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Heat Recovery of Low-Grade Energy Sources in the System of Preparation of Biogas Plant Substrates

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ABSTRACT

Preliminary preparation of waste for anaerobic digestion at thermophilic temperature conditions is the most energy-intensive stage of the process of anaerobic bioconversion of production and consumption waste organic matter; therefore, the search for ways to reduce energy consumption at this stage remains an urgent task. The article proposes a technological solution to maintain the temperature regime of the digester operation due to the utilization of existing waste low-grade energy sources using a compression heat pump. The flow diagram of the experimental biogas plant is shown, and a description of its operation is given. The dependences of the absolute and specific rates of heating of the influent and cooling of the effluent on the initial temperature of the effluent are given. The principal possibility of maintaining the temperature regime in the digester is shown by using the heat recovery of the effluent using a compression heat pump.

KEYWORDS

Anaerobic Processing, Biogas, Effluent Heat, Energy Efficiency, Heat Pump, Heat Recovery, Organic Waste, Preliminary Preparation of 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. (Nozhevnikova et. al., 2016) The negative impact of agricultural activities on the environment is associated not only with the increasing consumption of natural resources, but also, to a greater extent, with the formation of liquid and solid waste from agricultural and processing industries. In particular, raising animals, processing meat and dairy products, producing beer, sugar, starch, etc. are accompanied by the formation of a large amount of wastewater. (Izmaylov et. al., 2018; Artamonov et. al., 2018) In this regard, the use of methods for the biological conversion of organic waste with

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

According to the Strategy for Sustainable Development of Rural Areas of the Russian Federation for the period up to 2030, in the field of development of engineering infrastructure, it is necessary to maximize the use of non-traditional energy sources for power supply of rural settlements, including biogas plants.

The annual volume of agricultural waste is about 152 million tons. Livestock farms are the main source of organic waste (manure, droppings): cattle farms - 91 million tons; poultry farms - 32 million tons; pig farms - 26 million tons.

In the register of qualified generating renewable energy sources there is only one biogas power plant "Luchki" in the Belgorod region with a capacity of 2.4 MW with an annual consumption of 93 thousand tons of waste. At the same time, the total annual consumption of animal waste for biogas production is only 0.17% from the volume of organic waste generated at Russian agricultural enterprises

Thus, at present, the actual use of organic waste, potentially suitable for biogas production, is 2-3 orders of magnitude lower than the existing potential for organic waste. (Namsaraev et al., 2018a; Namsaraev et al., 2018b)

A recent trend in sustainable bioenergy solutions is the renewed interest in using anaerobic digestion (AD) technology to treat agricultural wastes and biomass for biogas production(Edwards et al., 2015;. Smith et al., 2015)

Unlike other renewable technologies, AD can uniquely capture harmful methane (CH_4) and nitrous oxide (N_2O) emissions released from manure, while simultaneously producing renewable bioenergy (Chadwick et al., 2011; Gerber et al., 2013; Moral et al., 2012).

Table 1 highlights the priority methods for intensifying the process of anaerobic processing of agro-industrial complex wastes, which make it possible to provide an increased yield of biogas with a simultaneous reduction in the consumption of external energy sources due to the recovery of existing waste sources of low-potential energy. (Badmaev, 2018;Kovalev et al., 2020d)

Table 1. Methods for intensifying the process of anaerobic bioconversion

The main directions of intensification of the process of anaerobic processing of agricultural waste	Priority methods of intensifying the process of anaerobic processing of agricultural waste
- study of the process of fermentation of organic waste with a concentration of solid particles of 30-50%; - multistage anaerobic digestion of organic waste based on the vital activity of acidogenic and methane-forming bacteria; - creation of highly active strains of microorganisms grown in special cultivators and introduced in the form of a starter culture into the digester; - study of the process of methane fermentation with the participation of psychrophilic bacteria.	- the use of various technological solutions, including the use of heat pumps, to reduce the consumption of thermal energy for the own needs of anaerobic bioconversion systems; - the use of the electromagnetic field of the vortex layer apparatus during the preprocessing of organic waste to maximize the transfer of organic substances into a dissolved state; - introduction of conductive materials into the substrate during pretreatment in vortex layer apparatus in the form of ferromagnetic microparticles, which are a catalyst for the process of anaerobic bioconversion; - the use of direct interspecies electron transfer in anaerobic bioreactors due to the influence of direct current; - recycling of the digested sludge and the use of anaerobic biofilters in the digestion chamber of the digester.

The stabilization of sewage sludge in anaerobic digestion tanks at different temperature ranges, enrichment of the methane content and purification of the produced biogas, and optimization of the total biogas production through the use of anaerobic digestion systems were discussed in several published studies (Sung et al., 2017; Latha et al., 2019; Alqaralleh et al., 2018; Elalami et al., 2020;