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STUDY OF OPTIMAL ENERGY PARAMETERS OF ELECTRO-HYDROPULSE TREATMENT FOR EFFICIENT EXTRACTION OF VALUABLE COMPONENTS FROM ORGANIC WASTE

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Abstract. *The article considers some aspects of solving the urgent problem related to waste processing, in particular, renewable biowaste from the food industry. Development and implementation of modern technologies for processing and recycling various organic waste will reduce dependence on fossil energy sources, achieve carbon neutrality and maintain environmental safety. The object of the study is organic waste of the agro-industrial complex in the form of bone mass. The possibilities of efficient extraction of the valuable component using electro-hydro-pulse processing were experimentally studied. A description of the basic diagram of the electro-hydro-pulse installation and testing methods for different processing modes are given. Optimum values of electrical parameters are determined, allowing to increase the degree of extraction of valuable components from organic raw materials while reducing the processing time.*

Keywords: electro-hydro-pulse installation, spark discharge, treatment, organic waste, bone mass, valuable components.

1. Introduction

Despite the rapid development of renewable (alternative) energy, almost 80% of the world's demand for electricity is still met by using traditional fossil fuels, which are still economically viable. At the same time, the exponential growth of the world's population is causing unprecedented crises. Of particular concern are energy security and environmental issues such as air pollution, greenhouse gas emissions, the emergence of mass diseases among the population, etc. [1-3]. One possible solution to these problems is a strategy of innovative development and cost-effective use of bioenergy for the production of energy from renewable biological sources such as agricultural and food industry waste. Bioenergy could be considered as a steady and environmentally energy source alternative to fossil fuel [1].

The need to use energy from waste is due to the fact that improper disposal of agricultural waste in the open air and burning of residues also contribute to greenhouse gas emissions [1]. The energy obtained during the processing and recycling of various types of waste, such as metal and plastic waste, organic waste, etc., can be used to produce heat and electricity [4-6]. The use of modern biomass processing technologies allows not only to produce an alternative energy source in the form of biofuel, but also to extract valuable components from food industry waste, such as organic raw materials in the form of bone mass.

In recent years, various types of force effects have been used to improve the efficiency of heat and mass transfer processes in the processing of organic waste, including ultrasonic, electrical, pulse and discrete-pulse [7-11]. The main attention in the development of such methods is focused on changing the structure of the cellular material in order to increase its diffusion permeability. In [8], the technological equipment and processes occurring during heat treatment of agricultural raw materials of various structures using electromagnetic radiation energy were studied. However, most of these methods and technologies are at the stage of laboratory and pilot tests, which indicates the presence of a number of unsolved theoretical and applied problems.

An analysis of publications and developments using a vapor-liquid flow formed under the influence of electric discharges during the processing of organic raw materials revealed a number of unsolved problems. The work [9] is devoted to the study of discharge phenomena accompanying electro-explosive energy conversion. Issues related to the capacitive accumulation of energy and its release in the discharge channel formed by a breakdown of a liquid or an explosion of a conductor are considered. In works [10-12] it is shown that shock waves and cavitation phenomena occurring at the initial stage of an electric discharge as a result of the formation of a discharge channel have a significant effect on particles of secondary raw materials in aqueous suspensions. It is shown that these processes accompanying a high-voltage discharge pulse with a nanosecond front contribute to the disintegration of the material and determine the intensity of mass transfer during the extraction process. In [13-15] the effect of frequency and intensity of an electric field was studied. The structure of cells was studied using transmission electron microscopy. The efficiency of the method depends on various factors such as time, temperature, field strength, frequency, sample selection and preparation, and it is effective even at lower field strengths.

In [16] an important problem related to the features of high-voltage electrical discharges in water or air is considered. This is due to the fact that the use of electro-hydro-pulse (EHP) technologies can lead to various adverse effects - from injury to people and animals to damage to electrical systems, fires and other emergency situations. A deep understanding of the mechanisms underlying these phenomena allows us to develop effective protective measures and increase the level of safety when using such technologies. Nevertheless, the experience of successful practical application of electro-hydro-pulse action for intensification of heat exchange [17], destruction and grinding of mineral materials for enrichment of mineral raw materials [5], etc. determines the real prospect of creating an energy-efficient technology that implements the advantages of this method.

