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Power optimization of bioreactor block with water bath stabilized temperature

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Abstract. The research based on a customized laboratory bioreactor system with water bath and changing environmental parameters. The effect of the individual environmental elements on the biogas formation was observed. We were intended to get values of biogas forming in our developed system near the yield values of a former validated laboratory reactor system. To check the development steps we examined the quantity and quality of the biogas forming in the reactors and the deviation of the characteristics.

Keywords: biogas; deviation; methane; anaerob fermentor

1 Introduction

The purpose of a laboratory equipment is the modeling of the technology used in the industry. However, the problem of the biological model is in it's size, because the magnitude less than in industrial applications and therefore extremely sensitive to environmental influences. For the laboratory experiments of biogas production well regulated blocks are needed, as according to the VDI 4630 - "Fermentation of organic materials" Directive [1] parallel measurements must be done. Commercially found professional-reactor blocks, such as the incubator cabinet or the Fermac bioreactor have good performance, but they are expensive. We proposed the setup of a self-made reactor block which meets the requirements of VDI 4630 and works with small deviation and great performance. An important aspect was that the periodic mixing of the raw material - which is impossible in an incubator cabinet- can be done in the reactors like in the industrial fermenters.

2 Introduction of the bioreactor block

The goal is the realisation of a laboratory device, so the material of parts contacting with biologically active substance have to be glass while the tubing is silicone rubber to achieve the biochemical neutrality of the system during the fermentation process. [1] The one-liter reactors have drilled screw caps, sealed by silicone rubber sheet. During the measurement, this so called the septum is perforated by a hypodermic needle that connecting a tube. The gas sampling also done through the septum with a gas syringe because the 20 Shore° hardness silicone close well the resulting holes. The bottle itself is heated by water bath. (**Fig. 1.**) Outside the reactor there are two bottles for measuring the volume of evolved biogas with positive displacement method. [2] [3]

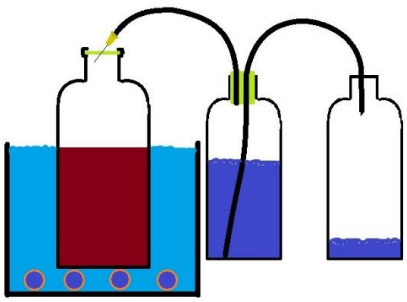

Fig. 1. Reactor block and the quantity measuring system (own pic.)

The fluid with constant temperature is held by a standard 600x400x300 sized food box. The water is in a closed, continuously circulated system – heated by an external heat source, a thermostat – delivers heat to the radiator, which heats the water and sustaining the temperature of the reactor units. The boxes have double insulation which an outer layer of polyfoam and foam pieces scattered on the surface of the water. As a result, the interior light and the evaporation of water decreasing at the same time. (**Fig. 2.**)

The 8 mixed reactors are driven by an individually designed gearbox with 8 outputs, mixing plugs and paddles were manufactured for the reactor bottles (**Fig. 2.**). An electric motor gives the mixing torque, the gearbox transmits the torque throught a Bowden cable that connects the mixing paddle.

Fig. 2. Insulated reactor block [5] and mixing for the reactor

The reactor block with water stabilised temperature was made, but the test series showed that the gas and methane yield of the system remains low, compared to reactors placed in the incubator cabinet at the laboratory. In addition, the values measured in the parallel experiments on eight reactors had great deviation.

3 Measurement method for the reactor operation

The performance of the reactor block was checked mainly by the biogas yield of the reactor bottles. Parallel experiments started simultaneously with the same parameters in the incubator cabinet and in our reactor-block. Comparing the biogas and methane yield results the development steps were proofed.. At the biogas trials the input of the raw materials to the reactor vessel of was made under the VDI 4630 recommendation as the basis of their solids (TS) and organic solids (oTS) content. [1]. To create an anaerobic space the gas phase was purged out with nitrogen, to remove the remaining oxygen from the reactor bottles. In the anaerobic degradation process the remainng oxygen in the system has negative impact on biogas yield because of obligate methanogens. [2] After it the reactor system installation was completed and the measuring started.

The amount of gas generated from the raw materials determined by displacement method, the analysis of the gas composition were performed by gas chromatography. The primer was digestum from the South-Pest sewage farm, the raw material was wheatstraw and microcrystalline cellulose.

We determined the pH of the fresh seed sludge and fermented slurry at the beginning and end of experiments. By this we were able to classify the adequacy and health of the bacterial culture in the fresh mud and checked the efficiency of the fermentation after the experiments.

The bacterial culture activity, the uniformity and quality of gas generation significantly affected by the light conditions. The ultraviolet radiation within 200 to 400 nm range of the polychromatic light has germicidal effect, so excessive light input can damage the bacteria, hold their growth, while the infrared rays within the range of 780 nm - 1 mm can cause some additional heat input, thus affecting the rate of gas production. [4] So the most preferred way to ensuring the greatest darkness for the fermentor tanks to obtain consistent performance. The reactors ambient lighting conditions were measured with a PCE-222 type instrument manufactured by PCE Instruments, in light measuring mode, with online data collection.

