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OPTIMAL PARAMETERS FOR THE FERMENTATION OF COMPLEX SUBSTRATES WHEN PRODUCING BIOGAS AT THE MAXIMAL METHANE CONCENTRATION

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ABSTRACT

Republic of Kazakhstan oil will last for 47.4 years, while gas production - 65.6 years. Given the Kashagan reserves, something else for a longer period, that is a very short periods of time with respect to the development of state and they can be extended only by the development of a technological breakthrough. Along with the question of the ever-growing needs of the population for energy resources, there is a question about the availability of annual waste generation as the impact of the rapid growth of the urban population, which is about 4% per year ("Population" encyclopedia of Astana, 2008). To cope with both problems simultaneously, the waste may be used as energy sources by fermentation technology. Among the urban wastes the organic waste is dominated, such as vegetables, fallen leaves, etc., that have the potential to produce biogas. The use of unsuitable materials as a natural catalyst of fermentation and the time spent on fermentation, are some of the existing barriers to the development of energy resources in urban areas. For this purpose a study was conducted to optimize the ratio of urban waste, animal waste and water in combination with the time of fermentation. The study used an experimental method with the random nature of the two-factor model. The first factor is the ratio of waste, manure, and the second quantity of water - during fermentation, which is fixed to each of 2, 4, 6, 8, 10, 12, 14, 16 and 18th day of the fermentation substrate. The study showed that the optimum proportion to obtain the maximum amount of biogas is a ratio of 500: 200: 300 waste, manure, and water, respectively. Furthermore, on the second day of fermentation the maximum amount of biogas produced.

UDC & KEYWORDS

■ UDC: 547.1 ■ FERMENTATION ■ OPTIMIZATION ■ INOCULUM ■ PLANT WASTE ■ BIOGAS

INTRODUCTION

In accordance with the Kyoto Protocol, by 2050 Kazakhstan should reach a target of 50 percent of energy production based on ecologically clean sources, which represents about 40 billion kWh (Nursultan Nazarbayev to the people of Kazakhstan, 2014). This direction will affect the development and use of alternative energy sources to replace energy from hydrocarbon products. Moreover, a rapid increase of urban population is correlated with an increasing amount of waste. Urban waste is still considered as a challenging issue in the country. Urban waste typically includes organic waste of plant origin. Hence, using fermentation technology, where methane bacteria from cattle manure serves as a natural catalyst, allows to coping with the shortage of energy resources. It is worth mentioning that a natural catalyst in the fermentation process of plant waste is not the only factor. Another important factor is a total duration of fermentation affecting the productivity of a biogas setting, which by itself is closely intertwined with the efficiency of effort and finance. The best solution to maximize biogas production is to optimize the amount of natural catalyst by dilution with water and by control of the total duration of fermentation (Lopes, Leite, & Prasad, 2004).

Materials and research methods

The materials used in this study are cattle manure, plant waste, municipal waste, and clean water.

In addition, the tools used in the experiment are: plastic tank of 3000 ml (a laboratory mini biogas setting) on the informational program.

The study was based on the experimental method of a two-factor model of an absolutely random nature. In particular, the proportion of cattle manure and water represents the first factor and the fermentation time represents the second factor. In the experiment we choose five samples with the proportion of cattle manure and water as follows:

C0 = 500 g of plant waste + 0 + 500 ml of water

C1 = 500 g of plant waste + 100 g of cattle manure + 400 ml of water

C2 = 500 g of plant waste + 200 g of cattle manure + 300 ml of water

C3 = 500 g of plant waste + 300 g of cattle manure + 200 ml of water

C4 = 500 g of plant waste + 400 g of cattle manure + 100 ml of water

C5 = 500 g of plant waste + 500 g of cattle manure

Meanwhile, the time spent on fermentation is measured at 2, 4, 6, 8, 10, 12, 14, 16 and 18th day. In total, during the study we conducted 162 tests consisting of the first factor with six different proportions and the second factor with nine control reports of duration measured three times. In our study we monitor the amount (volume) of biogas produced in a mini biogas setting. We also measure the pH level of each sample in six proportions. The obtained data was then statistically examined using univariate analysis of variance (ANOVA).

Results and discussion

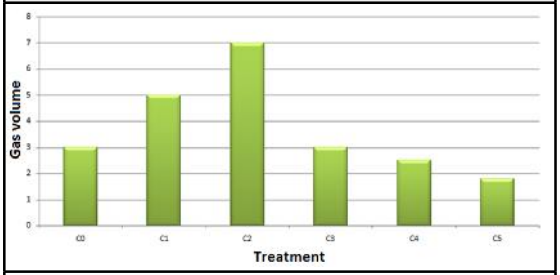
Test results on the variation of dilution and fermentation time with the 5% significance level show that dilution of substrate with water and the time of its fermentation obviously influence the amount of biogas produced ($P < 0.05$).

Nevertheless, it is not related to the interaction between dilution and fermentation time. According to the test results using the 5% significance level, we obtain $P > 0,05$. This means that there is no interaction between dilution and fermentation time.

The result of the continuous Duncan test is on follows figure.

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Figure 1: Effect of dilution of substrate with water on the amount of biogas produced

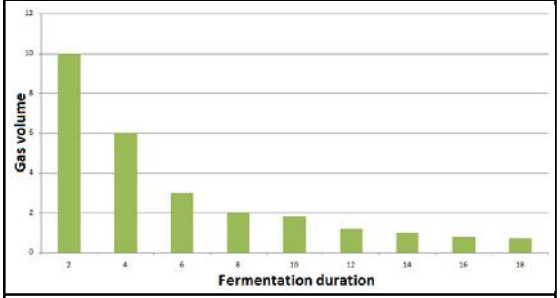


Source: Authors

Analysis of dilution of fermentation mass with water according to the method of Duncan (Figure 4) shows that proportion C_2 which is comprises 500 g of plant waste + 200 g of cattle manure + 300 ml of water is the best proportion. For proportion C_2 the shares of used components was ideal and, accordingly, the development of bacteria proceeded well.

We can also say that the share of water in some way provides favorable conditions for the growth of bacteria. The transformation process of organic acid into acetic acid requires water molecules. Hence, if we add more water, then more acetic acid will be formed, which will ultimately be reflected in the formation of bio-methane in the next stage (methanogenesis). The more water is added to the system, the more of biogas will be produced (McCarty, 1964). From the proportions of plant waste, cattle manure, and water shown in C_2, it follows that the share of cattle manure (catalyst) should be less than the share of water. Consequently, continuous testing according to Duncan determines that the longer is the duration of fermentation, the smaller will be the amount of biogas produced. Final data are described in Figure 2.

Figure 2: Effect of fermentation duration on the amount of biogas produced



Source: Authors

Figure 2 from our experimental design shows that during the second day of fermentation there was maximal biogas produced. This could happen because plant waste, which serves as the initial resource, was fully utilized, so that on the third day there was maximal biogas produced. This is the result of the postulate that the longer is the duration of fermentation, the lower is the volume of biogas production because plant waste, which serves as the primary resource, is completely utilized (Baader, Done, & Brennderfer, 2010).

Conclusion

Our experimental design suggests that the proportion consisting of 500 g of plant waste + 200 g of cattle manure + 300 ml of water leads to the maximal volume of biogas produced. The optimal duration of fermentation in order to achieve the maximal amount of biogas is 2 days. Methane production depends on the shares of water and cattle manure. A larger share of water leads to the maximal amount of methane gas. Because substrates are limited, we propose to use to the main substrates of plant waste, cattle manure, and water in the proportion 5:2:3 with a short duration of fermentation.

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