This article discusses the results of experimental studies to identify the most optimal modes of EHP treatment of organic waste in the form of bone mass, allowing for the efficient extraction of valuable components.

2. Materials and testing methods

A laboratory installation has been developed to conduct experimental studies using electro-hydro-pulse processing of organic waste and to determine optimal energy parameters, Fig. 1. The developed setup makes it possible to implement a method for processing organic waste from the agro-industrial sector in order to extract valuable components, degrease bone mass, produce biofuel, and process biological waste [18, 19]. Crushed organic waste 1, dissolved in water 2, are continuously heated through the metal wall of the main tank 3 by means of liquid located in the water jacket 4, which is connected by rubber hoses 5 to thermostat 6. Thermostat 6 has a contact thermometer that allows automatic maintenance and regulation of the «water jacket» temperature in the range from 20°C to 85°C.

Liquid is supplied to water jacket 4 from the upper part of the tank, covering the entire surface, and cooled water is discharged through tube 7 located in the lower part of the tank. The outer part of the tank is covered with felt 8 to maintain and preserve the temperature. The underwater spark discharge is carried out using electrodes. The positive electrode 9 is installed on the tank cover, and the second, the negative electrode 10, is located on the bottom of the main tank 3. The positive electrode 9 is connected by means of an antenna cable 11 to an electro-hydro-pulse installation 12, which includes a control panel, a generator with an air discharger, and a capacitor bank equipped with a protection system [20].

The essence of the EHP processing method is to use the impact of a pulsed shock wave, which accompanies spark discharges in the area of the material being studied and destroys the structure of organic waste. From the power grid with a standard voltage of 220 V through a transformer, energy is supplied to a capacitor bank. The capacitors are charged to a high voltage. Using the control panel, a signal is sent to the air spark gap, which causes an electric discharge breakdown between the electrodes immersed in the liquid. An electric discharge in a liquid medium (water) causes the formation of a shock wave. In addition to the impact of the resulting shock waves, cavitation and air bubbles collapsing in water contribute to the extraction of a valuable component in the form of fat through microcracks in solid organic waste materials.

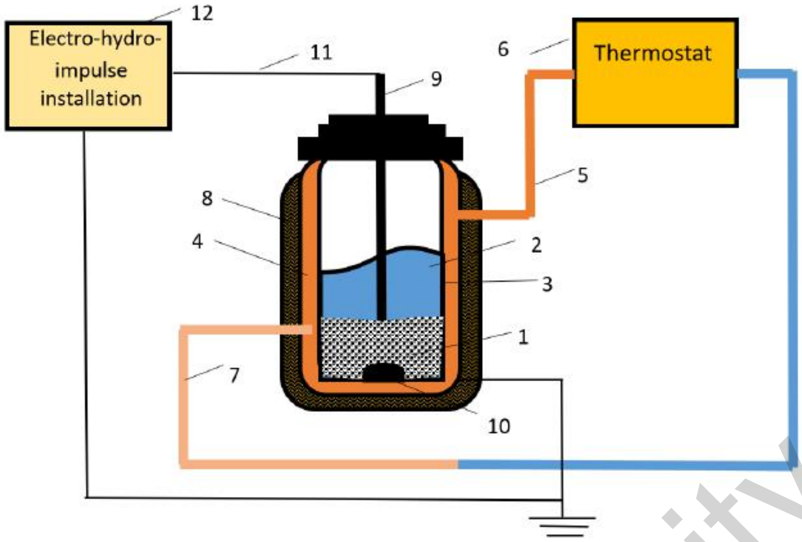

Fig. 1. General view of the laboratory EHP installation working cell.

Fig. 2 shows the dependence of the number of electric discharge pulses (n) on the change in the interelectrode distance l in the air spark gap (12), Fig.1. The number of electric discharge pulses was recorded using an electronic oscilloscope. It has been experimentally established that if the air gap electrodes are installed at a distance of 7 mm, then with a capacitor bank capacity of C2 = 0.25 μF, 720 electric discharge pulses can be produced in 5 minutes. With a capacity of C1=0.4 μF, the number of electric discharge pulses decreases to 600. For an interelectrode distance in an air gap equal to 9 mm with similar capacity values, the number of pulse discharges changes from 530 to 460, respectively.

