area 1 is the surface where we would like the experiment to develop because the values are closer to 37 ℃ but this does not depend on us and are very favorable for biogas production. Referring to area 3, it is the area in which the experiment can be developed but the biomethane concentration in biogas reaches low values, so the environment would be inadequate. If we set the average maximum temperature value and the average minimum temperature value in the average daily temperature graphs observed over a 5 year period (2013-2017) of Shkodra, Tirana and Vlora regions (refer to Figures: 9, 10 and 11), we will note that periods of biogas production would change. From this situation it turns out that the geographic position of these regions (as part of the Western Lowlands in Albania) and the large number of livestock farms is the reason we considered these three cities as part of our study. Based on regions of Shkodra, Tirana and Vlora, we see that the region of Vlora has the longest period of time with the average daily temperature (June 14 to October 1). From this reasoning emerges that Vlora as part of the Western Lowland is more favorable for the erection and erection of digestive plants for the production of biogas at environment temperature compared to the other two cities. The boundaries of the periods of time were determined by the small differences in the amplitude of the five years taken in the study.

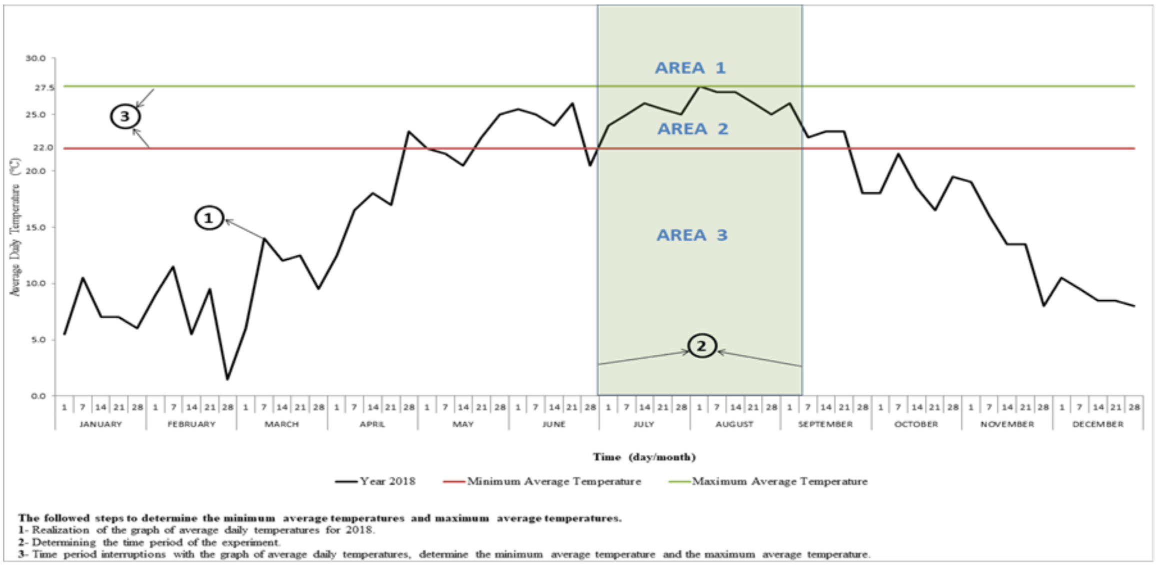
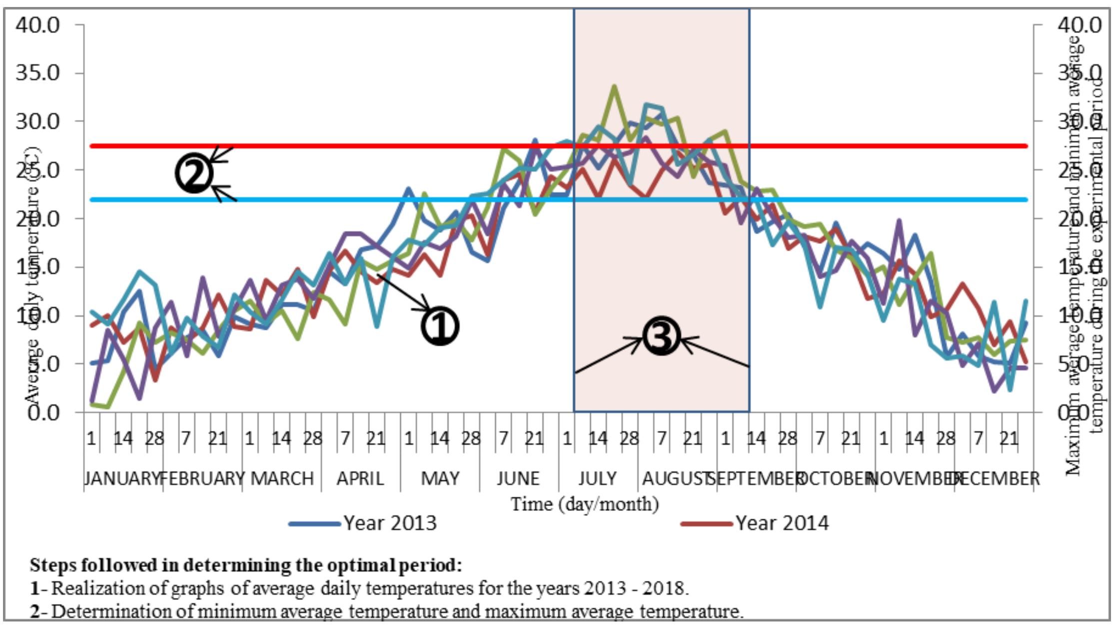