4 Experimental results and steps of development

4.1 Condition survey of the reactor block

The fundamental problem is the excessive lighting of the reactor tanks, so before the experiments light metering was performed on several zones in the interior and exterior space of the block. to To compare the we had to measure the light environment of the incubator cabinet too. (**Fig. 3.**)

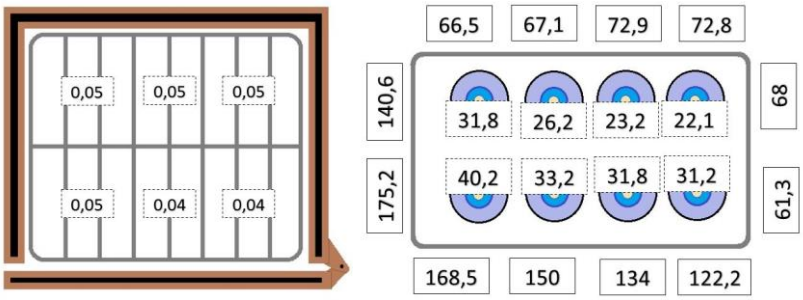

Fig. 3. Illumination maps of the incubator cabinet and the reactor block [lux]

In addition to the difference between light conditions we assumed the shortfall can be caused by the metering bottles operating on the displacement principle in the incubator cabinet were placed in a 37 C° space. Therefore at the first experiment two from the eight bottles of the reactor block were placed in the water bath with the measuring bottles.

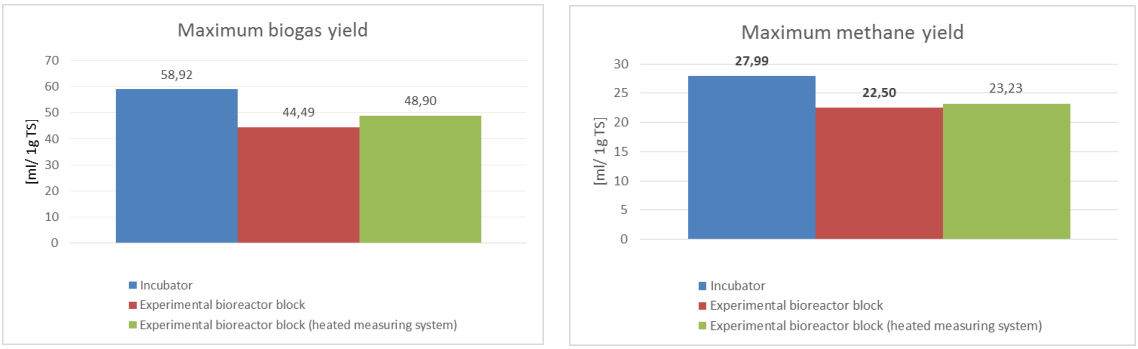

Fig. 4. Maximum gas yields

The chart above shows the positive effect of placing the reactor in the same space with the measuring system, the gas yield is better. The standard deviation values also showed the necessity to improve the system. The standard deviation values of biogas and methane in the incubator cabinet was 2.00 and 1.08 ml / GTS, in the water box-reactor block was 5.17 and 3.34 ml / GTS. (**Fig. 4.**)

4.2 The use of external insulation box

An exterior insulation was needed, which was a wooden, double-walled box. The external wall was made of pine-sheets, the inner of poplar plywood sheet. The space between the two walls was filled with polyurethane foam for the right thermal insulation, the surfaces was coated with linseed oil, then with matte black paint. So both thermal insulation and light insulation problem is solved. (**Fig. 5.**)

Fig. 5. Lightening map of covered box [lux]

During the development the waste heat of the water in the reactor block was used to create the internal climate. The light insulation testing was performed on the basis of the measurement methodology previously reported. (**Fig. 5.**)

The conversion is only partially brought the expected results. The crate had increased gas yield, the surplus yield was reduced in the incubator cabinet, the stabilized environment, good heat and light insulation had a positive effect on the fermentation. However, the differences due to the imperfections intensified within the system, the standard deviation was significantly higher between the reactors. The standard deviation values of biogas and methane in the incubator cabinet was 1.36 and 1.40 ml / GTS, in the water box-reactor block was 12.20 and 7.31 ml / GTS.

4.3 Using elevated bioreactors

The reactors had increased deviaton values due different temperatures caused by the heating pipe. To compensate this, a perforated platform was placed at the bottom of the chest, above the heating pipes, to extend the pipe's vicinity of the reactor. The thermal inertia of the water could be exploited to minimize the temperature differences. (6) The surface of the platform grid allowed testing the system with 6 reactors.