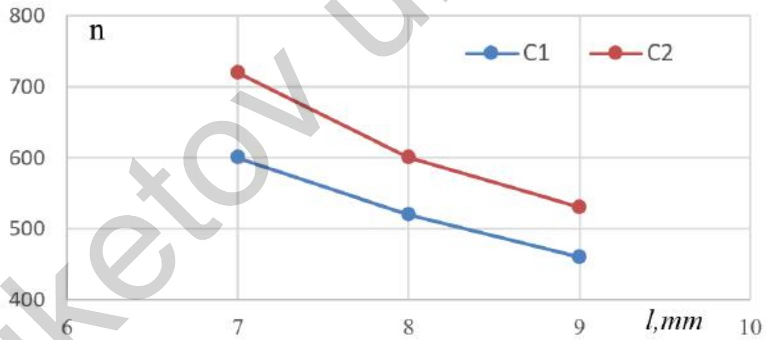

Fig.2. Dependence of the pulses number on the interelectrode distance in an air gap at different capacitance values.

It should be noted that the choice of this range of variation of the interelectrode distance *l* in the air spark gap is explained by achieving the optimal voltage value required to obtain a discharge breakdown. Multiple tests have shown that in this range of the interelectrode distance of the EHP air spark gap, the installation with this working cell operates in a stable mode. The probability of random premature discharges is reduced and complete discharge of the capacitors is ensured, which ensures obtaining a sufficient value of discharge energy to form shock waves. In the experiments, crushed cattle bones, which are waste from the food industry, were used as the processed organic raw material. To obtain raw material samples that are placed in a working container for EHP processing, the bones were crushed to particles of 2 mm to 10 mm in size and preliminarily placed in water.

In subsequent experiments, the duration of the EHP treatment was increased from 5 min to 30 min, while the number of received electric discharge pulses was from 1750 to 3000 with a specific energy of 1.8÷104 J/m. The difference of this EGI treatment technology is in the additional heating of the processed raw material using a water jacket in the temperature range from 32°C to 50°C. This is due to the fact that earlier the authors in the laboratory of hydrodynamics and heat transfer of the E.A. Buketov KarU conducted experiments with heating the processed raw material in the temperature range from 32°C to 38°C [19]. However, a detailed analysis of the raw material samples after EHP treatment showed that the valuable component was not extracted from the bone fractions completely enough.

3. Results and discussion

Experiments to study the electrophysical parameters and determine the optimal values of the operation energy modes of the (EHP) installation were carried out in the Laboratory of hydrodynamics and heat exchange of the E.A. Buketov Karaganda University. Taking into account the previously obtained research results of the authors [20], in order to achieve more intensive extraction of the valuable component from the organic raw material, the mixture was heated using the so-called "water jacket" in the temperature range from 10°C to 50°C. The effect of the temperature mode of heating the samples of organic raw materials on the extraction of the valuable component in the absence and presence of EHP treatment is shown in Figure 3.

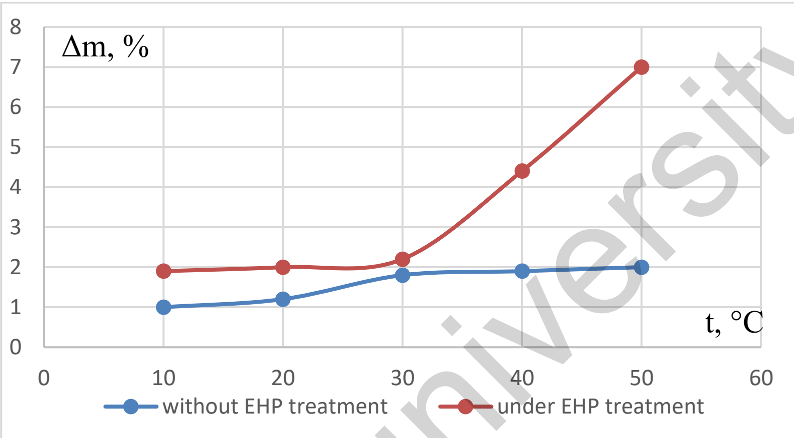

Fig.3. Dependence of a valuable component the extraction from organic waste materials on temperature without and under EHP treatment.

