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Intellectualized Control System for Anaerobic Bioconversion of Liquid Organic Waste

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ABSTRACT

The use of methods for the biological conversion of organic waste with the production of biogas while solving environmental issues from pollution is an urgent task. The aim of this work is the development of intellectualized control system of parameters of anaerobic bioconversion of organic waste liquid, including parameters of heating supply system of a biogas plant with optimization of the combustion process of biogas, while using the method of optimization of the anaerobic bioconversion of organic waste due to the multiple supply substrate to the bioreactor, ensuring the efficiency and stability of anaerobic bioconversion of organic matter. The developed system allows optimizing the process of biogas combustion with obtaining the heat carrier in the required quantity and quality while minimizing emissions of biogas combustion. Maintaining the optimal rate of supply of the daily dose of the substrate in the bioreactor allows to increase the resistance to organic matter overload; to increase resistance to ammonium nitrogen overloads; to reduce pH fluctuations in the bioreactor.

KEYWORDS

Anaerobic Treatment, Bioconversion of Organic Waste, Biogas Plant, Control System, Heat Supply, Hydraulic Retention Time, Optimization, Organic Waste

INTRODUCTION

In recent years, the attention of society has been increasingly drawn to solving two inextricably linked problems – the prevention of depletion of natural resources and the protection of the environment from anthropogenic pollution. The rapid use of reserves of natural fuel, the restriction of construction of hydro and nuclear power plants have aroused interest in the use of renewable energy sources, including the huge masses of organic waste generated in agriculture, industry, and municipal utilities. In this regard, the use of methods for the biological conversion of organic waste with the production of

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biogas and high-quality organic fertilizers while simultaneously solving a number of environmental issues from pollution is very promising (Nozhevnikova et al., 2016).

The technology of anaerobic fermentation of organic waste is a promising method for their disposal that meets the criteria of environmental friendliness, resource and energy conservation. The successful development of anaerobic technique and technology was made possible thanks to a deep study of the life of the symbiotic microbial communities involved in the process of anaerobic digestion, determination of the main kinetic constants of the ongoing biochemical processes. In connection with the rapid growth in the world of the number of working biogas plants, the urgent task is to increase the efficiency and reliability of their work, to improve and optimize design and technological parameters.

Rational use of fuel and energy resources is of paramount importance; therefore, the state of safety automation and control of combustion processes has special requirements, the fulfilment of which ensures economical trouble-free operation of the heat supply system of a biogas plant.

Modern boiler control as a heat source for a biogas plant should be implemented using intellectualized process control system based on microprocessor technology and controllers (Kovalev et al., 2020b).

The aim of this work is to improve the intelligent system of automatic control of the parameters of anaerobic bioconversion of liquid organic waste and approbation of its elements.

This aim can be achieved by combining a control system for the parameters of the heat supply system of a biogas plant with simultaneous optimization of the biogas combustion process obtained by anaerobic bioconversion of organic matter from liquid organic waste, with a method for optimizing anaerobic bioconversion of liquid organic waste by repeatedly feeding the substrate to the bioreactor, which ensures efficiency and stability of the continuous process of anaerobic bioconversion of organic matter.

BACKGROUND

The main energy costs for the needs of a biogas plant are the costs of low-potential thermal energy for maintaining the thermal regime of a biogas plant. When using modern heat-insulating materials, the cost of heat for heating the daily dose of the load to the process temperature comes first.

Figure 1 shows the calculated production and consumption of biogas for the own needs of a biogas plant with a working volume of 60 m^3 operating in a thermophilic mode.

The biogas plant has thermal insulation made of mineral wool 300 mm thick and is located in the Moscow Region. The daily loading dose is 10% of the working volume of the digester and is equal to 6 m^3 of cattle manure with a moisture content of 92% (Kovalev, 2014).

As can be seen from Figure 1, the main energy costs in a biogas plant are used to heat the daily loading dose, and only up to 40% of the biogas produced can be used for other purposes (Kovalev, 2014; Chen et al., 2014; Carrillo-Reyes et al., 2019).

In addition, the higher the process temperature, the narrower the range of its change, as for the mesophilic temperature regime (37 °C), the permissible temperature variation is 2,8 °C, and at a thermophilic temperature not more than 0,3 °C (Gunter& Goldfarb, 1991; Lindeboom et al., 2011).

Methantenks can work in periodic, continuous, and semi-continuous modes. When loading 1 time per day, the decomposition rate varies significantly in the period between downloads. In (Gunter& Goldfarb, 1991) shown that after loading the gas output is the highest and twice the gas yield before the next load. The sediment was investigated with a moisture content of 91,7%, containing 56,6% of organic matter; organic pollution load was 3,5 kg/(m^3 day), the duration of digestion was 13,3 days. With the continuous addition of sediment, the rate of decomposition of organic matter and the gas yield are constant. (I.I. Yukelson, 1960), using the theory of continuous processes, compared the efficiency of the reaction apparatus of continuous and periodic action to increase the reaction product (biogas yield) during the fermentation of urban wastewater sediments. Determining the order of the