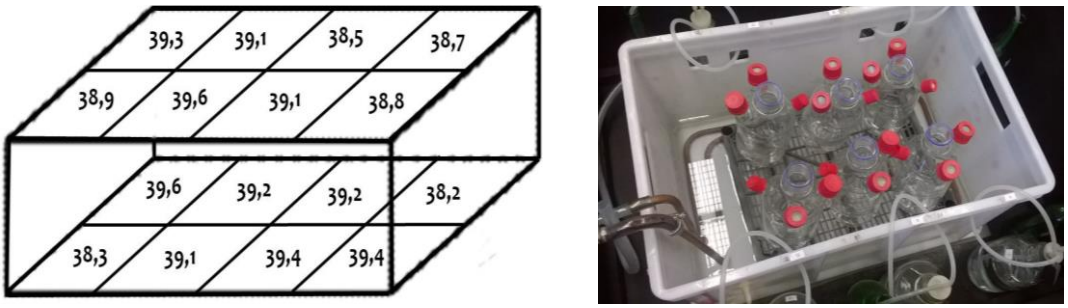

Fig. 6. Temperature map of the insulated box, the realisation of development (own pic.)

Table 1. Yield and deviation values compared to the incubator cabinet values

Compared samples	Biogas yield shortfall	Methane yield shortfall	Biogas deviation	Methane deviation
box ➔ compared to incubator cabinet	8,85 %	11,15 %	1,01 x	1,38 x

Based on the results of biogas experiment we found the objectives set by the development are achieved. (**Table 1.**) Both biogas and methane yields of the box were well close to the incubator cabinet values, but more importantly the deviation also decreased significantly.

4.4 The application of mixing and the result of the biogas reactor block development

Our designed temperature control box can recept mixing spirals too, so hoping the larger and more uniform gas yield bioreactors with periodically mixing units was also tested.

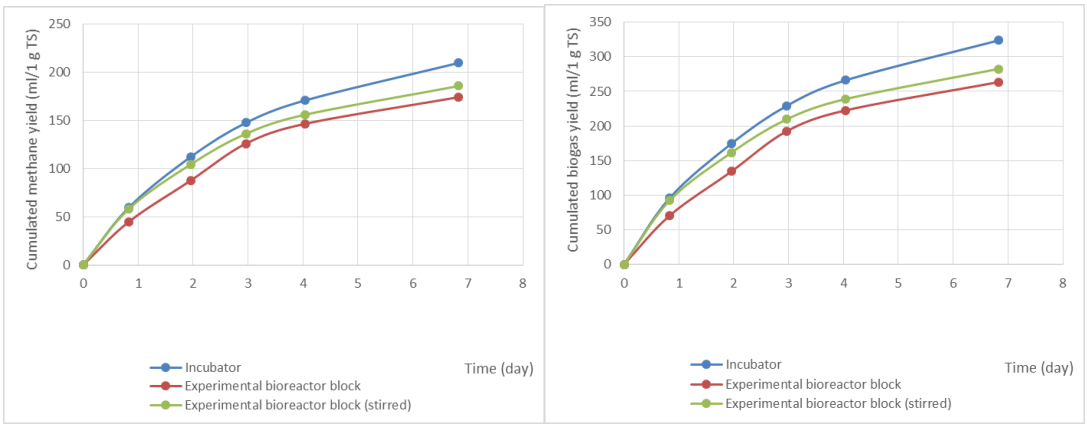

Fig. 7. Biogas and methane yield

The differences in biogas and methane yields decreased, 329 ml/gTS and 209 ml/gTS in the incubator cabinet, while 282 ml/gTS and 185 ml/gTS values was measured in the mixed reactor units. (**Fig. 7.**)

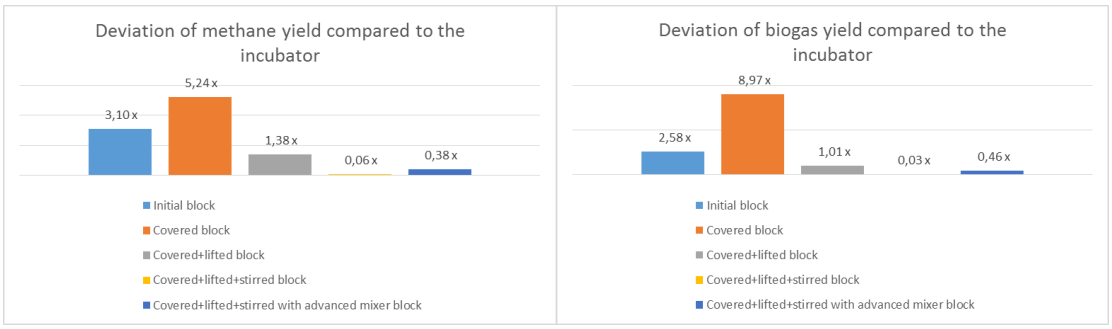

Fig. 8. Comparison of biogas and methane deviation.

The differences also continued to improve relatively to the incubator cabinet deviation values. Comparising deviation values of each development steps can be found in the following bar chart. (**Fig. 8.**)

It is apparent that the effects of engineering and other changes in the reactor block brought the expected results. In terms of the variance values the results were better than expected. In the view of reactor yield performance we approached the incubator cabinet values, the difference almost halved.

5 Conclusions

The development steps modeled those used in the industry, however examples included other natural anaerobic environment. The targeted, cost-effective, yet suitable for real laboratory measuring bioreactor block has been constructed. Taking into account the costs without quantifying the block requires sinificantly lower investment as the series-built ones.

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