In the experiments, samples of two types of organic waste with solid bone fraction sizes of 2 mm were studied. These organic waste samples were pre-placed in water for 24 hours. This method for preparing samples from organic waste is described in detail in [17]. Figure 4 shows the change in the extracted mass of the valuable component (Δm, %) depending on the capacity of the capacitor bank during EHI processing of a mixture with crushed fractions of organic waste samples.

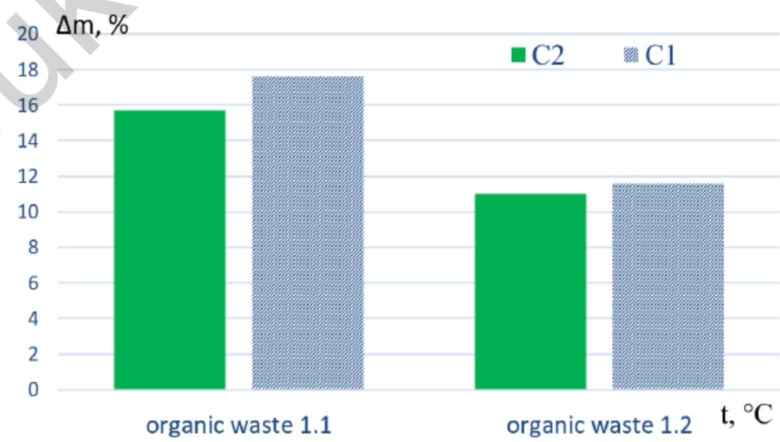

Fig.4. Dependence of extraction of valuable components from samples of two types organic waste at values of capacitor bank capacity C1 = 0.25 μF and C2 = 0.4 μF.

It is evident that water, which has saturated the bone mass structure, helps to enhance the destruction and extract valuable components from these organic wastes much more effectively. In organic waste 1.1, with a capacitor capacity of 0.25 μF, the extraction was 15.7%. With an increase in the capacitor capacity to 0.4 μF, the extraction of organic waste increases to 17.6%. And in organic waste 1.2, with an increase in the capacitor capacity, the extraction rate increased from 11.0% to 11.6. The graphs show that the extraction intensity can stabilize with capacity growth. This allows us to determine the optimal capacity values required to reproduce the experiments. Each point of the experimental graph represents the average value of 5 consecutive measurements; the average deviation does not exceed 3%.

Similar dependencies were obtained for organic waste samples with solid fraction diameters of 5 mm and 10 mm. However, the value of extraction of the valuable component from organic waste with these solid fraction size values remained virtually unchanged.

4. Conclusion

The results of the conducted experimental studies showed that the use of technology based on the generation of an electric pulse discharge in a liquid medium has prospects for the intensification of extraction processes. As a result of multiple experimental tests, it was found that this mode of electro-hydro-pulse treatment with the specified parameters is implemented with the lowest energy costs, i.e. it is economically advantageous. It was experimentally established that for a given working capacity, the most energetically advantageous is EHP processing with a capacitor capacitance value 0.4 μF.

Optimization of the energy parameters of the electro-hydro-pulse installation for the efficient extraction of a valuable component from secondary raw materials requires an integrated approach, including the study of the influence of various factors, such as discharge energy, pulse frequency, electrode configuration and ambient temperature. The study showed that the correct combination of these parameters can significantly increase the efficiency of bone mass fraction destruction, which contributes to an increase in the yield of the valuable component with minimal energy costs.

Conflict of interest statement

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Credit author statement

Duisenbayeva, M.S.: investigation, formal analysis; writing-original draft; **Schrager E.R.:** supervision, conceptualisation; **Sakipova S.E**.: data curation, writing – review & editing; **Nussupbekov B.R.:** project administration, methodology.
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