Figure 8. Determining the Minimum Average Temperature and the Maximum Average Temperature during the Period of Conducting the Environmental Experiment



Fugure 9. Determining the Optimal Period for Biogas Production at Environmental Temperatures in the City of Shkodra

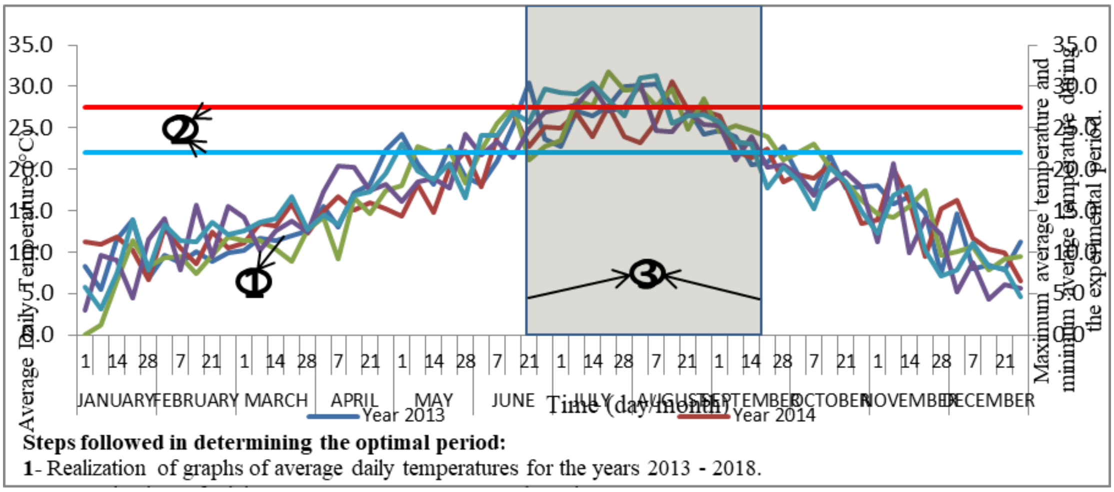


Figure 10. Determining the Optimal Period for Biogas Production at Environmental Temperatures in the City of Tirana

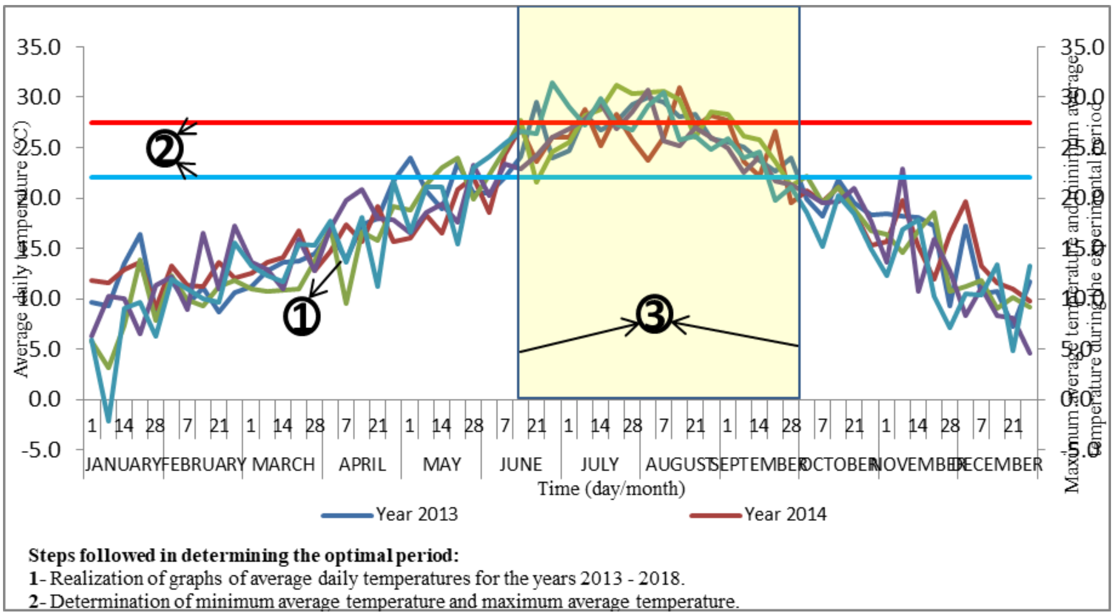


Figure 11. Determining the Optimal Period for Biogas Production at Environmental Temperatures in the City of Vlora

4. Conclusions

a) Biogas production in terms of environmental temperatures has a direct relationship, which was observed in production downturns whenever there was a decrease in external temperatures.

b) Inoculum-based biogas, in "greenhouse" environmental conditions, showed a more constant concentration of CH_4 (about 12 days) than biogas obtained from simple mixing.

c) The most optimal period of time, considering the duration of the weather, was the region of Vlora (14 June to 1 October) compared to the regions of Tirana and Shkodra.

Based on above points a, b and c, it turns out that: the most constant concentration of CH_4 in the produced biogas is inoculum base and the most optimal time period for the duration of the temperature is the region of Vlora. The region of Vlora (part of Albania Westlowland) offers the suitable area to implement biogas power plant as alternative fuel for the future.

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